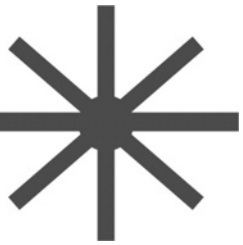
Advanced Laser Technologies

ALT' 11



19th International Conference on Advanced Laser Technologies

BOOK OF ABSTRACTS

3 – 8 September 2011
Golden Sands resort, Bulgaria

Editors:

Ekaterina Borisova
Anna Dikovska
Irina Bliznakova

19th International Conference on Advanced Laser Technologies – ALT'11, Golden Sands, Bulgaria, 3 – 8 September 2011

Book of Abstracts

Publisher: Institute of Electronics, Bulgarian Academy of Sciences
72 Tsarigradsko chaussee Blvd., 1784 Sofia, Bulgaria

Print: ZiZi print Ltd.
133 Tsarigradsko chaussee Blvd., BIC-IZOT. Corpus 1, office 315, 1784 Sofia, Bulgaria

The text was not submitted to any language revision.

Local venue, accommodation and social events for the participants at the 19th International Conference on Advanced Laser Technologies – ALT'11 are organized with the help of Alexander Tour Company - www.alexandertour.com

19th International Conference on Advanced Laser Technologies – ALT'11
is organized by:

Institute of Electronics,
Bulgarian Academy of Sciences

Prokhorov General Physics Institute,
Russian Academy of Sciences

International Laser Center
of M.V.Lomonosov Moscow State
University

Center for Laser Technology and
Materials

The Organizers have the pleasure to announce that we have received support from the Editors of three internationally recognized journals in the field of laser technologies and their applications for publishing of special issues – collection of selected papers presented on ALT'11.

We invite all the conference participants to submit their original and unpublished reports, presented on the 19th International Conference on Advanced Laser Technologies 2011, in the special issues of ***Quantum Electronics, Journal of Biophotonics*** and ***Journal of Innovative Optical Health Sciences***.

As the scientific quality is most important, the standard review process of the submitted papers will be used. For the format of the manuscript, authors are advised to follow the instructions, which they could find on the journals' internet sites. The deadline for manuscripts is October 15, 2011. The special issues will be published in the spring of 2012.

Quantum Electronics	Journal of Biophotonics	Journal of Innovative Optical Health Sciences
Turpion	WILEY KNOWLEDGE FOR GENERATIONS	World Scientific Connecting Great Minds

19th International Conference on Advanced Laser Technologies – ALT'11
is supported by:

NATIONAL CENTER
ON BIOMEDICAL PHOTONICS

RUSSIAN FOUNDATION
FOR BASIC RESEARCH

LASER QUANTUM

OCEAN OPTICS

HORIBA JOBIN YVON

ASTEL

Advanced Laser Technologies

ALT' 11

Conference Chairman
Ivan SHCHERBAKOV, Russia

Program Committee Co-chairs
Latchezar AVRAMOV, Bulgaria
Vitaly KONOV, Russia

Organizing Committee Co-chairs
Ekaterina BORISOVA, Bulgaria
Vladimir PUSTOVOY, Russia

Organizing Committee
Irina BLIZNAKOVA – Secretary, Bulgaria
Natalia KHAKAMOVA - Secretary, Russia
Anna DIKOVSKA, Bulgaria
Albena DASKALOVA-SHIVAROVA, Bulgaria
Rangel RANGELOV, Bulgaria

International Program Committee

Kerim ALLAKHVERDIEV, Turkey
Ekaterina BORISOVA, Bulgaria
Stefka CARTALEVA, Bulgaria
Aladar CZITROVSKY, Hungary
Boris DENKER, Russia
Dan DUMITRAS, Romania
Costas FOTAKIS, Greece
Sergey GARNOV, Russia
Tomas GRAF, Germany
Frans HARREN, Netherlands
Andrei KABASHIN, France
Armando LUCHES, Italy
Qingming LUO, China
Vladimir MAKAROV, Russia
Andreas MANDELIS, Canada
Vladislav PANCHENKO, Russia
Ivan PELIVANOV, Russia
Sergey PIMENOV, Russia
Alexander PRIEZZHEV, Russia
Valerio ROMANO, Switzerland
Nikola SABOTINOV, Bulgaria
Alexandros SERAFETINIDIS, Greece
Mark SENTIS, France
Koji SUGIOKA, Japan
Valery TUCHIN, Russia
Sandor VARRO, Hungary
Vadim VEIKO, Russia
Timo YAASKELAINEN, Finland
Dave ZELMONDE, USA
Alexey ZHELTIKOV, Russia

Advanced Laser Technologies

ALT' 11

Dear Colleagues,

It is a great pleasure and honor to welcome you at the **19th International Conference on Advanced Laser Technologies – ALT'11** held at the hotel Melia Grand Hermitage, Golden Sands resort, Bulgaria.

The ALT Conference series are focused on the recent achievements and advances in laser technology and laser applications in various areas.
These series of conferences, held annually since 1993, were established by Nobel Prize laureate Alexander Prokhorov, director of the General Physics Institute of the Russian Academy of Sciences. Previous conferences were organized in Russia, Czech Republic, Germany, Greece, France, Italy, Romania, Switzerland, United Kingdom, China, Hungary, Finland, Turkey and The Netherlands. The key topics of the conference are Biophotonics, Optoacoustics, Laser Diagnostics and Laser-Matter Interactions, Non-linear Optics Materials and Devices, Laser Systems and New Laser Materials, Terahertz Spectroscopy and Applications. Leading scientists and researchers from all over the world are invited to attend the Conference and make presentations reviewing the latest results in their field of interest.

The activities of the 19th International Conference on Advanced Laser Technologies will take place in Golden Sands Resort on Bulgarian Black Sea Coast. Golden Sands (Zlatni Piasaci) is one of the biggest holiday resort complexes along the northern coastline, famous for its healing hot-water mineral springs as well as its beautiful two-mile (4 km) stretch of fine sandy beach, making it a popular holiday destination. The resort is located 11 miles (18 km) north of Varna, and sits at the foot of the forested hills of the Zlatni Piasaci National Park. Its ideal weather conditions with plenty of entertainment, sporting activities, warm and clean water, year round luxury hotels and villas, restaurants, bars and spa treatments, making Golden Sands one of the more desirable destinations on the Black Sea Coast. This part of Bulgaria is also reach of historical places, romantic towns and beautiful natural landscapes, and we hope that you are able to spend some extra leisure time to visit some of them.

We do welcome you to this typical Bulgarian sea resort, with its well equipped conference center with extensive facilities. We hope that you will have a fruitful meeting, that you will make new friends and will meet old ones and will keep Bulgaria in your heart.

Host and Co-chair of the Organizing Committee
Ekaterina Borisova

Advanced Laser Technologies

ALT' 11

Programme at a glance

Saturday	Arrival and registration	15:00-19:00
September 3, 2011	Welcome party	20:00-21:30
Sunday	Welcome and Opening Remarks	09:00-09.30
September 4, 2011	Plenary talks	09:30-11:00
	Parallel sessions	11:30-12:50
	Lunch	13:10-15:00
	Parallel sessions	15:00-16:20
	Parallel sessions	16:50-18:50
Monday	Plenary talks	09:30-11:00
September 5, 2011	Parallel sessions	11:30-13:10
	Lunch	13:10-15:00
	Parallel sessions	15:00-16:20
	Parallel sessions	16:50-18:50
Tuesday	Social Program – excursion	09:00-14:00
September 6, 2011	Poster Session	16:30-18:30
	Conference dinner	19:30-22:00
Wednesday	Plenary talks	09:30-11:00
September 7, 2011	Parallel sessions	11:30-13:10
	Lunch	13:10-15:00
	Parallel sessions	15:00-16:20
	Parallel sessions	16:50-18:10
Thursday	Parallel sessions	09:00-10:40
September 8, 2011	Closing Ceremony	10:40-11:00

CODES APPLIED

- PL – plenary lecture
- I – invited lecture
- O – oral presentation
- P – poster presentation

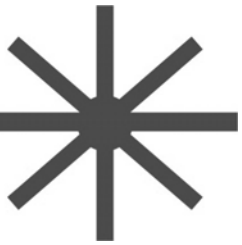
KEY TOPICS

- Biophotonics - BP
- Optoacoustics - OA
- Laser diagnostics - LD
- Laser-matter interactions - LM
- Laser systems and new laser materials - LN
- Non-linear optics materials and devices - NL
- Terahertz spectroscopy and applications – TH
- Ultrafast laser technologies and applications - UF
- Laser applications in material sciences - LA
- Active optical sensing and metrology - AO
- Laser remote sensing and ecology - LR
- Lasers in cultural heritage - LC
- Laser spectroscopy - LS

Code example: I-3-OA – invited lecture #3 in Optoacoustics topic
P-12-BP – poster #12 in Biophotonics topic

Advanced Laser Technologies

ALT' 11



PLENARY LECTURES

PL-1

UPCONVERTING NANOPARTICLES AS CONTRAST AGENT IN LUMINESCENCE IMAGING AND TOMOGRAPHY

Stefan Andersson-Engels[1], Haichun Liu[1], Can T. Xu[1], Pontus Svenmarker[1], Wu Xia[1], Haiyan Xie[1], Ola Jakobsson[2], Thomas Laurell[2], Fredrik Olsson[3], Sarah Fredriksson[3],
[1]*Department of Physics, Lund University, P.O. Box 118, SE-221 00 Lund, Sweden*
[2]*Department of Electrical Measurements, P. O. Box 118, Lund University, SE-221 00, Sweden*
[3]*Genovis A, P.O. Box 790, SE-22007, Lund Sweden*
stefan.andersson-engels@fysik.lth.se

Upconverting nanoparticles have recently drawn increasingly attention as a contrast agent for optical bioimaging[1,2]. Among upconverting nanomaterials, lanthanide-ions-doped $NaYF_4$ nanoparticles have been shown to be the most efficient. A major advantage with upconverting contrast agents is that due to the anti-Stokes shift of the emission, autofluorescence, otherwise yielding a relatively intense superimposed background signal, can completely be filtered out. This is because autofluorescence will be emitted in a different wavelength region than that from the nanoparticles[3]. Other advantages are the wavelength regions for the excitation and emission will be within the tissue optical window[4], and that the spatial resolution will be improved as compared to fluorescence-based contrast agents[5-8].

Currently, $NaYF_4$ nanoparticles are synthesized in batch-control modes in small volumes[9-10]. Although great achievements have been made, batch syntheses tend to suffer from irreproducibility, in terms of quality of the nanoparticles, from batch to batch and difficulty to implement fast screening. Microfluidic reaction systems offer a solution to these challenges and have an increasingly important role in synthesis of nanoparticles as highly controlled thermal and stoichiometric microenvironments can be obtained in the synthesis process [11].

Acknowledgements: We greatly appreciate the support from the Linneus Centre at Lund Laser Centre, The Swedish Research Council, and Genovis AB.

References:

1. S. F. Lim, R. Riehn, W. S. Ryu, N. Khanarian, C. –K. Tung, D. Tank, and R. H. Austin, Nano Lett. 6, 169 (2006).
2. C. Vinegoni, D. Razansky, S. A. Hilderbrand, F. Shao, V. Ntziachristos, and R. Weissleder, Opt. Lett. 34, 2566 (2009).
3. C. T. Xu, N. Svensson, J. Axelsson, P. Svenmarker, G. Somesfalean, G. Chen, H. Liang, H. Liu, Z. Zhang, and S. Andersson-Engels, Appl. Phys. Lett. 93, 171103 (2008)
4. Q.Q. Zhan, J. Qian, H.J. Liang, G. Somesfalean, D. Wang, S.L. He, Z.G. Zhang, S. Andersson-Engels, ACS Nano 5, 3744 (2011).
5. C. T. Xu, J. Axelsson, and S. Andersson-Engels, Applied Physics Letters 94, 251107 (2009)
6. P. Svenmarker, C. T. Xu and S. Andersson-Engels, Optics Letters 35, 2789-2791 (2010)
7. H. Liu, C. T. Xu, and S. Andersson-Engels, Optics Letters 35, 718-720 (2010)
8. C.T. Xu, P. Svenmarker, H. Liu, S. Andersson-Engels (to appear)
9. G. Chen, T. Y. Ohulchanskyy, R. Kumar, H. Agren, and P. N. Prasad, ACS Nano, 4, 3163 (2010).
10. X. Wang, J. Zhuang, Q. Peng, and Y. Li, Nature, 437, 121 (2005).
11. S. Marre, and K. F. Jensen, Chem. Soc. Rev. 39, 1183 (2010).

PL-2

OPTOACOUSTIC PLATFORM FOR NONINVASIVE MONITORING, SENSING AND IMAGING: FROM IDEA TO CLINICAL STUDIES

Rinat O. Esenaliev
University of Texas Medical Branch, Galveston, Texas 77555-1156, USA
riesenal@utmb.edu

Our group has pioneered optoacoustic technique for noninvasive, multiparameter monitoring, imaging, and sensing. The optoacoustic technique is based on detection of thermoelastic ultrasound waves induced in tissues by optical pulses and yields a noninvasive diagnostic modality with high optical contrast and ultrasound spatial resolution. For more than 2 decades we have been studying optoacoustic effects in tissues and developing optoacoustic monitoring, imaging, and sensing techniques and systems. At present, optoacoustics is the fastest growing area in biomedical optics.

One of our long-term objectives in this field is to improve the care of large populations of patients by developing the multiparameter, noninvasive, optoacoustic diagnostic platform that will accurately and continuously measure total hemoglobin concentration, venous oxygenation (both cerebral and central), cardiac output, circulating blood volume, cardiac index, systemic oxygen delivery, hepatic function, and other important physiological parameters. Currently, invasive measurements of these parameters are routinely used in patients including anemic patients (2 billion people worldwide), patients with traumatic brain injury (2 million per year in the USA alone), patients with circulatory shock, critically ill, surgical, and neonatal patients.

We built optoacoustic systems for monitoring of these parameters by probing specific blood vessels such as the radial artery, superior sagittal sinus, and central and peripheral veins. In these studies we used multiwavelength, OPO-based optoacoustic systems tunable in the 700-1064 nm spectral range and highly-portable, light-weight, inexpensive, laser diode-based systems. Oxygenation and total hemoglobin concentration were monitored noninvasively using the optoacoustic systems and were measured invasively using "gold standard" methods for accuracy assessment. We developed unique, highly-sensitive, wide-band (25 kHz – 10 MHz) probes for detection of optoacoustic waves induced in the blood vessels. By using these probes, reconstruction algorithms, and software specially developed for real-time, continuous optoacoustic signal acquisition and processing, we obtained high correlation between the optoacoustically predicted and reference blood parameters (R^2 = 0.95 – 0.99). Standard deviation and precision of measurements were several % and 1%, respectively. High-resolution (30 microns) ultrasound imaging Vevo system and standard clinical GE ultrasound imaging were used in some studies for ultrasound-guided optoacoustic monitoring.

Our results obtained *in vitro*, in large and small animals, in anemic patients, patients with traumatic brain injury, and neonatal patients indicate that the optoacoustic devices can quickly provide important information in both high acuity and low acuity environments and greatly facilitate prompt recognition and treatment of a variety of life-threatening illnesses.

Acknowledgements: This work is supported by the NIH (Grants# R01EB00763, R01NS044345, R41HL10309501), John Sealy Memorial Endowment Fund for Biomedical Research, Moody Center for Traumatic Brain Injury Research, 2 DOD grants, UTMB Business Acceleration Program, Texas Emerging Technology Fund founded by the Office of the Governor. Drs. Esenaliev and Prough are co-owners of Noninvasix, Inc., a UTMB-based startup that has licensed rights to optoacoustic monitoring, sensing, and imaging technology.

PL-3

3D INTEGRATION OF FUNCTIONALITIES INSIDE GLASS BY ULTRAFAST LASER

Koji Sugioka, Katsumi Midorikawa
RIKEN – Advanced Science Institute
ksugioka@riken.jp

Over the past few decades, the rapid development of ultrafast lasers is opening up new avenues for materials processing in micro and nano scales. The extremely short pulse width of the ultrafast laser of several tens fs ~ a few ps minimizes the formation of heat-affected zone in the processed region, allowing for high-quality microfabrication of soft materials, such as biological tissues [1], and hard or brittle materials, such as semiconductors and insulators [2]. In addition, the extremely high peak powers generated can induce strong absorption, even in materials such as glass that are transparent to the laser wavelength, due to nonlinear multiphoton absorption [3]. By focusing the laser beam inside the transparent materials with moderate pulse energy, the multiphoton absorption can be confined to a region near the focus point, and thereby internal processing of transparent materials including refractive index modification, precipitation of metal atoms, fabrication of three-dimensional (3D) microfludic structures, etc. is carried out [4, 5].

This paper presents 3D integration of different functions created by the ultrafast laser inside glass for application to fabrication of microchips used for biochemical analysis. The substrate used is photosensitive glass which is comprised of lithium aluminosilicate glass doped with trace amounts of silver and cerium. By the ultrafast laser direct writing, refractive index at the laser-exposed regions can be increased, resulting in formation of 3D optical waveguides. Thermal treatment after the laser irradiation grows a crystalline phase of lithium metasilicate and transforms the laser-exposed regions to visible brown color. This transformation can be used for formation of variable optical filters. Furthermore, the grown crystalline phase can be preferentially etched away by succeeding wet etching in a diluted HF acid solution. In this way, 3D hollow microstructures can be embedded in the glass, which can be adapted to fabricate microoptics such as mirrors and lenses as well as microfludics. These different structures and functions can be easily integrated in a single glass chip.

The integrated microchips are applied to efficient analysis of chemical fluid samples and exploration of dynamics and functions of aquatic microorganisms and bacteria [6-8].

References :

1. M. F. Yanik, H. Cinar, H. N. Cinar, A. D. Chisholm, Y. I. Jin, A. Ben-Yaker, Nature, 432, 822 (2004).
2. N. Barsch, K. Korber, A. Ostendorf, K. H. Toenshoff, Appl. Phys. A77, 237 (2003).
3. P. Rudolph, J. Bonse, J. Krueger, W. Kautek, Appl. Phys. A69, 763 (1999).
4. K. M. Davis, K. Miura, N. Sugimoto, K. Hirao, Opt. Lett. 21, 1729 (1996).
5. K. Sugioka, Y. Cheng, K. Midorikawa, Appl. Phys. A81, 1 (2005).
6. Y. Hanada, K. Sugioka, H. Kawano, I. S. Ishikawa, A. Miyawaki, K. Midorikawa, Biomed. Microdevices 10, 403 (2008).
7. K. Sugioka, Y. Hanada, H. Kawano, I. S. Ishikawa, A. Miyawaki, K. Midorikawa, AIP Conf. Proc. Vol. 1278, 426 (2010).
8. Y. Hanada, K. Sugioka, I. S. Ishikawa, H. Kawano, A. Miyawaki, K. Midorikawa, to be published.

PL-4

LASER-TISSUE INTERACTIONS IN CLEARING CONDITIONS

Valery V. Tuchin
Research-Educational Institute of Optics and Biophotonics,
Saratov State University, 83 Astrakhaskaya, Saratov, 410012 Russia
FiDiPro Program, University of Oulu, Finland
tuchinvv@mail.ru

The optical method at laser application is a tool for clinical functional imaging of physiological-conditions of tissues for cancer diagnostics and therapies which is of great interest due to its unique informative features, simplicity, safety and low cost in contrast to conventional x-ray computed tomography, magnetic resonance imaging and ultrasound imaging. However, the main limitations of the optical imaging techniques, including optical diffusion tomography, optical coherent tomography, confocal and nonlinear microscopy, reflectance spectroscopy, are caused by strong light scattering in tissue layers and blood, which in their turn cause low contrast and spatial resolution, as well as a small probing and laser treatment depth.

One of the prospective solutions of the problem is a reduction of light scattering of the tissue layers and blood that provides improvement of image quality and precision of spectroscopic information getting from tissue depth [1,2]. In laser surgery the reduction of light scattering by a tissue gives decreasing of irradiating light beam distortion and the possibility of its sharp focusing as well as reducing the radiant exposures. Various physical and chemical techniques, such as compression, stretching, dehydration, coagulation, and impregnation by biocompatible chemical agents as the tools for controlling of tissue optical properties and efficiency of laser-tissue interaction are described in this overview paper. In particular, we are discussing the optical immersion method based on refractive index matching of scatterers (collagen and elastin fibers, cells, and cell compartments) and the ground material (interstitial fluid and/or cytoplasm) of a tissue and blood under action of exogenous optical clearing agents (OCAs). Such control leads to essential reduction of scattering, and therefore causes much higher transmittance (optical clearing), appearance of a big amount of least scattered (snake) and ballistic photons allowing for successful application of different laser diagnostic and therapeutic techniques, and precise laser surgery, that will be demonstrated. Noninvasive glucose sensing and drug delivery monitoring are also good perspectives of the method.

The optical clearing of fibrous and cell-structured tissues and blood will be analyzed from the point of view of receiving more valuable, normally hidden, information from spectroscopic and polarization measurements, confocal microscopy, optical coherence and optical projection tomography, as well as from nonlinear spectroscopies, such as two-photon fluorescence and second-harmonic generation techniques. Some important applications of the immersion technique to glucose sensing, drug delivery monitoring, improvements of image contrast and imaging depth, non-distortive delivery of laser radiation, precision tissue laser photodisruption, *etc.* are also described. This paper presents recent results on tissue optical clearing that demonstrate further developments and new applications of the method for laser diagnostics and therapy.

References:

1. V Tuchin, "Optical Clearing of Tissues and Blood," SPIE Press, Bellingham, WA (2006)
2. . Genina, A.N. Bashkatov, and V.V. Tuchin, "Tissue optical immersion clearing," Expert Rev. Med. Devices 7(6), 825–842 (2010)

PL-5

ORGANIC NANOSTRUCTURES SYNTHESIZED BY ADVANCED PULSE LASER TECHNOLOGIES FOR BIOMEDICAL APPLICATIONS

Ion N. Mihailescu, Carmen Ristoscu, Felix Sima
National Institute for Lasers, Plasma and Radiations Physics, Lasers Department, 409 Atomistilor, P.O. Box MG-54, Magurele - Ilfov, RO-077125, Romania
ion.mihailescu@inflpr.ro

We review recent results on organic material thin films transfer by MAPLE technique. We mention that previously applied laser, plasma or chemical deposition methods, induced the irreversible deterioration of these "delicate" materials. The synthesized nanostructured layers were optimized following investigations by SEM, TEM, SAED, XTEM, GIXRD, XPS or FTIR methods. Biocompatibility, bioactivity and biodegradation were evaluated by dedicated in-vitro tests.

We deposited pullulan triacetate (a prospective candidate for drug delivery systems) by PLD and MAPLE techniques and found that only MAPLE is appropriate for a high fidelity compositional and structural transfer.

We showed that the composite PMMA-bioglass films deposited by MAPLE efficiently protects metal implants against corrosion in human fluids.

The coating of metallic implants with composite alendronate-hydroxyapatite (HA) layer was demonstrated to enhance human osteoblasts proliferation and differentiation, while inhibiting osteoclasts growth, with benefic effects for the treatment of osteoporosis.

Human plasma proteins (fibronectine, vitronectine) applied by MAPLE on PLD HA coated metallic implants significantly increased cell adhesion and activated osteointegration.

We immobilized urease in form of thin films and showed that it is active in breaking down and diagnose of urea content in blood.

We extended the application of MAPLE to the transfer and immobilization of IgG molecules. We investigated the influence of the incident laser fluence and the effect of the lipid addition in the initial solution upon the protein thin films adhesion to substrates.

The transfer of pure levan and oxidized levan by MAPLE was achieved without any addition of plasticizers or pigments. The samples presented a compact structure, good adhesion to substrate and a uniform, homogenous nanostructured surface. They exhibited high specific surface areas fully compatible with their potential use in biology or medicine.

We concluded that the thin films deposited by MAPLE technique were identical in composition, morphology and structure with the base material, and most likely preserved their functionality and biological performances.

PL-6

SINGLE-SHOT MEGAVOLTAGE THZ PULSES: METHODS OF GENERATION AND VISUALIZATION

S.V.Garnov, V.V.Bukin, I.A. Shcherbakov
A.M.Prokhorov General Physics Institute of RAS, Moscow, Russia
garnov@kapella.gpi.ru

Among a variety of methods and techniques developed for generation of pulsed terahertz beams we discuss in the present talk the most effective and powerful one – the based on optical rectification of femtosecond laser pulses with tilted pulse front in lithium niobate crystals. Aiming to reach a possibly higher THz electric field amplitude (as high as 10^7 V/cm) we developed the new laser-based terahertz system consisting of sub-terawatt femtosecond laser (pulsewidth 70 fs, energy 30 mJ, wavelength 912 nm) and a wide-aperture (30x10x10 mm^3) lithium niobate crystals ($MgO:LiNbO_3$). The developed experimental setup, the results obtained and the prospective applications of high-intensity THz radiation are described and discussed in details.

Acknowledgements. This work was partially performed under Russian Academy of Sciences Programs: "Extreme light fields and their applications", "Fundamental optical spectroscopy and its applications", and Russian Foundation for Basic Research project # 09-02-00861-a.

PL-7

FEMTOSECOND LASERS FOR MICROSURGERY OF CORNEA

S.K.Vartapetov[1], D.V.Khudyakov[2], K.E.Lapshin[1], A.Z.Obidin[1],
[1] Physics Instrumentation Center of General Physics Institute RAS, [2] Optosystems Ltd.
svart@pic.troitsk.ru

The ultra short duration laser pulses allow high laser intensity to be reached with very low pulse energies. Photodisruption of transparent media can be produced by focusing laser beam into the bulk of transparent media. Due to the short pulse duration the thermal effect is low.

Tissue processing with femtosecond laser pulses has been of growing interest since its high precision was demonstrated on a variety of different tissue types. Moreover, due to its sub μm precision, it is possible to perform surgical procedures like refractive surgery inside the human eye.

Many studies have compared femtosecond lasers and mechanical microkeratomes for corneal flap creation in laser in situ keratomileusis (LASIK). At present there are only several groups which use femtosecond laser for flap creation. All of these groups use bulk solid state femtosecond lasers for the surgery processes. The bulk solid state lasers can produce light pulses with extremely short time duration, but these have high sensitivity to environmental fluctuations. Therefore it is necessary frequent adjustment of the laser cavity that complicates the maintenance procedure.

Since it is necessary in actual laser surgeries to use energy values greater than the threshold, we need to use the shortest possible pulse width to introduce the lowest amount of energy into

the cornea. It is known, a light pulse with time duration of a few hundred femtoseconds is enough to reach the corneal ablation threshold. Femtosecond fiber lasers can provide us for the pulse duration as short as 100 fs and offer more environmental stability in comparison with bulk solid state lasers. Moreover, the femtosecond fiber lasers require only limited maintains for a long operating duty. Thus, the fiber femtosecond laser, as a stable and reliable source, is preferable laser for application in eye surgery.

This paper describes the new femtosecond laser system for ophthalmology. The laser system is based on the full fiber femtosecond laser with wavelength 1064 nm and pulse duration of ~ 400 fs. The repetition rate of laser pulses can be verified at the range from 200 kHz to 1 MHz. Small aberration objectives are used for focusing of the laser beam with about a microJoule pulse energy to spot size of several microns for optical breakdown in result. Different optical schemes were tested with the focal length of objectives at the range of 2 – 40 mm and numerical aperture of 0,2 – 0,65. The focal point of the optical system can be adjusted on the depth up to 1 mm of beneath the surface of tissue.

Both PMMA and Agarose Gel were used as a cornea tissue fantom during laboratory research study. Cutting procedure was performed with the speed up 5 m/sec. In a clinical research study less than 20 sec flap procedure time was obtained.

PL-8

DISK LASER - POWERFUL TOOL FOR BASIC RESEARCH

Friedrich Dausinger[1], Mikhail Larionov[1], Steffen Sommer[2]
[1]Dausinger + Giesen GmbH, Stuttgart, Germany
[2]TGSW mbH, Stuttgart, Germany
dausinger@dausinger-giesen.de

The competition between different laser concepts is going on. For high power applications the preferred geometries of laser active material are fibers and disks, nowadays, the slab geometry being still in the race. Each approach has his specific advantages and finds appropriate applications. As far as high pulse energies are concerned the disk laser is beyond controversy the front-runner. The same seems to be true when frequency doubling is tackled. Additionally an unprecedented flexibility in the choice of pulse duration showed up, recently.

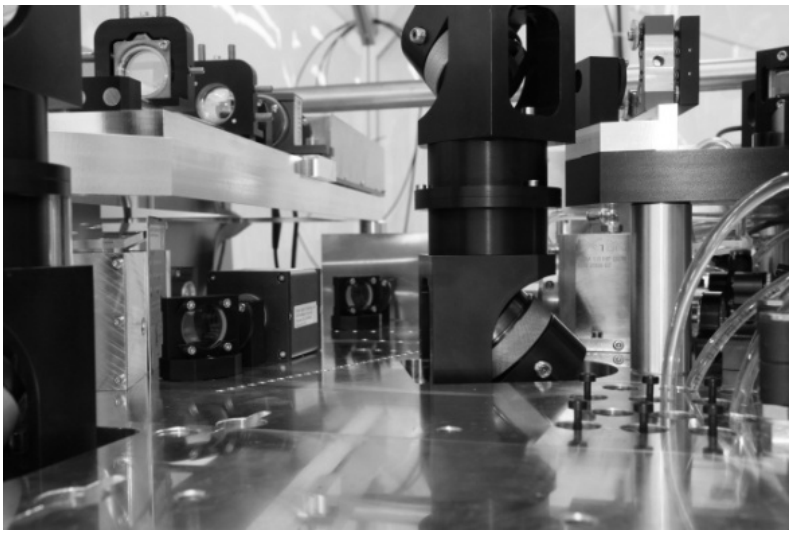


Fig. 1 View into 50 W laser VaryDisk offering pulse duration from 350 fs to 1 µs

The presentation illustrates the advantages of disk lasers by introducing recent disk laser components and systems developed for basic research purposes. Furthermore possible and realized applications and first results will be discussed.

PL-9

LASER ABLATION AND POLYMERISATION OF LIQUIDS

W. Marine, E. Chelnokov, A. Baronnet, D. Ferry, M. Rivoal, L. Bekere, N. Larina, and V. Khodorkovsky
Centre Interdisciplinaire de Nanoscience de Marseille (CINAM), UPR CNRS 3118, Case 913, Campus de Luminy, 13288 Marseille, France.
marine@cinam.univ-mrs.fr

The interaction of the high-power femtosecond pulses with molecules results in a variety of nonlinear phenomena including strong field induced polarization, alignment of molecules and excitation of molecules to the higher excited states than those available by the conventional sources of light. Such processes are inevitably accompanied by laser ablation along with heating and expansion of the ablated product, well recognized in the laser – condensed matter interaction.

In this presentation, for the first time, we demonstrate a constructive ablation of liquids leading to the unprecedented chemical reaction sequences giving rise to the formation of the polymeric nanomaterials.

Experimentally, we analyse the photo-physical and the photochemical processes occurring in the liquid alkyl substituted benzenes upon femtosecond laser irradiation using various spectroscopic approaches.

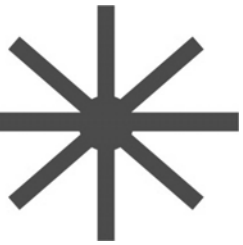
We used multiphoton absorption of 100 fs pulses at 800 and 400 nm to excite the aromatic molecules at fluencies of about 10^{12}–10^{14} W/cm^2. The transient and conventional optical spectroscopy showed the formation of a number of the intermediate species, which gave rise to the formation of the fulvene derivatives along with large nanoparticles (100 – 200 nm). The nanoparticle formation was observed already at the very beginning of the process by the dynamical light scattering. The resulting solid products, the particles of about 10 μm, were identified as polyacetylene by means of the chemical analysis, IR spectra and transmission electron microscopy. We showed that varying the chirp of the laser pulses and the volume of the interaction zone we can influence the yields of the final products.

Finally we discuss the basic principles of ablative photodecomposition of liquids by femtosecond laser irradiation and implications in the femtosecond laser ablation of liquids.

Acknowledgements: This work was supported by ANR (French Agency for National Research), project NEM, grant: #09-0107-01.

Advanced Laser Technologies

ALT' 11



INVITED LECTURES AND ORAL PRESENTATIONS

I. BIOPHOTONICS

I-1-BP

LIVE IMAGING OF RODENT EMBRYONIC DEVELOPMENT WITH OPTICAL COHERENCE TOMOGRAPHY: FROM *EX VIVO* TO *IN UTERO*

Kirill V. Larin[1,2,3], Saba H. Syed[1], Mary E. Dickinson[2], and Irina V. Larina[2]
[1]*Department of Biomedical Engineering, University of Houston, Houston, TX 77204, USA*
[2]*Department of Molecular Physiology and Biophysics, Baylor College of Medicine, Houston, TX 77584, USA*
[2]*Department of Optics and Biophotonics, Saratov State University, Saratov 410026, Russia*
klarin@central.uh.edu

Live embryonic imaging is required for investigating, understanding, and, possibly therapy of the congenital diseases associated with abnormal developmental processes. Mouse embryos have long served as an ideal model for the study of mammalian embryonic development. OCT is a promising technique introduced recently to developmental biology. In this talk we overview recent advances made in imaging of live mouse embryos from stage 7.5 (Fig 1) through 17.5 (Fig 2) days post-coitus (dpc) using Optical Coherence Tomography (OCT) technique. Our results suggest that OCT can serve as a powerful tool to image mouse embryos with a resolution of ~8 μm (at the level of a single red blood cell – Fig 3) and can help in understanding abnormalities in developmental processes caused by mutations, or toxic drugs.

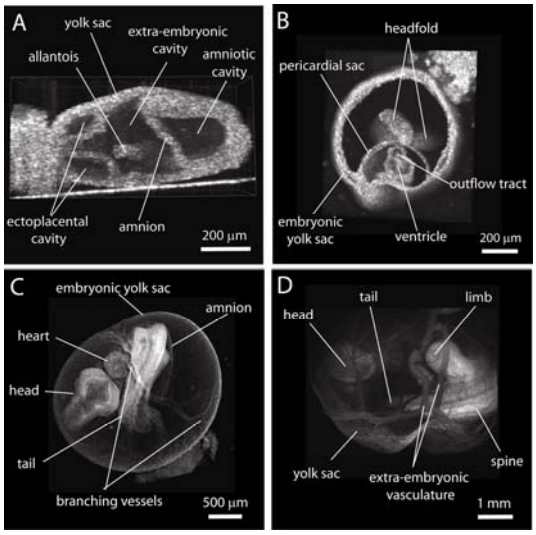


Figure 1: Structural imaging of early mouse embryos with OCT [1]. (A-D) 3-D reconstructions of live embryos cultured with the yolk sac at 7.5 dpc, 8.5 dpc, 9.5 dpc, and 10.5 dpc, respectively.

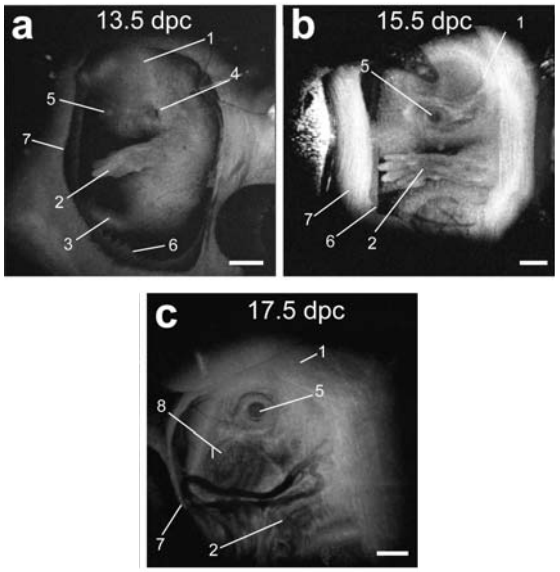


Figure 2: 3D reconstructions of mouse embryos *in utero* at different developmental stages [2]. 1, head; 2, forelimb; 3, hindlimb; 4, pinna of ear; 5, eye; 6, yolk sac; 7, uterine wall; 8, follicles of vibrissae. Scale bars correspond to 1mm.

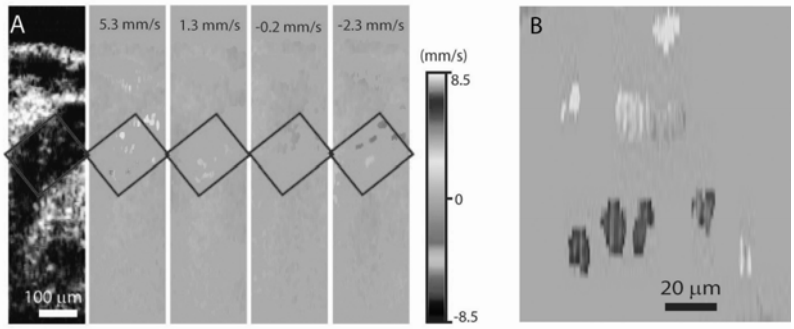


Fig. 3. Doppler OCT velocity signals from blood cells on the embryonic day 8.5 [3]. (A) Structural and corresponding color coded Doppler velocity images acquired at different phases of the heartbeat cycle. Green corresponds to zero velocity. Individual blood cells are distinguishable in the dorsal aorta. (B) Magnified view of the same area showing Doppler signal from single cells as well as a small group of cells.

References

1. K. V. Larin, I. V. Larina, M. Liebling, and M. E. Dickinson, "Live Imaging of Early Developmental Processes in Mammalian Embryos with Optical Coherence Tomography," Journal of Innovative Optical Health Sciences, vol. 2, pp. 253-259, 2009.
2. S. H. Syed, K. V. Larin, M. E. Dickinson, and I. V. Larina, "Optical Coherence Tomography for high resolution imaging of mouse development in utero," Journal of Biomedical Optics, vol. (in press), 2011.
3. I. V. Larina, S. N. Ivers, S. H. Syed, M. E. Dickinson, and K. V. Larin, "Hemodynamic measurements from individual blood cells in early mammalian embryos with Doppler Swept Source OCT " Optics Letters, vol. 34, pp. 986-988 2009.

I-2-BP

LASER TECHNOLOGIES FOR ASSESSING THE IN VITRO EFFECTS OF DIAMOND NANOPARTICLES ON BLOOD COMPONENTS

Alexander V. Priezzhev[1*], Andrei E. Lugovtsov[1], V.G. Ionova[2],
Chia-Liang Cheng[3], and E.V. Perevedentseva[3]
Physics Department and International Laser Center
M.V. Lomonosov Moscow State University,
Russia, 119991, Moscow, Leninskye Gory, b. 1, str. 2;
[2]*Research Center of Neurology, Russian Academy of Medical Sciences, Moscow, Russia;*
[3]*Physics Department, National Dong Hwa University, Hualien, Taiwan*
** avpriezz@gmail.com*

In our work, we studied the effect of NDs on blood microrheology, in particular, on the ability of red blood cells (RBCs) to deform in shear flow and to spontaneously aggregate. The research was motivated by the fact that the administration of NDs and other nanoparticles into a live organism is usually performed intravenously, i.e. via blood vessels. However the effect of nanoparticles on blood and on its ability to normally flow though the vessels of different radii is usually not accounted for.

To assess the effect of NDs on blood components, we used several laser technologies based on the detection of diffraction patterns from dilute suspensions of RBCs, diffuse light reflection from a layer of whole blood. We have conducted a series of *in vitro* measurements

of the deformability index and several parameters of aggregation kinetics, as well as on adsorption of protein molecules on ND surfaces. In our experiments, we used suspensions of NDs with sizes from 5 to 500 nm in bidistilled water of different concentrations, added to samples of freshly drawn human blood or protein solutions. The surface of ND particles was either raw or carboxylated (cND) to improve their biocompatibility.

We have found a concentration dependent negative effect of NDs and cNDs on both deformability and aggregation kinetics of RBCs in the *in vitro* experiments. In particular, incubation of RBCs with smaller NDs and cNDs (around 5 nm characteristic size) at lower concentrations (around 33 mg/mL) decrease the time of formation of both linear and 3D RBC aggregates and enhance the amplitude of spontaneous RBC aggregation in whole blood, which are overall negative physiologic effects. Incubation of RBCs with larger NDs and cNDs (around 500 nm characteristic size) as well as smaller ones in higher concentrations (around 330 mg/mL) lead to smaller negative effects which can be speculated as a result of small particles aggregation in concentrated suspensions and nonpenetration of relatively large ND particles and their aggregates into the RBCs through their membranes. Carboxylation of ND particle surface makes the negative effect of small cNDs less pronounced but does not totally abolish it. The effect of ND particles on shear deformability of RBCs is negative as well: the RBC deformability index is reduced all through the range of shear stresses (from 3 to 60 Pa). The reduction of the deformability index becomes more evident at higher concentrations (around 100 mg/ml).

The obtained results substantiate our conclusion on the importance of thorough studies of the effect of nanoparticles on blood rheologic properties, in particular, the concentration and size effects and the role of the particle surface functionalization, given the particles are to be delivered to the targets via the blood flow.

Acknowledgements: This work was supported by the RFBR grant 08-02-92002-HHC_a and the NSC grant 97-2923-M-259-001-MY3

I-3-BP

SINGLET OXYGEN AND BIOLOGICAL ACTION OF LASER RADIATION

A.A. Krasnovsky
A.N. Bach Institute of Biochemistry Russian Academy of Science – M.V. Lomonosov Moscow State University, Leninskii prosp., 33, Moscow, 119071, Russian Federation
phoal@mail.ru

It is known that pigment-photosensitized formation of reactive singlet molecular oxygen occurs upon laser irradiation of stained living cells and tissues. This process is thought to underlie laser-induced photodynamic killing of living cells and photodynamic therapy of cancer and bacterial infections. On the other hand, singlet oxygen can be generated by direct excitation of oxygen molecules by infrared laser radiation. Some time ago, an idea was advanced that this process might cause biological and therapeutic effects of infrared laser light (see [1,2] for refs on this subject). The present paper summarizes experiments of author's group devoted to modeling this effect in air-saturated organic and aqueous media under ambient conditions. It was found that laser irradiation at 1270 nm (30-1500 mW) and 760 nm (300-1500 mW) causes readily observed oxygenation of singlet oxygen traps tetracene and 1,3 diphenylisobenzofuran (DPIBF) dissolved in these media. The action spectra of photooxygenation measured in certain non-polar solvents and ethanol within the 1220-1290

and 740-790 nm range showed two narrow bands with the maxima at 1273±1 and 765±1 nm, coinciding with the major maxima of the absorption bands of molecular oxygen. Oxygenation was inhibited by quenchers of singlet oxygen β-carotene and sodium azide and accelerated with the increase of oxygen concentration. The data provide unambiguous evidence that photooxygenation of the traps occurs due to direct excitation of oxygen molecules according to the following mechanisms:

$$O_2 + h\nu_{765} \rightarrow {}^1O_2\,({}^1\Sigma g^+) \rightarrow {}^1O_2\,({}^1\Delta_g) \qquad (1)$$

$$O_2 + h\nu_{1270} \rightarrow {}^1O_2\,({}^1\Delta_g) \qquad (2)$$

$${}^1O_2\,({}^1\Delta_g) + \text{Trap} \rightarrow \text{oxygenation}$$

The obtained photochemical data allowed for estimation of the optical densities (A) and molar absorption coefficients (ε) of molecular oxygen corresponding to the transitions (1) and (2). The most accurate results were obtained from comparison of the photooxygenation rates upon direct and photosensitized oxygen excitation. In particular, it was found that for the 1270 nm band, ε is 0.003 in carbon tetrachloride, 0.0016 – in ethanol and 0.0007 $M^{-1}cm^{-1}$ in water with 0. 2 M detergent sodium dodecyl sulfate (SDS). For the 765 nm band, ε = 0.0009; 0.0006 and 0.00055 in these media. Significance of the obtained results for mechanistic studies of laser biological action and for elucidation of spectroscopy of dissolved oxygen molecules will be presented in discussion.

Acknowledgements: support of the Russian foundation for basic research and of the Program "Basic science- to medicine" of the Russian Academy of Science.

References:

1. A. Krasnovsky, Y. Roumbal, A. Strizhakov. Chem. Phys. Lett. 458, 195-199, 2008
2. A. Krasnovsky, J. Photochem. Photobiol., 196, 210-219, 2008
3. A. Krasnovsky, Y. Roumbal, A. Kozlov, Chem. Phys. Lett., submitted

I-4-BP

OPTICAL DIAGNOSTICS AND HYPERTHEMIA OF TUMOR WITH NANOTHERMOSENSITISERS

E. Zagaynova [1], Elagin V.[1,2], Sirotkina M. [1,2], Shirmanova M., Brilkina A.[2], Kamensky V[3], Kirillin M[3], Strikovsky A.[3], Yanin D.[3], Nadtochenko V.[4]
[1]Nizhny Novgorod State Medical Academy, Nizhny Novgorod, Russia
[2] N.I. Lobachevsky State University of Nizhny Novgorod, Nizhny Novgorod, Russia
3 Institute of Applied Physics Russian Academy of Science, Nizhny Novgorod, Russia
[4] Institute of Problems of Chemical Physics RAS, Moscow, Russia
ezagaynova@gmail.com

The aim of the research was to design a method of a local laser and microwave hyperthermia of a tumor with gold plasmon-resonant nanoparticles under noninvasive examination of the time of nanoparticles accumulation in tumor.

The cancer cells treatment was done by laser with the output power of 0.5 – 3 W for 10 min. The cells viability was estimated by MTT.

Cancer cells without nanoparticles didn't die after the laser treatment with the power up to 2 W. The cells with nanoparticles died at 0.5 W and reached 90 % level at 3W.

The laser and microwave treatment of experimental tumor was performed on CBA mice bearing with a cervical carcinoma transplanted subcutaneously and on human ovarian adenocarcinoma SKOV-3 cells. The gold nanorods had a plasmon resonance peak at 750 nm. The nanoparticles surfaces were coated with polyethylene glycol with 6000 and 40000 D molecular weight. Control of the nanoparticles accumulation in the tumor was carried out in vivo by means of optical methods (OCT, DOS) and a near-field microwave probing technique. In case of the laser hyperthermia the tumors were treated by an 810 nm diode laser for 20 minutes. The laser power was 1.2W. Two regimes of the microwave radiation were applied: 50 J and 150 J. The superficial and inner temperature was controlled noninvasively. The anti-tumor impact of the laser hyperthermia is confirmed by an inhibition of a tumor growth.

The time of nanoparticles accumulation in tumor was found to be maximal in 4-6 hours after intravenous injection. Heating of the tumor with nanoparticles occurred locally. The significant damage of the tumor with nanoparticles was obtained after microwave hyperthermia. Tumor growth inhibition was 64.7% (in case of laser treatment) and 74,3% (in case of microwave treatment).

Acknowledgements: The work was done under financial support of the Federal Agency in Science and Innovations (02.740.11.0713, 11.G.34.31.0017, 16.512.11.2053), the RFBR grant (09-02-00539).

I-5-BP

OCT IN DIAGNOSING OF TUMOR AND NON-TUMOR PATHOLOGIES

Natalia Shakhova[1], Irina Kuznrtsova[2], Olga Panteleeva[3], Olga Kachalina[4], Darja Bundina[4], Natalia Illarionova[5], Oxana Onoprienko[5], Ekaterina Yunusova[4]
[1]Institute of Applied Physics RAS, Ulyanov St.46, Nizny Novgorod, Russia;
[2]Regional Hospital, Rodionov St., 190, Nizny Novgorod, Russia;
[3]Clinical Hospital of the Russian Railways, 603011, Lenin Av., 18, Nizhny Novgorod, Russia
[4] Nizhny Novgorod Medical Academy 603000, Minin Sq., 10/1, Nizhny Novgorod, Russia
[5]Regional Oncological Clinic, Rodionov St., 192, Nizny Novgorod, Russia
shakh@ufp.appl.sci-nnov.ru

In spite of the rapid advance in medical sciences, problems of adequate diagnosing are still of great significance. In the recent years, different new methods of medical visualization are used[1-3]. However, information obtained by these methods is often not sufficient for identification of minor tissue alterations. In this study we demonstrate capabilities of optical coherence tomography (OCT) to detect tumor and non-tumor pathologies in gynecology. The important point here is that OCT was applied in difficult cases of diagnosis for detection of pathology with minimal clinical manifestation: early stages of cervical neoplasia, subclinical forms of pelvic inflammatory diseases (PID), "microscopic forms" of endometriosis, undiagnosed intrauterine disorders.

More than 500 female patients were enrolled in the study. The study was authorized by the Ethical Board, all the patients signed the informed consent. OCT imaging was performed during standard endoscopic procedures (laparoscopy, hysteroscopy, colposcopy) using different modalities (standard, high-speed and cross-polarization) of "OCT-1300U" (IAP RAS, BioMedTech Ltd., Nizhny Novgorod, Russia).

As a result OCT criteria of tumor and non-tumor disorders have been elaborated based on comparative analysis of the OCT data and the results of histological studies. It was shown that contrast of OCT images is decreased in tumor processes and, on the contrary, is increased in non-tumor pathologies. In cases of difficult interpretation of OCT data advantages of cross-polarization modality has been demonstrated.

Diagnostic value of OCT has been estimated with blind test of recognition of tumor (cervical neoplasia) and non-tumor (PID) pathologies. High diagnostic accuracy (on average 75%) has been shown.

Acknowledgements The authors thank the Russian Basic Research Foundation and Presidium of Russian Academy of Sciences (program "Fundamental Science for Medicine) for the financial support of this work. The authors are also grateful to the staff and management of the IAP RAS, Nizhny Novgorod Medical Academy, Regional Hospital, Regional Oncological Clinic and Clinical Hospital of the Russian Railways for the possibility to conduct this research study.

References:
1. K. Togashi, A. Nakai, A. Sugimura, «Anatomy and Physiology of the Female Pelvis: MR Imaging», Revisited Journal of magnetic resonance imaging. 13, 842–849 (2001)
2. M. Bazot, P. Malzy, A. Cortez, G. Roseau, P. Amouyal, E. Darai, «Accuracy of transvaginal sonography and rectal endoscopic sonography for the diagnosis of deep infiltrating endometriosis», Ultrasound Obstet. Gynecol. 30, 994–1001 (2007)
3. S. Basu, G. Li, A. Alavi, «PET and PET-CT Imaging of Gynecological Malignancies: Present Role and Future Promise», Expert Rev Anticancer Ther. 9(1), 75-96 (2009)

I-6-BP

ASSESSMENT OF MEDICAL TREATMENT EFFICIENCY BASED ON MULTIPLE BIOMARKERS MEASUREMENT

D. C. Dumitras[1*], S. Banita[1], A. M. Bratu[1], C. Matei[1], C. Popa[1, 2]
[1]*National Institute for Laser, Plasma and Radiation Physics,*
409 Atomistilor St., PO Box MG-36, 077125 Bucharest, Romania
[2]*Faculty of Physics, University of Bucharest, Romania*
** dan.dumitras@inflpr.ro*

Exhaled breath air analysis represents an attractive and promising novel approach for noninvasive detection of human biomarkers associated with different diseases. The breath air is a mixture of nitrogen, oxygen, carbon dioxide, water, inert gases, and traces of volatile organic compounds (VOCs). More than 1000 trace VOCs have been distinguished in human breath air, at concentrations from ppmV to pptV levels. To detect such low concentrations, we have developed a very sensitive instrument based on laser photoacoustic spectroscopy (LPAS) principles [1], able to measure trace gases with a sensitivity of 0.29 ppbV [2].

Due to extremely low level of the substances of interest in exhaled breath air and the interference of many components at a given laser wavelength, we investigated several measures to increase the accuracy for a single trace gas measurement: a) We studied the efficiency of absorptive trapping and cryogenic trapping to remove carbon dioxide and water vapors from exhaled breath samples. As a result, we found the minimum volume for the KOH trap and the optimum flow rate for transferring gas samples from collecting bags to the

photoacoustic (PA) cell [3]. b) We refined breath sample collection procedures from patients under medical treatment: alveolar collection vs. mixed expiratory collection; collecting bags; preparation of patients (antiseptic mouthwash, avoiding food for at least 12 hours); clean transfer of the gas samples from disposable bags to the PA cell in less than 6 hours [4]. c) We measured the photoacoustic signal at different CO_2 laser wavelengths to distinguish the influence of various absorbent gas components in the total content.

Our study involved assessment of breath ethylene and ammonia levels in patients with renal failure receiving hemodialysis (HD) treatment. The absorption coefficients of ethylene and ammonia at CO_2 laser wavelengths (9-11 μm) were precisely measured previously [1, 5]. Our measurements demonstrated that HD determines simultaneously a large increase of ethylene concentration in the exhaled breath (due to the oxidative stress) and a reduction of the ammonia concentration, correlated to the blood urea nitrogen level [6]. Analysis of ethylene and ammonia traces from breath may provide insight into severity of oxidative stress and metabolic disturbances and give information for determining efficacy and endpoint of HD.

References

1. D.C. Dumitras, *et al*., "*Laser photoacoustic spectroscopy: principles, instrumentation and characterization*", J. Optoelectron. Adv. Mater. 9, 3655-3701 (2007)
2. D.C. Dumitras, *et al*., "*Ultrasensitive CO_2 laser photoacoustic system*", Infrared Phys. Technol. J. 53, 308-314 (2010)
3. A.M. Bratu, *et al*., "*Removal of interfering gases in breath biomarker measurements*", J. Optoelectron. Adv. Mater. 13 (2011)
4. C. Popa, *et al*., "*Qualitative and quantitative determination of human biomarkers by laser photoacoustic spectroscopy methods*", Laser Phys. 21, No. 7 (2011).
5. D.C. Dumitras, *et al*., "*Evaluation of ammonia absorption coefficients by photoacoustic spectroscopy for detection of ammonia levels in human breath*", Laser Phys. 21, 796 (2011)
6. C. Popa *et al*., "*Ethylene and ammonia traces measurements from the patients breath with renal failure via LPAS method*", Appl. Phys. B 103 (2011)

I-7-BP

FIBRE-OPTIC SYSTEMS OF LASER LIGHT DELIVERY TO INTERNAL ORGANS AND TISSUE

V.Volkov
Prokhorov Institute of General Physics, Moscow , Vavilov 38, 11999, Russia
vlvlvolkov@yandex.ru

Fluorescence diagnosis (FD) and photodynamic therapy (PDT) are promising new directions in a wide spectrum of medical disciplines such as urology, dermatology, gynecology and neurosurgery. Fibers fabricated from polymers, glasses and other specialized materials have been successfully used in biomedical sensing and administration of light-induced therapy for more than a half of century. Ordinary light scattering fibre tips such as frontal or cylindrical ones have undoubtedly found a wide spread medical application for PDT in different clinics.

An optical probe combined with a laser electronic spectrum analyzer (LESA) produced by Biospec company is widely used as a common device for FD. It can be modified and adapted to different medical equipment by choice of receiving fiber number and its construction. For example, for FD and PDT of urology diseases like the bladder cancer an optical catheter based on a three-way Foley catheter has been designed for clinical trials. Now such systems

are being tested in Moscow clinics for PDT of bladder and prostate. The similar approach is acceptable for curing in a gynecology and neurosurgery.

A suitable quartz or sapphire introducer [1] can be connected with an optical fiber which has a cylindrical diffuser distal length ranging from 5 to 35 mm. There are few methods for a diffusing tip preparation of quartz fiber distal end such as HF-etching of quartz core, UV-laser microdrilling and others. We propose a simple method of cylindrical scattering surface preparation by means of TiO2 deposition. The real way to obtain even a monatomic layer on a bare quartz core is to put it in the solution of tetraethoxytitanium. In ambient due to a hydrolysis thin amorphous layers of TiO2 can be fabricated. Under annealing at 300-350 C the amorphous layer crystallizes in anataze structure. The attachment consisting of introducer and fiber diffusing tip matches to laser sources produced by Biospec Company in the wavelength of 600-970 nm range and power supply up to 30 Wt. The temperature can be changed from 36 up to 125ºC and the control is realized with use of an IR video camera.

The light delivery inclusive an introducer with quartz cylindrical diffuser enables to provide laser-induced therapy runs in internal organs by treatment on gold nanoparticles. Gold nanoparticles are promising to use them in the field of noninvasive photothermal therapy of cancer.

At present a large interest is shown in polymer-coated up-conversional nanoparticles loaded by photosensitizer molecules because they are considered as drug delivery systems for PDT administration of internals. High efficient PDT procedure of internals can be provided by introducer with long diffusing fiber tip.

References:
1. Shikunova I.A., Volkov V.V., Kurlov V.N., Loshchenov V.B. Sapphire needle capillaries for laser induced therapy of cancer. Al'm. Klin. Med., 17, 152 (2008)

I-8-BP

SENSITIVE AND FAST LASER-BASED SPECTROSCOPIC TECHNIQUE FOR ON-LINE DETECTION OF BIOLOGICAL TRACE GASES

Simona M. Cristescu, Denis D. Arslanov, Julien Mandon and Frans J. M. Harren
Molecular and Laser Physics, Institute for Molecules and Materials,
Radboud University, Nijmegen, the Netherlands
simona@science.ru.nl

Trace gases are distinctive indicators of biological processes that occur in plants, animals and humans. An excellent method for highly sensitive and selective detection of these volatile organic compounds is laser spectroscopy in the mid-IR spectral region, where many molecules have strong distinctive absorption patterns. To capture the dynamics of the gas concentrations and detect multi-component gas samples, a fast-scanning continuous wave singly-resonant Optical Parametric Oscillator (OPO) pumped by a fiber-amplified diode laser has been used. The OPO has several advantages in comparison with other sources of coherent radiation in the mid-IR region such as continuous tuning in the 3 - 4 μm wavelength range, narrow linewidth of 100 MHz, wavelength coverage of up to 5 cm^{-1} mode-hop-free tuning range at a speed of up to 100 THz/s and continuous wave output radiation power of 1.2 W.
All of these advantages in combination with cavity enhanced spectroscopy can be used to build a rapid and sensitive trace gas detector for a number of biologically relevant gases in the

mid-IR region at the sub-ppbv level of concentrations in a sub-second time scale. A fast response time of the system is demonstrated by measuring methane (CH_4), ethane (C_2H_6), water (H_2O), carbon dioxide (CO_2) and acetone (C_3H_6O) in exhaled human breath using OPO based Integrated Cavity Output Spectroscopy in its off-axis configuration.

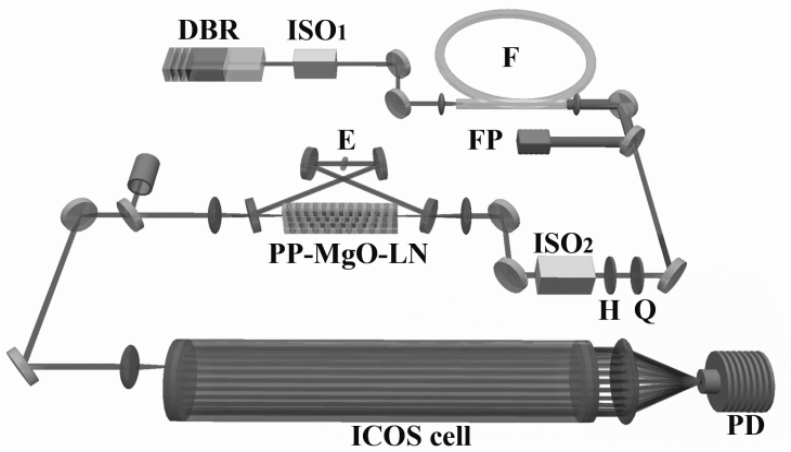


Fig. 1. Experimental setup. DBR- Distributed Bragg Reflector diode laser, ISO 1 and 2- isolators, F- double clad Yb-doped fiber, FP- fiber pump diode laser bar, Q- quarter-wave-plate, H- half-wave-plate, PP-MgO-LN- MgO-doped periodically poled lithium niobate crystal, E- intra-cavity etalon, ICOS cell- integrated cavity output spectroscopy cell, PD- photodetector.

References:

1. D. D. Arslanov, S. M. Cristescu, and F. J. M. Harren, "Optical parametric oscillator based off-axis integrated cavity output spectroscopy for rapid chemical sensing," Opt. Lett. **35**, 3300-3302 (2010).

I-9-BP

BIOPHOTONICS OF AQUATIC PHOTOSYNTHETIC ORGANISMS

V.V. Fadeev[1] and M.Y. Gorbunov[2]
[1]*Physics Department, M.V. Lomonosov Moscow State University, Russia*
[2]*Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Road, New Brunswick, NJ 08901, U.S.A.*
vfadeev@physics.msu.ru

Aquatic photosynthetic organisms (PSO) are the basal element of marine food webs and are responsible for oxygen evolution and carbon fixation. Biophotonics of PSO is complex and, despite of a century of research, is not fully understood. Application of novel technologies, for example, pico- and femtosecond laser spectroscopy, provides unprecedented insight into the photophysical and photochemical processes in PSO. Fluorescence spectroscopy is particularly important for the studies and diagnostics of PSO, because it exhibits much better sensitivity compared to absorption spectroscopy and allows one to perform measurements in a remote mode. Fluorometry provides information on the photophysical processes in the cell that are coupled to the processes of solar energy utilization and cellular defense against environmental stresses.

Here we present our developed fluorometric technologies, including Fluorescence Induction and Relaxation (FIRe) technique and Non-linear Laser Fluorometry (NLF), and overview their applications for biophotonics of aquatic PSO. The first technique allows one to determine a comprehensive set of photophysical parameters of the photosystem as a whole, whereas the second approach – molecular photophysical characteristics of chlorophyll *a* and other pigments.

The FIRe parameters characterize the excitonic energy transfer in the light-harvesting antennae, the photochemistry in Photosystem II, and the electron transport to carbon fixation. The NLF parameters include optical excitation cross sections, the rates of energy transfer including that of exciton-exciton annihilation, the lifetimes of excited states, and the quantum yield of fluorescense. PSO exhibit extremely fast rates of the energy transfer among pigments in the light-harvesting antennae and high efficiency of exciton-exciton annihilation that leads to the saturation of laser-induced fluorescence under much lower photon flux densities than it does in weak solutions of organic molecules. Because these photophysical parameters and related processes are particularly sensitive to environmental conditions, the fluorescence technology provides the basis for diagnostics and identification of natural and anthropogenic stressors.

Integration of FIRe and NLF allowed us to better understand how the photophysical processes in eukaryotic algae and cyanobacteria are affected by environmental factors, such as excess irradiance, nutrient limitation, change in salinity, and toxic pollution. We present and discuss applications of these technologies for assessment of nutrient limitation of primary production in the open ocean, thermal stress in coral ecosystems, and ecotoxicology (herbicides, heavy metals and petroleum toxicity).

The basic research on biophotonics of PSO provided the background for development of bio-optical technologies for non-invasive assessment of the physiological status of the organisms and for identification of natural environmental factors and anthropogenic stressors. These approaches and developed algorithms can also be used for fluorescent studies of other complex systems as ordinary and fluorescent proteins.

I-10-BP

NOVEL CHALLENGES IN 2D AND 3D MICROSCOPY OF LIVING CELLS

Herbert Schneckenburger[1,2], Michael Wagner[1], Petra Weber[1], Thomas Bruns[1], Verena Richter[1], Sarah Schickinger[1], Rainer Wittig[2]
[1]*Hochschule Aalen, Institut für Angewandte Forschung, 73430 Aalen, Germany*
[2]*Institut für Lasertechnologien in der Medizin und Messtechnik an der Universität Ulm, Helmholtzstr. 12, 89081 Ulm, Germany*
herbert.schneckenburger@htw-aalen.de

In addition to high spatial, spectral and temporal resolution, use of 3D models and application of low light doses are present challenges in live cell fluorescence microscopy. High resolution microscopy of 3-dimensional cell or tissue cultures, however, needs tomographic methods with selective information from individual planes. While confocal or multi-photon laser scanning microscopy are well established techniques, present experimental work is concentrated on wide-field microscopy with structured or single plane illumination. In addition, variable-angle total internal reflection fluorescence microscopy (VA-TIRFM) [1,2]

proved to be a valuable method for measuring cell-substrate topology with nanometre precision.

Presently, microscopic methods are optimized for 2D and 3D cell cultures of human glioblastoma cells and Chinese hamster ovary (CHO) cells. In addition, spectral and temporal resolution is used for spectral imaging and fluorescence lifetime imaging microscopy (FLIM). Applications include detection of tumour cells, pharmacological tests and studies of membrane dynamics in view of an early detection of neurodegenerative diseases [3,4].

Tolerable light doses for maintaining viability of native cells as well as cells incubated with various dyes or transfected with fluorescent protein encoding vectors were determined by a colony forming assay [5]. Based on these experiments, all microscopic measurements are performed under strict limitation of the applied light dose.

Acknowledgements: Present research is funded or financed by Land Baden-Württemberg, Europäische Union – Europäischer Fonds für die regionale Entwicklung –, Bundesministerium für Bildung und Forschung (BMBF), and Baden-Württemberg-Stiftung gGmbH.

References:
1. H. Schneckenburger, "Total internal reflection fluorescence microscopy: technical innovations and novel applications", Curr. Opin. Biotechnol, 16, 13-18 (2005).
2. M. Wagner, P. Weber, W.S.L. Strauss, H.-P. Lassalle, and H. Schneckenburger, "Nanotomography of cell surfaces with evanescent fields" Advances in Optical Technologies, Vol. 2008, Doi:10.1155/2008/254317E (2008).
3. C.A.F. von Arnim, B. von Einem, P. Weber, M. Wagner, D. Schwanzar, R. Spoelgen, W.S.L. Strauss, and H. Schneckenburger: "Impact of cholesterol level upon APP and BACE proximity and APP cleavage", Biochem. Biophys. Res. Commun. 370, 207-212 (2008).
4. P. Weber, M. Wagner, H. Schneckenburger: "Fluorescence Imaging of Membrane Dynamics in Living Cells", J. Biomed. Opt. 15, 046017 (2010).
5. M. Wagner, P. Weber, T. Bruns, W.S.L. Strauss, R. Wittig, H. Schneckenburger: "Light dose is a limiting factor to maintain cell viability in fluorescence microscopy and single molecule detection", Int. J. Mol. Sci. 11, 956-966 (2010).

I-11-BP

PHOTODYNAMIC MEDICINE - EXPECTATION OR DISAPPOINTMENT

Latchezar Avramov
Institute of electronics, Bulgarian Academy of Sciences,
1784 Sofia, 72, Tsarigradsko shossee blvd.
avramov@ie.bas.bg

Photodynamic Medicine (PDM) is a relatively new medical direction which appeared in the last several decades on the cross area of photophysics, photochemistry and quantum electronics. The terminology of PDM is an amazing combination of imprecise terms. Nevertheless, it is considered as a very promising medical field, both in diagnostics and treatment activities.

The oxygen-dependent photodynamic reactions were discovered by Oscar Raab in 1898 in Munich, during his research experiments with unicellular microorganisms paramecia influenced by light and different dyes, like acrydine. It was noted that an acrydine solution

killed paramecia after light irradiation. In the absence of light there was no such effect observed.

The key term - "photodynamic action" was introduced in 1904 by Raab's supervisor - prof. Hermann von Tappeiner, director of the Pharmacological Institute of the Ludwig-Maximilians University in Munich. It is not completely clear why he called the process "dynamic". His own latest attempt to change the term with "photochemical therapy" was unsuccessful because it already has taken place in the scientific vocabulary.

Photodynamic therapy (PDT) is a combination of three key components leads to the destruction of tumor cells. Its mechanism of action involves a photosensitizer, light with wavelength appropriate for the photosensitizer, and tissue oxygen. The treatment is used for eradicate premalignant and early-stage cancer and reduce the tumor size in end-stage cancers.

In 1995, the first system for early detection of bladder cancer was introduced into the market with the name Photodynamic diagnosis (PDD). PDD is based on the generation of a colour contrast, in which early malignant alterations can be differentiated from normal tissue. Photodynamic diagnosis may involve an application of a photosensitizer, which is injected into the tissue some time before the observation. Although this process also has no dynamic component it allows a significant increase in diagnostic results.

In this lecture the large diagnostic and treatment capabilities of the PDM will be shown, based on own results and on examples from the international experience. Also, the limitations related to factors of tissue optics and competition from alternative methods will be discussed.

References:

1. J. Moan, Q. Peng, "An outline of the history of PDT", in Photodynamic Therapy. Compr. Ser. Photochemistry and Photobiology, pp. 1–18, doi:10.1039/9781847551658, 2003.
2. A. O'Connor, W. Gallagher, A. Byrne, "Porphyrin and nonporphyrin photosensitizers in oncology: preclinical and clinical advances in photodynamic therapy", Photochem Photobiol., 85(5):1053-74, 2009.
3. P. Pavlova, E. Borisova, L. Avramov, El. Petkova, and P. Troyanova, "Investigation of relations between skin cancer lesion's images and their fluorescent spectra", Laser Physics, Vol. 20, No. 3, pp. 1–8, 2010.

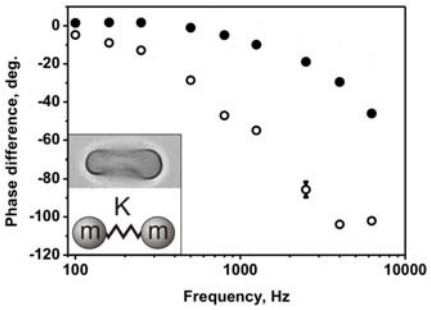
O-1-BP

DYNAMIC MEASUREMENTS OF RBC ELASTIC PROPERTIES BY MEANS OF OPTICAL TRAPPING TECHNIQUE

Khokhlova M.D. [1], Lyubin E.V. [1], Skryabina M.N. [1] and Fedyanin A.A. [1]
[1] *M.V. Lomonosov Moscow State University, Faculty of Physics, Moscow 119991 Russia*
khokhlova@nanolab.phys.msu.ru

Local methods for studying the elastic characteristics of complex materials at the microscale are of great practical and fundamental importance. Optical tweezers technique is a unique tool for exploring the problems related to the quantitative characterization of the objects at the microscale. This method is widely used to determine the elastic properties of cell membranes, in particular of the red blood cell (RBC) membrane. In this work optical tweezers technique is combined with a correlation analysis of the optically trapped RBC movement. This approach allows allocating correlated displacements of the RBC edges. These displacements are much

smaller than the amplitude of the cell's Brownian motion in the trap, and they can quantitatively characterize the elastic properties of individual RBC membrane.



Dual beam optical tweezers setup was arranged using two infrared lasers (980 nm and 1064 nm). Single erythrocyte was doubly trapped with the cell being not stretched or deformed. One of the traps was stable while the second one was oscillating with an amplitude of 100 nm in the range from 100 Hz to 1 kHz causing the displacements of the cell edge. Laser radiation scattered on the edges of the cell was used to measure the positions of the RBCs edges using QPD. This allowed measuring the phase difference in the movement of the erythrocyte edge in the stable trap relative to the edge which was controlled by an oscillating trap. A significant change in the phase difference between oscillations of the opposite edges of living RBCs and RBCs with rigid membranes fixed by glutaraldehyde was found (see figure below). Time dependence of the phase difference between oscillations of the opposite RBC edges with fixed frequency of forced oscillations of 5 kHz revealed a decrease in the phase difference value, which corresponds to an increase in the membrane stiffness.

O-2-BP

FLUORESCENCE DIAGNOSIS OF SKIN CANCER - CLINICAL ASPECTS

E. Borisova[1], E. Pavlova[2], P. Troyanova[2], P. Pavlova[3], L. Avramov[1]
[1]*Institute of Electronics, Bulgarian Academy of Sciences, 72, Tsarigradsko chaussee Blvd., 1784 Sofia, Bulgaria*
[2]*University hospital "Queen Jiovanna-ISUL", 8, "Bjalo more" str., Sofia, Bulgaria*
[3]*Technical University-Sofia, branch Plovdiv, 25 "Tsanko Djustabanov" str. Plovdiv 4000 Bulgaria*
borisova@ie.bas.bg

Laser-induced autofluorescence spectroscopy is very promising from a technical point of view due to the easy coupling with optical fibres for delivering the excitation light to every part of the human body without significant losses of light power, as is the case of incoherent light sources, as well as because of the possibility to use information from naturally occurring endogenous fluorophores, without adding external fluorescent markers. LIAFS is also notable among the other non-invasive diagnostic techniques, as it offers real-time detection and differentiation of the lesion investigated with promising precision, selectivity and specificity. The fluorescent technique is widely applied to cutaneous lesions' investigations, including erythema, psoriasis, vitiligo, and skin cancer. This method yields information about the biochemical composition of the tissue under study.

Our work is a stage in the development of methods for skin cancer diagnostics on the basis of autofluorescence spectra. The preliminary analysis showed that the spectra of lesions differ

from those obtained from normal tissue, with the differences observed depending on the type of pathology. Problems for development of reliable diagnostic fluorescence system for skin cancer detection are related to the great variety of benign and malignant forms of skin pathologies, Advantage is the fact that we could use LIAFS for evaluation of the lesion stage, drawback is that we will need to compare this exact situation with great variety of other possibilities, such as lesion kind, stage of growth, and even patient skin general conditions, such as influence of medicines, ages, cutaneous phototype, etc.

Our investigations are a part of a clinical trial for introduction of spectral diagnostic system for skin cancer detection in the common practice of the dermatological department of UH "Queen Jiovanna-ISUL". Autofluorescence spectroscopy is applied to several different classes of malignant non-melanoma cutaneous lesions. Initially, they were classified visually and dermatoscopically. Second step was detection of lesion' and surrounding normal skin autofluorescence using different excitation wavelengths, namely 365, 385, and 405 nm. In the end for every lesion histological examination is used as a "gold standard" for all our investigations.

The spectra and dermatoscopic evaluations were obtained from more than 350 patients up to now. Spectral properties of variety of benign cutaneous lesions are also evaluated for development of more precise discrimination algorithms for diagnosis of cancer lesions. The origins of diagnostically significant spectral features are evaluated and differentiation schemes will be discussed in our report. Clinical trial is currently under implementation and with broadening of the database with fluorescence spectra of major skin benign and malignant pathologies we expect to receive objective tool for detection and evaluation of skin lesion type, which could become a basis for reliable system for fluorescence detection of non-melanoma skin cancer.

Acknowledgements: This work was supported by the National Science Fund of Bulgaria of the Ministry of Education, Youth and Science under grant DO-02-112/08 "National Center on Biomedical Photonics"

O-3-BP

LASER FLUORESCENCE ANALYSIS METHOD USE FOR EXPRESS-DIAGNOSIS OF ANTIBIOTIC EFFICIENCY AMONG PERITONITIS AND ABDOMINAL SEPSIS PATIENTS

V.K.Gostishchev[1],V.A.Khomenko[2],G.B. Ivakhov[1],A.G.Kuzmina[1],G.P.Kuzmin[3], O.G. Gaponenko[2]

[1]First Moscow State Medical University by I.M.Sechenov, 119992 , Mochovaya, 11, Moscow
[2]Central TB Research Institute of the Russian Academy of Medical Sciences, 107564, Yauzskaya alley,2, Moscow
[3]Prokhorov General Physics Institute of the Russian Academy of Sciences/ 119991, Vavilov 38, Moscow
kuzmin@kapella.gpi.ru

Sepsis micro-biological diagnosis is defining to choose adequate regimes for anti-bacterial therapy. Etiotropic sepsis therapy results are much better than empirical ones. One of the fundamental instants of fast patient recovery is rational anti-bacterial therapy at early after operation period. Microbiological test methods of antibiotic efficiency are fairly long /till 7 days, according to micro-organism culture) and expensive. Therefore, at the most important period (early) antibacterial therapy is appointed without sensitivity or resistance patient confirmation to the given antibiotic sort.

Nowadays, the approach of the adequate antibiotic method choice is being developed with the laser fluorescence analysis blood plasma method with laboratory-diagnostic device "Spectrolux-MB" use /1/. It is used the microorganisms ability and products of their vital functions to fluoresce with laser radiation use in depending on features and physiological process activity in them. Different patient sensitivity to the same antibiotic for the same microbe sort is various as well. One of the advantages of fluorescence analysis method is to define the organism reaction on adequate antibacterial drug infusion and its influence on micro-flora that allows treating the patient not the disease.

The method includes the blood sampling from a patient vein and antibacterial therapy assignment - volume 20 ml (9 test tubes). After that the patient is provided by essential operative assistance. The test tube blood is centrifuged within 5 minutes. Antibiotics, which are often used in treatment, are diluted by the instruction in calculated min and max concentrations, added to the researched samples. One test tube - control. After that in automatic regime there is the fluorescence spectrum indicators measurement within 24 hours with 30 minutes break. There is the thermostat in the device which keeps 37^{o} C. The fluorescence level decrease indicates about the adequacy of chosen antibacterial drug , the changes lack or fluorescence increase - effect lack - the resistance to this antibiotic sort. Obtained results are confirmed by a microbiological research way. The plasma of 50 patients with various acute surgical pathology was researched. Each patient was taken blood sampling 3 times: at the checking in before the operation, after the operation, in 2 days to estimate the providing antibacterial therapy efficiency. If necessary there was an extra blood sampling for the antibacterial therapy correction.

The fluorescence analysis method has great prospects in urgent surgery and other medicine brunches due to its high information contest, low cost (compared with other methods of express-diagnostics) and information obtaining speed.

1. Alexandrov M.T., Kuzmin G.P., Gaponenko O.G., Khomenko V.A., Khokhlov E.M., Tikhonevich O.V. and Vasiliev E.N. Laser fluorescence spectroscopy and factor analysis in diagnostics of microbial diseases. Laser Physics, 2007, v.17,N3,p.p.290-295.

O-4-BP

MULTIWAVE MEDICAL DEVICE ON THE DIODE PUMPED SOLID STATE LASER FOR THE MICROBE NATURE DESEASE TREATMENT

G.P.Kuzmin[1], A.G.Kuzmina[2], O.V.Lovacheva[3], A.A.Sirotkin[1]
[1]*Prokhorov General Physics Institute of the RAS, 119991, Vavilov 38, Moscow*
[2]*First Moscow State Medical University by I.M.Sechenov, 119992 , Mochovaya, 11, Moscow*
[3]*Central TB Research Institute of the Russian Academy of Medical Sciences, 107564, Yauzskaya alley,2, Moscow*
kuzmin@kapella.gpi.ru

The laser medical device "Maria" on the basis krypton - fluoride eximer laser with the wavelength radiation 248 nm for the treatment of destructive lung tuberculosis forms has been developed in Prokhorov General Physics Institute of the Russian Academy of Sciences./1/. Treatment technique with the device use has been developed in Central TB Research Institute of the Russian Academy of Medical Sciences. The high technique efficiency of endocavernous treatment for destructive tuberculosis forms has been proved. However, laser medical device "Maria" has not been spread properly in medical practice because of its high

price. To its disadvantages we can relate clearance, weight and necessity to work with aggressive gas mixtures which demand specialized safety and periodical filling.

Based on the above, multiwave laser medical device "Livadia" has been developed used either for bactericidal or for therapeutic impact on the affected organism parts. This device is on the diode pumped solid state laser and main wavelength radiation conversion 1.064 mkm into the second harmonic 532 nm and forth harmonic 266 nm.

Therapeutic effect of the device use is achieved by multiwave radiation function in UF, visible and IR wavelength ranges. There is the opportunity to use either separate wavelengths or their combinations that allows choosing the most optimal radiation regime for each certain desease. Combined radiation effect can be used for endocavernous treatment for destructive lung tuberculosis forms. The alternative region use is purulent-inflammatory soft tissue processes treatment: combined radiation effect on the purulent-inflammatory process focus in soft tissues causes pathogenic microorganisms growth inhibition and simultaneous stimulation in reparative tissue processes. That is very actual in gynecology, otolaryngology, therapy and especially in purulent surgery.

In Central TB Research Institute of the Russian Academy of Medical Sciences the device "Livadia" clinical trials have been developed for bronchia tuberculosis treatment and nonspecific endobronchitis with endobronchial radiation use. It has been shown that UF radiation on the wavelength 266 nm on bronchia mucosa with various inflammation types improves regenerative processes in bronchia tissues that comes to treatment deadline decrease.

Acknowledgements: This work supported by Advanced Energy Technologies LTD

1. V.G.Dobkin, G.P.Kuzmin, O.V.Lovatcheva et al. Eximer Laser "Maria" in treatment lung and bronchia tuberculosis. International conference ALT'03,UK,2003,p.p.19-23.

O-5-BP

PROTEIN LAYERS TRANSFERRED BY MAPLE: STRUCTURAL, BIOCHEMICAL AND BIOLOGICAL CHARACTERIZATION

F. Sima[1,3], P. Davidson[2], E. Pauthe[3], O. Gallet[3], K. Anselme[2], C. Ristoscu[1], I.N. Mihailescu[1]
[1]*National Institute for Lasers, Plasma and Radiation Physics, Bucharest, Romania*
[2]*IS2M, CNRS LRC7228, Haute-Alsace University, 68057 Mulhouse Cedex, France*
[3]*ERRMECE, Cergy-Pontoise University, 95302 Cergy-Pontoise Cedex, France*
felix.sima@inflpr.ro

Proteins are complex in chemistry and structure with unpredictable charges which influence their attachment to surfaces. They easily can lose their structure and biochemical activity. Slow freezing or thawing could be source of their irreversible degradation. The protein conformation and activity preservation is therefore a difficult and challenging task. We report on matrix-assisted pulsed laser evaporation (MAPLE) transfer of intact protein molecules from a cryogenic target obtained by freezing a protein-saline buffer solution. Molecules of proteins (fibronectin or vitronectin) with distinctive active domains for cell signaling, were disrupted from frozen targets by KrF* excimer laser irradiation, attached and immobilized on neighbor substrates. Uniform distribution of proteins was revealed by Ponceau staining after control experiments on nitrocellulose paper. Well-organized particulates with heights from

hundreds of nm up to more than 1μm packed in a homogenous and uniform matrix were evidenced by optical microscopy and profilometry. This matrix acts as an organizing mediator for molecules and was found by micro- and nano-scale investigations to be composed of protein and buffer molecules. The buffer co-existing with protein molecules on solid substrates could further act as stabilizer for the protein. Comparison of infrared spectra of dropcast and MAPLE-deposited protein confirmed the preservation of composition and showed no degradation of the protein secondary structure either in the solution or after MAPLE transfer. The intact form of protein was demonstrated by antibody staining. Small aggregates along with fluorescent fibrils were visualized by fluorescence microscopy. Superior attachment of human osteoprogenitor cells to MAPLE protein layers in comparison with different control samples proved the presence of stable and intact molecules after MAPLE transfer.

O-6-BP

APPLICATION OF NONLINEAR LASER FLUORIMETRY FOR STUDYING PHOTOPROTECTIVE PROCESSES IN PHOTOSYNTHETIC ORGANISMS

Timofey Gostev[1], Victor Fadeev[1], Maxim Gorbunov[2]
[1]*Quantum Electronics Division, Department of Physics, Lomonosov Moscow State University. Leninskie Gory, 1, Block 2, Moscow, 119991, Russia*
[2]*Institute of Marine and Coastal Sciences, Rutgers University. 71 Dudley Road, New Brunswick, New Jersey, 08901, USA*
onewhowaits@mail.ru

Carotenoids play essential role in the functioning of photosynthetic apparatus. While under optimal conditions they contribute to the absorption of light and transfer the excitation energy to chlorophyll *a* (Chl *a*) molecules, under supra-optimal irradiance they also help to dissipate the excess excitation energy in the light–harvesting antennae of Photosystem II (LHC II). This is called non–photochemical quenching (NPQ) of the excited states of Chl *a* molecules and it is due to light stress–induced conversion of the carotenoid violaxanthin to pigment zeaxanthin (xanthophyll cycle). The role of the latter is still not clear: whether zeaxanthin leads to strong aggregation of the LHC II, or it can directly quench the excited states of Chl *a.*

We apply Nonlinear Laser Fluorimetry technique for studying photoprotective processes associated with zeaxanthin formation. The technique employs pulsed laser radiation with high photon flux density to excite Chl *a* fluorescence, and allows us to obtain a set of molecular photophysical parameters, including the effective excitation cross section of Chl *a* and rates of singlet–singlet annihilation. In case of the 660 *nm* laser excitation, the cross section is equal to the absorption cross section of Chl *a*, while in case of the 532 *nm* excitation the excitation of Chl *a* mostly originates from the energy transfer from carotenoids. Another photophysical parameter obtained using the proposed technique is the rate of singlet–singlet annihilation of the excited states of Chl *a* molecules, which is very sensitive to conformational changes (aggregation) in the photosynthetic antennae. In combination with Fluorescence Induction and Relaxation (FIRe) technique, the described method allows for complex study of the photophysical parameters of the LHC II pigments and the PSII in general, and their relation to the photophysical processes in the cell, including NPQ (particularly, related to the xanthophyll cycle).

In order to evaluate the proposed approach, we conducted laboratory experiments on the green alga, *Chlorella pyrenoidosa*, using a custom–built laser fluorimeter with dual–wavelength excitation (532 and 660 *nm*) and a FIRe fluorimeter. Photophysical parameters were measured for the alga in a dark adapted state and with induced NPQ, the excitation cross section, photochemical quenching rate and NPQ rate were obtained.

After the NPQ was induced, the 532 *nm* excitation cross section decreased by the amount of 15%, which is probably due to conversion of violaxanthin to zeaxanthin. This allows for rough estimation of the local concentration of violaxanthin in the LHC II. The rate constant of singlet–singlet annihilation increased by roughly 4 times, which indicates strong aggregation of LHC II.

The analysis of the whole set of photophysical parameters obtained using Nonlinear Laser Fluorimetry technique allows for clarification of the mechanisms of photoprotection (particularly, related to xanthophyll cycle).

O-7-BP

OPTICAL BIOINDICATION OF PROTEIN INTERACTION UNDER HEAVY METAL ION INFLUENCE

E.Shirshin[1], N. Zhdanova[1], A. Maskevich[2], V. Stepuro[2], M.Gorbunov[3], V. Fadeev[1]
[1]*Physics Department, M.V. Lomonosov Moscow State University, Russia*
[2]*Y. Kupala Grodno State University, Grodno, Belarus*
[3]*Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Road, New Brunswick, NJ 08901, U.S.A*
eshirshin@gmail.com

Aggregation of proteins in living systems caused by heavy metal ion influence is a common problem leading to number diseases. Therefore, new methods for indication of the aggregation processes are of great interest to medicine from both fundamental and a practical point of view.

This work was aimed at development of novel method of optical bioindication of aggregation processes at early stages based on the use of non-linear fluorimetry.

Classical (in the linear mode of excitation) fluorescence spectroscopy (fluorometery) is widely used to indicate the processes of aggregation. It usually operates with the rate of electronic excitation energy transfer (FRET) within a single macromolecule and between them that allows to determine the size and, in some cases, the geometry of the aggregates. However, usually there are no donor-acceptor pairs in protein aggregates – all fluorophores are identical in their spectral characteristics. Moreover, the determination of FRET rate with the use of classical methods has some restrictions (e.g., the value of donor's excited stated lifetime in the absence of acceptor is required).

A new method based on nonlinear laser fluorimetry and the model of collective states that allows to determine the rate of energy transfer in aggregates of proteins is covered in the report. The model of collective states of pairs of fluorophores is generalized to the case of oligomers. The rate of singlet-singlet annihilation, depending on the local concentration of fluorophores, is proposed as an indicator of aggregation. Model of collective states allows to obtain an analytical expression for the dependence of the rate of annihilation on the number of

subunits in the oligomer. In the case of large aggregates is possible to construct a model that takes into account the heterogeneity of distribution of the spectral properties of proteins along the radius of the oligomer (the simplest example of such a system is a BSA protein, in which the parameters of tryptophan inside and on the surface of the globule are different) – in this case the monomers are no longer identical.

O-8-BP

OPTICAL PROPERTIES OF WATER PLANTS IN THE PRESENCE OF SYNTHETIC SURFACE ACTIVE SUBSTANCES

Zakharov V.P., Timchenko E.V., Timchenko P.E., Bratchenko I.A., Zolotuhina A.D., Alembekov S.V.
Samara state aerospace university, Russia, Samara, Moskovskoe shosse street, 34
vorobjeva.82@mail.ru, zakharov@ssau.ru

In view of the ability to accumulate different types of pollutants aquatic plants are effective markers of the ecological state of the hydrosphere. They express the resistive function of the biological environment to the external influence. The definition of functional dependencies of optical characteristics of the plant tissue of aquatic plants on the concentration of pollutants in the aquatic environment is principle for remote ecological monitoring of the hydrosphere.

The freshwater macrophyte Elodea Brazilian (Elodea Brazilian, Egeria densa) was used as the object of the research. One-time volley ejection of pollutants (synthetic surface-active agents and/or salts of cadmium) with a fixed concentration of them was simulated in tanks with water at a constant intensity and regularity of the light flux. Water tanks were separated from external influence. Differential backscattering coefficient of plant tissue was experimentally registered. The presence of pollutants leads to a decrease in this coefficient over time. However, if in the case of heavy metal ejection the differential coefficient has quasi linear time dependence, then for surfactants impact the coefficient saturates at a characteristic period of 10-15 days. These qualitative differences were revealed by microscopic analysis of the plant using the confocal fluorescence microscopy. It was found that, in case of heavy metal salts impact the process of chlorophyll molecules "binding" is started, which microscopically appears as their "sticking" near the cell membrane. The total number of chlorophyll molecules varies only slightly, while the effective volume occupied by chlorophyll decreases quasi-linearly, leading to similar dependence of differential optical coefficient. In contrast, in the presence of surfactants the distribution of chlorophyll in the cell remains uniform, but its concentration decreases with increasing of surface-active agents concentration, leading to complete degradation of chlorophyll when the surfactants concentration exceeds tenths of a percent. The latter is due to the fact that surfactants solubilize proteins of the cell membrane, increasing its penetrability. It promotes the release of pigments from plants, thereby reducing their concentration and changing the differential optical coefficient.

Acknowledgments: This work was supported by the federal target program "The scientific and scientific-pedagogical staff of Innovative Russia" in 2009 - 2013.

O-9-BP

MICROSCOPIC DIAGNOSIS OF BONE IMPLANTS

Bratchenko I.A.[1], Zakharov V.P.[1], Timchenko P.E.[1], Volova L.T.[2], Boltovskay V.V.[2], Timchenko E.V.[1]
[1] *Samara state aerospace university, Russia, Samara, Moskovskoe shosse, 34*
[2] *Institute of Experimental Medicine and Biotechnology of the Samara state medicine university, Russia, Samara, Gagarina street, 20*
timpavel@mail.ru, zakharov@ssau.ru

A microscopic analysis of lyophilized bioimplants made from human connective tissue using «Lioplast» technology was performed. The analysis was performed using laser confocal fluorescence microscopy system, based on Olympus IX71 microscope and laser combine ANDOR. This system provided the scanning speed of up to 25 layers per second with resolution up to 400 nm.

The dynamics of osteoblasts in the model media studying showed that they form a monolayer with much greater length and surface area of the cells than in the natural medium (50-100 microns). Consequently, in confocal mode, the image has low contrast (not more than 0,2-0,3), which does not identify the internal structure of cells. Using phosphoramidite Cy3 derivatives, excited by laser radiation at the wavelength of 561 nm, allowed to increase the image contrast up to 0.9 and register the cell growth dynamics: the osteoblasts rms speed was 7-8 microns per hour. A partial monolayer is formed within the first 20 hours, on the second day cell spikes are connected to each other and their number is doubled. Complete monolayer is formed on the 6 day, after that the process of growth goes into the stationary phase. The same method was used for studying of the integration of osteoblasts in the bone implant. The porous structure of the implant absorbed fluorophore. However, the contrast of the image remains quite high (about 0,5-0,6) for reliable visualization of osteoblasts. Analysis of the micrographs suggests that osteoblasts actively integrate into the bone implant, mostly distributing on its surface and forming colonies near the exits of the pores of the implant. On the eighth day the density of active osteoblast is 500-700 cells/mm^2. The advantage of the developed technique is the ability to provide the dynamic control of osteoblast growth.

Acknowledgments: This work was supported by the federal target program "The scientific and scientific-pedagogical staff of Innovative Russia" for 2009 - 2013.

O-10-BP

DIFFUSE-REFLECTANCE SPECTROSCOPIC AND IMAGING DIAGNOSTIC METHODS FOR URINARY BLADDER

N. Kalyagina[1], W. Blondel[2], C. Daul[2], T. Savelieva[1], D. Wolf[2] and V. Loschenov[1]
[1]*Prokhorov General Physics Institute, Russian Academy of Sciences, 119991,Russia, Moscow, Vavilov Str., 38*
[2]*Centre de Recherche en Automatique de Nancy (CRAN UMR 7039), Nancy University, CNRS), 2 avenue de la forêt de Haye, 54516 Vandœuve-Les-Nancy, France*
nina.kalyagina@ensem.inpl-nancy.fr

Introduction: Laser light interaction with biological tissues can provide information on its structure and state on a cellular, multicellular and molecular level, which can be taken as a

basis of the diagnosis [1]. The laser wave, penetrated into a medium, changes its direction and intensity in a unique way in each tissue, due to the big variety of inner tissue morphology: density and structure, chromaticity and concentration of the scattering elements inside. Even though, the precise information about the tissue state at a microscopic level can be revealed by tissue biopsy, which is an invasive method, and sometimes is taken randomly, the optical techniques have a strong potential to be non-invasive and sensible to the micron changes, and to be applied for in vivo determination of tissue optical parameters.

At dysplasia, the small initial changes of a tissue, such as growth of the diameter, changes in the form, population density, and chromaticity [2], contribute to the light scattering and absorption processes of the tissue, and can be detected by a video camera on the tissue surface; while the presence of the photosensitizers in the pathological tissues influence on the Diffuse-Reflected Spectroscopic signal of the fluorescent light, which allows to estimate the tissue alterations by following the accumulations of the photosensible drug in the tissue.

Materials and Methods: Forward and inverse problems are commonly used for problematic solutions analysis of the tissue optical properties. In the forward problems, where several input parameters are known, the understudy process can be described by mathematical calculations, while in the inverse problems the unknown parameters can be obtained. Due to the similar construction of the diagnostic tools and conditions, the presented method allows combining the Diffuse Reflectance Imaging and Spectroscopy, which both focus on the surface light, back-scattered from the tissue.

Results: The areas of the surface Diffuse-Reflected signals change its size subject to the changes of the tissue optical properties. However, the differences become less visible with the approaching to the centre of the images, which makes the central signal of the Diffuse-Reflected light less informative, and allows providing analysis in a "contact" mode. It is figured out that the nuclei size growth gives the most significant impact to the DR distribution changes, while the population density augmentation can be hardly seen. The presented method may be used for the calibration for clinical diagnostics, and afterwards as an inverse method for determination of the optical parameters of the urinary bladder wall in a non-invasive form.

References:

1. E. Cauberg, D. de Bruin, D. Faber, T. van Leeuwen, J. de la Rosette, T. de Reijke, "A New Generation of Optical Diagnostics for Bladder Cancer: Technology, Diagnostic Accuracy, and Future Applications" European Urology Vol. 56, 287-297 (2009)
2. V. Backman, M. Wallace, L. Perelman, J. Arendt, R. Gurjar, M. Müller, Q. Zhang, G. Zonios, E. Kline, J. McGilligan, S. Shapshay, T. Valdez, K. Badizadegan, J. Crawford, M. Fitzmaurice, S. Kabani, H. Levin, M. Seiler, R. Dasari, I. Itzkan, J. Van Dam, M. Feld, "Detection of preinvasive cancer cells: Early-warning changes in precancerous epithelial cells can now be spotted in situ", Nature Vol. 406, 35-36 (2000)

II. OPTOACOUSTICS

I-1-OA

FUTURE BIOMEDICAL APPLICATIONS OF OPTOACOUSTIC TOMOGRAPHY

Alexander A. Oraevsky
TomoWave Laboratories, 675 Bering Dr., Houston, Texas, 77057
aao@tomowave.com

Detection of ultrasound resulting from the optical absorption represents a very sensitive means for detection of absorbing molecules in gases and liquids. However, applications of the optoacoustic spectroscopy without spatial resolution are limited. Biomedical applications of the laser optoacoustics exploded upon introduction made by our group of the physical principles governing acquisition of spatially resolved images in the depth of live tissues [1,2].

Our lecture will discuss the present accomplishments and prospectives of optoacoustic imaging starting with its physical principles, systems and finally biomedical applications that include diagnostic imaging cancerous tumors, monitoring cancer therapy and angiography. Ideas that made this rapidly developing technology possible were that (1) laser pulses may be effectively used to produce acoustic pressure in biological tissues, (2) the resulting acoustic (ultrasonic) waves can propagate in tissues with minimal distortion, (3) 2D and 3D maps (images) of the absorbed optical energy can be reconstructed with high resolution under the illumination condition of pressure confinement in the course of the optical energy deposition into a voxel to be resolved. Optoacoustic system provides optical contrast in tissue while mapping tissue structures with ultrasonic resolution. The main advantages of the optical contrast is the applicability of spectroscopic optoacoustic imaging to (1) map distributions of blood concentration and its oxygen saturation (functional imaging) in the given tissue, and (2) map distribution of molecules of interest, such as cancer receptors or other biomarkers (molecular imaging) using nanoparticles as contrast agents.

High optical contrast of hemoglobin in blood in the near-infrared spectral range makes optoacoustic imaging well suitable for visualization of vascular diseases. Three-dimensional images of the whole body of a mouse and a human arm will be presented to demonstrate applications of the optoacoustic tomography in angiography [3,4]. Capability to differentiate hypoxic blood from normally oxygenated blood makes diagnostic characterization of the tumor angiogenesis possible, thereby providing functional information for differentiation of malignant and benign tumors in the clinical practice [5]. The idea that drives present developments in the field of optoacoustic imaging is that coregistration of optoacoustic and ultrasonic images would be a useful enhancement of almost every application of medical ultrasound [6].

References:

1. A.A. Oraevsky et al: Determination of tissue optical properties by time-resolved detection of laser-induced stress waves. *Proc. SPIE v.*1882: 86-101 (1993).
2. A.A. Oraevsky et al: Laser based optoacoustic imaging in biological tissues, *Proc. SPIE v.*2134A: 122-128 (1994)
3. H.-P. Brecht et al: Whole body three-dimensional optoacoustic tomography system for small animals, *J. Biomed. Optics* v.14(6), 0129061-8 (2009).
4. M.P. Fronheiser et al: Real-time optoacoustic monitoring and three-dimensional mapping of a human arm vasculature; *J. Biomed Opt*. v.15(2): 021305 (2010).
5. S.A. Ermilov et al: Laser Optoacoustic Imaging System for Detection of Breast Cancer, *J Biomed Opt*. v.14(2): 024007 (2009).
6. S.Y. Emelianov et al: Combined ultrasound, optoacoustic and elasticity imaging, *Proc. SPIE* vol.5320: 101-112 (2004).

I-2-OA

ULTRASONICALLY BREAKING THROUGH THE OPTICAL DIFFUSION LIMIT: PHOTOACOUSTIC TOMOGRAPHY AND TIME-REVERSED ULTRASONICALLY ENCODED (TRUE) OPTICAL FOCUSING

Lihong V. Wang
Department of Biomedical Engineering, Washington University, St. Louis, Missouri, USA
LHWANG@WUSTL.EDU

Photoacoustic tomography (PAT) has been developed for functional and molecular imaging by physically combining optical and ultrasonic waves via energy transduction. Key applications include early-cancer and functional imaging. Light provides rich contrast but does not penetrate biological tissue in straight paths as x-rays do. Consequently, high-resolution pure optical imaging (e.g., confocal microscopy, two-photon microscopy, and optical coherence tomography) is limited to depths within one optical transport mean free path (~1 mm in the skin). Ultrasonic imaging, on the contrary, provides good image resolution but suffers from poor contrast in early-stage tumors as well as strong speckle artifacts. PAT—embodied in the forms of computed tomography and focused scanning—overcomes the above problems because ultrasonic scattering is ~1000 times weaker than optical scattering. In PAT, a pulsed laser beam illuminates the tissue and generates a small but rapid temperature rise, which induces emission of ultrasonic waves due to thermoelastic expansion. The short-wavelength ultrasonic waves are then detected to form high-resolution tomographic images. PAT broke through the diffusion limit for penetration and achieved high-resolution images at depths up to 7 cm in tissue. Further depths can be reached by thermoacoustic tomography (TAT) using microwaves or RF waves instead of light for excitation.

Light focusing plays a central role in biomedical imaging, manipulation, and therapy. In scattering media, direct light focusing becomes infeasible beyond one transport mean free path. All previous methods to overcome this diffusion limit lack a practical internal "guide star." We proposed and experimentally validated a novel concept, called Time-Reversed Ultrasonically Encoded (TRUE) optical focusing, to deliver light into any dynamically defined location inside a scattering medium. First, diffused coherent light is encoded by a focused ultrasonic wave to provide a virtual internal "guide star"; then, only the encoded light is time-reversed and transmitted back to the ultrasonic focus. The TRUE optical focus—defined by the ultrasonic wave—is unaffected by multiple scattering of light. Such focusing is especially desirable in biological tissue. Various fields including biomedical and colloidal optics can benefit from TRUE optical focusing.

References:

1. X. Wang et al., Nature Biotechnology 21, 803 (2003).
2. Y. Xu and L. V. Wang, Physical Review Letters 92 (3), 033902 (2004).
3. V. Ntziachristos et al., Nature Biotechnology 23 (3), 313 (2005).
4. H. F. Zhang et al., Nature Biotechnology 24, 848 (2006).
5. H. F. Zhang et al., Nature Protocols 2, 797 (2007).
6. H. Fang et al., Physical Review Letters 99, 184501 (2007). Editor's suggestion.
7. L. V. Wang, Nature Photonics 3 (9), 503 (2009).
8. M. S. Yavuz et al., Nature Materials 8, 935 (2009).
9. X. Xu et al., Nature Photonics 5, 154(2011).
10. J. F. Lovell et al., Nature Materials 10, 324(2011).

I-3-OA

LISTENING TO LIGHT AND SEEING BETTER: EVOLUTION OF OPTOACOUSTIC MOLECULAR IMAGING TECHNOLOGIES

Daniel Razansky
Institute for Biological and Medical Imaging
Technical University of Munich and Helmholtz Center Munich, 85764 Neuherberg, Germany
dr@tum.de

Biomedical optoacoustics has emerged in the recent decade as a powerful tool for high resolution visualization of optical contrast, overcoming a variety of longstanding limitations imposed by light scattering in deep tissues [1]. But true performance of optoacoustic imaging techniques can only be exploited when excitation at multiple wavelengths is used in order to enable highly sensitive spectral differentiation of intrinsic bio-markers and extrinsically-administered contrast agents [2]. By detecting tiny sound vibrations, resulting from selective absorption of light at multiple wavelengths, multi-spectral optoacoustic tomography (MSOT) can now deliver volumetric spectrally-enriched (color) images from deep living tissues at high spatial resolution and in real time [3].

These new-found imaging capabilities directly relate to pre-clinical screening applications in animal models and are foreseen to significantly impact clinical decision making as well [4]. This talk provides the technical essentials of MSOT, including latest developments in the inverse theory, spectral processing algorithms and imaging instrumentation. Furthermore, the state-of-the-art of molecular imaging applications using MSOT are discussed.

References:
1. L. V. Wang, "Photoacoustic Imaging and Spectroscopy", CRC Press, Boca Raton, FL (2009).
2. D. Razansky, M. Distel, et al., "Multispectral opto-acoustic tomography of deep-seated fluorescent proteins in vivo", Nature Phot. Vol. 3, 412-417 (2009).
3. V. Ntziachristos and D. Razansky, "Molecular Imaging by Means of Multispectral Optoacoustic Tomography (MSOT)", Chem. Rev., Vol. 110, 2783-2794 (2010).
4. D. Razansky, A. Buehler, et al., "Volumetric real-time multispectral optoacoustic tomography of biomarkers", Nature Prot., Vol. 6 (2011).

I-4-OA

PHOTOACOUSTIC MOLECULAR IMAGING AND TARGETED THERAPY USING GOLD NANOPARTICLES

Pai-Chi Li
Graduate Institute of Biomedical Electronics and Bioinformatics
Department of Electrical Engineering
National Taiwan University
paichi@cc.ee.ntu.edu.tw

Among various molecular imaging modalities, ultrasonic imaging and photoacoustic imaging provide unique advantages and also face specific challenges. Ultrasonic molecular imaging, on one hand, is based on mechanical properties of the image object and many unique

applications have been developed. With the aid of superior spatial resolution, high frequency ultrasound imaging has also evolved from clinical anatomical imaging to probing of molecular processes on small animals for pre-clinical research. Photoacoustic imaging, on the other hand, combines advantages of both optics and acoustics. Research developments in imaging physics and instrumentation have also found promising biomedical applications. In addition, microbubbles typically used in ultrasonic imaging as the contrast agent present unique mechanical properties and the associated acoustic cavitation has been exploited for therapeutic purposes. Similarly, gold nanoparticles are found to be an ideal contrast agent for photoacoustic imaging for its bioconjugation capabilities and presumed safety. The efficient light absorption of gold nanoparticles and abilities to tune their optical properties have also led to new photothermal therapy techniques. In this talk, physics, instrumentation and applications of ultrasonic and photoacoustic imaging will be reviewed. New development in combined diagnosis with therapy for both modalities will also be introduced, with a discussion on possible synergy and the technical difficulties that each modality faces, before critical clinical impact can be made.

O-1-OA

ACCUMULATION AND DETECTION OF RARE CELL TYPES IN THE CIRCULATION USING PHOTOACOUSTIC IMAGING AND COUPLED CONTRAST AGENTS

[a]Matthew O'Donnell, [a,b]Ivan Pelivanov, [a]Xiaohu Gao, [a]Jinjun Jia,
[a]Chen-wei Wei, and [a]Xiaoge Hu
[a]Dept. of Bioengineering, University of Washington, Seattle, WA 98195-2180, USA
[b]Moscow State University, Russia
odonnel@engr.washington.edu

All molecular imaging systems are limited by background signals from tissue. For example, nanoparticle agents with high optical absorption in the near infrared have been used to target diseased cells and increase specific contrast in photoacoustic (PA) imaging. However, background signals from tissue have limited the specificity of these agents. This is especially problematic for detecting targeted cells circulating in the vasculature where the large PA signal from blood can completely mask the contrast agent signal. For sensitive detection of targeted cells in the vasculature, their PA signal must be greatly enhanced compared to the blood background. Using a new class of contrast agents called coupled particles, we have developed technologies that can potentially accumulate and concentrate targeted cells while simultaneously enhancing their specific contrast compared to background signals. This approach leverages the high optical absorption and magnetic properties of composite nanoparticles including both magnetic and gold components. By manipulating these particles with an applied magnetic field, targets can be accumulated within the flow field and differentiated photoacoustically through motion processing algorithms providing excellent sensitivity and high contrast specificity. In this talk we will discuss the basic coupled agent technology, procedures for manipulating these agents for cellular accumulation and differentiation, and challenges remaining to translate this technology into clinical use.

O-2-OA

OPTOACOUSTIC TEMPERATURE MONITORING DURING THERMAL IMPACT ON BIOLOGICAL TISSUES: IN-VITRO STUDY

Sergey M. Nikitin[1], Tatiana D. Khokhlova[2,3], Ivan M. Pelivanov[1,2]
[1]*M.V. Lomonosov Moscow State University, Physics Faculty, 119991, Moscow, Russia*
[2]*International Laser Center of M.V. Lomonosov Moscow State University, 119991, Russia*
[3]*Center for Industrial and Medical Ultrasound, University of Washington, Seattle, WA, USA*
pelivanov@ilc.edu.ru

Preliminary study of the possibility of the optoacoustic (OA) method application in dynamic monitoring of temperature impact on biological tissues, for example induced by high intensity focused ultrasound (HIFU), is performed. HIFU therapy is a new promising method for treatment of different diseases, but the absence of a temperature monitoring tool prevents it from being widely used in clinic.

The proposed OA method is based on the temperature dependence of the efficiency of light-to-sound transformation in tissues and organs. Layered samples consisted of healthy and thermally coagulated tissues as well as the samples with HIFU lesions inside were studied experimentally to prove the OA method applicability in monitoring of a lesion location. The next stage of the current study was in the measurement of calibration curves: the dependences of the OA signal amplitude on the temperature in different *ex-vivo* tissues in the temperature range of 20°C - 80°C. We used chicken breast as a model of muscle, porcine liver as a model of richly perfused tissue, and lard as a model of fatty tissue. Characteristic features of the temperature dependencies in tissues under study were described in terms of the difference of its structures. Finally we performed the numerical simulation of the OA image dynamics during a typical HIFU impact within a tissue volume. It is shown that the temperature dependence of the OA image maximum coincides within a constant factor with the calibration dependence, justifying thus the possibility of real-time temperature reconstruction. Thus, the possibility of the dynamic temperature monitoring inside the tissue was demonstrated.

Acknowledgements: Authors appreciate Prof. O. Sapozhnikov for the help in the experiments with HIFU transducer, S. Il'in and Prof. V. Khokhlova for the help in simulation of the temperature field induced by HIFU. This work was partially supported by Russian Foundation for Basic Research (projects No. 07-02-00940-a, 10-02-01468-a) and International Science and Technology Center (project No. 3691).

O-3-OA

PHOTOACOUSTIC IMAGING USING AN ADAPTIVE INTERFEROMETER WITH A PHOTOREFRACTIVE CRYSTAL

A. Hochreiner[1], T. Berer[1,2], H. Grün[2], S. Zamiri[1], B. Reitinger[1,2], and P. Burgholzer[1,2]
[1]*Christian Doppler Laboratory for Photoacoustic Imaging and Laser Ultrasonics, Altenberger Strasse 69, 4040 Linz, Austria*
[2]*Research Center for Non Destructive Testing GmbH (RECENDT), 4040 Linz, Austria*
armin.hochreiner@recendt.at

In this paper we acquire photoacoustic signals remotely by using a two-wave mixing interferometer (TWMI). This setup allows measurement of ultrasonic displacements on a sample surface without the need of a coupling agent or a water bath [1].

Photoacoustic signals are generated by pulses from Nd:YAG nano-second laser. The signals are acquired utilizing a TWMI, as depicted in figure 1. In the TWMI interferometer a cw-laser with a wavelength of 532nm is split into a reference and signal beam. The latter is focused onto the sample surface and the back reflected light is collected by a lens system. Both beams are then interfered in a $Bi_{12}SiO_{20}$ photorefractive crystal (PRC). The PRC is operated in drift regime by applying an electric field of 7kV/cm. Interference of the deflected reference and signal beam is measured with a fast photodiode and a low noise amplifier.

We present remote measurements on a human forearm without the need for a coupling agent or water bath and three-dimensional imaging of artificial blood vessel networks. The artificial blood vessels consist of polymer tubes filled with human blood and are immersed in water/milk solutions. After data acquisition the initial pressure distribution is reconstructed by a Fourier domain synthetic aperture focusing technique (F-SAFT). In figure 2 (left and middle) F-SAFT reconstructions of a vessel network are depicted. The diameter of the vessels is 180µm. A photograph of vessel network is given in figure 2 (right).

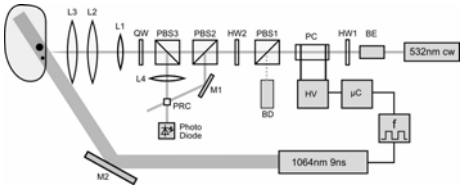


Figure 1) Schematic of the measurement setup

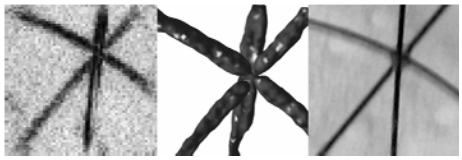


Figure 2) F-SAFT reconstructions of a blood vessel phantom: maximum intensity plot (left) and 3D plot (middle). (right) photograph of the phantom.

Acknowledgements: This work has been supported by the Christian Doppler Research Association, the Federal Ministry of Economy, Family and Youth, the Austrian Science Fund under project numbers S10503-N20 and TRP102-N20, the European Regional Development Fund in the framework of the European Union program Region 13, and the federal states of Upper Austria.

References:

1. T. Berer, A. Hochreiner, S. Zamiri, P. Burgholzer, "Remote photoacoustic imaging on solid material using a two-wave mixing interferometer" Opt.Lett 35, 4151-4153 (2010)

O-4-OA

COMPARISON OF FIBER OPTIC LINE DETECTORS FOR PHOTOACOUSTIC TOMOGRAPHY

T. Berer[1,2], H. Grün[1], I. Veres[1], K. Felbermayer[1], and P. Burgholzer[1,2]
[1]*Research Center for Non Destructive Testing GmbH (RECENDT), 4040 Linz, Austria*
[2]*Christian Doppler Laboratory for Photoacoustic Imaging and Laser Ultrasonics, Altenberger Strasse 69, 4040 Linz, Austria*
thomas.berer@recendt.at

In this paper various fiber-optical integrating line detectors used for photoacoustic imaging are examined experimentally and theoretically. Usually point-like piezoelectric detectors are used to measure photoacoustic signals. Integrating detectors, which integrate the pressure at

least along one spatial dimension, have been recently introduced [1, 2]. Thereby the three dimensional imaging problem is reduced to a two dimensional problem.

In this work we compare different types of fiber-optic detectors. We realized Fabry-Perot detectors and Mach-Zehnder detectors with glass optical fibers (GOF) and polymer optical fibers (POF). We show photoacoustic imaging utilizing these types of detectors. In addition we present calculated mechanical-optical transfer functions of the used fibers (figure 1). In general the response of the fibers is frequency dependent. Analytical models based on scattering problems are applied to predict the acoustically induced changes of the refractive index and birefringence in bare single mode fibers. An extension of the classical scattering problem, homogeneous cylinder submerged in water, has been applied for coated fibers as inhomogeneous layered cylinders [3]. Polymer-optical fibers show, because of their lower Young's modulus and their better impedance matching to water, a higher sensitivity. Moreover they exhibit virtually no birefringence.

Furthermore, we show simulations of ultrasonic wave detection with the mentioned fibers and analyze the influence of their frequency response on the quality of reconstruction.

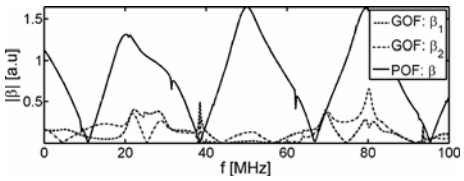


Fig. 1Calculated frequency response of a glass optical fiber (GOF), for two different polarization states parallel and perpendicular to the incoming wave (β_1 and β_2), and a polymer optical fiber

Acknowledgements: This work has been supported by the Austrian Science Fund under project numbers S10503-N20 and TRP102-N20, the Christian Doppler Research Association, the Federal Ministry of Economy, Family and Youth, the European Regional Development Fund in the framework of the EU-program Region 13, and the federal state of Upper Austria.

References:

1. M. Haltmeier, O. Scherzer, P. Burgholzer, G. Paltauf, "Thermoacoustic computed tomography with large planar receivers" Inverse Problems 20, 1663-1673 (2004)
2. P. Burgholzer, C. Hofer, G. Paltauf, M. Haltmeier, O. Scherzer, B. Reitinger, O. Höglinger, "Thermoacoustic tomography with integrating area and line detectors", IEEE Trans Ultrason. Ferroelectr. Freq. Contr. 52, 1577-83 (2005)
3. W. Huang, Y. J. Wang and S. I. Rokhlin, "Oblique scattering of an elastic wave from a multilayered cylinder in a solid. Transfer matrix approach", J. Acoust. Soc. Am. 99, 2742-2754 (1996)

O-5-OA

SHOCK WAVE STUDIES OF NANOSECOND LASER-INDUCED OPTICAL BREAKDOWN IN ABLATIVE PLUME AND DELAYED EXPLOSIVE BOILING

Sergey I. Kudryashov,[1] A.A. Ionin,[1] S.V. Makarov,[1] L.V. Seleznev,[1] D.V. Sinitsyn,[1]
K. Lyon,[2] P. Stanley,[2] S.D. Allen[2]
[1]P.N. Lebedev Physical Institute, RAS, 119991 Moscow, Russia
[2] Arkansas State University, Jonesboro, 119991 Arkansas, USA
sikudr@sci.lebedev.ru

Time-resolved ultrasonic studies revealed a second, delayed ablative pressure pulse after the first primary sub-critical ablative plasma pressure pulse in a silicon wafer irradiated by a 266-

nm, 10-ns laser. The intensity-dependent delay time for the second pulse indicates the existence of a corresponding intensity-dependent homogeneous vapor bubble nucleation time in the superheated molten silicon prior its phase explosion and ablative removal, since the integral pressure correlates with the ablation rate. The transient hot ablative plasma with calculated peak temperature ~ 30-90 eV and pressure ~ 20-110 GPa is suggested to superheat the bulk silicon via short-wavelength recombination and Bremsstrahlung emission.

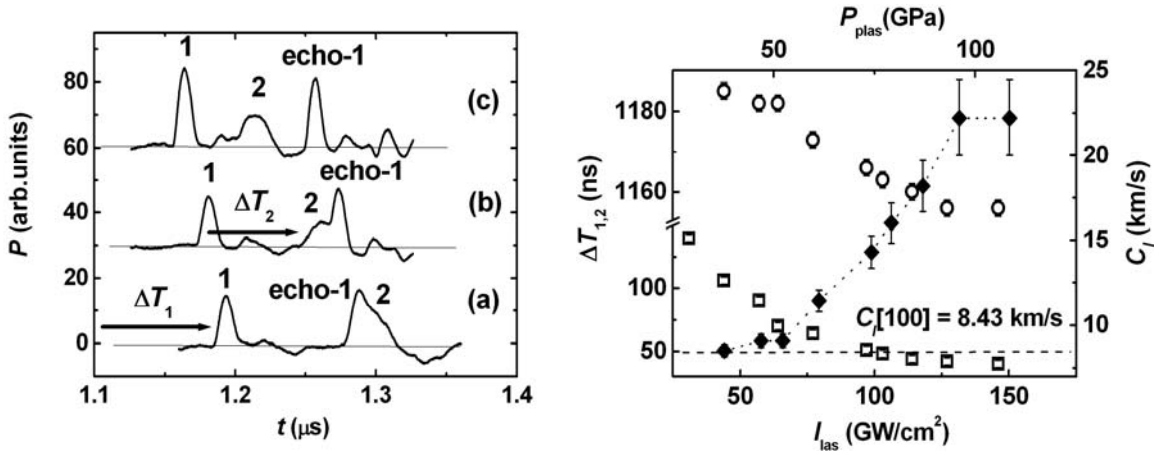


Fig.1. (left) Typical ultrasonic transients at laser intensity I_{las} = 44 (a), 77 (b) and 127 (c) GW/cm^2. The numbers *1,2* denote the first and second recoil ablative compression pulses, *echo-1* represents the round-trip echo of the pulse *1*, while ΔT_1 and ΔT_2 are the corresponding delay time relative to the laser pulse and the interpulse (1-2) delay time, respectively. (right) (left and bottom axes) Delay times ΔT_1 (light circles) and ΔT_2 (light squares) versus I_{las}. (right and top axes) Shock wave velocity C_l (dark rhombs) in the 400-μm thick silicon wafer versus calculated plasma pressure P_{plas} on its surface. The dashed horizontal line shows the normal longitudinal sonic velocity in Si in the [100]-direction, C_l[100].

Acknowledgements: This work was supported by Russian Foundation for Basic Research (projects nos. 10-08-00941-a, 11-02-01202-a and 11-08-01165-a).

References:

1. A.A. Ionin, S.I. Kudryashov, L.V. Seleznev, Near-critical phase explosion promoting breakdown plasma ignition during laser ablation of graphite, Phys. Rev. E **82**, 016404 (2010).
2. S.I. Kudryashov, S. Paul, K. Lyon, S.D. Allen, Dynamics of laser-induced surface phase explosion in silicon, Appl. Phys. Lett. (2011, accepted).

O-6-OA

DETECTOR OF MICROWAVE NANOSECOND PULSES BASED ON THERMOACOUSTIC EFFECT

Valeriy Andreev[1], Vladimir Vdovin[2]
[1]*Acoustics Dept., Faculty of Physics, Moscow State University, Moscow, Russia*
[2]*Institute of Radio Engineering and Electronics, Moscow, Russia*
andreev@acs366.phys.msu.ru

We present the results of testing a novel microwave detector based on the use of the thermoacoustic effect. The operation principle and the design of this detector were described in [1]. The detector is located in free space and is designed to record microwave pulses having

durations from 1 to 500 ns in the frequency range 3–3000 GHz with a pulse repetition rate of up to 5 kHz. Structurally, the detector is manufactured as a cylinder of 60 mm in diameter and 100 mm in height. The diameter of the input radiotransparent window is 20 mm.

The operation principle of this device is based on the fact that when electromagnetic radiation is absorbed in a medium, a mechanical stress arises, which leads to an excitation of the acoustic pulse whose shape is determined by both the properties of the absorber and the temporal profile of the electromagnetic signal. A specific feature of the proposed design is the use of a layered structure comprising a radiotransparent window, an absorbing medium in the form of a nanometer-thick metal film, and a liquid contacting the film. The choice of metal films with thicknesses about several nanometers is due to their ability to absorb efficiently incident electromagnetic waves. In particular, for aluminum film deposited on a quartz substrate, the maximum absorption coefficient amounts to 60% and is observed for the film thickness ranging from 2 to 3 nm [2].

The thermoacoustic detector was tested in experiments with the use of three sources of high-power microwave pulses. It is shown that for a pulse duration of 120 ns, the shape of the signal recorded by the thermoacoustic detector completely corresponds to the signal of a tube-diode detector of microwave pulses. The response of the thermoacoustic detector to shorter pulses (3 and 5 ns long) is a pulse with a duration of 18 ns which is determined by a limited frequency band of the acoustic receiver.

Acknowledgements: Work was supported by RFBR.

References

1. V. G. Andreev and V. A. Vdovin. A thermoacoustic detector for recording high-power nanosecond microwave pulses. Instrum. Exp. Tech., Vol. 52, No. 2, 226 (2009).
2. Andreev V.G., Vdovin V.A., Voronov P.S. An experimental study of millimeter wave absorption in thin metal films. Technical Physics Letters, Vol. 29, 953-955 (2003).

III. LASER DIAGNOSTICS

I-1-LD

NEEDLE RADIATION AND WIDE–ANGLE INTERFERENCE

Sándor Varró
Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences
1525 Budapest, POBox 49, Hungary
varro@mail.kfki.hu

According to the concept of needle radiation, as introduced by J. J. Thomson in 1903, in the elementary process of light emission, the radiations from a source are not distributed equally in azimuths, but are concentrated in certain directions. In 1905 A. Einstein introduced his point-like "Lichtquanten" ('light quanta' or 'photons'), on the basis of which the kinematics of the photoelectric effect could be explained. However, neither of these concepts could explain interference phenomena properly, and, in particular, both of them contradicted to the experimental results reported by Selényi [1] in 1911, Schrödinger (1920), and Gerlach and Landé (1926). In analysing the "crisis of the light quantum theory" in 1928, P. Jordan pointed out the fundamental significance of Selényi's classic wide-angle interference experiment. Later W. Kossel [2] considered Selényi's experiment as an optical analogon and the precursor of the observation of fine structure, Kossel-lines, in x-ray interference in crystals (see Fig.1). On the occasion of the centenary of Selényi's experiment, we discuss what relevance the question of needle radiation and wide-angle interference have in modern optics research.

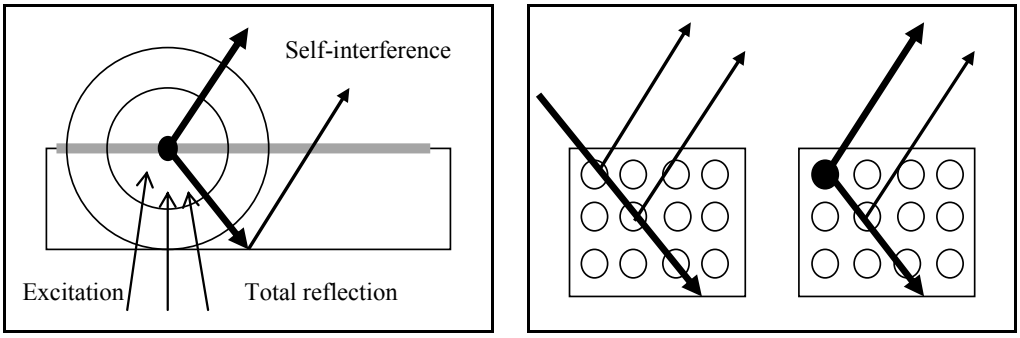


Figure 1. Sketch showing the analogy between the wide angle interference in Selényi's experiment [1] and the formation of Kossel lines in x-ray interferometry [2]. Left: A *very thin* fluorescent dye layer was put on the surface of a glimmer plate. The elementary radiation from an excited molecule is coherent over the whole solid angle. Right: the left part illustrates the fringe formation originating from an outer source by Bragg reflections. The secondary waves are coherent only *between each other*, because they are stemming from the *same* incoming ray, but the initial phase drops out. Right: the right part shows that a source atom *within the crystal* emits spherical waves, and the interference with the secondary waves results in the additional fine structure of fringes.

Acknowledgements. The present work has been supported by the Hungarian National Scientific Research Foundation, OTKA Grant No. 73728.

References:

1. P. Selényi, "Über Lichtzerstreuung im Raume Wienerscher Interferenzen und neue, diesen reziproke Interferenzerscheinungen". Ann. Phys. 17, 444-460 (1911). P. Selényi, "Wide-angle interference and the nature of the elementary light sources". Phys Rev. 56, 477-479 (1939)
2. W. Kossel, "Röntgeninterferenzen aus Gitterquellen". Ergebnisse der Exakten Natur-wissenschaften XVI pp. 295-352. (Springer-Verlag, Berlin, 1937)

I-2-LD

OPTICAL DIAGNOSTICS OF SEMICONDUCTOR NANO- AND MICROSTRUCTURES USING MICRO-RAMAN AND TIP-ENHANCED RAMAN SPECTROSCOPY

Tatiana Perova
Department of Electronic and Electrical Engineering,
Trinity College Dublin, Dublin 2, Ireland
perovat@tcd.ie

The analysis of the chemical composition, local mechanical stress and defects within semiconductor nanostructure with spatial and lateral resolutions at the nanometer scale are the most important problems in nanostructure science and technology today. In this presentation the results of our recent investigation of different submicron and nanostructure layers formed on silicon and germanium, namely carbon related materials (amorphous carbon, carbon nanotubes, SiC and graphene) as well as strained-Si, ultra-thin SiGe layers, Ge/Si quantum dots and Ge-on-insulator (GeOI) using micro-Raman and Tip-Enhanced Raman spectroscopy (TERS) are discussed.

The advantages of one-dimensional and two-dimensional Raman mapping techniques are demonstrated, for example, for composition and defect analysis of SiGe graded layers as well as for beveled Ge substrates subjected to ion implantation for layer transfer application. The Raman mapping of samples, beveled at angle of $<1^{o}$, provide a possibility of measurements with resolution of few nanometers along thickness direction. The results on peak position, linewidth and intensity of Raman spectra for dopant profiling, obtained for samples of Ge implanted with hydrogen and helium, are in good correlation with Secondary Ion Mass Spectrometry (SIMS) and spreading resistance profilings (SPR).

TERS, combining the advantages of surface imaging techniques such as Atomic Force microscopy (AFM) or Scanning Tunneling Microscopy (STM) and micro-Raman spectroscopy, is a uniquely powerful technique for the characterization of nanostructure properties at the nanometer scale. We demonstrate TERS-signals with a lateral resolution of less than 50 nm from single Ge/Si dome-shaped dots and from single-wall carbon nanotubes. Ge quantum dots have a base width of 50-100 nm and a height of 6-15 nm. The Raman shifts and the relative intensities of the TERS bands from single dots are in agreement with our data obtained earlier using a polarized micro-Raman technique for the Ge/Si dot with Ge content of $x \sim 0.5$.

The theoretical and experimental results on Raman signal enhancement for single layer of graphene, deposited on dielectric layers of different thicknesses, as well as for SiC layer grown on the top of the voids, formed in Si substrate during solid-gas phase epitaxial growth of 3C-SiC thin films, are also presented.

I-3-LD

OPTICAL DIAGNOSTICS OF SEMICONDUCTOR NANOCRYSTALS

V. Yu. Timoshenko
M.V.Lomonosov Moscow State University, Physics Department, 119991 Moscow, Russia
timoshen@physics.msu.ru

Semiconductor nanocrystals (SNC) are interesting objects for basic research and applications. Light emmiting properties of SNC can be applied in new generation of optoelectronic devices as light-emmiting diods, lasers and optical amplifiers. Silicon nanocrystal (nc-Si) structures are known to be light-emitting under optical or electrical excitation. One of the methods of nc-Si structure preparation is SiO_x ($1<x<2$) thin layer deposition and subsequent high temperature annealing. The nc-Si formation occurs at the annealing temperatures higher than some critical one, while at lower temperatures presumably amorphous nanoclusters grow. In our work the structure and optical properties of thermally annealed SiO_x ($x\sim1$) films were investigated using transmission electron microscopy (TEM) and spectroscopic methods of infrared absorption, Raman scattering and photoluminescence (PL). Also the PL properties of colloidal SNC (quantum dots) of CdSe and Cd(Cu)Se with mean size of 3-4 nm have been investigated.

The reactive evaporation of SiO powder was used to grow 500 nm SiO_x films on quartz and sapphire substrates. The deposited films were then annealed in N_2 atmosphere at temperatures (T_a) ranged from 350 ^oC to 1200 ^oC. The samples annealed at $T_a<950$ ^oC exhibit the Raman scattering band at about 480 cm^{-1}, which is typical for amorphous Si. The Raman line at 519 cm^{-1} is detected for the samples annealed at $T_a=950$ ^oC that indicates the formation of nc-Si. The intensity of the peak at 519 cm^{-1} grows with increasing T_a, which can be explained by an expansion of the nc-Si fraction in SiO_x matrix. It should be noted that the maximum of the Raman spectra of nc-Si is shifted down as compared with 520.5 cm^{-1} peak position for the bulk crystalline Si. This shift is usually attributed to the phonon confinement in nc-Si with sizes of 3- 4 nm. The Raman scattering analysis agrees with the TEM data. It was found that PL intensity of SiO_x films depends non-monotonically on T_a, namely two PL intensity maxima were observed at 600 ^oC and 1100 ^oC. The observed modifications of the Raman and PL spectra of SiO_x films are explained by a model of the structure transformations of silicon-rich suboxide, which result in growth of amorphous or crystalline nanoclusters in SiO_2 matrix. The samples with nanocluster network can be recommended for applications in Si-based light emitting devices excited by electrical current.

The PL properties of SNC of Cd(Cu)Se are found to be different for those of undoped ones. In particular the PL spectrum of Cd(Cu)Se SNC exhibits a broad peak with maximum at 1.5 eV. SNC doped with copper exhibited different PL lifetimes. While the PL transients of undoped SNC are well described by bi-exponential law, the PL transients of copper-doped SNC follow so-called stretched exponential decay. The observed modification of PL spectra and lifetimes can be explained by copper-induced transformations of the luminescent centers in Cd(Cu)Se nanocrystals.

Acknowledgements: This work is supported by the Russian Foundation for Basic Research (grants # 11-02-01342-a) and by the Ministry of Education and Science of the Russian Federation.

I-4-LD

LASER DIAGNOSTICS OF METAL OXIDES NANOPARTICLES IN DIELECTRIC MATRICES

Vladimir Gayvoronsky
Institute of Physics NAS of Ukraine, pr. Nauki 46, 03680 Kiev, Ukraine
vlad@iop.kiev.ua

It is difficult to find any field of the contemporary applications without nanocomposites based on metal oxides nanoparticles. Fuel and solar cells, antireflective and protective coatings, biocompatible materials and food additives, dyes/pigments, waste air/water treatment and catalysis materials, new types of junctions, essential part of many optical/optoelectronic applications, light emitting, recording devices and sensors are based on utilization of their bulk/interface characteristics combination. The general property of the metal oxide nanoparticles is an existence of the oxygen vacancies both in the bulk and at their developed interface that have corresponding deep gap state [1]. A resonant excitation of the state provides a universal tool to control photogenerated carriers' separation, efficiency of the redox reactions and local field enhancement at the nanoparticles interface. The effect of the giant nonlinear response was observed in porous layers of the TiO_2 nanocrystals (anatase modification) with enhancement of cubic nonlinear optical (NLO) susceptibility of six orders of magnitude in comparison with bulk one due to the resonant excitation of the oxygen vacancies within picosecond range laser pulses [2]. The effect correlates within defect and ESR active centers concentration, and can be applied for the photocatalytic activity of the titania. The similar phenomena were observed for the alumina, ZrO_2, Si/SiO_2 porous layers.

We have studied the quadric and cubic NLO responses of novel nanocomposite materials based on metal oxides nanoparticles (NPs) incorporated into the KDP single crystal for laser frequency conversion efficiency control. It was shown that the incorporation has no essential effect on structural perfections of the composite materials. In the growth process the KDP matrix can capture the NPs between the growth layer stacks forming the 1D structure …KDP:TiO_2:KDP… with spatial period ~ 15 μ. The incorporated NPs reveal a giant cubic NLO response [2] without decreasing the laser damage threshold and optical quality [3] at low particle mass loadings. Within single pulse excitation of mode-locked Nd:YAG laser at 1064 nm we have observed the following effects: (i) sign inversion of the refractive index NLO variation – self-defocusing effect in the KDP turns to self-focusing one in the KDP:TiO_2 at moderate intensity range [3], whereas photoinduced absorption increases insignificantly; (ii) enhancement of the second harmonic generation efficiency at about 20 % in comparison with the KDP crystal in phase-matching conditions. So essential transformation of the NLO response can be explained by the partial contribution of the anatase NPs subsystem and by its possible non-local impact on the matrix hydrogen bonding network caused by the NPs giant NLO effect.

Acknowledgements: The research was partially supported by the STCU grant # 4956 and joint SFFR-RFBR grant Φ40.2/098.

References:

1. M. Ganduglia-Pirovano, A. Hofmann, J. Sauer " Oxygen vacancies in transition metal and rare earth oxides" Surf. Sci. Rep. 62, 219 – 270 (2007).
2. V. Gayvoronsky, A. Galas, V. Timoshenko et al. "Giant nonlinear optical response of nanoporous anatase layers" Appl. Phys. B 80, 97–100 (2005).
3. I. Pritula, V. Gayvoronsky, M. Kolybaeva et al. "Effect of incorporation titanium dioxide nanocrystals on bulk properties of KDP crystals" Opt. Mat. 33, 623-630 (2011).

I-5-LD

LASER SPECTROSCOPY OF CESIUM-VAPOR LAYERS WITH NANOMETRIC THICKNESS

S. Cartaleva[1], A. Krasteva[1], L. Moi[2], A. Sargsyan[3], D. Sarkisyan[3], D. Slavov[1], P. Todorov[1], K. Vaseva[1]
[1]*Institute of Electronics, Bulgarian Academy of Sciences, boul. Tzarigradsko shosse 72, 1784 Sofia, Bulgaria*
[2]*CNISM and Physics Department, University of Siena, via Roma 56, 53100 Siena - Italy*
[3]*Institute for Physical Research, National Academy of Sciences of Armenia, Ashtarak-2, 378410, Armenia*
stefka-c@ie.bas.bg

High resolution laser spectroscopy of alkali vapor contained in conventional thermal optical cells with centimeter dimensions is widely used for various applications: among them wavelength references, atomic clocks, precise optical magnetometers, slow and stored light etc. For these photonic sensors, the reduction of their dimensions is of significant importance.

Our communication will concern the high resolution laser spectroscopy of alkali vapor confined in unique optical cell with nanometric thickness, further on called Extremely Thin Cell (ETC). The dimensions of such cell differ significantly [1]. The distance between the high-quality cell windows L varies from 100nm to (1-6)μm. At the same time, the windows diameter is about 2cm. Therefore, a strong spatial anisotropy is present for the time of interaction between the atoms and the laser radiation, which leads to a strong reduction of the Doppler effect. Two kinds of atoms can be distinguished – "slow" and "fast", which leads to observation of a significant difference between the fluorescence and transmission spectra. The main peculiarities of fluorescence and absorption spectra of atoms confined in nanometric cells will be presented and analyzed using the developed theoretical model in Ref.[2]. In such an atomic ensemble a series of coherent effects occurs [3], which are subject of intensive current study. Results will be presented related to Electromagnetically induced transparency preparation in ETC with thickness $L = 1.5\lambda$, where $\lambda = 852$nm is the wavelength of the laser light resonant with Cs D_2 line. The ETC properties could make possible optical cell miniaturization without buffer gas using. Beside for optical cell miniaturization, the proposed two-laser system could be advantageous for further Dicke effect study in ETC. The spectral behavior of the open and closed hyperfine optical transitions will be discussed as a promising approach for the investigation of atom-light, atom-atom and atom-cell window surface interactions. Results to be presented will contribute to further advancement in the fundamental studies of the coherent effects, saturation and optical pumping processes in alkali-vapor layers with nanometric thickness. The main possibilities for practical applications of the systems involving ETCs will be discussed.

Acknowledgements: The work is partially supported by the Bulgarian NCSR (grant No: DO 02-108/22.05.2009) and Indian -Bulgarian (BIn-2/07) bilateral contract**.**

References

1. D. Sarkisyan, D. Bloch, A. Papoyan, and M. Ducloy, "Sub-Doppler spectroscopy by sub micron thin Cs vapour layer", Opt. Commun., Vol.200, 201-208 (2001).
2. C. Andreeva, S. Cartaleva, L. Petrov, S.M. Saltiel, D. Sarkisyan, T. Varzhapetyan, D. Bloch, M. Ducloy, "Saturation effects in the sub-Doppler spectroscopy of Cesium vapor confined in an extremely thin cell", Phys. Rev. A, Vol.76, 013837 (2007).
3. S. Cartaleva, S. Saltiel, A. Sargsyan, D. Sarkisyan, D. Slavov, P. Todorov, K. Vaseva , "Sub-Doppler spectroscopy of cesium vapor layers with nanometric and micrometric thickness", JOSA B, Vol. 26, 1999-2006 (2009).

O-1-LD

PHOTOLUMINESCENCE PROPERTIES OF CADMIUM SELENIDE QUANTUM DOTS

G.I. Tselikov[1], S.G. Dorofeev[1], G.A. Shandryuk[2], A.S. Merekalov[2], V. Yu. Timoshenko[1]
[1]*Moscow State University, 1, building 2-3, Leninskiye Gory, Moscow, Russia 119991*
[2] *A.V. Topchiev Institute of Petrochemical Synthesis, Russian Academy of Sciences, 29 Leninskii prospect, Moscow, Russia, 119912*
celikov@physics.msu.ru

Semiconductor nanocrystals - quantum dots (QDs) have received much attention in the last years. On the one hand, the investigations of such systems are motivated by possible applications in optoelectronic devices. On the other hand, QDs are of great interest for basic research. We studied photoluminescence (PL) properties of colloidal CdSe and Cd(Cu)Se QDs with mean size of 3-4 nm [1] as well as CdSe QDs embedded in polymer matrix of liquid crystal BA-6PA [2]. The experimental results revealed nonmonotonic dependence of the PL peak position for colloidal CdSe QDs as function of the excitation photon energy varied from 2.41 to 3.68 eV. This effect can be explained by considering both the size distribution of nanocrystals and the specific spectral dependence of absorption coefficient [1].

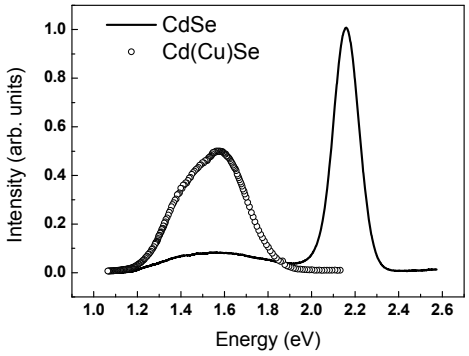


Fig. 1. Typical PL spectra of the investigated QDs.

The PL properties of Cd(Cu)Se QDs are found to be different for those of undoped QDs. In particular the PL spectrum of Cd(Cu)Se QDs exhibits a broad peak with maximum at 1.5 eV (Fig. 1). Furthermore it was found that QDs doped with copper exhibited different PL lifetimes. While the PL transients of undoped QDs are well described by a bi-exponential law, the PL transients of copper-doped QDs follow so-called "stretched" exponential decay. The observed modification of PL spectra and lifetimes can be explained by copper-induced transformations of the luminescent centers in Cd(Cu)Se QDs.

The PL properties of polymer/CdSe nanocomposites are found to be strongly dependent on the concentration of QDs in the polymer matrix. In particular, an increase of the PL intensity of QDs and PL lifetime changes were observed for the samples with larger QD concentration. The experimental results are explained by the energy transfer between the polymer matrix and QDs.

References :

1. G.I. Tselikov, S.G. Dorofeev, V.Yu Timoshenko, "Photoluminescence properties of doped with copper cadmium selenide quantum dots" Semiconductors 45(9) 1222-1224 (2011).
2. R.V. Tal'roze, G.A. Shandryuk, A.S. Merekalov et. al., "Alignment of nanoparticles in polymer matices", Polymer Science A, 51 1194-1203 (2009).

O-2-LD

SILICON NANOPARTICLES OBTAINED BY MECHANICAL GRINDING OF POROUS SILICON FILMS AND THEIR BIOIMAGING APPLICATIONS

L.A. Osminkina[1], R.A. Galkin[1], K.P. Tamarov[1], A.P. Sviridov[1], M.B. Gongalsky[1], A.A. Kudryavtsev[2] and V.Yu. Timoshenko[1]
[1] *Moscow State M.V. Lomonosov University, Physics Department, 119992 Moscow, Russia*
[2] *Institute of Theoretical and Experimental Biophysics, Russian Academy of Science, Pushino, 142290 Moscow region, Russia*
osminkina@vega.phys.msu.ru

It is known that crystalline silicon (c-Si) has a dominant role in electronics industry, but in fact it also can play important roles in biomedicine. For example, the biocompatibility and biodegradability of porous nanoparticles were demonstrated [1].

The nanoparticles of porous silicon (nc-PSi) were fabricated from porous silicon (PSi) films by using mechanical grinding (milling) in water. It was done in a planetary mill «Pulverisette 7 premium line» (FRITSCH). PSi films were formed by the standard method of electrochemical etching of (100)-oriented c-Si wafers. Size of nc-PSi was measured in a transmission electron microscope (TEM) LEO912 AB OMEGA. Photoluminescent (PL) properties were investigated by using a N_2-laser radiation at 337 nm for the excitation. *In vitro* experiments were carried out with cancer cells Hep-2 (human laryngeal cancer).

Stable aqueous suspensions of nc-PSi with size of nanoparticles of about 200 nm have been prepared and investigated. The TEM analysis revealed periodic arrangement of the electron diffraction pattern, which indicates that the nc-PSi particles retain their crystalline structure (see fig.1 and the inset). The PL spectra of nc-PSi are characterized by intensive broad band centered near 1.6 eV. These PL spectra can be interpreted as the radiative recombination of excitons confined in Si nanocrystals with mean sizes of about 3 nm [2].

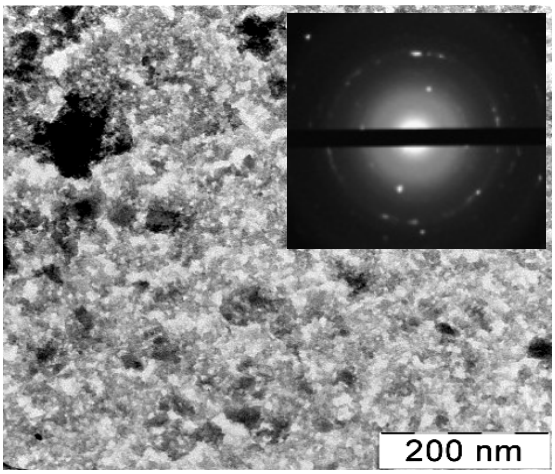


Fig.1 TEM images of nc-PSi; inset: transmission electron diffraction patterns from nc-PSi.

In vitro experiments showed that nc-PSi nanoparticles can penetrate into cancer cells, and the PL properties of incorporated nc-PSi are survived at least for 24 hours. Our experiments demonstrate that Si nanoarticles obtained by mechanical grinding of PSi can be used for bioimaging application and then for cancer diagnostics and therapy.

Acknowledgements: The samples were fabricated by using equipment of the Center of User Facilities of M.V. Lomonosov Moscow State University.

References:

1. L.T. Canham, "Nanoscale semiconducting silicon as a nutritional food additive" Nanotechnology, 18, 185704, 1-6 (2007).
2. D. Kovalev, H. Heckler, G. Polisski, F. Koch, "Optical Properties of Si Nanocrystals" Phys. Stat. Sol. (b), 215, 871-932 (1999).

O-3-LD

NANOCRYSTALS FORMING POROUS SILICON AS PHOTOSENSITIZERS FOR PHOTODYNAMIC THERAPY

M.B. Gongalsky, A.Yu. Kharin, L.A. Osminkina, V.Yu. Timoshenko
Lomonosov Moscow State University, Faculty of physics,
1, Leninskie gory, Moscow, Russia, 119991
mgong@mail.ru

Porous silicon (PSi) is a nanostructured material with typical sizes of nanocrystals (nc-Si) and pores from 2 to 50 nm [1]. A remarkable property of PSi is efficient photoluminescence (PL) in visible and near-infrared spectral regions. This effect can be explained by quantum confinement of charge carriers in nc-Si, where the formation of excitons with high probability of the radiative recombination occurs [2]. The interaction between excitons in nc-Si and oxygen molecules (O_2) results in formation of an active form of O_2, i.e. singlet oxygen ($^1O_2$), which has a wide field of applications, e.g. photodynamic therapy of cancer (PDT).

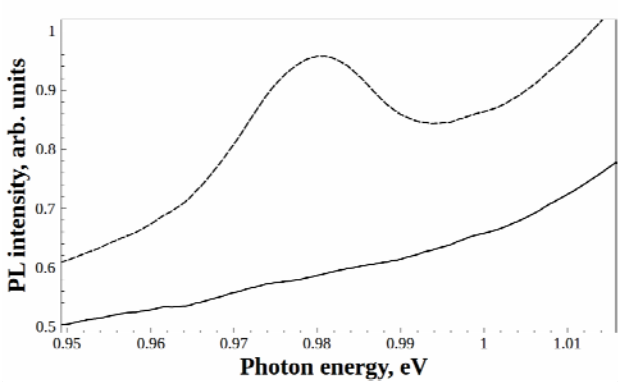


Fig. 1. Infrared spectra of porous silicon in vacuum (solid line) and in oxygen ambient (dashed line). Peak centered at 0.98 eV corresponds to $^1\Delta$-$^3\Sigma$ transition in O_2 molecule.

Efficiency of photosensitizing by nc-Si was found to be comparable with efficiency of widely-used photosensitizers such as chlorines or porphyrins. But also photodegradational processes were observed in porous silicon. Therefore, photosensitization of singlet oxygen generation in porous silicon (PSi) was investigated by simultaneous measurements of the photoluminescence (PL) of silicon nanocrystals (nc-Si) and the infrared emission of the $^1\Delta$-state of oxygen molecules at 1270 nm (0.98 eV) at room temperature (see Fig. 1). Photodegradation of the nc-Si PL properties was found to correlate with the efficiency of singlet oxygen generation. Lifetime of singlet oxygen was estimated to be about 15 ms. The kinetics of nc-Si PL intensity under cw excitation undergoes a power law dependence with the exponent dependent on the photon energy of luminescence. The experimental results are explained with a model of photodegradation controlled by the diffusion of singlet oxygen molecules in a disordered structure of porous silicon. In according with this model significant spacial separation of nc-Si is required for increasing efficiency of the photosensitizing.

References:

1. A.G. Cullis, L.T. Canham, and P.D.J. Calcott, J. Appl. Phys. 82, 909 (1997).
2. D. Kovalev, H. Heckler, G. Polisski, F. Koch, Phys. Status Solidi B. 215, 871 (1999).

O-4-LD

DIODE-LASER SPECTROSCOPY OF WATER VAPOR KINETICS IN ADSORBENT

Artemov V.G., Kapralov P.O., Tikhonov V.I., Volkov A.A.
A.M. Prokhorov General Physics Institute of Russian Academy of Sciences,38 Vavilov str., 119991, Moscow, Russia
vartemov@bk.ru

The specialized device and measurement methods for studying the adsorption and diffusion kinetics of water molecules in adsorbents are developed. The specific device feature is an ability to measure concentration of water vapor by tunable diode laser (TDL) spectrometer. Concentration is determined by the absorption lines of vibrational-rotational transitions of water molecules near the wavelength of 1.85 microns by fitting the experimental data with Voigt profile. TDL makes it possible to measure water partial pressure over the porous medium surface in a real time scale with speed up to 1000 s^{-1} in wide concentration-time window (0.1 - 5000 Pa and 0.01 - 10000 s).

Two types of experiments have been made. The first one was aimed to detect (with a maximum time resolution) the decrease of concentration in the dosing volume as a result of transition of water molecules from the gas phase into the adsorbent. Another one consists in measurements of the water vapor breakthrough curves.

We report about results of measurements of diffusion-adsorption kinetics of water vapor by TDL on a different liquid and solid media near the room temperature: nanoporous polymer adsorbents and resins, microporous charcoals, nonporous SiO_2, geological materials, glycerol, aggregates of nanodiamonds and others.

Several new effects have been found: 1) Abnormally high mobility of molecules in the adsorbent in short times [2]. 2) Super fast passing of water molecules through a porous-granular adsorption column [3]. 3) Deviation of the normal 3:1 spin-isomeric ortho-para ratio in water vapor during adsorption [4]. The last one relates to the still unresolved general problem of water separation into ortho and para spin-isomeric modifications [5].

The developed technique can be used as a powerful tool for the studying of the water vapor kinetics in a various physical, chemical, and biological processes.

References:

1. P.O. Kapralov et al., "A Diode-Laser Spectrometer for Measuring Ortho/Para Composition of Water Vapor" Instruments and Experimental Techniques, 51, 894 (2008).

2. P.O. Kapralov et al., "On the Possibility of Sorting Ortho and Para Water Molecules During Diffusion in Nanopores", Bull. of the Russian Academy of Sciences, Physics, 72, 1679 (2008).
3. V.G. Artemov et al., "Precursor Effect during Water Vapor Diffusion in a Porous Medium" Bull. of the Russian Academy of Sciences, Physics, 74, 1645 (2010).
4. P.O. Kapralov et al., "Deviations from the Normal ortho/para Ratio for Water (3:1) in the Vapor Phase in Dynamic Sorption" Russ. Journal of Phys. Chemistry A 83, 663 (2009).
5. V.I. Tikhonov, A.A. Volkov, "Separation of Water into Its Ortho and Para Isomers" Science 296, 2363 (2002).

IV. LASER-MATTER INTERACTIONS

I-1-LM

DESIGNER PULSES FOR OPTIMAL ABLATION: GUIDING HEAT IN ULTRAFAST LASER ABLATION PLASMA

R. Stoian, J. P. Colombier
Laboratoire Hubert Curien, CNRS UMR 5516, Université de Lyon, Université Jean Monnet, 42000, Saint Etienne, France
razvan.stoian@univ-st-etienne.fr

The possibility of choosing thermodynamic trajectories for the excited matter is a determinant factor for controlling a typical laser ablation process, particularly when we approach irradiation on ultrafast timescales. This specifically concerns the nature and the energetic characteristics of the ablation products subsequent to laser irradiation. In this respect, designing the energy delivery rate using programmable pulse shaping methods in the temporal domain is a powerful way for controlling excitation and thermodynamic relaxation of the material and, equally, its hydrodynamic advance.

We focus here on ultrafast laser irradiation of metals, with the objective of maximizing heat load in the ablation products. Using experimental and theoretical adaptive loops [1,2] based on hydrodynamic codes we indicate the shapes of optimal pulses on ultrashort and short timescales required to reach extreme thermodynamic states at limited energy input. These waveforms, particularly impulsive pulses on picoseconds pedestals, affect the excitation level and the energetic content of the ablation products, as well as the balance between thermal and mechanical energy. As the material states rapidly vary from solid to plasma phases, the optimal interaction scenario usually imply light coupling into the incipient material hydrodynamic motion. This triggers transitions to weakly-coupled front plasmas at critical optical density favoring energy confinement with low mechanical work. Additional collisional heating occurs in denser regions above the critical point, reaching states that spontaneously decompose in excited atomic species.

The consequences are manifold and are particularly visible in the formation of atomic, ionic, and cluster species, their kinetics and spectral emissivities, and in the ejection of nanoscale liquid droplets. A discussion on the nature of these resulting exotic thermodynamic states, mostly implying supercritical paths, will be given. The results are interesting for remote spectroscopy applications, e.g. LIBS and secondary sources, ablation process quality, and for the laser-assisted generation of nanoparticles and PLD.

References:

1. J.P. Colombier, P. Combis, A. Rosenfeld, I.V. Hertel, E. Audouard, R. Stoian "Optimized energy coupling at ultrafast laser irradiated metal surfaces by tailoring intensity envelopes. Consequences for material removal from Al samples" Phys. Rev. B 74, 224106/1-16 (2006)

2. Guillermin, J.P. Colombier, S. Valette, E. Audouard, F. Garrelie, R. Stoian, "Optical emission and nanoparticle generation in Al plasmas using ultrashort laser pulses temporally optimized by real-time spectroscopic feedback" Phys. Rev. B 82, 035430/1-16 (2010)

I-2-LM

SURFACE STRUCTURING OF METALS WITH PS-LASERPULSES: HOW TO OPTIMIZE PROCESS EFFICIENCY AND SURFACE QUALITY

B. Neuenschwander[1], B. Jäggi[1], G. Hennig[2], M. Schmid[1] and M. Muralt[1]
[1]Institute for Applied Laser, Photonics and Surface Technologies,
Bern University of Applied Sciences, Pestalozzistrasse 20, 3400 Burgdorf, Switzerland
[2]Daetwyler Graphics, Flugplatz, 3368 Bleienbach, Switzerland
beat.neuenschwander@bfh.ch

The interest in ps-laser pulses for industrial applications has significantly increased in the last few years. For a profitable industrial use of this technology high process efficiency and cost effective systems are required. Today, available ps-lasers are industrially applicable turnkey systems, set up in a MOPA arrangement with rod or disk amplifiers and mostly have pulse durations of about 10ps. The change to fiber based amplifier technologies would help to build more compact systems but with pulse durations between 20ps and 50ps. Interesting applications are in the field of surface and 3-d structuring, where often a high surface quality (low surface roughness, minimized surface melting and no oxidation processes) is desired. These measures are also strongly affected by the structuring strategy i.e. aside the laser parameters the process optimization has also to take the structuring strategy into account.

The volume ablation rate can be maximized by distributing a given total energy or fluence onto the optimal number of pulses. Based on the logarithmic ablation law $z_{abl} = \delta \cdot \ln(\phi / \phi_{th})$ (δ: energy penetration depth, Φ_{th}: threshold fluence, Φ: fluence applied) it can be shown, that for a top-hat shaped beam the ablation depth corresponds to the penetration depth at this optimum point i.e. the ablated volume per pulse is given by $\Delta V = \pi \cdot w_0^2 \cdot \delta$ (w_0: spot radius).

The latter result also holds for Gaussian shaped pulses. At this optimum point the fluence directly scales with Φ_{th} i.e. the maximum ablation rate is mainly given by Φ and Φ_{th} [1]. Both material parameters strongly depend on the number of pulses applied [2] and the pulse duration as well. Especially the pulse duration dependence of δ: leads to significant drop of the maximum volume ablation rate for metals when the pulse duration is raised from 10 ps to several 10 ps [3].

Most 3-d surface structures are generated with galvo-scanners in a 2½-d process where the desired structure is divided into several slices with hatched outline. Minimum surface roughness is obtained with a hatch distance of half a spot radius w_0 and a pitch between two pulses exceeding w_0 [4]. To match these requirements at the point of maximum volume ablation rate a marking speed in the range of 10 mm/s per Watt average power is needed. Having the latest developments of ultra short pulsed systems to several 100 Watts average power in mind, this is a serious challenge to future beam guiding systems.

References:

1. B. Neuenschwander et al, "Processing of metals and dielectric materials with ps – laser-pulses : results, strategies, limitations and needs", Proc. SPIE Vol. 7584, paper 26 (2010)
2. G. Raciukaitis et al., „Use of high repetition rate and high power lasers in microfabrication: How to keep the efficiency high?", JLMN journal of Laser Micro/Nanoengineering Vol. 4 (3) 186 (2009)
3. M. Schmid et al. "Processing of metals with ps – laser pulses in the range between 10ps and 100ps" Proc. SPIE Vol. 7920, paper 8 (2011)
4. B. Neuenschwander at al., "Pocessing of dielectric materials and metals with ps – Laser-pulses", Proc. ICALEO, paper M101 (2010)

I-3-LM

PROPAGATION AND ADSORPTION OF LIGHT IN CAPILLARIES AND ITS IMPACT ON MELT FLOW DURING LASER DRILLING AND DEEP-PENETRATION WELDING

R. Schuster[1], A. Michalowski[1], Y. Qin[2], P. Berger[1], F. Abt[1], T. Graf[1]
[1]*Institut fuer Strahlwerkzeuge, Pfaffenwaldring 43, 70569 Stuttgart, Germany*
[2]*School of Science, Xiaolingwei 200, 210014 Nanjing, China*
rainer.schuster@ifsw.uni-stuttgart.de

An overview of actual work at the IFSW on light propagation and absorption in capillaries is given. In addition, observations of the behaviour of such capillaries with a novel high speed X-ray micro focus videography system are presented.

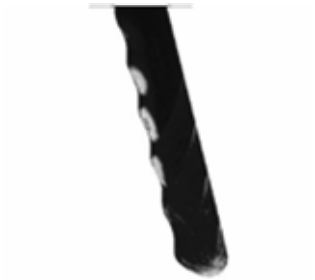


Fig.2: Capillary with wavy structure at the front; colour indicates absorbed intensity.

Ablation in laser drilling as well as heat transfer to the weld pool in laser deep-penetration welding is determined by the distribution of the absorbed intensity in the generated capillary. Numerical simulations were performed based on both, geometric optics and wave optics resulting in absorbed intensity distributions in drilling and welding capillaries. Results for both methods are given. Applicability of geometrical optics calculations depending on capillary size, angle of incidence and polarisation is discussed. For many real capillary shapes only small differences between wave optics and geometrical optics are found (Fig.1). Besides the basic capillary shape, the absorbed intensity distribution also depends on the unevenness of the capillary walls. Arising steps at the liquid capillary front make the absorbed intensity alternate at the location of these steps (Fig.2). Resulting localised melt evaporation causes material flow downwards the capillary front. Numerical simulation enables understanding of resulting dynamic effects and of the re-solidification process (Fig.3).

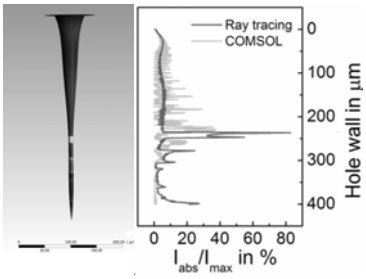


Fig.1: left: capillary shape, right: absorbed intensity calculated by geometric optics (blue) and wave optics (red).

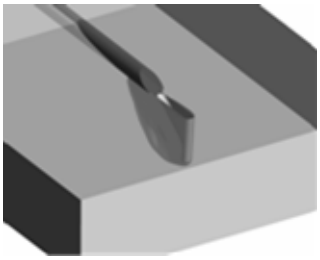


Fig.3: 3-D-simulation of a melt bath for laser deep penetration welding.

Besides modelling these transient phenomena numerically, the novel IFSW-X-ray system allows getting real time insight into the dynamics of the capillary and melt pool (Fig.4). It is capable of a frame rate of more than 5 kHz and recognizing feature sizes down to 50 µm. Capillary shapes and fluid flow can be visualized via melting or non melting tracer material.

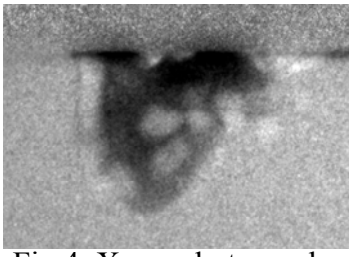


Fig.4: X-ray photography of a weld pool during laser welding of aluminium. light: pores, capillary, dark: weld pool (contrast enhanced by tracer material).

I-4-LM

ULTRAFAST LASER MODIFICATION IN GLASSES: BASIC AND NOVEL ASPECTS AND APPLICATIONS

N.M. Bulgakova[1,2], V.P. Zhukov[3], Yu.P. Meshcheryakov[4], P.G. Kazansky[2]
[1]*Institute of Thermophysics SB RAS, 1 Lavrentyev Ave., 630090 Novosibirsk, Russia*
[2]*Optoelectronics Research Center, University of Southampton, SO17 1BJ, United Kingdom*
[3]*Institute of Computational Technologies SB RAS, 6 Lavrentyev Ave., Novosibirsk, Russia*
[4]*Design and Technology Branch of Lavrentyev Institute of Hydrodynamics SB RAS, Tereshkovoi street 29, 630090 Novosibirsk, Russia*
nbul@itp.nsc.ru

Ultrashort laser pulses are a powerful tool for modifying the structure and properties of transparent materials. Depending on material properties and irradiation conditions, a wide variety of modifications can be induced such as surface and bulk periodic structures (nanogratings), densification with associated refractive index change, microvoids and void chains, phase transitions, etc. This gives rise to numerous technological applications based on 3D photonic structures in bulk optical materials (waveguides, Bragg gratings, Fresnel zone plates, rewritable optical memories, and others). Among transparent materials, optical glasses are of prime importance for optoelectronics and photonics due to their relatively low cost, processability, and possibility of governing refractive index and inducing optical anisotropy. The physics behind laser-induced glass modification is extremely rich and involves the multiplicity of the consecutive processes initiated by radiation absorption during the laser pulse and extending to millisecond time scales when the final structure becomes "frozen" in the glass matrix. While tremendous achievements have been made toward laser-writing techniques and assembling integrated optics, the physical mechanisms underlying glass modifications have not been fully understood. However, further development of laser-writing techniques for controllable generation of desired modifications in transparent materials is impossible without deep understanding of the governing mechanisms of modifications.

In this report, we will review the physical processes and mechanisms responsible for various forms of glass modification. Different routes of photoexcitation with creation of dense plasma inside glass bulk will be analyzed depending on the irradiation conditions. Relative contributions of multi-photon and tunneling ionizations and the avalanche process will be considered. The thermodynamic and thermomechanical processes following plasma recombination at different space and time scales will be discussed. A number of intriguing experimental evidences will be canvassed with their detailed theoretical analysis. The results of modeling based on the Maxwell's equations will be presented for the particular irradiation regimes when different modifications are observed such as nanograting structures and microvoids. The levels of plasma densities and glass matrix temperature distributions upon plasma recombination will be compared and a criterion of glass rupture will be discussed. On the basis of the theory of thermoelastoplastics, we will show that void formation is not obligatory involves the TPa or GPa pressure levels. A special attention will be paid to the collective plasma effects whose role in formation of exotic structures inside and on the surface of transparent materials is highly underestimated. In particular, we will show that the standing waves in confined plasmas can strongly influence the dynamics of laser light absorption. Finally, the most intriguing effects upon laser-induced glass modification which still require explanations and adequate theoretical descriptions will be outlined.

Acknowledgement: This research is supported by Marie Curie International Incoming Fellowship grant of the corresponding author, No. 272919.

I-5-LM

ADVANCED FEMTOSECOND LASER TECHNOLOGIES WITH ATOMIC AND MOLECULAR CLUSTER BEAMS

Gordienko V.M., Djidjoev M.S., Fedorov D.O.,
Platonenko V.T., Pribytkov A.V., Trubnikov D.N., Zhvania I.A
M.V.Lomonosov Moscow State University, Moscow , Russia
gord@phys.msu.ru

The interaction of ultrashort intense laser pulses with atomic and molecular clusters has become an important area of laser-matter research. Gases formed of clusters exhibit extremely efficient absorption of femtosecond laser radiation, creating hot nanoplasma in a low average density target. The observation of characteristic x-ray emission from laser-irradiated clusters suggested its potential as an X-ray source due to a highly nonlinear conversion of IR radiation that combines the advantages of solid targets (large x-ray yields) and gaseous targets (no need to refresh target surface).

We study the X-ray production from large Xe, Ar, SF_6, CF_3I clusters submitted to superintense ($I\sim10^{16}W/cm^2$) femtosecond pulses from Cr:forsterite and Ti:sapphire laser systems.

We used a seeding technique to promote the formation of larger clusters. In a gas mixture consisting of a low concentration of heavy seed gas in light carrier gas, the characteristics of the supersonic beam are dominated by the more abundant lighter gas. This method allows the seed gas to be accelerated to the beam velocity of the carrier gas and also allows the internal degrees of freedom of the heavier gas to be cooled considerably.

In our experiment it was shown that the heavier species tend to concentrate on the gas jet axis. As a result, the enhancement of clustering efficiency and X-ray yield were obtained.

The formation of Xe clusters in the presence of light carrier gas (Ne) was found to narrow the Xe cluster beam and enhance the x-ray yield (at about 4 keV) with X-ray generation efficiency of 10^{-8}.

The parameters of laser induced characteristic sulfur K_α-rays generated from SF_6 (2.3keV) and iodine L_α-rays (4keV) generated from CF_3I clusters in the mixture with argon will be discussed. It has been found that excitation of large SF_6 and CF_3I clusters with superintense laser pulse under the optimal experimental parameters is accompanied by the high-efficiency generation of the characteristic X- rays. The total flux of characteristic X-ray photons in 4π reaches 10^6 photons/shot with a conversion efficiency of 10^{-7} at pulse laser energy of 5mJ.

It has been shown that the third harmonic generation process can be used to characterize the spatial size of the cluster plasma. We observed a strong self-focusing effect of intense femtosecond pulses in a clustered gas.

We propose to use supercritical fluids of different composition, consisting of several components to produce nanoparticles of metals and metal oxides in the free form and in the form of microcapsules with a given particle size distribution. To obtain a new cluster targets generator of nanoparticles is established. The formation of clusters occurs as a result of the supercritical fluids expansion into the vacuum.

In the talk we will discuss various aspects of the physics of X-ray productions with large clusters and will discuss our plans for applications of characteristic X-ray generated by superintense femtosecond IR laser.

I-6-LM

SYNTHESIS AND OPTICAL CHARACTERIZATION OF ZNO NANO-CRYSTALS BY NANOPARTICLE-ASSISTED PULSED LASER DEPOSITION

D. Nakamura, K. Okazaki, I. A. Palani, M. Higashihata, T. Okada
Department of Electrical Engineering, ISEE, Kyushu University,
744 Motooka, Nishi-ku, Fukuoka Japan 819-0395
dnakamura@ees.kyushu-u.ac.jp

Zinc oxide (ZnO) is one of the promising materials for optoelectronic applications in particular ultraviolet (UV) region such as UV-LEDs, UV-lasers, and UV-photosensors, because of exceptional properties of a direct wide band-gap of 3.37 eV and a relatively large exciton binding energy of 60 meV at room temperature. Especially, ZnO nanostructures have been attracting increasing interest due to their unique electronic and optoelectronic properties.

For the practical optoelectronic applications based on the ZnO nanowires, however, important issues are essentially required. The first is control of nanowire growth direction, shape, density, and position etc. As a secondary issue, especially to utilize the electro-optical property of semiconductors, it is a prerequisite to obtain both *n*- and *p*-type conductivities. Another important issue for optoelectronic applications based on the ZnO nanowires is that fabrication of layered structures for *p*-*n* junction. In our study, we have succeeded in synthesizing various nanostructures, such as the vertically and horizontally aligned ZnO nanowires [1,2] by nanoparticle-assisted pulsed-laser deposition (NAPLD) without any catalyst. Besides, the density-controlled growth of vertically aligned ZnO nanowires has been successfully achieved by varying substrate–target distance, repetition rate, and laser energy. Recently, we found that ZnO film and nanowires were synthesized in one NAPLD chamber with changing the deposition condition. This predicts the ZnO nanowire layered structures, such as core/shell structure, can be fabricated in a simple experimental setup. Fig. 1 shows the SEM image of one of the ZnO nanowire layered structures. The pure ZnO nanowires were synthesized after deposition of a Li-Ni codoped ZnO film. This indicates the film-wire layered structure consisting of different ZnO targets is fabricated in the simple experimental setup. In addition, ZnO core/shell nanowires also were successfully synthesized. The ZnO nanowires grew uniformly in the radial direction after deposition of the shell, indicating that ZnO shell coats the entire nanowire. The thickness of the shell is able to be controlled by the deposition time.

In this presentation, recent progress in synthesis of various ZnO nano-crystals by NAPLD and application to the optoelectronic devices such as a LED and a photosensor will be discussed.

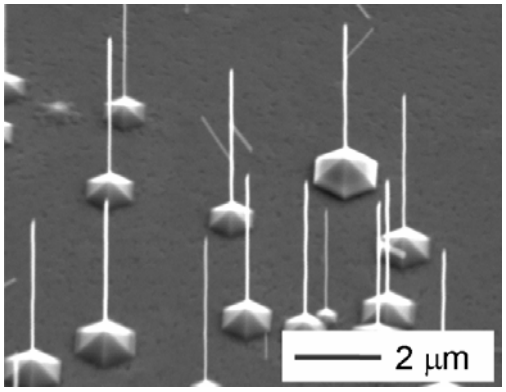


Figure 1 SEM image of ZnO nanowires.

References:

1. R. Q. Guo, J. Nishimura, M. Ueda, M. Higashihata, D. Nakamura, T. Okada, "Vertically aligned growth of ZnO nanonails by nanoparticle-assisted pulsed-laser ablation deposition", Appl. Phys. A, 89, 141-144 (2007)
2. R. Guo, M. Matsumoto, T. Matsumoto, M. Higashihata, D. Nakamura, T. Okada, "Aligned growth of ZnO nanowires by NAPLD and their optical characterizations", Appl. Sur. Sci., 255, 9671-9675 (2009)

I-7-LM

SIMULATION AND EXPERIMENTAL RESULTS OF PERIODIC SURFACE NANO-TEXTURING BY INTERFERING FEMTOSECOND LASER

Yoshiki Nakata[1], Kazuma Momoo[1], Noriaki Miyanaga[1] , Takuya Hiromoto[2]
[1]*Institute of Laser Engineering, Osaka University, 2-6 Yamadaoka, Suita, 565-0871 Japan*
[2]*Furukawa Electric Co., Ltd., 6 Yawata-Kaigandori, Ichihara, Chiba, 290-8555 Japan*
nakata-y@ile.osaka-u.ac.jp

We have generated periodic and nano-sized structures (nanomaterials, metamaterials) by interfering femtosecond laser processing of metallic thin film.[1-3] In the process, periodic induction of energy result in liquid process of solute film, and characteristic nano-sized structures can be generated. The unit structures are nanobump, nano-waterdrop, nano-whisker, nanomesh etc., and can be controlled by experimental conditions.

Interference pattern of four countering beams can be explained as follows.

$$I(x,y,\theta,\varphi) \propto \int \left| \sum_{I=1}^{4} \underset{i}{E}(x,y,z,\theta,\varphi,t) \right|^2 dt \,, \quad E_i = E_{0i} \cos\left(k \cos\theta \bullet \; z \pm k \sin\theta \bullet \; x - \omega t + \varphi_i\right) \tag{1}$$

where k is wave number, ω is angular frequency, φ_i is phase, t is time and E_i is amplitude of electric field. For example, four symmetric beams forming pyramidic axes result in a uniform interference pattern as shown in Fig. 1 (a). In the case of three beams, a unit structure is ellipsoidal, as shown in (b). In addition, by controlling the phase between the beams, duplicated pattern appear as shown in (c). These patterns are transferred to structures by material processing, as shown in Fig. 1 (d), (e) and (f). Nanomesh and ellipsoidal nanomesh can be generated from gold thin film on silica glass substrate, as shown in Fig. 1 (d) and (e). With phase shift, duplicated structure in which different nano-sized unit structures (nano-waterdrop and nano-bit) appear alternately can be generated as shown in Fig. 1 (e).

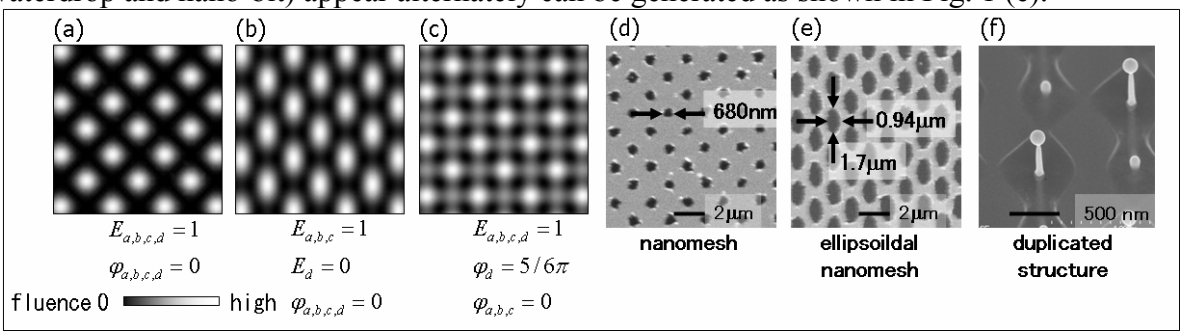


Fig. 1 (a), (b), (c): simulation of interference patterns, (d), (e), (f): nanomaterials generated by interfering femtosecond laser processing.

Acknowledgements: This research was partly supported by Japan Society for the Promotion of Science (JSPS) Grant-in-Aid for Scientific Research (B), and The Ministry of Education, Culture, Sports, Science and Technology (MEXT) Grant-in-Aid for Scientific Research on Innovative Areas.

References:

1. Y. Nakata, T. Hiromoto, N. Miyanaga, "Mesoscopic nanomaterials generated by interfering femtosecond laser" Appl. Phys. A 101, 471-474 (2010).
2. Y. Nakata, K. Tsuchida, N. Miyanaga, H. Furusho, "Liquidly process in femtosecond laser processing" Appl. Surf. Sci. 255, 9761-9763 (2009).

3. Y. Nakata, T. Okada, M. Maeda, "Nano-sized hollow bump array generated by single femtosecond laser pulse" Jpn. J. Appl. Phys 42, L1452-L1454 (2003).

I-8-LM

LASER GENERATED NANOPARTICLES AND THEIR APPLICATIONS

Arseniy Kuznetsov, Laszlo Sajti, and Boris N. Chichkov
Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover, Germany
b.chichkov@lzh.de

Novel methods for high-speed fabrication of colloidal nanoparticles and large-scale periodic arrays of nanoparticles have been developed. These methods are based on laser ablation in liquids and combination of lithographic methods with laser-induced transfer [1-3]. Millions of identical nanoparticles can be transferred simultaneously by a single laser pulse. The transferred particles have spherical shape and are arranged into hexagonal arrays (Fig.1a&b). Both the nanoparticle size and period of the nanoparticle array can be independently controlled. In such nanoparticle arrays a collective plasmonic mode with diffractive coupling between the nanoparticles can be excited. Excitation of this mode leads to the appearance of a narrow (FWHM = 14 nm) resonance dip in the optical transmission spectra. The spectral position of this dip is sensitive to the refractive index changes of the local environment which is promising for sensing applications (Fig.1c). The sensitivity of 365 nm/RIU and the figure of merit (FOM) of 21.5 have been demonstrated in the visible spectral range using test water-glycerin solutions. This high sensing performance together with the fast and cheap fabrication procedure makes this nanoparticle array sensor promising for biomedical applications.

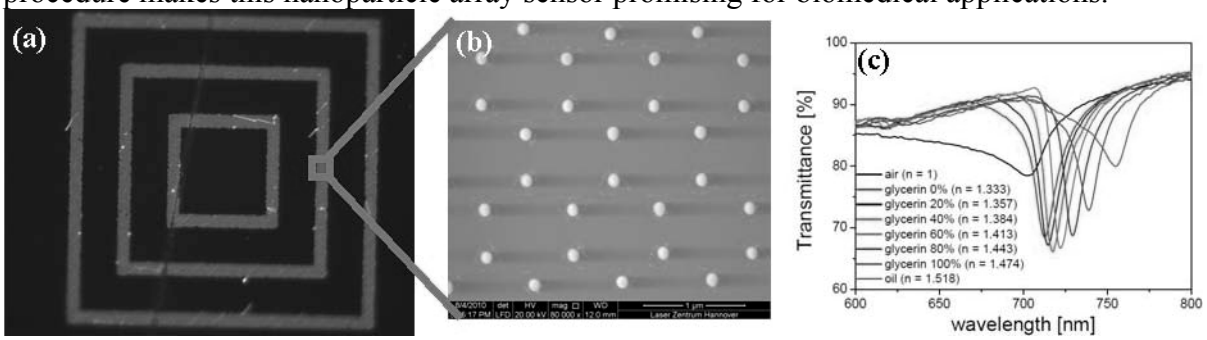


Fig.1 (a)&(b) Structure of spherical gold nanoparticles with diameters of 110 nm fabricated by a combination of nanosphere lithography and laser-induced transfer. **(c)** Transmission spectra of a gold nanoparticle array on a polymer substrate (similar to that in Fig 1a&b) immersed in water solutions of glycerin with different glycerin concentrations.

References:

1. A.I. Kuznetsov, J. Koch, and B.N. Chichkov, "Laser-induced backward transfer of gold nanodroplets", *Opt. Express* 17 (2009), pp. 18820-18825.
2. A.I. Kuznetsov, A. B. Evlyukhin, C. Reinhardt, A. Seidel, R. Kiyan, W. Cheng, A. Ovsianikov, and B.N. Chichkov, "Laser-induced transfer of metallic nanodroplets for plasmonics and metamaterial applications" *J. Opt. Soc. Am. B* 12 (2009) special issue "Plasmonics and Metamaterials", pp. B130-B138.
3. A.I. Kuznetsov, R. Kiyan, B.N. Chichkov, "Laser fabrication of 2D and 3D metal nanoparticle structures and arrays", *Opt. Express* 18 (2010), pp. 21198-21203.

I-9-LM

MAPLE DEPOSITION OF TiO_2 NANORODS: FILM STRUCTURE AND APPLICATIONS

A.P. Caricato[1], M. Belviso[2], D. Cozzoli[2], M. Cesaria[1], A. Luches[1], M.G. Manera[3], M. Martino[1], R. Rella[3], A. Taurino[3]
[1]*Department of Physics, University of Salento, Via Arnesano, 73100 Lecce, Italy*
[2]*CNR-Nano, Via Arnesano, 73100 Lecce, Italy*
[3]*Institute for Microelectronics&Microsystems, IMM-CNR, Via Monteroni, 73100 Lecce, I*
Armando.Luches@le.infn.it

TiO_2 nanorods in the brookite phase, having a mean size of 5 nm × 50 nm, were prepared through a chemical route. The nanorods were dissolved in pure toluene (0,016 wt % TiO_2). The solution was frozen at the liquid-nitrogen temperature and used as a target for the matrix-assisted pulsed laser evaporation (MAPLE) process. Target irradiation was accomplished with a KrF excimer laser (λ=248 nm, τ=20 ns), operated at fluences from F=25 to 350 mJ/cm^2. Films were deposited at the repetition rate of 10 Hz using 6000 laser pulses. Film thickness resulted to be ~ 100 nm at the highest fluence. It was not possible to use a higher number of laser pulses due to the melting of the target (~ 5 mm thick with a diameter of ~ 2.5 mm), even if continuously refrigerated at the LN temperature. Several substrates were used to fully characterize the deposited layers: <100> single-crystal Si wafers, silica slides, Cu carbon-coated grids and alumina interdigital slabs. High-resolution scanning and transmission electron microscopy investigations evidenced the formation of quite rough films incorporating individually distinguishable TiO_2 single nanorods. Crystalline spheres were also detected in films, starting from the threshold fluence of 50 mJ/cm^2. Surface density and dimension of the spheres increase with increasing laser fluence. The sphere formation process and the target melting are discussed and attributed to nanosize effects. Films were positively tested as resistive sensors towards very low NO_2 concentrations (≅1 ppm).

I-10-LM

LASER TRAPPING FOR OPTICAL MANIPULATION OF FUNCTIONAL MICRO- AND NANOPARTICLES

E.V. Lyubin, M.D. Khokhlova, M.N. Skryabina, A.G. Zhdanov, and A.A. Fedyanin,
Faculty of Physics, Lomonosov Moscow State University, Moscow 119991, Russia
fedyanin@nanolab.phys.msu.ru

This work is devoted to recent achievements in using of optical tweezers' technique as photonic force microscope for diagnostics of force interactions between functional particles of submicrometer. Optical tweezers have been proved to be an efficient tool for micro-objects manipulating and has found lots of applications mainly in biology. However applications of this unique method both in solid state physics are not so wide-spread. The main idea of optical tweezering lies in trapping of microobjects utilizing forces of optical pressure. If the trapped particle is transparent this method turns out to be non-disturbing way of diagnostics of single objects of micrometer scale. Microparticle is usually placed into cavity with liquid and is trapped by strongly focused beam. Physical properties of single magnetic micro- and nanoparticles can differ significantly from the properties of both bulk samples and thin films,

and at the same time are of the greatest interest in the whole range of applications connected with novel micromagnetic devices. It makes the problem of single microparticles diagnostics really challenging. In this paper optical tweezers are suggested as a tool for magnetic nanoparticles diagnostics. The way of optical trapping of nanoparticles with the sizes less then the typical gradient of optical field is suggested and discussed. The influence of magnetic field on the shape and position of magneto-optical trap is experimentally observed and analyzed. Another application of optical tweezers which will be discussed is the direct measurements of red blood cell (dis)aggregation forces by double optical tweezers [1,2]. The force characteristics of the red blood cell (RBC) (dis)aggregation are determined using the double trap optical tweezers. The (dis)aggregation force is measured as a function of the RBC overlapping supporting the model of the ring-shaped contact area of RBCs in the rouleau. Dependence of the RBC aggregation force upon the time of rouleau formation was obtained demonstrating strong influence of random time processes on the rouleaux formation. Experimental information provided gives an opportunity to suggest new model of RBC aggregation mechanisms assuming the coexistence of two main theories – bridging and depletion. Quantitative comparative analysis of aggregation properties for normal and pathological blood samples on individual RBCs is performed. Four different end-points of RBC rouleau breaks are revealed depending on the force of interaction between the cells. Correlation between the end-points of disaggregation and the type of blood – healthy or pathological (SLE), is obtained. Direct measurements of aggregation speed for pairs of erythrocytes shows a strong difference between normal and SLE blood samples: the aggregation speed value for the normal RBCs is almost two times lower than that for SLE ones. This shows an extreme sensitivity of the optical tweezers technique in distinguishing the difference in the aggregation properties for normal and pathological blood at the level of individual cells.

References:

1. M.D. Khokhlova, E.V. Lyubin, A.G. Zhdanov, S.Yu. Rykova, I.A. Sokolova and A.A. Fedyanin, "Direct Measurements of Red Blood Cell (Dis)Aggregation Forces by Double Optical Tweezers", J. Biomed. Opt., 2011, in press.
2. Khokhlova M.D., Lyubin E.V., Zhdanov A.G., Rykova S.Yu., Krasnova T.N., Sokolova I.A., and Fedyanin A.A., "Peculiarities of RBC aggregation studied by double trap optical tweezers", Proc. of SPIE Vol. 7715, 77150M (2010).

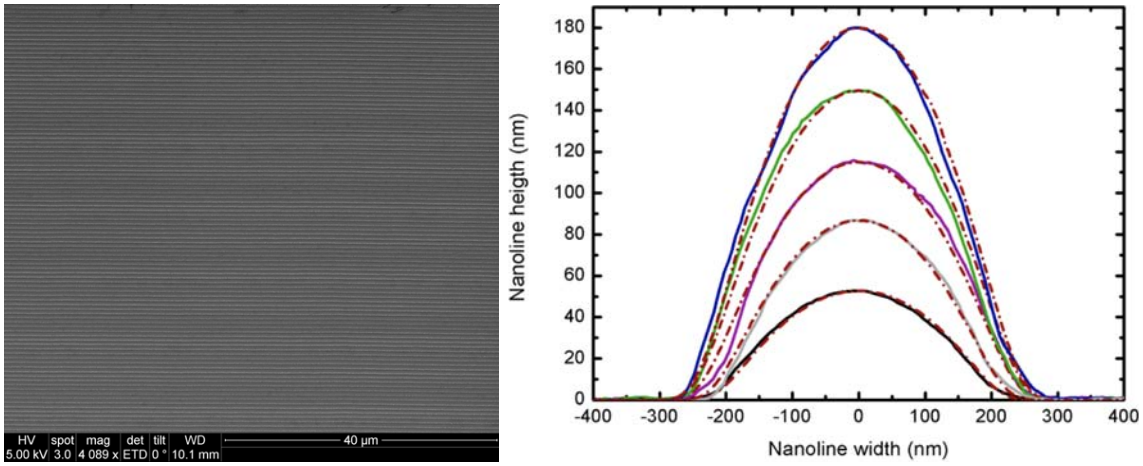
I-11-LM

NONLINEAR LASER LITHOGRAPHY: FEMTOSECOND LASER-CONTROLLED HIGHLY ORDERED "SELF-ASSEMBLY" OF SELF-SIMILAR TITANIA NANOSTRUCTURES

F. Ömer Ilday
Physics Department, Bilkent University
ilday@bilkent.edu.tr

We demonstrate ultrafast-laser-controlled self-assembly of titania (TiO_2) nanostructures on Ti. The formation process is governed by a nonlinear feedback mechanism, involving interplay between the laser beam and scattering of light from existing nanostructures. The spatial profile of these structures, created by a self-similar fiber laser, is also self-similar. The governing dynamics and material properties completely determine all key features of the nanostructures, resulting in an unprecedented level of uniformity, approaching that of

established laser lithographic techniques. By scanning the laser beam over the sample, various structures are obtained with orientations controlled by the laser polarization. New structures can be self-stitched to existing structures without discontinuities or irregularities, allowing coverage of arbitrarily large areas fast and with low-cost equipment. We also demonstrate that Ti thin films can be used as an intermediary to imprint titania nanostructures onto, *e.g.*, silicon substrates. This flexible process is immune to large variations in laser power, spot size or scanning speed, thus allowing, for example, creation of structures on non-planar surfaces.



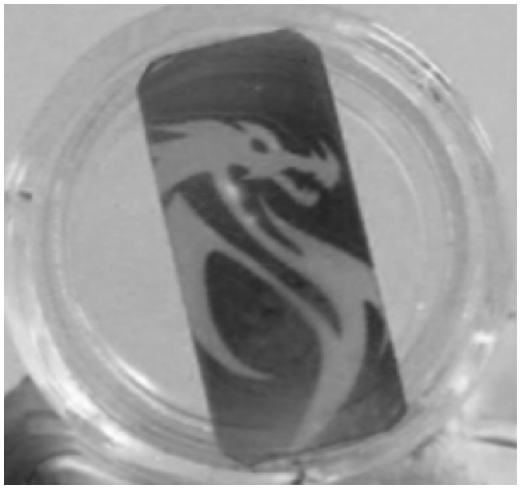
Left: Scanning electron microscopy of large-area structures created by the self-stitching of a large number of lateral scans of the laser beam. Right: cross-sectional profile of the nanostructures (solid lines) and parabolic fit (dashed lines).

I-12-LM

OPTICAL RESPONSE OF ALKALI METAL ATOMS CONFINED IN NANO-POROUS GLASS

L. Moi[1], A. Burchianti[1], C. Marinelli[1], E. Mariotti[1], A. Bogi[1], L. Marmugi[1], S. Veronesi[1,2]
[1]*CNISM and Physics Department, University of Siena, via Roma 56, 53100 Siena - Italy*
[2]*NEST and Physics Department, University of Pisa, Largo Bruno Pontecorvo 3, Pisa - Italy*
moi@unisi.it

Adsorption, desorption and nanoparticle growing processes are of great importance in the study of atom-surface interactions. The possibility to understand and to control the underlying mechanisms has a remarkable impact on fundamental physics as well as on technological applications. Indeed the ability to manipulate the atomic adsorption-desorption and nucleation rates opens new perspectives for fabrication of nanostructured surface layers and nanoparticle arrays.



We study the influence of optical radiation on adsorption-desorption and cluster growth of alkali metals confined at the nano-scale [1]. Atomic layers and quasi-spherical nanoparticles are formed in nanoporous glass samples by vapor loading in the dark. As light hits the porous matrix, the

equilibrium inside the nanopores between nanoparticles, atomic layers and vapor phase is suddenly broken, so that the system evolves, with peculiar dynamics, through different non-equilibrium states. In fact light, depending on its frequency and intensity, detaches atoms either from clusters and/or from atomic layers [2], while a small fraction of desorbed atoms diffuses out of the porous sample [3], behaving as an atomic source controlled by light and not by temperature. All the other atoms, still trapped in the glass matrix, re-condense on the pore walls, forming either nanoparticles or layers. Therefore the net result is that light can move atoms from layers to clusters and viceversa. The shift is clearly visible as particle formation induced by light produces a deep bluish colouring of porous samples. This is shown in the figure where a dragon is recorded on porous glass loaded with Rb. Optical measurements show that: metallic clusters formed by light inside the glass nanopores, can be manipulated by proper tuning of the light frequency and intensity; "memory" effects are observed when series of light pulses of different frequencies are used; optically controlled atomic sources have been realized; the last results will be discussed.

References:

1. A. Burchianti, A. Bogi, C. Marinelli, E. Mariotti, L. Moi, "Light induced atomic desorption and related phenomena", Phys. Scr. TI.35 014012 (2009)
2. A. Burchianti, A. Bogi, C. Marinelli, C. Maibohm, E. Mariotti, S. Sanguinetti, L. Moi, "Optical characterization and manipulation of alkali metal nanoparticles in porous silica", Eur. Phys. J. D 49, 201-210 (2008)
3. A. Burchianti, A. Bogi, C. Marinelli, E. Mariotti, L. Moi, "Optical stabilization of Rb vapor density above thermal equilibrium", J. Mod. Optics 57, 1305-1310 (2010)

I-13-LM

SPECTROSCOPIC ANALYSIS AND LASER CLEANING OF OLD PAPER WITH FOXINGS

I.A. Balakhnina[1], N.N. Brandt[1], A.Yu. Chikishev[1], and N.L. Rebrikova[2]
[1]*Physics Department and International Laser Center, Moscow State University, 119991, Moscow, Russia*
[2]*State Research Institute for Restoration, ul. Gastello, 44, 107114, Moscow, Russia*
ach@lasmed.phys.msu.ru

Laser methods are widely employed in the study and conservation of the objects of cultural heritage. One of the main reasons for the degradation of paper is related to the oxidation of the cellulose fibers, which leads to the general yellowing of paper and the formation of foxing stains. The nature of foxings remains debated in spite of extensive research works: two hypotheses are discussed (oxidation in the presence of iron and effect of microorganisms). Effective experimental methods are needed for the control of paper degradation and for monitoring of paper samples that were processed using various chemical methods.

In this work, the samples of old paper with foxings are studied using the methods of ATR FTIR and Raman spectroscopy. With the aid of the existing spectral databases and assignments, we fit the measured spectra in the interval 1500–1800 cm^{-1}, which can be used to characterize the oxidation processes. The fitting curves are employed for the interpretation of the observed spectral changes related to the degradation of paper and the formation of foxings. The spectra of foxing stains substantially differ from the spectra of homogeneous old paper.

We consider the effect of laser radiation with a wavelength of 532 nm on old and modern paper. The measurements are performed using the pulsed and cw laser radiation. In the experiments with the pulsed laser, the pulse duration is 5 ns, the repetition rate is 10 Hz, the mean power is 3 W, and the diameter of the laser spot on the sample is 5 mm. The samples are rotated at a rate of 6000 rpm, so that the trace of the laser spot on the sample is a ring with a mean diameter of 2 cm. The experiments with the cw laser irradiation are performed at a significantly lower mean power of about 100 mW and the same irradiation doze (about 2 kJ/cm^2).

We study the irradiated paper samples using the ATR FTIR and fluorescence spectroscopy. It is demonstrated that the two regimes of the laser irradiation lead to different results. The laser cleaning of old paper and partial elimination of foxing stains are demonstrated. The spectra of the laser-irradiated paper are compared with the spectra of the same samples measured several years after the laser treatment and the long-term effects are discussed.

Acknowledgements: This work was supported by the Russian Foundation for Basic Research (project no. 11-06-00423).

O-1-LM

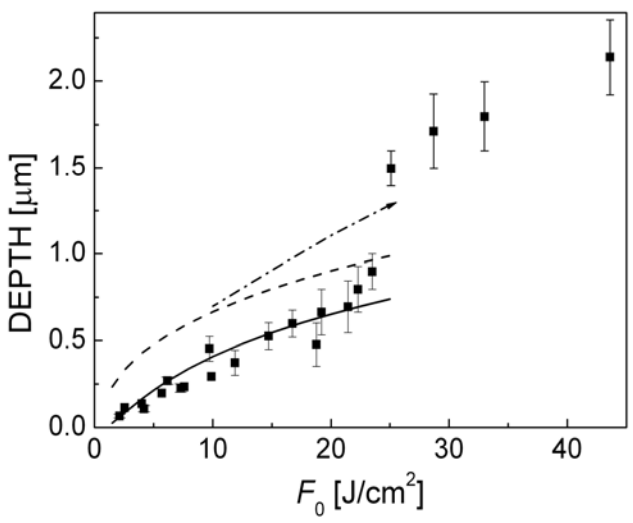
ROLE OF LASER-INDUCED PLASMA PLUME IN INITIATION OF THE EXPLOSIVE ABLATION REGIME

A.V. Bulgakov[1], N.M. Bulgakova[1], A.B. Evtushenko[1], Yu.G. Shukhov[1], S.I. Kudryashov[2]
[1]*Institute of Thermophysics SB RAS, 1 Lavrentyev Ave., 630090 Novosibirsk, Russia*
[2]*P.N. Lebedev Physical Institute RAS, 53 Leninsky Ave., 119991 Moscow Russia*
bulgakov@itp.nsc.ru

Effects of the laser-induced plasma plume on the initiation of the explosive vaporization regime (often called as phase explosion) are investigated both experimentally and theoretically. Measurements of mass removal by 7-ns, 532-nm laser ablation of polycrystalline graphite revealed a drastic increase in the ablation depth at a threshold fluence of around 22 J/cm^2. Acoustic experiments also demonstrate a sharp increase in the recoil pressure at the same threshold value. The observed rates of the explosive vaporization (up to several micrometers per pulse) cannot be explained by the conventional thermal model since the calculated ablation and melting depths altogether are considerably smaller than the experimental ablation depths (Fig. 1). It is suggested that such ultradeep drilling is due to radiative effects of the ablative plasma. An improved model of thermal laser ablation has been developed by introducing an additional heat source term due to plasma radiation, both bremsstrahlung and recombinative. On the basis of combined thermal and gasdynamic modeling, we show that a considerable part of the laser energy absorbed by the plasma is reradiated back toward the target. The resulting radiative heating considerably deepens the molten layer, thus explaining the observed crater depths (Fig. 1).

Another intriguing observation is that the explosive vaporization in vacuum occurs only for relatively small irradiated spot areas, less than about 0.1 mm^2, while for larger spots it is essentially suppressed.

This effect is suggested to be due to plasma plume expansion whose character at early stages is spot-size dependent, planar for large spots and spherical-like for sharp focusing conditions. The dynamics of the pressure relief above the irradiated surface is analyzed for the different



expansion regimes. We demonstrate that the laser-induced plasma plume can act, depending on the irradiation conditions, as a factor suppressing or stimulating the explosive ablation.

Fig. 1. Measured graphite ablation depth as a function of laser fluence (squares). Modeling results on the ablation depth are shown by the solid line. The other lines show the calculated maximum depths of melting (with respect to the initial target surface) obtained with the conventional thermal model (dashed line) and with the improved model taking into account the plasma radiative heating (dot-dashed line).

Acknowledgements: This work was supported by the RFBR (projects Nos. 10-08-00941 and 10-03-00441).

O-2-LM

STRUCTURAL MODIFICATIONS IN BULK FUSED SILICA AFTER INTERACTION WITH ULTRASHORT LASER PULSES

K. Mishchik, G. Cheng, C. Mauclair, A. Boukenter, Y. Ouerdane, R. Stoian
Laboratoire Hubert Curien, UMR 5516 CNRS, Université de Lyon, Université Jean Monnet, 42000 Saint Etienne, France
konstantin.mishchik@univ-st-etienne.fr

Refractive index changes are the building blocks of laser-induced optical functions in bulk transparent materials, for example, in fused silica. Depending on the regime of laser interaction, focused ultrashort pulses could induce either positive or negative isotropic refractive index changes (usually denoted as type I) or produce nanoscale self-arranging layered structure resulting in form birefringence (type II regime) [1]. As these types of refractive index changes have consequences in the functionality and performances of 3D optical devices (e. g. embedded waveguides) an investigation of the laser-induced structures is particularly useful [2]. We propose photoluminescence (PLM) and Raman microscopy (RM) to investigate defects formations and other types of reorganization of the glass network. These are the major factors in changing the electronic and thermodynamic properties of fused silica and, consequently, its optical constants. Information provided by a spectroscopy study is also useful for understanding of mechanisms causing the structural changes.

We equally explore primary stages of birefringent regions, where we observed that nanosacale reorganization is preceded by voids formation due to self-focusing effects. The repetitive character of interaction leads finally to a regular periodic alternance of high and low density layers. Therefore, investigation of single and multiple pulse irradiation effects allows to emphasize several key factors defining laser modification, particularly its dependence on the energetic dose, pulse duration and focusing conditions.

The proposed spectroscopy study distinguishes type I and type II regions by E'_δ and non-bridging oxygen hole centers (NBOHC) formation and distribution. Birefringent regions

(found to be consisting of oxygen deficiency layers) show a considerable amount of E'_δ defects, generated by liberation of atomic oxygen from the silica network and its subsequent migration. Additionally, RM reveals signs of densification in the refractive index changes region. At the same time, zones with high concentration of NBOHC where no visible refractive index changes and densification signs were detected. We propose that these defects generation occurs as a result of bond breaking after self-trapped exciton relaxation. If this process is efficient enough, non-bridging atoms favored by local increase of temperature could create new bondings forming network corresponding to compacted silica. This investigation provides, thus, key elements in further elucidating of the nature of ultrafast laser induced changes in the bulk of dielectrics.

References.

1. R. Taylor, C. Hnatovsky, and E. Simova, "Applications of femtosecond laser induced self-organized planar nanocracks inside fused silica glass," Laser and Photon. Rev. 2, 26–46 (2008)
2. K. Mishchik et al., "Nanosize structural modifications with polarization functions in ultrafast laser-irradiated bulk fused silica," Optics Express, 18, 24809-24824, (2010).

O-3-LM

PICOSECOND LASER MICROSTRUCTURING IN THE BULK OF DIAMOND

S.M. Pimenov,[1] I.I. Vlasov,[1] A.A. Khomich,[1] B. Neuenschwander,[2] M. Muralt,[2] V. Romano[2]
[1]*Natural Sciences Center, Prokhorov General Physics Institute, Moscow 119991, Russia*
[2]*Bern University of Applied Sciences, Engineering & Information Technology, Burgdorf CH-3400, Switzerland*
pimenov@nsc.gpi.ru

In this paper we report on the bulk microstructuring of diamond using a picosecond MOPA laser system (with 10 ps pulselength) which has demonstrated excellent performance in microprocessing of various materials (metals, dielectric materials, semiconductors) with high precision and reliability [1]. Our studies were focused on (i) characteristics of the formation of graphitized microstructures in the bulk of diamond in dependence on the ps-laser parameters, (ii) fabrication of arrays of through microstructures in the diamond plates, and (iii) ps-laser-induced structural modifications in the bulk of single crystal diamonds. Particular attention was paid to the behaviour of the 3H defect center in correlation with the structure transformation induced in the type IIa diamonds by ps-laser multipulse irradiation.

Different samples of single crystal diamonds were used in our experiments, including type Ib HPHT diamond sample and type IIa CVD single crystal diamond plate of 6.0x6.0x1.2 mm size. Diamond microstructuring was carried out at the wavelength λ=532 nm; the pulse energy, pulse repetition rate and translation speed were the laser processing variables. A video imaging system was applied for real-time observation of the growth of a laser-modified microscopic region in the bulk of diamond – from the rear side to the front side of the diamond plates – in the course of multipulse laser irradiation, as described elsewhere [2]. The structural properties of the diamond plates and laser-modified regions were examined using micro-Raman and photoluminescence (PL) spectroscopy.

Using the developed technique, arrays of through laser-graphitized microstructures have been fabricated in the 1.2-mm-thick diamond plates at different pulse energies and repetition rates.

The pulse energy was found to strongly influence the growth rate and diameter of the produced microstructures, with the growth rates reaching the values as high as 4 mm/s (at pulse energy of several μJ and pulse repetition rate of 50 kHz). Raman and PL spectroscopy examination evidenced the diamond structure transformation to amorphous carbon and graphitic phases and the formation of radiation defects pronounced in the PL spectra as the interstitial related center, the 3H center at 504 nm [3]. It is important to note that the laser-induced structural modifications in the bulk were observed to occur along preferred crystallographic planes of the crystal. The correlations observed between the laser-modified structure, 3H luminescence and other centers (vacancies, N-V centers) will be discussed.

Acknowledgements: The work is supported by the SNSF project IZ73Z0-128088/1.

References:

1. B. Neuenschwander, G.F. Bucher, C. Nussbaum, B. Joss, M. Muralt, U.W. Hunziker, P. Schuetz, Proc. SPIE 7584, 75840R (2010).
2. T.V. Kononenko, M.S. Komlenok, V.P. Pashinin, S.M. Pimenov, V.I. Konov, M. Neff, V. Romano, W. Lüthy, Diamond Relat. Mater. 18, 196 (2009).
3. J.W. Steeds, T.J. Davies, S.J. Charles, J.M. Hayes, J.E. Butler, Diamond Relat. Mater. 8, 1847 (1999).

O-4-LM

SILICON NANOCRYSTALS: LASER-ASSISTED FABRICATION AND OPTICAL PROPERTIES

S.V. Zabotnov[1], A.A. Ezhov[1], I.O. Dzhun[1], P.A. Perminov[2], P.K. Kashkarov[2], E.A. Sergeeva[3], P.D. Agrba[3], M.Yu. Kirillin[3]
[1]*M.V. Lomonosov Moscow State University, 1/2 Leninskie Gory, Moscow, 119991 Russia*
[2]*Russian Research Center "Kurchatov Institute", 1 Kurchatov sq., Moscow, 123182 Russia*
[3]*Institute of Applied Physics RAS, 46 Uljanov str., Nizhny Novgorod, 603950 Russia*
zabotnov@vega.phys.msu.ru

Miniaturization of silicon-based objects discovers new prospects for their use in modern optoelectronics [1], laser physics [2] and biomedicine [3]. One of the actual problems in this direction is fabrication of silicon nanocrystals and evaluation of their physical and optical properties. Such particles being strongly light scattering may be used, for example, as contrasting agents in the optical coherent tomography (OCT) owing to their biocompatibility, toxic safety and high backscattering cross-section.

We prepared the silicon nanocrystals via the picosecond laser irradiation of monocrystaline Si wafers in water. This method has a number of advantages compared to the traditional nanocrystal nanofabrication (electrochemical etching, pyrolysis): free and chemically pure nanoparticles with relatively small size dispersion can be produced. Our nanoparticles have the spherical shape and crystalline structure accordingly to the atomic-force microscopy and Raman spectroscopy studies. The nanocrystals size varies from 10 to 200 nm.

The measurements of the collimated transmission, total transmission and diffuse reflectance for the water suspension of produced nanoparticles in the visible and near infrared range (400-1100 nm) allowed calculating the scattering coefficient which value amounts to 1 cm^{-1} in order. The scattering have the non-Rayleigh nature which is confirmed by the value of calculated scattering anisotropy factor varying from 0.4 to 0.6 in the studied range. Mie theory

calculations indicate the presence of nanoparticles with diameters in range from 10 to 200 nm in suspension which is in agreement with the microscopy analysis.

In order to test contrasting properties of silicon nanocrystals, pilot experiments on OCT imaging of a nanocrystal suspension drop on agar gel surface mimicking biotissue were performed. We observed significant increase in the OCT-signal from the areas of presence of nanocrystals allowing to consider these particles as effective contrasting agents in the case of their target delivery.

Acknowledgements: We are grateful to Dr. L.A. Golovan for fruitful discussions, the work is supported by RFBR (projects №№ 09-02-00888 10-02-00744, 11-02-01129 and 11-02-01087), grant of the President of Russian Federation MK-1127.2010.2, and FTP "Scientific and Scientific-Educational Brainpower of Innovative Russia" (project №. 14.740.11.0253).

References:
1. A.G. Gullis, L.T. Canham, P.D.J. Calcott, "The structural and luminescence properties of porous silicon" Appl. Phys. Lett., vol. 82, pp. 909 – 965 (1997).
2. V.Ya. Gayvoronsky, L.A. Golovan, M.A. Kopylovsky, et al., "Two-photon absorption and nonlinear refraction of birefringent mesoporous silicon films" Quantum Electronics, vol. 41, pp. 257–261 (2011).
3. D. Rioux, M. Laferriere, A. Douplik, et al. "Silicon nanoparticles produced by femtosecond laser ablation in water as novel contamination-free photosensitizers" J. Biomed. Opt., vol. 142, 021010 (2009).

O-5-LM

APPLICATION OF FEMTOSECOND LASER PULSES FOR NANOMETER ACCURACY PROFILING OF QUARTZ AND DIAMOND SUBSTRATES AND FOR MULTI-LAYERED TARGETS AND THIN-FILM CONDUCTORS TREATMENT

D.S. Sitnikov, O.V. Ovchinnikov
Joint Institute of High Temperatures, Russian Academy of Sciences, Moscow Russia
Sitnik.ds@gmail.com

There is a plenty of papers concerning interaction of laser radiation with semiconductor and dielectric targets. Fundamental investigations of target exposure to nano-, pico-, and femtosecond laser pulses have been carried out by leading scientific laboratories all over the world. There are also papers reporting a successful application of femtosecond laser systems for profiles and micro-holes formation in silicon and quartz substrates [1–3].

The results of application of femtosecond laser pulses for micromachining are presented. Experimental setup consists of the laser, attenuation block, 3-D motorized stage for sample movement, vision-based inspection system, and target illumination system. Laser radiation is focused into a spot with diameter 1 – 10μm depending on the objective applied. The radius of ablation crater on target surface is determined by the ratio of laser fluence in the center of the spot to the threshold ablation value of target substance, as well as the laser spot diameter.

Thus, in order to form a "well" of several hundreds of microns in size, a special technique is required. It includes several stages. Formation of special equidistant line pattern (called a "layer") is performed at first. The depth of ablation crater after a single-shot of femtosecond laser is typically several tens of nanometers. Thus, removing the substance to the specified depth requires multiple passes of laser spot along the trajectory of "layer" (the second stage). Optimal number of passes is chosen experimentally. If the desired depth of a "well" can not

be achieved even in case of multiple-pass mode, then moving the laser spot in Z-direction (perpendicular to the target plane) is performed (the third stage). Experimental results on determination of optimal Z-step are also presented.

Surface layer removing in multilayer targets is another vital problem. Because the depth of ablation crater is on the order of several tens of nanometers (10 – 50 nm depending on the material), this feature offers the challenge of high-precision laser machining with nano-layers removal possibility. Experimental results of laser processing of thin metal films on a glass substrate with thicknesses of ~350 nm for aluminum and ~70 nm for gold target are also presented. The purpose of the researches conducted is removing the metal layer along the trajectory specified to obtain a minimal conductivity. The obtained width of the groove is about 1 – 2 μm; the conductivity value is ~10^{-11} S

References:
1. A. Zoubir, M. Richardson, "Optical properties of infrared femtosecond laser-modified fused silica and application to waveguide fabrication", J. Opt. Soc. Am. B., Vol. 22, p. 2138–2143 (2005).
2. M. Meunier, B. Fisette, "Processing of metals and semiconductors by a femtosecond laser-based microfabrication system", SPIE Proc., Vol. 4978, p. 169–179 (2003).)
3. S. Nikumb, Q. Chen, "Precision glass machining, drilling and profile cutting by short pulse lasers", Thin Solid Films, Vol.47, p. 216–221 (2005).

O-6-LM

A NEW MECHANISM OF LIQUID REMOVAL FROM A SHALLOW BATH UNDER LASER PULSE IRRADIATION

L.I. Antonova[1], G.G. Gladush[1,2]*, A.F. Glova[1], S.V. Drobyazko[1], A.G. Krasyukov[1], V.S. Mainashev[1], V.K. Rerikh[1], M.D. Taran[1]
[1]*State Research Centre of Russian Federation "Troitsk Institute for Innovation and Fusion Research", ul. Pushkovykh, vladenie 12, 142190 Troitsk, Moscow region, Russia*
[2]*Institute on Laser and Information Technologies RAS, Shatura, Moscow Region, Russia*
** gladush@triniti.ru*

The data of experiments in cutting and drilling metals by the radiation of two lasers suggest that the melt may also be removed from the interaction region in the case when the boiling melt area, which is in the region of irradiation by a repetitively pulsed moderate-average-power laser, is much smaller than the entire area of the melt formed by the radiation of a high-power cw laser. The next radiation pulse of the repetitively pulsed laser completely removes the melt 'prepared' during the inter pulse time, while the resultant bore is close in dimension to the region of the melt prior to its removal. Conceivably the character of melt motion being removed will differ from that considered earlier because of the indicated strong difference of the boiling melt area and the entire melt area. Information about this subject is missing in the literature. At the same time, in the practical implementation of the method of cutting metals by the radiation of two lasers, the issue of the character of melt motion and removal is of fundamental importance from the standpoint of maximising the cutting efficiency. The experimental investigation into the metal melt dynamics is hindered under these conditions; however, significant information may be gained from model experiments, when any other liquid, for instance water, is employed in lieu of the metal melt.

An experimental investigation was made of the water removal from a shallow bath(3-mm-deep square cuvette with transparent side walls and a bottom measuring 2 × 20 mm.) under the action of a CO2-laser radiation pulse(τ = 80 ms, d = 1.6 mm, E = 0.54 J.). The energy aspect of removal and its dynamics were considered. We showed that the specific energy expenditure required for the removal of water is defined by the intensity of laser radiation at its surface and is two – three orders of magnitude lower than the evaporation energy and the energy required to heat water to the boiling temperature. Single frame photography of the removal revealed its unusual dynamics, which had not been described in the literature. This process exhibits jet-like behaviour, whereby water is removed only along the walls of the cavern, which expands horizontally for a long time after cessation of the laser pulse(T=7ms), and is similar to the dynamics of fluid surface splash attending the fall of a droplet into a shallow bath.

This analogy was the reason for undertaking numerical simulations of the water flow. In the numerical simulation of water removal we employed the classical SOLA – VOF technique for simulating the motion of an incompressible viscous fluid. Solved with the aid of this technique on an arbitrary nonuniform Eulerian grid are the Navier – Stokes equations for a fluid in a gravitational field. Our simulations suggest that this flow may be described in the framework of a transient model of an incompressible fluid with a free boundary. The resultant data supposedly reflect the processes occurring in the cutting and drilling metals by the radiation of two lasers and may be used for interpreting the data obtained in the processing materials with this technique.

O-7-LM

MODIFICATION OF SURFACE OPTICAL PROPERTIES OF SOLIDS BY FEMTOSECOND LASER PULSES

S.V. Makarov[1], E.V. Golosov[2], O.A. Golosova[2], Ionin A.A.[1], Yu.R. Kolobov[2], S.I. Kudryashov[1], A.E. Ligachev[3], L.V. Seleznev[1] and D.V. Sinitsyn[1], V.P. Korolkov[4], R.V. Samsonov[4], A.I.Masliy[5], A.Zh.Medvedev[5], B.G.Goldenberg[6]
[1] *Lebedev Physical Institute, Russian Academy of Sciences, Moscow, Russia*
[2] *Belgorod State University, Belgorod, Russia*
[3] *Prokhorov Institute of General Physics, Russian Academy of Sciences, Moscow, Russia*
[4] *Institute of Automation and Electrometry, Russian Academy of Sciences, Novosibirsk, Russia*
[5] *Institute of Solid-State Chemistry and Mechanochemistry, Novosibirsk, Russia*
[6] *G.I.Budker Institute of Nuclear Physics, Novosibirsk, Russia*
makarov_sergey_vl@mail.ru

Recently method of opaque material marking by writing of laser-induced periodical surface structures (LIPSS) has been developed with using single beam of femtosecond laser irradiation [1]. We investigate the effect of diffraction color marking of Si [3], Al [4], Ti [5] and Cu using femtosecond laser pulses ($\lambda \approx 744$ nm, $\tau \approx 100$ fs). Laser-induced surface gratings (LIPSS) have well-defined relief with nonsinusoidal [2, 3] profile that gives diffraction colorizing of surface. The period of such surface laser-induced grating can be estimated by using the plasmon-polariton model [6] and additional calculated instantaneous optical characteristics of the surface photoexcited by fs-irradiation [2, 4]. This method of metal and semiconductor colorizing allows creating spots (the parts of the picture) very fast with any color and with different brightness (possibility to creating black and gray points).

We also examined whether the LIPSS on Ni/Cu bilayer foil could be used to produce an anti-reflective coating on polymer replicas of the Ni/Cu surface relief pattern [7]. The polymer surface with the characteristic nanostructure periods obtained in this study $\Lambda \approx 400 – 450$ nm may show up anti-reflective behavior in the near-IR spectral region. Indeed, in our experiments the polymer with modificated surface by discussed technic shows increasing of 20% of light transmission at wavelengths above 2250 nm.

Consequently, the advantages of the femtosecond laser lithography (inexpensively, high speed of writing and ability to create surface with unique chemical characteristics) can be used successfully in applications where requirements of relief precision characteristics are not very high.

Acknowledgements: This work was partially supported by the Russian Foundation for Basic Research (project Nos. 10-08-00941a, 09-02-12018OFI_M, 11-02-01202a, 11-08-01165a, 09-02-01065-a).

References:

1. B. Dusser, Z. Sagan, H. Soder et al**.** *Opt. Expr*. 18, 2913 (2009).
2. A.A. Ionin, S.I. Kudryashov et al. *Phys. Rev. B* 83, 115426 (2011).
3. A.A. Ionin, S.I. Kudryashov et al. *Appl. Phys. A* (2011) (published online).
4. A.A. Ionin, S.I. Kudryashov et al. *Nanotech. in Russia* 3-4, 247 (2011).
5. E.V. Golosov, V.I. Emel'yanov et al. *JETP Lett*. 90, 107 (2009)
6. S. A. Akhmanov, V. I. Emel'yanov et al. *Sov. Phys. Usp.* 28, 1084 (1985)
7. V.P. Korolkov, A.A. Ionin et al. *Quantum Electron*. 41, 387 (2011)

O-8-LM

NONLINEAR-OPTICAL EFFECTS IN MAGNETIC NANOSTRUCTURES

T.V. Murzina[1], I.A. Kolmychek[1], S.I. Mitryukovskiy[1], V.L. Kryutyanskiy[1]
[1] *Department of Physics, Moscow State University, 119991 Moscow, Russia*
murzina@mail.ru

Metallic nanostructures attract much attention as they reveal unique properties that are absent for the case of bulky structures. Excitation of localized surface plasmons is one of the most intensively studied phenomena first of all because of a possibility to exploit it in optical and magnetooptical sensing devices. At the same time, the sensitivity and spectral selectivity of nonlinear-optical effects can be much higher as compared with those of linear optics, which can also be of practical importance. Third-order nonlinear-optical effects, such as nonlinear refraction and absorption, are of special interest in this field. Another issue which is of high importance is the development of novel experimental techniques for the characterization of nanostructures. A distinguished place here belongs to optical second harmonic generation (SHG). This effect is known for its high sensitivity to the properties of surfaces and internal interfaces, including magnetic ones [1]. Thus a study of the main SHG properties of magnetized surfaces is an important task.

In this work we present the results on the nonlinear-optical diagnostics of different types of nanostructures using the second- and third-order nonlinear-optical effects. The following magnetic metallic nanostructures were studied: (i) isotropic ferromagnetic Au/Co films on Si(001) substrate, (ii) an array of nickel nanorods and (iii) core-shell Au-Fe_2O_3 nanoparticles in a polymer matrix. Nonlinear-optical studies were performed when using the output of a femtosecond Ti-sapphire (wavelength range 710-850 nm) or nanosecond OPO laser system

(wavelength range 450-700 nm) lasers as the fundamental radiation. For the magnetic measurements, the samples were placed in a transversal DC magnetic field of 3 kOe.

(i) Magnetization-induced effects in the SHG reflected from a structurally isotropic magnetic film was studied in Au/Co films. We demonstrate that magnetization of the films leads to the appearance of a pronounced SHG anisotropy, including that for the s-polarized SHG component that is prohibited in nonmagnetic structures. The relative values of magnetization-induced $\chi^{(2)}$ susceptibility are shown to be comparable with nonmagnetic $\chi^{(2)}$ components.

(ii) SHG spectroscopy was studied in an array of Ni nanorods, formed by electrochemical deposition inside the porous alumina oxide [2]. The plasmon excitation in Ni nanorods is responsible for the observed spectra of the s-polarized SHG. Second harmonic interferometry along with the nonlinear magneto-optical Kerr effect demonstrate a large changes in the SHG phase in the vicinity of the plasmon excitation wavelengths.

(iii) Resonant many-fold amplification of the nonlinear refraction and absorption effects is attained in the vicinity of the excitation of localized surface plasmons in core-shell Au-Fe_2O_3 nanoparticles. The measurements are performed using the spectroscopic Z-scan technique performed in the spectral range of the fundamental radiation of 500-640 nm. The observed enhancement is due to the resonant amplification of the local optical field in plasmonic nanoparticles.

References:

1. T.V. Murzina, E.M. Kim et. al., "Magnetization-induced optical third-harmonic generation in Co and Fe nanostructures", Phys. Rev. B, **73**, 140404(R) (1-6) (2006).
2. A. A. Stashkevich et. al., "Spin-wave modes in Ni nanorod arrays studied by Brillouin light scattering", Phys. Rev. B, page-page (2009).

O-9-LM

INVESTIGATION OF CARBON THIN FILMS PRODUCED BY FEMTOSECOND VACUUM LASER ABLATION

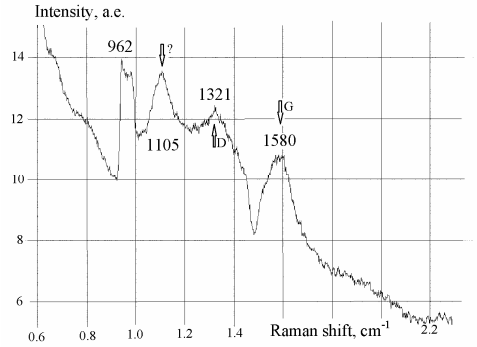
M.N. Gerke, K.S. Khorkov, V.G. Prokoshev, S.M. Arakelian
Vladimir State University, Dept. of Physics and Applied Mathematics, Gorky St., 87, P.C. 600000 Vladimir, RUSSIA
laser@vlsu.ru

The given work is devoted for experimental studying of the nanostructures arising at laser ablation of carbon targets and deposition of ablation's products on a substrate. Optical scheme of our experiment is similar to one that offered in [1].

The focused laser radiation gets on a target's surface under 45^0 to beam axis. The sprayed material of a target scatters in volume of the vacuum chamber and deposits on a cold substrate. Sufficiently compound structures are formed on a substrate in dependence of experimental parameters.

The following output parameters were used in our experiments with femtosecond Yb:KGW laser system: a pulse repetition rate of 10 kHz, a pulse duration of 300 fs and average radiation power of 1.5 W. Laser beam has an opportunity to scan along target's surface with galvoscanner. Amorphous glasscarbon and pirographite were used as source of carbon atoms and polished plates of quartz glass and silicon - as substrate for vapor deposition.

The researches have been carried out by means of AFM and SEM, show, that the deposition area consists of the several zones with own scale of the formed nanostructures. Raman spectra of carbon films is an object of special interest.



Near well-known D and G carbon peaks at 1321 cm^{-1} and 1580 cm^{-1} a new one was found at 1105 cm^{-1}. In accordance with [2] this peak can identified with diamond nanoclasters. Independent method such as X-ray diffraction is necessary for additional research of this nanostructures.

References:

1. S. Eliezer, N. Eliaz, E. Grossman, D. Fisher, I. Gouzman, Z. Henis, S. Pecker, Y. Horovitz, M. Fraenkel, S. Maman, V. Ezersky, and D. Eliezar, "Nanoparticles and nanotubes induced by femtosecond lasers", Laser and Particle Beams, 15-19 (2005)
2. V.P. Novikov, A.T. Matveev, L.L. Klimovich, "Metod selektivnogo travleniya v elektrohimicheskom sinteze metastabil'nyh form ugleroda", Aktual'nye problemy fiziki tverdogo tela, Minsk. 732-757 (2003)

O-10-LM

EXCIMER LASER INDUCED NANOABLATION OF DIAMOND MATERIALS

M.S. Komlenok[1], V.V. Kononenko[1], V.G. Ralchenko[1], S.M. Pimenov[1], V.I. Konov[1]
[1] *Natural Sciences Center, A.M. Prokhorov General Physics Institute, Vavilov str. 38, Moscow 119991, Russia*
komlenok@nsc.gpi.ru

Possibility of ultra-precise laser induced etching of diamond materials was investigated. Natural single crystal diamond, nanocrystalline diamond, amorphous diamond-like films were irradiated in air and low vacuum with excimer laser (λ=248 & 193 nm, τ=20 ns) at fluencies 0.01÷20 J/cm^2. It is found that depending on material, laser fluence and wavelength physical and chemical regimes of such materials ablation are realized. The role of surface graphitization and oxidation, charge carriers generation in diamond material is studied. It is shown that ablation rates as low as 10^{-3}-10^{-4} nm/pulse can be obtained. The process was called nanoablation due to extremely low rate of material etching and was applied to diamond surface nanostructuring. Two regimes of nanoablation are considered both being observed only in air. The first is specified by laser induced surface graphitization and subsequent oxidation by the following laser pulses. Specific features of short pulsed surface chemical reaction will be discussed. Particular attention will be paid to water adsorption in atmospheric air. The second regime is observed at fluencies of UV radiation below surface graphitization threshold but sufficient to induce high concentration of charge carriers in diamond. It is considered that such carriers excitation creates on the surface less bonded carbon atoms or clusters that can react easier with oxygen.

O-11-LM

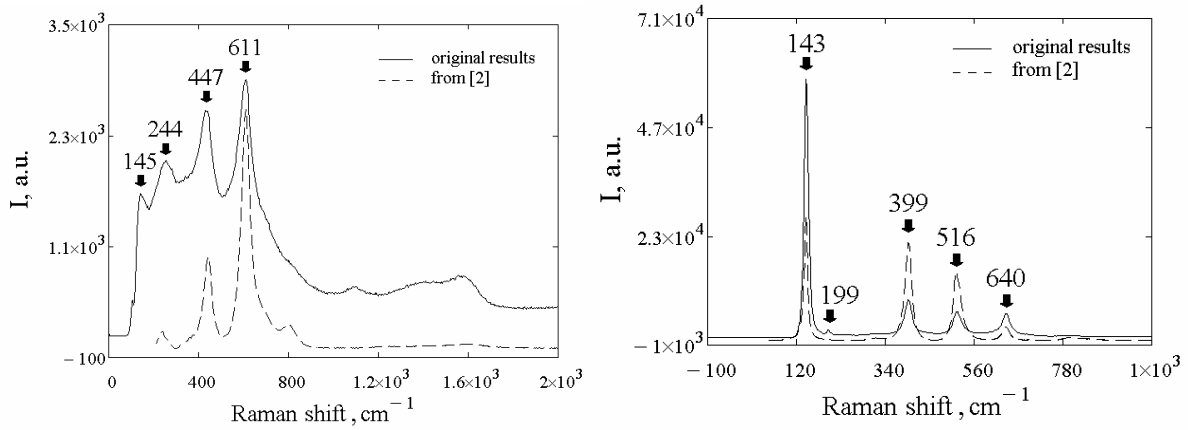
INVESTIGATION OF TITANIUM THIN FILMS PRODUCED BY FEMTOSECOND LASER ABLATION

M.N. Gerke, K.S. Khorkov, Noman Mustafa A.A.,V.G. Prokoshev, S.M. Arakelian
Vladimir State University, Dept. of Physics and Applied Mathematics, Gorky St., 87, P.C. 600000 Vladimir, RUSSIA
laser@vlsu.ru

The given work is devoted experimental researching of the nanostructures arising at laser ablation of titanium targets and deposition of ablation's products on a substrate. The optical scheme of our experiment is similar to the scheme offered in work [1].

The focused laser radiation gets on a target located under a corner 45^0 to it. The sprayed material of a target scatters in volume of the vacuum chamber and deposites on a cold substrate. Depending on adjustable parametres of experiment on a substrate sufficiently compound structures are formed.

In our experiments we used two different laser systems. The femtosecond Ti:Sapphire laser system providing following parametres: a pulse repetition frequency of 1 kHz, a radiation pulse duration of 50 fs and average radiation power of 1 W. And the femtosecond Yb:KGW laser system: a pulse repetition rate of 10 kHz, a pulse duration of 300 fs and average radiation power of 1.5 W.



First of all it would be desirable to concentrate on properties of films produced by Ti:Sapphire laser system. After withdrawal a substrate with the raised dust film from the vacuum chamber in the central zone occurs an interaction of active nanoparticles with atmospheric oxygen. Quasiperiodic structures reminding folds are formed. And the analysis of raman spectrums has shown the crystal form of titan`s oxide – rutile [2].

At the dusting of films with Yb:KGW laser system uniform distribution of nanoparticles without formation of oxides is formed. But at experiments in air also it is formed oxide of titan but already other crystal form - anatase.

References:

1. S. Eliezer, N. Eliaz, E. Grossman, D. Fisher, I. Gouzman, Z. Henis, S. Pecker, Y. Horovitz, M. Fraenkel, S. Maman, V. Ezersky, and D. Eliezar, "Nanoparticles and nanotubes induced by femtosecond lasers", Laser and Particle Beams, 15-19 (2005)
2. Romanian database of raman spectroscopy: www.rdrs.uaic.ro

O-12-LM

MULTIFUNCTIONAL SI-BASED NANOPARTICLES FOR BIOLOGY AND MEDICINE

A. Vladimirov[1], S. Korovin[1], V. Pustovoy[1], A. Surkov[1]
[1] *A.M. Prokhorov General Physics Institute,*
119991, Russia, Moscow, 38 Vavilov st.
vladimirov.alex@gmail.com

The experiments for producing of the silicon-based composite nanoparticles were made. Synthesis of nanoscale powder was carried out in the flow reactor in a stream of gas mixture: silane SiH_4 and additional gases (helium, ammonia, methane, BCl_3). From the TEM images the mean diameter of samples are 10 nm with narrow size distribution. Electron diffraction images showed that samples have crystal lattice corresponded to silicon and amorphous Si_2B_3.

After $HF+HNO_3$ and $HF+FeCl_3$ treatment and washing with water the luminescence clearly visible by naked eye appeared. Luminescence show tunable character depending on the excitation wavelength and the etching time. Also production the composite nanoparticles with Si-N, Si-C and Si-B bonds was showed.

These results are perspective for developing the silicon optical markers for medicine.

V. LASER SYSTEMS AND NEW LASER MATERIALS

I-1-LN

LOW-NOISE RAMAN AMPLIFICATION WITH CO-PROPAGATING PUMPING BY SEMICONDUCTOR DISK LASERS

Jussi Rautiainen, Oleg G. Okhotnikov
Optoelectronics Research Centre, Tampere University of Technology,
FIN-333101 Tampere
jussi.rautiainen@tut.fi

Optical pumping of Raman fiber lasers and amplifiers with semiconductor disk lasers represents novel advantageous approach as compared to conventional pumping techniques based on diode lasers and/or fiber converters. Short pulse generation and low noise amplification are experimentally demonstrated using this pumping concept. High power, low noise and diffraction-limited beam quality naturally attributed to disk laser geometry promises significant positive impact on optical amplifier technology to be expected.

The distinct advantages of Raman fiber lasers and amplifiers have been demonstrated when semiconductor disk lasers are implemented as a high-power and low-noise pumping sources. Low relative intensity noise of -140 dB/Hz combined with multi-Watt power launched from disk lasers into single-mode fibers at wavelength range covering the O-band to L-band spectra opens up a new possibility particularly for optical communications. Mode-locked Raman fiber lasers with high-quality pulses are obtained both at normal and anomalous dispersion regime. The laser operating in a normal dispersion regime demonstrates stable mode-locking without dispersion compensation with 2.7 ps pedestal-free. In the anomalous dispersion regime, a SESAM was implemented instead of a nonlinear polarization evolution for establishing mode-locked operation. This resulted in 1.97 ps pulse generation with time-bandwidth product of 0.69 that is only by a factor of 1.36 higher than the transform limit. Simultaneous pumping by several disk lasers allows short pulse generation at various wavelengths using the same laser cavity. Efficient low-noise pumping scheme offered by disk lasers demonstrates promising potential for Raman fiber lasers and hybrid amplifiers.

References:

[1] O.G Okhotnikov (ed.), *Semiconductor disk lasers, physics and technology*. Weinheim: Wiley-VCH, 2010.
[2] A. Chamorovskiy, J. Rautiainen, A. Rantamäki, and O. G. Okhotnikov, "Low-noise Raman fiber amplifier pumped by semiconductor disk laser," *Opt. Express* , vol. 19, pp. 6414-6419, 2011.
[3] A. Chamorovskiy, J. Rautiainen, A. Rantamäki, K. M. Golant, and O. G. Okhotnikov, "1.3 μm Raman-bismuth fiber amplifier pumped by semiconductor disk laser," *Opt. Express*, vol. 19, pp. 6433-6438, 2011.
[4] A. Chamorovskiy, J. Rautiainen, J. Lyytikäinen, S. Ranta, M. Tavast, A. Sirbu, E. Kapon, and O. G. Okhotnikov, "Raman fiber laser pumped by a semiconductor disk laser and mode locked by a semiconductor saturable absorber mirror," *Opt. Lett*., vol. 35, pp. 3529-3531, 2010.
[5] A. Chamorovskiy, A. Rantamäki, A. Sirbu, A. Mereuta, E. Kapon, and O. G. Okhotnikov, "1.38-μm mode-locked Raman fiber laser pumped by semiconductor disk laser," *Opt. Express*, vol. 18, pp. 23872-23877, 2010.

I-2-LN

APPLICATION OF LASER-BASED METHODS IN AEROSOL MEASUREMENTS

A. Czitrovszky, A. Nagy, A. Kerekes, D. Oszetzky
Research Institute for Solid State Physics and Optics
H-1525 Budapest, P. O. Box 49.
czi@szfki.hu

Determination of the size distribution, concentration, absorption, scattering, extinction, transmission, refractive index and shape factor of aerosol particles using optical methods is crucial to estimating the condition of the atmosphere.

The common feature of the these methods is the possibility to perform *non-contact*, *real time*, mainly *in situ* measurements with a short sampling time and high accuracy. As the media holding the information is the light itself, in the most cases the sampling can be done in a distance from the sample. The next advantage of the optical methods is the possibility to determine simultaneously a number of different parameters – concentration, size distribution, complex refractive index (real and imaginary part), density, etc.

In last decades using laser-based technologies we developed a number of non-contact methods and instruments for measurement of these parameters and applied them to environmental monitoring, health care, pharmacology, chemical industry, medicine, microelectronics, biology, etc.

The aim of this presentation is to give a short overview of existing light scattering methods, the state of the art of their application in the micron and in the sub-micron range particle measurements, to demonstrate some examples of the development of the particle measurement instrumentation, emphasizing the development of new airborne particle counters and sizers, new methods for determination of their optical properties, electrical charge, density etc., comparison of different instruments and to present a short analysis of the possible further applications.

We introduce also the theoretical and experimental background of our developments, show the principle of new methods and overview the different applications.

Acknowledgements: The authors acknowledge the support of the National Innovation Office - ELI Helios project.

References:

1. W.W. Szymanski, A. Nagy, A. Czitrovszky, P. Jani, A new method for the simultaneous measurement of aerosol particle size, complex refractive index and particle density, Measurement Science and Technology, 13, 303-307 (2002).
2. A. Nagy, W.W. Szymanski, A. Golczewski, P. Gál, A. Czitrovszky, Numerical and experimental study of the performance of the Dual Wavelength Optical Particle Spectrometer, Journal of Aerosol Science, 38 467-478 (2007).

I-3-LN

GENERATION OF MULTI-MILLIJOUL FEW-CYCLE PULSES IN MID-IR: BENEFITS AND CHALLENGES

A. Pugžlys[1], G. Andriukaitis[1], T. Balčiūnas[1], S. Ališauskas[1], D. Kartashov[1], A. Baltuška[1], T. Popmintchev[2], M.-C. Chen[2], M.M. Murnane[2], H.C. Kapteyn[2]
[1]*Photonics Institute, Gusshausstrasse 27-387, A-1040, Vienna, Austria*
[2]*JILA, University of Colorado at Boulder, Boulder, CO 80309-0440*
pugzlys@tuwien.ac.at

In recent years much attention has been paid to the development of energetic femtosecond light sources operating in the IR spectral range. The increase of the optical cycle duration plays a crucial role for the generation of coherent keV-photon-energy X-ray pulses via the mechanism of higher-order harmonic generation (HHG) in atomic gas targets, because the HHG cutoff energy scales as a square of the wavelength of the driving source. Furthermore, recently by employing IR optical parametric amplifiers (OPA) pumped by Ti:sapphire lasers it was demonstrated that unfaivorable λ^{-5} HHG photon flux scaling in the atomic dipole regime can be overcome by implementing phase matching techniques [1]. The extension of the OPA output into the mid-infrared (MIR) above 3 μm at multi-mJ pulse energy levels and few-cycle duration is challenging because the traditional combination of a Ti:sapphire amplifier as a pump source and efficient BBO/BIBO crystals becomes impractical due to the IR absorption in the crystal and the intrinsic limitation of the $\chi^{<2>}$-based frequency conversion scheme. Furthermore, to ensure that the HHG process is fully phase matched, the required intensity of the MIR driver pulse must reach 10^{14}-10^{15} W/cm^2, which corresponds to the pulse energy of several mJ for the obtained bandwidth. Therefore, HHG with MIR pulses becomes progressively "energy hungry" with the increase of the driver wavelength, whereas the scaling of the MIR pulse energy becomes progressively more challenging because of the diminishing energy fraction carried by the MIR idler wave in the OPA frequency conversion process.

Recently we have developed a compact 20-Hz-repetition-rate MIR OPCPA system operating at the central wavelength of 3.9 μm and delivering 8-mJ per pulse [2]. The pulses are compressed to 83 fs (< 7 optical cycles) and reach a peak power of 90 GW. Because of the long optical period (~13 fs) and a high peak power, the system opens a range of unprecedented opportunities for tabletop ultrafast science. By using the OPCPA system we have generated bright coherent HHG X-rays at photon energies >1.6 keV (<7.8 Å or > 5031th harmonics of the 3.9-μm pump). Full phase matching of HHG in the keV region of the spectrum assures high photon flux that, if scaled up to a 1kHz rep rate, would correspond to ~10^8 photons/sec in a fractional bandwidth of $\Delta\lambda/\lambda \approx 1\%$ at 1 keV. Such fluxes would enable bio and nano-imaging in the water window and beyond, as well as element-selective magnetic imaging. In another demonstration of the unprecedented potential of the 3.9-μm source, we achieved first-ever femtosecond filamentation in MIR. Filaments were observed in Ar and N_2 accompanied by spectral broadening extending from UV to > 5 μm, which opens new perspectives for understanding the fundamentals of plasma formation and filamentation dynamics and holds promise for practical applications of MIR sources in remote sensing.

References:

1. T. Popmintchev, M.-C. Chen, P. Arpin, M.M. Murnane, and H.C. Kapteyn, "The attosecond nonlinear optics of bright coherent X-ray generation," Nature Photonics 4, 822-832 (2010), and references therein.

2. G. Andriukaitis, T. Balčiūnas, S. Ališauskas, A. Pugžlys, A. Baltuška,T. Popmintchev, M.-C. Chen, M.M. Murnane, H.C. Kapteyn, "90-GW Peak-Power Few-Cycle Mid-IR Pulses from an Optical Parametric Amplifier", Opt. Lett., in pres.

I-4-LN

MODE-LOCKING OF SOLID-STATE LASERS BY SINGLE-WALLED CARBON-NANOTUBE BASED SATURABLE ABSORBERS

Valentin Petrov
Max-Born-Institute for Nonlinear Optics and Ultrafast Spectroscopy, Max-Born-Str 2A, D-12489 Berlin, Germany
petrov@mbi-berlin.de

Recent developments indicate that single-walled carbon nanotubes (SWCNTs) can be successfully employed as ultrafast saturable absorbers (SAs) for mode-locking of solid-state lasers, representing a real alternative to the widely spread semiconductor saturable absorber mirrors (SESAMs). However, while SESAMs exhibit a spectrally narrowband nonlinearity, require sophisticated manufacturing processes and mandate controlled defect implantation to warrant ultrafast response times, SWCNT-SAs are characterized by broadband absorption with large third-order nonlinearity and can be fabricated by relatively simple methods. The absorption band of SWCNT-SAs can be controlled by varying the nanotube diameter and chirality and, depending on the electronic transitions of semiconducting nanotubes, covers the near-IR spectral range from ~0.8 up to ~2.0 μm.

The first demonstration of passive mode-locking with a SWCNT-SA was realized with Er-doped fiber lasers [1] and most of the subsequent efforts were restricted to such fiber lasers because their single-pass gain can easily tolerate relatively high non-saturable insertion losses.

For application of SWCNT-SAs in bulk solid-state lasers it is necessary to reduce the non-saturable losses to the lowest level possible. The first demonstration of bulk laser mode-locking was based on the same Er^{3+} transition in glass at 1.57 μm [2]. This stimulated a lot of activities with various solid-state lasers based on rare-earth and transition metal dopants exhibiting very different spectroscopic characteristics such as emission cross sections, fluorescence linewidths and lifetimes [3]. In this talk, the results obtained in the picosecond and femtosecond (with intracavity dispersion compensation) regimes using transmission and reflection type SWCNT-SAs in various bulk solid-state lasers operating between 0.8 and 2 μm will be reviewed. These include femtosecond Ti:sapphire lasers near 0.8 μm, femtosecond Yb- and femtosecond/picosecond Nd-lasers in the 1 μm range, femtosecond Cr:forsterite lasers near 1.25 μm, picosecond Nd-lasers near 1.34 μm, femtosecond Cr:YAG lasers near 1.5 μm, and picosecond Tm-lasers near 1.95 μm.

Careful control of the SWCNT bundling and curl in an optimized SA manufacturing process enabled the fabrication of one single device providing extremely broad (>500 nm) ultrafast saturable absorption as well as hybrid devices with octave spanning absorption coverage. Thus, mode-locking of different bulk solid-state lasers in an almost 1000 nm wide spectral range (from ~1 to ~2 μm) could be achieved with one and the same transmission type SWCNT-SA.

References:

1. S. Y. Set , H. Yaguchi, Y. Tanaka, M. Jablonski, J. Lightwave Technol. 22, 51-56 (2004).

2. T. R. Schibli, K. Minoshima, H. Kataura, E. Itoga, N. Minami, S. Kazaoui, K. Miyashita, M. Tokumoto, Y. Sakakibara, Opt. Express 13, 8025-8031 (2005).
3. W. B. Cho, J. H. Yim, S. Y. Choi, S. Lee, A. Schmidt, G. Steinmeyer, U. Griebner, V. Petrov, D.-I. Yeom, K. Kim, F. Rotermund, Adv. Funct. Mater. 20, 1937-1943 (2010).

I-5-LN

RESONANCE ENHANCEMENT OF THE NONLINEAR PHOTOLUMINESCENCE IN GALLIUM SELENIDE

Ch. Angermann[1], P. Karich[1], L. Kador[1], K. R. Allakhverdiev[2,3], M. Ö. Yetiş[2], T. Baykara[2], E. Yu. Salaev[3]
[1]*Institute of Physics and Bayreuther Institut für Makromolekülforschung (BIMF), University of Bayreuth, Germany*
[2]*Turkish Scientific and Technological Research Council (TÜBITAK), Marmara Research Center (MRC), Gebze/Kocaeli, Turkey*
[3]*Azerbaijan National Academy of Sciences, Institute of Physics, 370073 Baku, Azerbaijan*
kerim.allahverdi@mam.gov.tr

The layered chalcogenide semiconductor gallium selenide (GaSe) has one of the highest coefficients $\chi^{(2)}$ of optical second-order nonlinearity. Upon irradiation of focused HeNe laser light (632.8 nm), the material emits blue-shifted luminescence with a quadratic intensity dependence. This effect, which was also observed in mixed crystals of the form $GaSe_{1-x}S_x$ with low sulfur content ($x \leq 0.05$), had been interpreted as second-harmonic generation followed by the formation and radiative decay of Wannier excitons.[1] We demonstrate that the effect shows very strong resonance enhancement upon heating, which shifts the absorption edge and the exciton levels of the materials to lower energies (*i.e.*, towards the laser line).

The photoluminescence appears to be strongest when the energy level of the direct exciton, which emits it, is resonant with the photon energy of the laser. The previously observed apparent enhancement of the photoluminescence by electric fields[2] is interpreted in this context: It is caused by the concomitant slight red shift, which is either due to the Franz-Keldysh effect or weak heating of the electrode chip. The origin of the nonlinear process is most probably a sequence of two one-photon transitions involving the exciton state. But also resonance-enhanced second-harmonic generation and two-photon absorption, although less likely, cannot be ruled out completely.

References:

1. C. Pérez León, L. Kador, K. R. Allakhverdiev, T. Baykara, A. A. Kaya, ″Comparison of the Layered Semiconductors GaSe, Gas, and $GaSe_{1-x}S_x$ by Raman and Photoluminescence Spectroscopy″ J. Appl. Phys. 98, 103103-1 - 103103-5 (2005).
2. Y. Fan, M. Bauer, L. Kador, K. R. Allakhverdiev, E. Yu. Salaev, ″Photoluminescence Frequency Up-Conversion in GaSe Single Crystals as Studied by Confocal Microscopy″ J. Appl. Phys. 91, 1081-1086 (2002).

O-1-LN

THE STUDY OF DIODE-PUMPED TM:SC_2SIO_5 LASER

Yu.L. Kalachev, Yu.D. Zavartsev, A.I. Zagumennyi, S.A. Kutovoi, V.A. Mikhailov, V.V. Podreshetnikov, I.A. Scherbakov
A.M. Prokhorov General Physics Institute, RAS, 38 Vavilov str., 119991 Moscow, Russia
kalachev@kapella.gpi.ru

The idea of realization of diode pumped Tm:Sc_2SiO_5 (Tm:SSO) laser was appeared not long ago [1]. It was supposed that Tm:SSO crystal can be effectively used for lasing in 2-μm range. But the successful laser operation of this crystal was firstly reported by our group only this year [2]. One of the main problem on the way of obtaining of effective Tm:SSO lasing is possibility of crystal growth with good optical quality. We grew a Tm:SSO crystal boule of laser quality with dimensions: 60 mm long with the cross section 10 x 14 mm. The concentration of Tm^{3+} ions was ~ 5 at. %. In experiments we used laser elements in the form of a cube with 3 mm edges and uncoated plane-parallel faces. Absorption spectrum of Tm:SSO crystal is shown in fig. 1. As we can see shortwave part of spectrum practically has not additional broad bend color center absorption presence which is one of the main reasons of laser efficiency reduction.

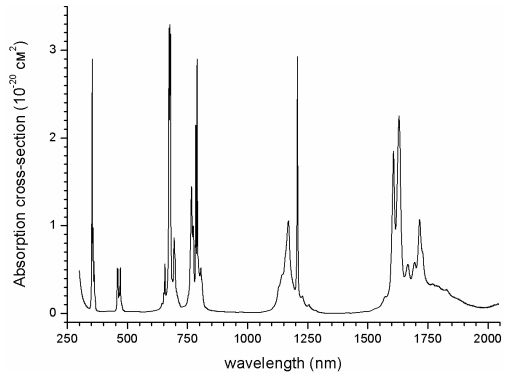


Fig. 1. Absorption spectrum of Tm:SSO crystal.

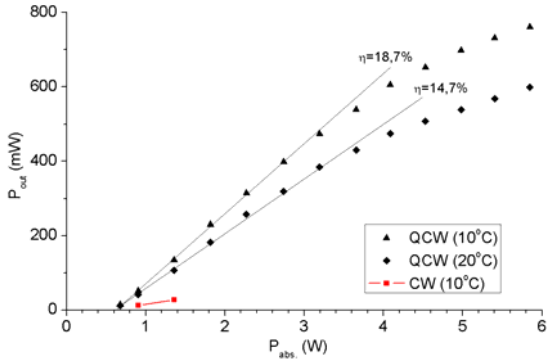


Fig. 2. Output power vs. absorbed pump power for different lasing conditions.

In our laser experiments we used the two-mirror laser cavity which was formed by a plane high reflecting for 2 μm mirror and an output coupler of 52 mm radius of curvature and 98% reflectivity. The pumping at a wavelength of 792 nm was performed using a fiber-coupled diode array; the numerical aperture, the fiber diameter, and the maximum cw output power were 0.22, 0.116 mm, and 10 W, respectively. It was experimentally realized for the first time lasing of Tm:Sc_2SiO_5 crystal at diode pumping (Fig. 2). The highest laser efficiency was 15.3% at the slope efficiency ~ 18.7%. The output power reached 760 mW. The temporal, spatial and spectral laser characteristics were investigated.

Acknowledgements: This work was sponsored by the Russian government in the frame of contract no. 14.740.11.0069.

References:

1. Lihe Zheng, Jun Xu, Liangbi Su, Hongjun Li, W. Ryba-Romanowski, R. Lisiecki, and P. Solars "Crystal structure and optical study of Tm:Sc_2SiO_5 single crystal" Appl. Phys. Lett. 96, 121908 (2010)
2. Yu.D. Zavartsev, A.I. Zagumennyi, Yu.L. Kalachev, S.A. Kutovoi, V.A. Mikhailov, V.V. Podreshetnikov, I.A. Scherbakov "Diode-pumped Tm:Sc_2SiO_5 laser (λ = 1.98 μm)" Quant. Electron. 41, (5), pp. 420-422 (2011) (will be published)

O-2-LN

ZERO-DISTANCE PULSE FRONT AS A GRAPHIC GROUP DELAT CHARACTRERISTIC OF THE TWO-GRATING STRENCHER

Andrey Gitin
Max-Born-Institut für Nichtlineare Optik und Kurzzeitspectroskopie,
Max-Born-Str. 2 A, 12489 Berlin, Germany
agitin@mbi-berlin.de

Two-grating dispersion delay lines (Treacy's compressor [1] and Martinez's stretcher [2]) are now widely used for correction of the dispersion of ultrafast laser pulses. In these delay lines the group delay τ for a monochromatic wave of wavelength λ is proportional to the geometrical path length p of its trajectory: $\tau(\lambda) = p(\lambda)/c$; where c is the speed of light in vacuum [1-4]. In [3] using the unfolding technique we have shown that the natural visual graphic characteristic of description of Treacy's compressor is the so-called "zero-distance pulse front". Let us show that the natural visual graphic characteristic of description of the two-grating Martinez's stretcher is the "zero-distance pulse front" too.

The Martinez's stretcher [2] consists of a pair of identical reflection gratings and a perfect axisymmetrical reflecting optical system between them (see Fig.1). The first grating G^{S1} splits an input polychromatic ray into a diverging homocentric beam of the spectrally coloured rays with the center at the point of incidence P. The perfect optical system turns this diverging homocentric beam of rays into a mirror symmetrical converging homocentric beam of rays with the center at the point P'. The second grating G^{S2} turns the converging homocentric beam into a parallel beam of spectrally coloured rays. It is a spatial chirp of Martinez's system.

A ray of the spatial chirp can be continued in its reverse direction to a point P*, where points P and P* are equidistant from the point M: |P*M| = |MP|. If the wavelength λ changes the point M moves over the second grating. The points P* form the curve τ^{Mar} depending on λ. This curve can be called "zero-distance pulse front" of Martinez's stretcher.

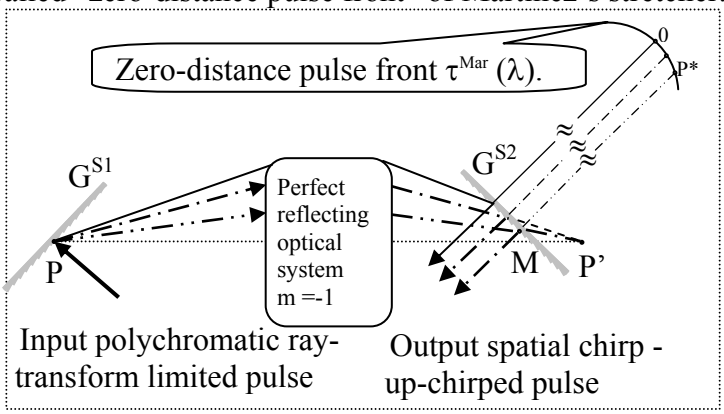


Fig.1. Zero-distance pulse front of Martinez's stretcher. The red ray is shown by the double dash-and-dot line and the blue ray is shown by the dash-and-dot line.

References:

1. E.B. Treacy, "Optical pulse compression with diffraction gratings", IEEE Jornal of Quantum Electronics, Vol. QE-5 (9), 454-458 (1969).
2. O.E. Martinez, "3000 Times Gratig Compressor with Positive Group Velocity Dispersion: Applicatiom to Fiber Compensation in 1.3-1.6 μm Region", IEEE Journal of Quantum Electronics, Vol. QE-23 (1), 59-64 (1987).
3. A.V. Gitin, "Zero-distance pulse front as a group delay characteristic of the two-grating compressor", Optics Communication, Vol. 283, 1090-1095 (2010).

O-3-LN

SOME IMPORTANT ISSUES IN HIGH-POWER LASER DRIVE DEVELOPMENT

Jianqiang Zhu , Baosuan Chen,Yanli Zhang, Junyong Zhang, Dean liu, Xuejie Zhang,Zhaoyang Jiao, Yan Zhang, Pingping Sun, Jie Miao
Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, No. 390, Qinghe Road, Jiading District, Shanghai 201800, China
jqzhu @shcnc.ac.cn

Laser driver is the key element in experimental study of Inertial confinement fusion (ICF), which requires not only that the driver has very high laser power and good near-field beam quality, but also has a very high load capacity. Construction of such a huge device is almost impossible in laser physics and engineering. Several important issues during the development of high-power laser drivers are studied in this paper. The influence of these issues on the laser design and operation are also analyzed, which includes laser transmission, digital diagnostic and feedback control technology, and laser beam pointing and engineering. The laser transmission is mainly related with fundamental beam propagation, such as noise sources in devices, light transmissions in spatial filter, and physical and load capacity of final optics system. For the digital diagnostic and feedback control technology, the online digital control technology, the feedback control framework, the automated fault diagnostics and feedback control technology of the whole physical process are related. As to the laser beam pointing and engineering, the stability of beam pointing in laser drivers, the application of finite element analysis in laser engineering and the processing quality of optical components are mainly concerned.

References:

1. Evolution of low-frequency noise passing through spatial filter in high power laser system Pingping Sun, Dean Liu, Yanli Zhang, Xiaoyan Li, Yan Zhang, and Jianqiang Zhu Proc. SPIE 7789, 778910 (2010)
2. Study on the Ghost Images Spatial Distribution in High Power Laser Facilities, Zhang Yan, Zhang Yanli, Sun Pingping, Zhu Jianqiang, 2010 SPIE Optics&Photonics, 2010.8
3. Jia Xu,Jianqiang Zhu,Fang Liu,Pengqian Yang. Specific Stability Design Criteria Based On Coupled Motion Considerations For Optomechanical System In SGⅡ Facility,[C] Laser Optics 2010. St.Petersburg.

O-4-LN

NEW METHOD FOR INCREASING THE LIFETIME OF HIGH POWER COPPER BROMIDE VAPOR LASER

Krassimir Dimitrov, Todor Petrov, Nikola Sabotinov
Institute of Solid State Physics, Bulgarian Academy of Sciences, 72, Tzarigradsko Chaussee, Blvd., 1784 Sofia, , Bulgaria
krasimir @issp.bas.bg

The lifetime of a sealed - off 40 W copper bromide vapor laser has been studied. During the investigation time, the power supply parameters were maintained constant. The sealed – off laser tube was filled with 20 Torr Ne and 0.5 Torr H_2.

The length of the laser tube was 2000 mm and the bore diameter was 58 mm. The active zone was 1500 mm, limited by diaphragms. The electrodes were made from oxygen free porous copper and multifibre copper wire.

The electric supply was provided by a high-voltage pulse block (based on a thyratron EEV 1535 and EEV 1835). The lifetime was investigated at 13 kV U_a and 17.6 kHz PRF. Laser output power was 41 W in the beginning. The wall of the zone far from the discharge was maintained at room temperature. During the first 300 hours the change of the parameters was insignificant. The fluctuations were result of unstable supply voltage. In the next few hundred hours the output power decreased to 38 W. The output power felt down to 30 W in the next 50 hours.

We assumed that there were two ways to restore the optimal proportion between the components in the laser tube, as well as the output parameters of the laser:

- First, to increase the hydrogen gas pressure in the tube using special construction hydrogen getter mounted in the tube;
- Second, to reduce the contaminations by using a cooling trap.

The first hydrogen replenishment was set off at 450 h. The hydrogen getter was heated up to 650˚C. The output power did not obtain the expected values and improvement was not observed.

Next step was to apply the second idea – a cooling trap. A small thermos was fixed below the cool part of the laser tube. The volume of the cooling trap was filled with liquid nitrogen. The wall temperature was reduced to –10˚C by the evaporated nitrogen. The results were: (1) restored lasing power P_{out} of about 40 W; (2) current pulse amplitude restored to the optimal values and shape; (3) good parameters of beam profile. The tube was monitored from the 450th up to the 515th hour at these conditions; the average output laser power was over 40 W.

After these preliminary investigations the cooling trap was fixed on the laser tube wall closely to the windows. The cold trap was spot made by Peltier element. The temperature at this area could be varied from room temperature to -35^0C. The average output power as a function of the temperature of the cooling trap was monitored. The optimum conditions were found in the temperature range of -6^oC ÷ -10^oC. Up to now the lifetime reached 1000 h.

Acknowledgements: This work was supported by the project NATO SfP-972685 "SfP-Copper Bromide Laser".

O-5-LN

NEW KINDS OF OSCILLATIONS IN SOLID-STATE RING Nd:YAG LASERS

Aulova T.V.[1], Checkina S.N.[2]
[1] *M.V.Lomonosov Moscow State University, Physics Department, Moscow, Russia*
[2]*SINP MSU, Moscow, Russia*
tatyana.v.aulova@gmail.com

Diode-pumping solid-state nonplanar ring oscillator (NPRO) is complicated nonlinear dynamic system in which a large number of oscillation modes may be caused by variety of different parameters. Detailed studies of the dynamics of NPRO are of great interest in practical applications such as laser gyroscopes, precision measurements, as well as in

understanding the fundamental processes of propagation and nonlinear wave interaction in the medium.

Solid-state ring Nd:YAG chip laser investigated and described in [1] is an example of NPRO. Self standing chip laser operates in the self-modulation regime of the first kind (see Fig.1a). An applying of external magnetic field reveals a unique opportunity in driving with new kind of oscillations in the laser. It is of great interest in studying of fundamental dynamics processes. Report the experimental observation of new generation regimes of solid-state ring chip laser Nd:YAG under the influence of external magnetic field produced by magnet parallelepiped bar slowing on the top facet of laser candy bar. A parameter varied was distance x between center of magnet and center of chip laser prism. Dynamics of laser oscillation evaluates with x. At Fig.1. you can see intensity oscillograms in two counter propagating waves of four kinds of self-modulation oscillations. Fig.1a shows self modulation oscillation of the first kind taking place in chip-laser without magnetic field. Fig. 1b shows unidirectional oscillations modulated on a frequency of relaxation oscillation of the laser. Fig.1c – self-modulation oscillations with in- phase pulse envelope. Fig 1d – self-modulation oscillations with small modulation depth. All of regemes shown on fig.1(b–d) were not observed previously.

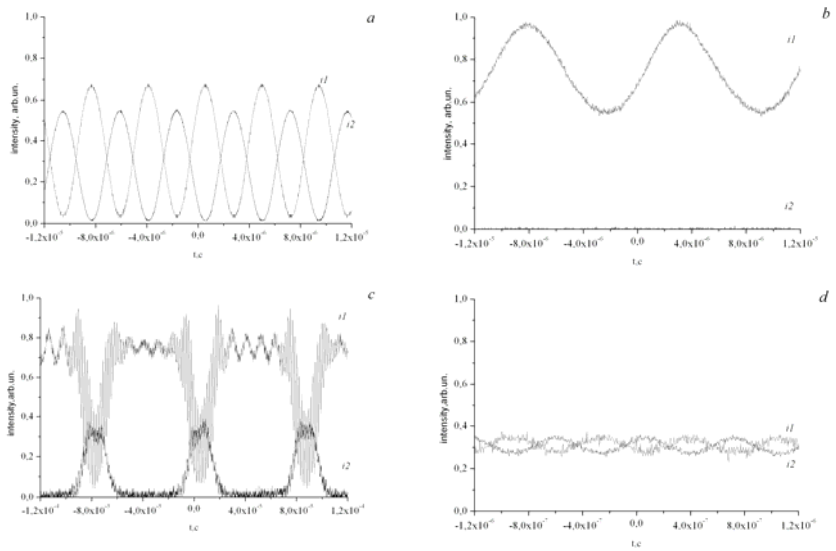


Fig.1

We studied dynamic features and regions of existence in details. The dependence of various spectral and amplitude characteristics of these regimes on the physical characteristics of the laser is revealed in the numerical simulation.

Acknowledgements: We thank N.V.Kravtzov and E.G.Lariontzev for useful discussions. Also we acknowledge support from the RFBR (grant 11-02-00080).

References:

1. T.V. Aulova, N.V.Kravtsov, E.G.Lariontzev, S.N. Checkina, "Quasiperiodic self-modulation regime whith low-frequency envelope in ring chip-laser", Quantum Electronics, Vol.41, pp.13-16 (2011)

O-6-LN

PASSIVELY Q-SWITCHED, COMPOSITE, ALL-POLY-CRYSTALLINE CERAMICS Nd:YAG/Cr^{4+}:YAG LASER

G. Salamu[1], O. Sandu[1], N. Pavel[1*], T. Dascalu[1], D. Chuchumishev[2], A. Gaydardzhiev[2] and I Buchvarov[2]
[1]*Laboratory of Solid-State Quantum Electronics, National Institute for Laser, Plasma and Radiation Physics, Bucharest R-077125, Romania*
[2]*Department of Physics, Sofia University, 5 James Bourchier Blvd., BG-1164, Sofia, Bulgaria*
** nicolaie.pavel@inflpr.ro; gabriela.salamu@inflpr.ro*

The passive Q-switching technique yields laser pulses that are of great interest for scientific, medical and industrial applications that do not require temporal accuracy better than microseconds range. This method provides lower output performances compared to electro-optic or acousto-optic Q-switched lasers, but presents various advantages, such us simply design, good efficiency and reliability, compactness, or low cost. Most of the previous developed Nd:YAG/Cr^{4+}:YAG lasers were made of single-crystals components [1]. Nowadays, the advancement in ceramics techniques has reached a maturity stage, especially in obtaining poly-crystalline cubic laser media of very good optical quality. It is then recognized that laser ceramics is an alternative to the crystalline optics, especially due to an easier manufacturability and lower price. To date there are only few reports on Q-switched emission of Nd:YAG/Cr^{4+}:YAG [2] or Yb:YAG/Cr^{4+}:YAG [3] ceramics lasers, with laser pulses of low (few hundreds of μJ) energy at high (few kHz) repetition rate. In this work we report laser performances obtained from passively Q-switched, Nd:YAG/Cr^{4+}:YAG media that were made of all-poly-crystalline Nd:YAG and Cr^{4+}:YAG ceramics bonded together.

Two composite, all-poly-crystalline ceramics Nd:YAG/Cr^{4+}:YAG media were prepared for experiments by diffusion bonding at elevated temperature (Baikowski Japan Co., Ltd.). The first medium consisted of a 1.1-at.% Nd:YAG ceramics that was bonded to a Cr^{4+}:YAG SA ceramics with initial transmission T_0= 0.30. The total length of this ceramics was 9.5 mm. The second, 7.5-mm thick Nd:YAG/Cr^{4+}:YAG ceramics consisted of an 1.5-at.% highly-doped Nd:YAG and a Cr^{4+}:YAG SA as described before. The Nd:YAG surface acted as the rear mirror of the laser and the out-coupling mirror was coated on the free surface of Cr^{4+}:YAG. Green laser pulses at 532 nm were obtained by single-pass second harmonic generation in a LiB_3O_5 nonlinear crystal (type I phase matching, 25°C room temperature).

The influence of pump-beam spot size on laser pulse performances was investigated, and a theoretical model was used to explain the experimental results. Laser pulses at 1.06 μm with 2.5-mJ energy and 1.9-MW peak power were obtained from the 1.1-at.% Nd:YAG/Cr^{4+}:YAG ceramics. Single-pass frequency doubling yielded green laser pulses of 0.36-mJ energy and 0.3-MW peak power, with a conversion efficiency of 0.27. Such a system offers a solution for realizing high-peak power laser pulses into visible and ultraviolet regions by single-pass nonlinear conversion.

Acknowledgements: This work was financed through the PN 09.39.02.01 project of the Romanian Ministry of Research, Education and Youth. Partial support from the Romania-Bulgaria bilateral project (455CB/20.10.2010 RO, DRG02-4/2010 BG) is acknowledged.

References

1.Zayhowski J. J., "Passively Q-Switched Microchip Lasers," in Solid-State Lasers and Applications, A. Sennaroglu, ed. (CRC Press, 2007), p. 1-76.
2. Y. Feng *et al.,* Appl. Opt. 43, 2944 (2004).
3. J. Dong *et al.*, Opt. Express 15, 14516 (2007).

VI. NON-LINEAR OPTICS MATERIALS AND DEVICES

I-1-NL

ADVANCES IN FREQUENCY CONVERTERS WITH STRUCTURED FERROELECTRICS

Valdas Pasiskevicius, Carlota Canalias, Katia Gallo, Fredrik Laurell
Department of Applied Physics, Royal Institute of Technology, KTH, Roslagstullsbacken 21, 10691 Stockholm, Sweden
vp@laserphysics.kth.se

This year, 2011, marks the 50-th anniversary of the first experimental demonstration of frequency conversion employing second harmonic generation in crystal quartz [1]. Only one year later, in 1962, the seminal paper by J Armstrong and co-workers [2] proposed the principle of quasi phase-matching (QPM) as a generic method to increase the efficiency of second order interactions in different classes of materials. However only since the mid-1990's the QPM frequency conversion started to make serious inroads into the field of nonlinear optics and applications. Substantial effort over the last 10 years has been devoted to tailor the properties of the most popular oxide ferroelectrics used for QPM structure fabrication, $KTiOPO_4$ (KTP), $LiNbO_3$ (LN) and $LiTaO_3$ (LT). The flexibility of engineered nonlinear interactions by appropriately designing QPM structure proved to be very enticing for many applications of nonlinear optics. Some of these capabilities unique for QPM nonlinear media will be reviewed in this talk.

Mirrorless optical parametric oscillator [3] exploiting counter-propagating nonlinear interaction in QPM crystals structured with sub-micrometer periodicity [4], and 2D nonlinear photonic crystals where optical parametric generation of two coherently coupled processes occurs [5], are good examples of the unique capabilities of the QPM technique. Advances in structuring techniques of nonlinear ferroelectrics allow design of the transversal phase distribution of the waves generated in the nonlinear interaction leading to some interesting properties of the output beams [6]. The QPM technique allows realizing of the noncritical nonlinear interactions over the whole transparency range of the ferroelectric crystals, particularly in $KTiOPO_4$, where small-period structuring is well established. However, up to recently it was assumed that the QPM frequency converters are suitable only for low energy applications. Recent developments in nonlinear ferroelectric materials now allows fabrication of large optical aperture crystals suitable for generation of nanosecond pulses with energies substantially exceeding 100 mJ in mid-infrared spectral range [7].

References:

1. P. A. Franken, A. E. Hill, C. W. Peters, G. Weinreich, "Generation of optical harmonics," Phys. Rev. Lett. **7**, 118-119 (1961).
2. J. A. Armstrong, N. Bloembergen, J. Ducuing, P. S. Pershan, "Interaction between light waves in a nonlinear dielectric," Phys. Rev. Vol. 127, 1918-1939 (1962).
3. S. E. Harris, "Proposed backward wave oscillation in the infrared," Appl. Phys. Lett., Vol. 9**,** 114–116 (1966).
4. C. Canalias, V. Pasiskevicius, "Mirrorless optical parametric oscillator," Nature Photonics, Vol. 1, 459-462 (2007).
5. K. Gallo, M. Levenius, F. Laurell, V. Pasiskevicius "Twin-beam optical parametric generation in nonlinear photonic crystals," Appl. Phys. Lett., Vol. 98, 161113 (2011).
6. T. Ellenbogen, N. Voloch-Bloch, A. Ganany-Padowicz, A. Arie, "Nonlinear generation and manipulation of Airy beams," Nature Photonics, Vol. 3, 395-398 (2009).

7. A. Zukauskas, N. Thilmann, V. Pasiskevicius, F. Laurell, C. Canalias, "5 mm thick periodically poled Rb-doped KTP for high energy optical parametric frequency conversion," Optical Mat. Express, Vol. 1, 201-206 (2011).

I-2-NL

COMPLEX MODELING AND OPTIMIZATION OF UV AND VUV PULSED GENERATION BY NON-LINEAR LASER MIXING UNDER THERMAL AND PLASMA EFFECTS

Oleg A. Louchev
Advanced Science Institute, RIKEN, 2-1 Hirosawa, Wako, Saitama, 351-0198, Japan
oleglouchev@riken.jp

In this communication we present our recent results on complex simulation and numerical optimization of non-linear laser wave mixing for generation of: (i) UV radiation by $\chi^{(2)}$-process in quasi-phase-matched periodically poled $LiTaO_3$ crystal and (ii) vacuum UV radiation by $\chi^{(3)}$-process in Kr-Ar phase-matched mixture.

First, the feasibility of the cascaded second (SHG) and third harmonic generation (THG) $\chi^{(2)}$-nonlinear process for generation of 355 nm radiation at the output of a monolithic two-sectioned periodically poled $LiTaO_3$ crystal is analyzed. Simulation using computational non-linear optical model rigorously coupled with the thermal model [1] suggests that 25-30 % THG efficiency can be achieved for 3 W power 20 ns pulsed 1.064 μm laser operating at frequency 10 kHz if the crystal is composed with optimized section lengths for: (i) ≈8.0 μm periodic first-order SHG structure and (ii) ≈6.6 μm periodic third-order THG structure. Significant inhibition of THG efficiency arises due to absorption of SH and TH, the heat release along the crystal, associated with thermal dephasing and lensing which can be effectively compensated by decreasing the temperature of the operating crystal below the quasi-phase matching temperature.

Second, we present a computational study of a $\chi^{(3)}$-nonlinear process for generation of *Lyman-a* (≈122) nm radiation using sum-difference frequency mixing of 212.6 nm and tunable infrared radiation (820-850 nm) for slow muon generation by laser resonant ionization [2]. The optical problem is rigorously coupled with optical discharge in which the non-steady-state four wave amplitude equations are integrated with the kinetics equations of optical discharge and electron avalanche ionization in Kr-Ar gas [3]. The model [3] is validated by earlier experimental data [2] showing strong inhibition of the generation of pulsed, tunable *Lyman-a* radiation. The rigorous computational approach to the problem reveals the possibility and mechanism of strong auto-oscillations of generated *L-alpha* radiation due to the combined effect of (i) 212.6 nm (2+1)-photon ionization producing initial electrons, followed up by (ii) the electron avalanche dominated by 843 nm radiation and (iii) the final breakdown of the phase matching condition. The model shows that the final wave-mixing efficiency of *Lyman-a* radiation generation can achieve a value of about $5x10^{-4}$ which is restricted by the total combined absorption of the fundamental and generated radiation, which increases with the interaction length of the mixed laser beams.

References:

1. O. A. Louchev and S. Wada, "Numerical model and study for cascaded third harmonics generation in two-sectioned periodically poled Mg-doped $LiTaO_3$ structure", *Journal of Applied Physics* 106, 093106 (2009).

2. P. Bakule et al., "Slow muon experiment by laser resonant ionization method at RIKEN-RAL muon facility", *Spectrochimica Acta* B **58,** 1019 (2003).
3. O. A. Louchev et al., "Coupled mechanism and numerical model of *Lyman-α* radiation generation by high intensity laser four-wave mixing in Kr-Ar gas", *Phys. Rev. A,* in press (2011).

I-3-NL

CNOIDAL WAVE IN MEDIA WITH LOCAL AND NONLOCAL CUBIC NONLINEARITY AS PARTICULAR SOLUTION OF NONITEGRABLE PROBLEM

V.A. Makarov, I.A. Perezhogin, V.M. Petnikova, N.N. Potravkin, V.V. Shuvalov
M.V. Lomonosov Moscow State University, Vorob'evy Gory, Moscow 119991, Russia
vsh@vsh.phys.msu.su

The concept of multi-component cnoidal waves (CWs) as self-consistent periodic solutions of systems of nonlinear equations is widely used in many areas of physics. One of the best known examples of such two-component solution in optics is so-called elliptically polarized CWs in media with linear gyrotropy and local cubic nonlinearity [1]. However, the question about a possibility to realize such solutions in media with nonlinear gyrotropy is almost not studied. Most of all, this is due to a system of truncated wave equations, which describes self-consistent (thanks to self- and cross-modulation effects) propagation of two orthogonally-polarized wave components and evolution of polarization, becomes nonintegrable [2]. It is therefore not so surprising that only few particular solitary solutions of such kind obtained analytically [3] (for a linear relation between the amplitudes of two orthogonally-polarized field components) and numerically [4] (for no such relation) have been previously discussed.

In our presentation, we consider one of the most important classes of particular periodic solutions of the described above problem. In this particular case, two light field components consistently propagate inside their common nonlinear waveguide. We will show that the considered case is identical to introducing an additional second-order integral. It is why the system of wave equations can be divided to a pair of independent nonlinear Schrödinger equations and easily solved. After that the amplitudes of both orthogonally-polarized field components can be expressed in terms of Jacobi elliptic functions. Notice that earlier a similar approach has been used to build general multi-component solutions of solitary (solitons) and periodic (CWs) types in fully integrable case of self-consistent propagation of two (or more) field components through a photorefractive crystal [5].

In the presentation, we describe all the families of particular periodic solutions (elliptically polarized CWs) of such type as well as their solitary asymptotes, polarization features, and domains of existence. Notice also that, with taking into account a possibility of different nonlinear phase shift of the orthogonally-polarized field components, sometimes the resulting wave polarization state vary aperiodically, forming something similar to polarization "chaos".

Acknowledgements: The authors are grateful to the Russian Foundation for Basic Research (Grant # 11-02-00653-a)

References:
1. N.N. Akhmediev, E.A. Ostrovskaya, "Elliptically polarized spatial solitons in cubic gyrotrpopic materials" Opt. Commun. v.132, 190-204 (1996).

2. H.S. Chiu, K.W. Chow, "Periodic and solitary waves in systems of coherently coupled nonlinear envelope equations" J. Computer Mathematics,v.87, 1083–1093 (2010).
3. V.A. Makarov, K.P. Petrov, "Solitons and solitary waves in a nonlinear gyrotropic medium with frequency dispersion" Quant. Electron. v.23, 880–884 (1993).
4. V.A. Makarov, I.A. Perezhogin, N.N. Potravkin, "Specific features of the self-action of elliptically polarized light pulses and the formation of vector solitons in an isotropic medium with the anomalous frequency dispersion and the spatial dispersion of cubic nonlinearity" Laser Physics, v.19, 322-329 (2009).
5. V.M. Petnikova, V.V. Shuvalov, V.A. Vysloukh, "Multicomponent photorefractive cnoidal waves: stability, localization, and soliton asymptotics" Phys. Rev. E, v.60, 1009-1018 (1999).

I-4-NL

NONLINEAR SPECTROSCOPY OF MOLECULAR FLUIDS IN NANOPORES

V.V.Arakcheev[1], V.N.Bagratashvili[2], V.B.Morozov[1], V.K.Popov[2]
[1])*International Laser Center and Physics Department of M.V. Lomonosov Moscow State University Moscow 11999, morozov@phys.msu.ru*
[2]) *Institute of Perspective Laser and Information Technologies of Russian Academy of Science, Troitsk, Moscow Region,* 142190, *Russia*
morozov@phys.msu.ru

Natural and synthetic nanoporous materials are used in a variety of physical, chemical and biological processes. Composite systems consisting of transparent nanoporous host with specific inclusions incorporated into the pores give unique possibilities for development of devices for nonlinear optics and photonics. In a numerous technological applications, porous materials are filled with a nearcritical or supercritical molecular fluids that acts as a chemical reagent or a transport media. Chemical and physical properties playing the key role in such processes are naturally connected with molecular media phase behavior, which is substantially defined by pore size, degree of their interconnection and other topological and morphological characteristics.

Nonlinear optical spectroscopy methods and coherent anti-Stokes Raman scattering (CARS) technique in particular can be an effective tool for probing composite systems consisting of transparent nanoporous host material with a fluid inside pores. The CARS signal in this case is assumed to be determined by resonant contribution of Raman-active fluid and nonresonant background from host material. The fluid confined in nanopores can be in the gaseous, adsorbed on pore walls and liquid-like states simultaneously, that are characterized by definite values of spectral width and shift therefore multi-component composite system should be taken into consideration. The interference nature of CARS spectra can serve for characterization of such nanocomposites as well as for sensing low content admixtures in a fluid. On the other hand, probing the molecular media filling internal pore volume of a transparent nanoporous material or matrix makes it possible to study molecular interaction with pore walls, peculiar properties of molecular dynamics and phase behavior at nanoconfined geometry inside pores that are significantly different from ones in a bulk volume. Available transparent materials like nanoporous glasses, polymers, aerogels, zeolites provide a wide range of pore radiuses and morphology and allow realizing different confinement conditions. Recently we applied CARS method to study fluid adsorption and

condensation in pores of nanoporous glasses [1,2]. A thermodynamic description of a fluid phase behavior in nanopores yields a good accordance with the experimentally observed spectral features. In the present paper, we apply the effective medium theory to calculate the nonlinear optical response of composite samples. The results of calculations are compared to experiment.

Acknowledgments: The work is supported by Russian Foundation for Basic Research (projects 11-02-01309-a, 11-02-12112-ofi-m-2011).

References:

1. V.G.Arakcheev, A.A.Valeev, V.B.Morozov, AN.Olenin, "CARS Diagnostics of Molecular Media under Nanoporous Confinement" Las. Phys., **18**, 1451-1456 (2008).
2. O.V.Andreeva, V.G.Arakcheev, V.N.Bagratashvili, *et al*. "CARS diagnostics of fluid adsorption and condensation in small mesopores". J.Ram.Spectr., (2011), *in press*.

O-1-NL

MULTISOLITON VECTORIAL SELF-FREQUENSY SHIFT: TOWARD A MEHAGERTZ FIBER FEW-CYCLE LIGHTWAVE SYNTHESIZER

D.A. Sidorov-Bityukov, A.A. Voronin, A.A. Podshivalov, I.V. Fedotov,
A.B. Fedotov and A.M. Zheltikov
International Laser Center Physics Department M.V. Lomonosov Moscow State University
sidorov@phys.msu.ru

Microstructured fibers [1, 2], i.e., fibers where a cladding has a form of a two dimensional (often periodic, i.e., photonic-crystal) array of closely packed glass capillaries drawn at a high temperature, offer elegant and practical solutions to many problems of fiber, nonlinear, and ultrafast optics, frequency metrology, spectroscopy, and biomedical applications.

The generation of ultrashort light pulses with a high contrast and a high quality of temporal envelope requires not only a broad spectrum but also an appropriate profile of the spectral phase of the electromagnetic field [3]. Self- and cross-phase modulation processes [4], as well as high-order stimulated Raman scattering [5], are known to induce spectral profiles of the nonlinear phase suitable for the generation of few-cycle light pulses.

Soliton self-frequency shift in a highly nonlinear photonic-crystal fiber (PCF) is shown to enable an efficient wavelength conversion of 100-fs 70-MHz output of a solid-state ytterbium laser, allowing the generation of sub-100-fs laser pulses with a central wavelength tunable from 1060 to 1400 nm. In the single soliton regime, laser pulses are efficiently converted into isolated wavelength-tunable bands, with a photon-number conversion efficiency of 82% achieved for ytterbium-laser pulses converted to a spectral band at 1125 nm supporting 35-fs transform-limited pulses. For high input powers, the ytterbium-laser pulses are coupled to multiple solitons inside the fiber, enabling efficient supercontinuum generation through involved soliton dynamics. Frequency-shifted solitons in a highly nonlinear PCF are shown to give rise to high visibility interference fringes in PCF output spectra, indicating flat spectral phase profiles of individual solitons in the PCF output. This experimental finding, supported by numerical simulations, suggests a promising method of fiber-format pulse shaping and an attractive technology for few-cycle pulse synthesis through a coherent addition of frequency-shifted solitons generated in a highly nonlinear fiber.

Acknowledgements : This work was supported by Russian Foundation for Basic Research (09-02-1076, 10-02-91226, 10-02-91173)

References:
1. P.St.J. Russell, Science 299, 358 (2003).
2. J.C. Knight, Nature 424, 847 (2003).
3. T. Brabec and F. Krausz, Rev. Mod. Phys. 72, 545 (2000).
4. Y. R. Shen, The Principles of Nonlinear Optics (Wiley, 1984).
5. N. Zhavoronkov and G. Korn, Phys. Rev. Lett. 88, 203901 (2002).

O-2-NL

HIGH ENERGY kHz MID-IR TUNABLE PPSLT OPO PUMPED AT 1064 NM

Danail Chuchumishev, Alexander Gaydardzhiev, Anton Trifonov, Ivan Buchvarov
Department of Physics, Sofia University, 5 James Bourchier Blvd., BG-1164 Sofia, Bulgaria
ivan.buchvarov@phys.uni-sofia.bg

Sub-nanosecond coherent sources tunable in the mid-IR spectral region (2.5-4 microns) have wide-ranging medical and material science applications based on the vibrational bands of the organic molecules that are in this spectral range. Many of these applications require optical pulses shorter than the characteristic thermalization time of the material, and pulse energies sufficiently high enough for material ablation. In addition the average power of the laser has to be large enough to enable "high - throughput" and acceptable product yields. Optical parametric oscillators (OPO) based on highly nonlinear periodically poled (PP) quasi phase-matched (QPM) materials pumped by 1 micron Q - switched lasers are an effective way to obtain the required radiation. Recently, there have been studies with PPLN based OPOs in the mid-IR, either at high repetition rate (1-10 kHz) and very modest output energy (few microjoules) or at low repetition rate (tens of Hz) and high output energy (>mJ), but consequently very modest output power [1,2].

Here, we report a single frequency sub-nanosecond OPO based on periodically poled stoichiometric lithium tantalate (PPSLT), pumped by an amplified microchip laser at 1064 nm at a repetition rate of 0.25-1 kHz. Using a 11 mm long PPSLT crystal polled with three different domain periods (30.2, 30.3, 30.4 μm) and changing the temperature of the crystal form 20°C to 265°C, we achieved wavelength tuning between 2990 nm and 3500 nm. The experimental results are in very good agreement with the theoretically calculated curves, where we used the Sellmayer equations [3]. The high nonlinearity of the used medium and the large aperture (2 mm) ensure maximum idler output energy of >0.5 mJ in the whole tuning range, corresponding to average ~13% conversion efficiency (overall quantum conversion efficiency ~42 %) and over x100 mW of average power. Sub-nanosecond pulse durations were obtained for the idler as a result of the 1 ns pulse duration of the pump. We employ a 11 mm long, 10 mm wide, and 2 mm (along z axis) thick PPSLT crystal with three different polled zones with domain inversion periods (30.2, 30.3 and 30.4 μm respectively). The crystal is with very high stoichiometry ratio (49.94% Li_2O / 50.06% Ta_2O_5), ensuring low coercive filed (800 V/mm) and high poling quality. Due to the short duration of the pump in order to increase the idler cavity roundtrips the OPO cavity length is chosen as short as possible i.e. 23 mm. The idler pulse duration is obtained by measuring the pulse duration of its frequency doubled pulse in a 5 mm thick KTP crystal and then deconvoluted with the measurement setup response function (470 ps). Thus the idler pulse duration is found to be 714 ps, shorter

than the undepleted pump pulse duration (1 ns). The obtained average power is limited by the damage threshold of the OPO rear mirror and potentially reaching of watts level of output power is obvious by replacing the metal rear mirror with dielectric one. **Acknowledgements:** We acknowledge financial support under grants D02-134/2009 and partially DRG02-4/2009 of the Bulgarian Ministry of Science and Education.

References:

1. A. Zukauskas, N. Thilmann, V. Pasiskevicius, F. Laurell, C. Canalias, "5 mm thick periodically poled Rb-doped KTP for high energy optical parametric frequency conversion," Opt. Mater. Express 1, 201-206 (2011)
2. N. Dixit, R. Mahendra, O. Naraniya, A. Kaul, A. Gupta, "High repetition rate mid-infrared generation with singly resonant optical parametric oscillator using multi-grating periodically poled MgO:$LiNbO_3$," Optics & Laser Technology 42, 18-22 (2010).
3. I. Dolev, A. Ganany-Padowicz, O. Gayer, A. Arie, J. Mangin, G. Gadret, "Linear and nonlinear optical properties of MgO:$LiTaO_3$." Applied Physics B-Lasers and Optics **96**(2-3): 423-432, (2009).

VII. TERAHERTZ SPECTROSCOPY AND APPLICATIONS

I-1-TH

GENERATION AND DETECTION OF BROADBAND THZ RADIATION FROM THE OPTICAL BREAKDOWN PLASMA: FROM BASIC MECHANISMS TO APPLICATIONS

A.V.Borodin[1], M.N.Esaulkov[1], A.A. Frolov[2], I.A.Kotelnikov[3], I.I.Kuritsin[1], A.P.Shkurinov[1]
[1]*Department of Physics, M.V.Lomonosov Moscow State University, Moscow, Russia.*
[2]*Institute for High Energy Densities, RAS, Moscow, Russia*
[3]*Budker Institute of Nuclear Physics, Novosibirsk*
ashkurinov@gmail.com

Simultaneous generation and THz pulse radiation detection in plasma breakdown named «ABCD technique» [1] allow us to create THz time-domain systems with an extraordinary spectral range. Self-descriptiveness and adequacy of the information obtained with the help of such systems is determined by mutual influence of generation and detection processes in plasma media. Each of them in itself is fairly hard to describe, but being combined together for proper interpretation of the received data they demand, first of all, the detection process simulation.

One of the methods of the THz pulsed radiation detection is connected with the detection of second harmonics (SH) $2\omega_0$ of laser radiation which appears as a result of nonlinear interaction of laser radiation at the carrier frequency ω_0 with THz wave in rarefied plasma, formed as a result of air photoionization [2].

We assume in our model that at some distance from the laser beam waist air ionization practically disappears due to the decrease of radiation intensity. Therefore, a sharp boundary appears which separates the area taken by the plasma from the area with non-ionized air. In connection with this we assume that THz radiation generation will take place owing to the propagation of laser pulse in this area of the sharp density gradient. This mechanism has been well known since 1962 and is called "transitional radiation" [3].

In this work to describe numerically the THz pulse and the detection SH generation process of laser radiation we used the Maxwell equations for electric field **E** and magnetic field **B** and also hydrodynamic equations for velocity **V** and **n** density of plasma electrons.

In the experiment and simulations we used Ti: Spp laser generating pulses at the wavelength λ_0=0.8 μm with duration τ_{FWHM}=32 fs and the power W_l=1.2 mJ. The dependence of the normalized spectral energy of THz radiation is shown in figure. The theoretical and experimental spectra have got two maxima, one of them is sharper and is around the frequency of 11 THz and corresponds to the radiation of at plasma frequency. The second peak – which is much more gentle and wide is in the low frequency area of the spectrum around 1.3 THz. We should note a good coincidence of the theoretical results here for the positions of the peaks in the theoretical and experimental radiation and detection spectrum.

References:

1. Dai, X. Xie, and X.-C. Zhang, "Detection of broadband terahertz waves with a laser-induced plasma in gases," *Phys. Rev. Lett*. 97, 103903 (2006).
2. I.A.Kotelnikov, A.V.Borodin, A.P.Shkurinov, "Miltiphoton ionization of atom by dual color laser pulse" JETP, 139 (6) 1081 (2011).
3. G.A.Askarian, "Cherenkov and transition radiation from electromagnetic waves", JETP, 42 (5) 1360 (1962).

I-2-TH

ADVANCES IN REAL-TIME TERAHERTZ IMAGING USING THE NOVOSIBIRSK FREE ELECTRON LASER: IMAGING DEVICES AND APPLICATIONS

Boris A. Knyazev
Budker Institute of Nuclear Physics SB RAS, 630090 Novosibirsk, Russia
& Novosibirsk State University, 630090 Novosibirsk, Russia
knyazev@inp.nsk.su

Novosibirsk free electron laser is nowadays the most intense source of terahertz radiation. It generates monochromatic coherent radiation as a continuous stream of 100-ps pulses with a repetition rate of 5.6 MHz. Radiation wavelength can be, at present, gradually tuned within spectral ranges 120-240 μm and 40-70 μm. Average power of the radiation at the user stations reaches several hundred watts. Unique features of NovoFEL radiation, from one hand, require development of techniques for radiation imaging and characterization and, from other hand, enable the development of new metrological methods and techniques. In this paper the principles of operation and operating characteristics of four imaging devices developed will be described. The results of pioneer experiments on "classic" terahertz holography, "optical" coherent tomography, speckle photography and surface plasmon study, where these devices were used, will be also described in the presentation.

I-3-TH

THZ SOURCES BY DEFERENS FREQUENCY GENERATION AND TWO-COLOR VANADATE LASERS

A.A. Sirotkin, S.V. Garnov, A.I. Zagumennyi, Yu.D. Zavartsev, S.A. Kutovoi, V.I. Vlasov, I.A. Shcherbakov
Prokhorov General Physics Institute of the Russian Academy of Sciences,
119991, Vavilov 38, Moscow, Russia
saa@kapella.gpi.ru

Terahertz-wave radiation has been wide used in THz spectroscopy, biomedical applications, DNA analysis and security applications. THz sources based on femtosecond lasers are extremely expensive and complex. One of alternative cost-effective and robust THz sources to use two-color lasers with THz converters for difference frequency generation with nonlinear optical crystals.

Here, we present a novel two-color diode-pumped solid state MOPA systems based on *a*-cut (π- and σ-polarization) and *c*-cut Nd:$GdVO_4$ and Nd:YVO_4 crystals with parallel and orthogonal polarization.

It should be noted that the luminescence spectra of vanadate crystals ***a***-cut for σ polarization exactly coincide with the spectra of the ***c*** - cut crystals, which were measured previously [1]. Therefore, all opportunities for ***c*** - cut crystals lasers [2] can be realized for σ polarization.

We have shown experimentally, for the first time as far as we know, that lasers with nonselective resonator based on ***a***-cut for σ- polarized vanadate crystals (Nd:YVO_4, Nd:$GdVO_4$, or mixed $YGdVO_4$) work at difference wavelengths. The different wavelength for π- and σ- polarizations allows creating two-color lasers with orthogonal polarization,

which is important for the conversion to terahertz in the GaSe nonlinear optical crystals as convertor for example.

Two-color lasing has been obtained in the ***a***-cut (π- and σ-polarization) and ***c***-cut C-cut $Nd:GdV0_4$ and $Nd:YVO_4$ crystal at the spectral lines separated by 2.3 nm and 3.8 nm with parallel and orthogonal polarization.

QW, mode-locking and Q-switching regimes with passive Cr^{4+}:YAG saturable absorber and active acoustic-optical modulators were realised for two-color lasers.

The master lasers used for the system was a 200 mW passively Q-switched two-color $Nd:GdV0_4$ and $Nd:YVO_4$ with a pulse duration of 8 ns. The grazing incidence multipass amplifier based on 1 at.% **c**-cut $Nd:YVO_4$ slab (dimensions: 20 mm × 5 mm × 2 mm) was used for the amplifier two-color radiation with parallel and orthogonal polarization.

The GaSe crystal used for the generation of pulsed THz radiation. This crystal is excellent nonlinear optical element for difference-frequency generation (DFG). Terahertz radiation at wavelength 0.56 and 0.96 THz was detected.

References

1. V.I. Vlasov, S.V. Garnov, Yu.D. Zavartsev, A.I. Zagumennyi, S.A. Kutovoi, A.A. Sirotkin, I.A. Shcherbakov, Quantum Electronics 37, 938 (2007).
2. A. A. Sirotkin, S. V. Garnov, A. I. Zagumennyi, Yu. D. Zavartsev, S. A. Kutovoi, V. I. Vlasov, L. Di Labio, W, Lüthy, T. Feurer, and I. A. Shcherbakov", Laser Physics, 2009, Vol. 19, No. 5, pp. 1083–1091, (2009).

O-1-TH

LIGHT INDUCED TERAHERTZ EMISSION FROM GRAPHENE-BASED STRUCTURES

P. Obraztsov[1,2], Yu. Svirko[1] S.Garnov[2], N. Kanda[3] ,
M. Kuwata-Gonokami[3] and A. Obraztsov[2,4]
[1]*Department of Physics and Mathematics, University of Eastern Finland, Joensuu, Finland*
[2]*A.M. Prokhorov General Physics Institute, Moscow, Russia*
[3]*Department of Applied Physics, the University of Tokyo, and JST-CREST, Japan*
[4] *Department of Physics, Moscow State University, Moscow, Russia*
p.obraztsov@gmail.com

Nanocarbon materials with dominating sp^2 hybridization of orbitals and especially graphene have recently attracted great attention due to their ability to support ballistic electron transport. Although anomalous electron mobility and the ballistic current carrying capability can be hampered by contact resistance, the submicron free pass and very low electron momentum relaxation rate makes these materials interesting for spintronics, valleytronics and quantum computing. Despite the fact that single- and multilayered graphene possess the giant absorption cross section in the spectral range from THz to UV, works on the injection and control of ballistic currents in graphene and other nanocarbon materials with sp^2 orbital hybridization are scarce [1]. Recently we have demonstrated that combination of quasi-ballistic conductivity and strong electron photon coupling opens a unique opportunity to launch ballistic current in prescribed direction by transferring the photon momentum to electrons. This phenomenon is referred to as photon drag effect and manifests itself as a direct current voltage generated under illumination by intense light beam [2].

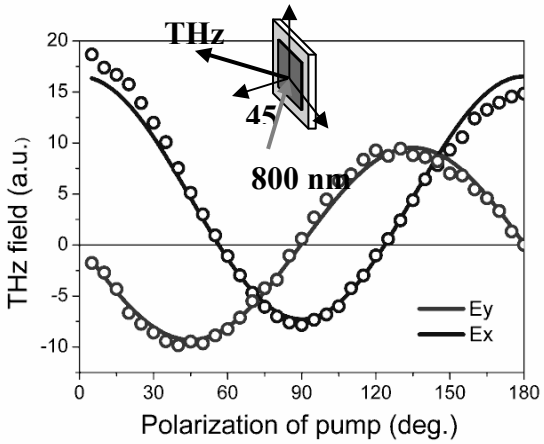


Fig. 1: Results of pump polarization dependence of THz radiation from multilayered CVD graphene

Here we report the excitation of the THz photocurrents in unbiased multilayer CVD graphene using linearly polarized 200 fs long pulses of the Ti:S regenerative amplifier at 45° angle of incidence. The amplitude of the THz field is a linear function of the pulse intensity, while orthogonal polarizations of the THz field have pronounced dependence on the polarization azimuth of the laser beam (see Fig. 1). Our analysis shows that the THz emission originates from the photon drag effect, i.e. from the, transfer of the photon momentum to free carriers and can be employed for coherent control of the photoinduced carriers in graphene.

References:

1. D. Sun, C. Divin, J. Rioux, J.E. Sipe, C. Berger, W.A. de Heer, P.N. First, T.B. Norris, Nano Lett., 10,1293 (2010).
2. Obraztsov P.A., Mikheev G.M., Garnov S.V., Obraztsov A.N., Svirko Y.P, App. Phys. Lett., 98, 9, 091903 (2011).

O-2-TH

LARGE-APERTURE SYNCHRONISM OF TERAHERTZ GENERATION IN LiNbO3 CRYSTALS USING FEMTOSECOND PULSES WITH TILTED INTENSITY FRONT

V.V. Bukin, S.V. Garnov
Prokhorov General Physics Institute
vladimir.bukin@gmail.com

The tilted pulse front scheme of generation of terahertz radiation by optical rectification of femtosecond laser pulses is most perspective technique in terms of scalability for multiterawatt laser systems. One of the main problems of such technique is the narrowing of terahertz pulse spectra.

In the present work we conduct the analysis of the scheme of formation of femtosecond laser pulses with tilted amplitude front. It was shown, that by selection of the optimal geometry of the scheme of tilted pulse formation provide high efficiency of generation of terahertz radiation in the nonlinear crystals for working aperture up to several centimeters. The analytical solution of the spectrum of the terahertz pulse was given.

Advanced Laser Technologies

ALT' 11

POSTER PRESENTATIONS

I. BIOPHOTONICS

P-1-BP

RESEARCH OF INORGANIC PARTICLES BASED ON GADOLINIUM-BORON DOPED WITH Nd^{3+} IONS FOR EARLY DIAGNOSTICS AND NEUTRON-CAPTURE THERAPY OF CANCER

A.V.Popov[1], V.A.Krut'ko[2], M.G.Komova[2], O.B.Petrova[3], A.V.Ryabova[1], V.B.Loschenov[1]
[1] *A.M.Prokhorov General Physics Institute of RAS, Vavilov st., 38, Moscow, Russia*
[2] *N.S.Kurnakov Institute of General and Inorganic Chemistry of RAS, Moscow, Russia*
[3] *D.I.Mendeleev University of Chemical Technology of Russia, Moscow, Russia*
avpopov@lst.gpi.ru

The presented article is dedicated to the research of nanosize particles (10-200 nm) based on B-Gd-containing inorganic materials doped with rare-earth ions which are characterized by strong absorption and luminescence bands into NIR (0.8-1.1μm is transparence of a tissue). The application of specimens based on these particles will allow to diagnose early cancer with use of luminescence and radio sensitive methods (because Gd nucleus have strong sensitivity at NMR spectroscopy [1]). As soon as the particles have been accumulated by a tumor, the boron (gadolinium)-neutron-capture therapy will be realized and then the tumor will be selectively disrupted [2]. The principal possibility of application of these materials as biosensors for tumor detection was presented in article [3].

We use some methods to prepare particles (the polycrystals of $GdBO_3$, $Gd_{14}B_6Ge_2O_{34}$, the glasses Gd-3B-6O with Na_2O as an admixture) doped with Nd^{3+} ions (0.5-7 at.% Gd^{3+} are replaced by Nd^{3+}): solid-state reaction, co-deposition of initial components with the following heating the final product, sol-gel synthesis, glass synthesis. The final products are step-by-step produced by mechanical dispersion in an agate mortar and ball vibrating mill to the state of fine particles, next chemical etching and ultrasonic dispersion and functionalization of the surface of the particles with a surfactant. The distribution of the particles according to their size in water solutions was measured with the method of dynamic light scattering spectroscopy (Photocor Complex device). According to the microhardness measurement the compositions of these origin materials was changed to achieve the minimum of hardness. The Nd^{3+} concentration was optimized (about 3-4 at% of Gd^{3+} are replaced by Nd^{3+}) according to the research of luminescence and decay kinetics of Nd^{3+} ions in these particles.

Acknowledgements: This work is supported by the Russian Foundation of Basic Research (grant № 11-08-01322-a) and the Foundation of President of Russian Federation for Support of Russian Young Scientists (№ МК-105.2010.2).

References:

1. A.B.Luk'yanchenko, B.I.Dolgushin, V.N.Sholokhov, "Radiological methods of diagnostics of tumor and tumor liver lesions" Russian Journal of «Together Against Cancer». № 1, (2005). http://netoncology.ru/expert/diagnostics/diagnostic_methods/1398/
2. N.G.Kozlovskay, V.N.Kulakov at al, "The boron neutron-capture therapy of spontaneous melanoma dogs with different stages of tumor", Russian Scientific session MEPHI-2005. Vol. 5, 56-57 (2005).
3. A.V.Popov, A.V.Ryabova, V.A.Krut'ko, M.G.Komova, O.B.Petrova, V.B.Loshchenov, Yu.K.Voron'ko, "Spectroscopy of nanoparticles based on $Gd_{14}B_6Ge_2O_{34}$ polycrystals and La_2O_3-B_2O_3 glasses, activated by Nd^{3+} ions, for cancer diagnostics" Quantum Electronics. V. 40, 1094-1097 (2010).

P-2-BP

SOME ASPECTS OF PHOTO-IMMUNOLOGICAL REACTIONS UNDER LIGHT IRRADIATION DURING PHOTODYNAMIC THERAPY

A. Zhelyazkova, L. Avramov
National Center on Biomedical Photonics
Institute of Electronics, Bulgarian Academy of Sciences
72, Tsarigradsko chaussee Blvd., 1784 Sofia, Bulgaria
alexandra_jivkova@abv.bg

Laser immunotherapy is a new method for treatment of metastatic tumors. It combines a selective photothermal laser-tissue interaction for direct tumor destruction and an immunoadjuvant-directed simulation for immune responses.

In the last few years, a new low invasive photothermal treatment is using for more effective removal of deeply located tumors. A near-infrared laser diode and a laser-absorbing dye-Indocyanine Green (ICG) are applied to achieve maximal destruction of the tumor mass. The method is based on ICG absorption of laser irradiation causing photothermal destruction into the tumor. Recently, a new adjuvant glycated chitosan (GC) is using to stimulate immune system in this new treatment modality. GC is a synthetic compound, which is water soluble and could be used as a carrier of ICG. Laser immunotherapy includes an intratumoral injection of an ICG and GC solution followed by laser irradiation.

Several groups work to obtain optimal effect after treatment with different initial parameters (irradiation by various wavelengths and drugs). Our further work is related to combine systematic photodynamic therapy with using chlorine and evaluation of following photoimmunic response.

The combination of laser irradiation and laser-absorbing dye lead to selective photothermal tissue destruction with release of tumor-antigen determinants. The adjuvant stimulated the immune system causes a specific immune response against other tumor cells and metastasis. This new method for treatment of primary tumors induced anti-tumor resistance in host animals. It is possibile to continue work on optimizing and exploring opportunities for implementing photoimmunology therapy for clinical applications.

P-3-BP

FTIR AND THz SPECTROSCOPY OF CHYMOTRYPSIN IN VARIOUS SOLVENTS

N. N. Brandt, A. Yu. Chikishev, A. A. Mankova, M. M. Nazarov, and A. P. Shkurinov
Physics Department and International Laser Center, Moscow State University,
119991, Moscow, Russia
mankova@physics.msu.ru

Chymotrypsin is one of well-studied serine proteases. In native (aqueous) solutions, it performs hydrolysis of peptide bonds between aromatic amino acid residues. It is known that in several organic solvents, chymotrypsin exhibits inversion of catalytic activity. The activity of chymotrypsin can be different in different solvents.

Several experimental methods allow the investigation of the protein molecular structure. Note the efficiency of the optical vibrational spectroscopy (Raman, CARS, and IR spectroscopy). In particular, the analysis of vibrational bands amide I (1600-1700 cm^{-1}), amide II (1500-1600 cm^{-1}), and amide III (1200-1300 cm^{-1}) makes it possible to determine the relative contents of the secondary-structure elements.

THz absorption spectroscopy is a unique method of study of low frequency dynamics of proteins. It allows spectral measurements in the range 0.1-100 cm^{-1}. Thus, intra- and intermolecular vibrations of large molecules (e.g., proteins) can be revealed.
In this work, we study the low frequency vibrations of chymotrypsin in organic solvents (acetonitrile and cyclohexane). The corresponding changes in the chymotrypsin catalytic activity are discussed. We compare the results with the Raman data.

To determine the variations in the secondary structure of chymotrypsin related to the changes of functioning, we measure the ATR-FTIR spectra of the lyophilized enzyme, its solutions in normal and heavy water, tablets wetted in acetonitrile and cyclohexane, and suspensions in these solvents. The experimental results show that the most significant structural changes (a decrease in the content of α-helical fragments and an increase in the content of β-sheets) are related to the transition from the aqueous solution to the lyophilized sample. Similar but less developed structural changes are observed for the transition from the lyophilized sample to the suspensions in organic solvents. With respect to the secondary structure, the conformation of chymotrypsin molecules in the lyophilized sample is intermediate relative to the conformations in the aqueous solution and the suspension in organic solvent. Hence, we can assume that the functional activity of the protein in the lyophilized sample is between the hydrolytic activity of the enzyme in aqueous solution and the synthetic activity in the suspension.

P-4-BP

COMMON APPLICATIONS OF EXOGENOUS SENSITIZERS IN PHOTODIAGNOSTICS, PHOTODYNAMIC THERAPY AND BORON NEUTRON CAPTURE THERAPY

E. Borisova, L. Avramov
Institute of Electronics, BAS, 72, Tsarigradsko Chaussee Blvd., 1784 Sofia, Bulgaria
borisova@ie.bas.bg

Boron Neutron Capture Therapy (BNCT) therapeutic modality for cancer treatment, is based on the $^{10}B(n,^{4}He)^{7}Li$ nuclear reaction which occurs when a ^{10}B nucleus captures a reactor-generated low-energy neutron to produce cytotoxic high linear energy transfer particles ($^{4}He^{2+}$, $^{7}Li^{3+}$) [3], see figure 1. Due to their tendency to selectively accumulate in neoplastic tissue, the family of exogenous sensitizers are attractive boron carriers for BNCT. From the various nuclides that have high neutron capture cross-sections, ^{10}B is the most attractive for the following reasons: 1) it is non radioactive and readily available, comprising approximately 20% of naturally occurring boron; 2) the particles emitted by the capture reaction ^{10}B(n, alpha)^{7} Li are largely high "Linear Energy Transfer", dE/dx, (LET); 3) their combined path lengths are approximately one cell diameter; about 12 microns, theoretically limiting the radiation effect to those tumor cells that have taken up a sufficient amount of ^{10}B, and simultaneously sparing normal cells; and 4) the well understood chemistry of boron allows it to be readily incorporated into a multitude of different chemical structures. Its current biggest

disadvantage is a lack of appropriate boron carriers, which could accumulate large amounts of boron in the tumor cells under treatment. Therefore many investigators try to find and use advantages from other developed therapeutic modalities, or to use new drug carriers for boron transfer to the diseased tissues.

Such improvement could come from photodynamic therapy (PDT) therapeutic modality. Our group has significant experience in application of PS for diagnosis and therapeutic applications cancer research field. BNC therapy would be one of major output modalities for biomedical applications foreseen, according Sofia research reactor exploitation plans. Combination of PDT and BNCT will allow us rapid start and fast achievement of the level of international groups working in the field of BNCT applications. Additive value to the standard BNCT treatment would have application of PSs as delivery system compounds, which would allow achievement of high contrast of boron concentration between healthy and tumor cells.

Acknowledgements: This work is supported by the Bulgarian Ministry of Education and Science under grant DO-02-58/2008 "Development of infrastructure for neutron therapy in Bulgaria".

P-5-BP

POISONOUS EFFECT OF LOW CONCENTRATION OF HEAVY METAL IONS ON SOME ENZYMES IN THE SOLUTIONS

G. Petrova, M. Gurova, I. Sergeeva, T. Tichonova, K. Fedorova, Z. Xialey
Physics Department, M.V. Lomonosov Moscow State University, Moscow, Russia
petrova@phys.msu.ru

In the recently our works the behavior of some proteins and enzymes molecular parameters in water solutions in the presence of different toxic metals ions were investigated. Interaction of the proteins and enzymes in solutions containing heavy metal ions results in the formation of large (nanosized) dipole clusters.

Laser light scattering method (photon correlation) were used for intermolecular interaction study of ions with different value of ionic radius and some enzymes in water solutions at the very low concentrations of the salts. Lyzozyme, collagenase, kreatin kenase and pepsin in water solutions containing some heavy metal ions at different ionic strengths were study. The main result - the presence of the ions with large ionic radii like Pb^{2+}(1,2 Å), Rb^{+}(1,47 Å), Cs^{+}(1,65 Å), Eu^{++} (1,33 Å) stimulate the forming of nanoparticles with the mass more than one order to molecular mass of macromolecules M_o. In the presence of Na^{+} (0,9 Å) in protein solutions the nanocluster are absent. In the region of small ion concentration (I-ionic strength) the dependences of particle mass in the solutions have a initial part practically linear (Langmuir monolayer). With the increase of ion concentration (I) the saturation in this dependences is observed, which can be connected with the difference in the sorption processes of the ions. As the result we can conclude that the "poisoning" effect at very small concentrations of toxic ions is connected with the beginning of forming clusters, that corresponded to maximum permissible concentration (MPC).

P-6-BP

ON THE SCATTERING OF A LASER BEAM IN BIOLOGICAL-TISSUE-LIKE TURBID MEDIA

I. Bliznakova, L. Gurdev, T. Dreischuh, O. Vankov, L. Avramov, D. Stoyanov
Institute of Electronics, Bulgarian Academy of Sciences,
72 Tsarigradsko chaussee, 1784, Sofia, Bulgaria
irbliznakova@abv.bg

The propagation is investigated of a continuous laser beam through homogeneous tissue-like turbid media such as diluted emulsions of Intralipid having sharply forward directed indicatrices. The cross sectional radial distributions of the detected forward-propagating light power at different depths along the beam axis in each medium of interest are experimentally determined. The detected-power spatial distribution is also described analytically by a solution of the radiative transfer equation in the so called small-angle approximation. The experimental results are consistent with the analytical expressions obtained that allow one to estimate in principle the extinction, reduced-scattering and absorption coefficients and the g-factor of the investigated media. The values obtained of the above-mentioned parameters of the dilutions of concern are reasonable and behave, depending on the dilution turbidity, in a way observed formerly in other similar experiments.

Acknowledgements: This work has been supported by the Bulgarian National Science Fund under contract DO 02-112/08. One of the authors (IB) is thankful to the World Federation of Scientists (WFS) and the World Laboratory, Geneva, Swiss for the financial support.

P-7-BP

FROM THE PHOTODYNAMIC THERAPY (PDT) TO THE LIGHT PROMOTION OF DRUG ACTION (LPDA)

I. Angelov[1], V. Mantareva[1], A. Kril [2], R. Dimitrov [3], E. Borisova[4], L. Avramov[4]
[1]*Institute of Organic Chemistry, BAS, BG*
[2]*Institute of Experimental Morphology, Pathology and Anthropology with Museum, BAS, BG*
[3]*Institute of Biology and Immunology of Reproduction "Acad. Kiril Bratanov", BAS, BG*
[4] *Institute of electronics, Bulgarian Academy of Sciences*
ipangelov@gmail.com

One of the most important problems ahead of the human public health is the management and observing in real time the delivery of drugs to the target objects of specific tissues, activation of impact to the cells or to the concrete cell structure and achieving positive results of this action with minimum quantity of drugs /1/. With the main role for successful outcome of the treatments with drugs are also the absence of resistance against applied medicine and the controlled and quickly release the active substance from the tissues and human body after effect to avoid damage of healthy tissues /2/. In the same time the intensive research works during last decade in area of PDT as antitumor therapy/3/ as a method for inactivation of pathogen microorganisms and viruses, because of specificity and multifactor dependency on the method, given more detailed ideas of problems in topics of administration of drug delivery, activation and release. Many of investigators find that by irradiation with light with

proper temporal and spectral characteristic and with use of light sensitive biocompatible macromolecules or conjugates as a carrier of active substances it is possible to overcome some of the problems with selective binding, high accumulation and effective action only with regard to the target-treated micro- or macro objects. Therefore it is time to increase scientific studies for the role of irradiation on biological objects with radiation with different characteristics (temporal, spectral, power, spatial and s.o.), in combination with applying of light sensitive and bioactive conjugates, as a promoter factor for solving some of problems with administration of drugs delivery, activation, efficacy and release.

In our investigation the complexes of metal phthalocyanines (Pc's) conjugated with carbohydrates were used for obtaining the differences in distribution of substance in the cells after irradiation with light. The subcellular localization of amphiphilic galaktopyranosil Zn(II)-phthalocyanines was studied in several human breast cancer cell lines. The influence of the position of the substituents to ZnPc on the distribution of the photosensitizer substances within tumor cells was evaluated, as compared to the distribution of non-substituted ZnPc. The effect of light irradiation with different spectrum of light on the PS penetration, re-localization in the cells and uptake was assessed.

Obtained results showed that at irradiation with proper spectrum of applied light and at specific light doses it is possible to manage penetration value of light sensitive active molecules in the cells. Therefore this is a first step in realize of mechanism in which by light with different characteristics should be possibly to promote drug activity.

Acknowledgements: The support by the National Science Fund, Bulgaria (Grants DO-02-177 and DO-02-112) is gratefully acknowledged.

References:

1. A. G.-Bennett, M. Nees, B. Fadeel. "In Search of the Holy Grail: Folate-Targeted Nano particles for Cancer Therapy", Biochemical Pharmacology, Vol.81, Is.8, p. 976-984 (2011).
2. P. Rai, S. Mallidi, X. Zheng, R. Rahmanzadeh, Y. Mir, S. Elrington, A. Khurshid, T. Hasan "Development and applications of photo-triggered theranostic agents", Advanced Drug Delivery Reviews, 62 ,p .1094–1124 , (2010).
3. T. Dai, Y.-Y. Huang, M. R. Hamblin, "Photodynamic therapy for localized infections-State of the art", Photodiagnosis and Photodynamic Therapy, Vol. 6, Is. 3-4, p. 170-188, (2009).

P-8-BP

APPLICATION OF LOW-LEVEL LASER THERAPY (LLLT) IN PATIENTS WITH AGE-RELATED MACULAR DEGENERATION (AMD)

K. Koev[1], L. Avramov[2], E. Borisova[2]
[1]*Department of ophthalmology, Medical University-Sofia, 2, Zdrave str., Sofia, Bulgaria*
[1]*Institute of Electronics, Bulgarian Academy of Sciences, 72, Tsarigradsko chaussee Blvd., 1784 Sofia, Bulgaria*
k00007@abv.bg

Objective: The objective of this study is an examination of the low-level laser therapy (LLLT) effects in patients with age-related macular degeneration (AMD).

Patients and metods: For LLLT, a He-Ne laser (Mediray 04, Optella Ltd., Sofia, Bulgaria) with emission wavelength at 632 nm and power density of 0.1 mW/cm2 fitted with collimating optics (spot diameter 2 cm) was applied. Patients with AMD of all stages (dry and

wet exudative forms) were included in the study. In total, 42 patients (20 men and 22 women) with AMD of various stages (84 eyes) and a mean age of 66.3 ± 4.2 were included in the study. Progressive exudative AMD was diagnosed in 22 eyes. Sixty two eyes had drusen or were depigmented. Laser radiation was applied transpupillary to the macula for 3 min. Six treatments were administered (every other day). Fifteen patients with AMD (30 eyes) were randomly selected to receive mock treatment (control group of 7 men and 8 women with a mean age of 66.5±5.2 years).

Results: Visual acuity was assessed by projection after optimal correction of refraction with blinding. Visual acuity was measured at each visit. The perimetry and Amsler test were used to screen central scotomas. Fluorescein angiography of AMD and control groups was applied for examination of treatment effectiveness. Visual acuity remained unchanged in all patients in the control group.

There was a statistically significant increase in visual acuity for AMD patients. The prevalence of metamorphopsia, scotoma in AMD group was reduced. In patients with wet AMD after irradiation edema and bleeding were reduced.

Conclusion: In conclusion, this study shows that LLLT may be a novel therapeutic option for treatment of both forms of AMD. LLLT could be used as complimentary modality to the basic therapy. This is highly effective treatment for improvement of the visual acuity and decrease of the edema and bleeding in wet AMD.

References:

1. Boris T. Ivandic, Tomislav Ivandic, Low-level laser therapy improves vision in patients with age-related macular degeneration, Photomedicine and Laser Surgery, 26(3):241-5, 2008 Jun.
2. Evans, J.R., Antioxidant vitamin and mineral supplements for age-related macular degeneration. Cochrane Database, 2002, Syst. Rev. CD000254.
3. Rosenfeld, P.J., Brown, D.M., Heier, J.S., Boyer, D.S., Kaiser, P.K., and Chung Kim, R.Y. Ranbizumab for neovascular age-related macular degeneration. N. Engl. J. Med. 14, 2006, 1419-1431.
4. Desmettre, T., Maurage, C.A., and Mordon, S. Transpupillary thermotherapy (TTT) with short duration laser exposures induce heat shock protein (HSP) hyperexpression on choroidoretinal layers. Lasers Surg. Med. 33, 2003, 102-107.

P-9-BP

THEORETICAL AND EXPERIMENTAL DEVELOPMENT OF LASER DIFFRACTOMETRY OF RED BLOOD CELLS

A. E. Lugovtsov, S.Yu. Nikitin, A. V. Priezzhev
Physics department and International laser center
of M.V. Lomonosov Moscow State University,
Russia, 119991, Moscow, Leninskye Gory, b. 1, str. 2
anlug@tut.by

Laser diffractometry is an advanced optical techniques used for *in vitro* determination of the sizes and ability of red blood cells (RBCs) to deform and change their shape when passing through capillaries with small diameters. In this method, the diffraction of laser beam on a suspension of RBCs is observed. Usually the suspension is placed into a thin gap between a

stationary cup and a bob that can be rotated with prescribed rate (so called Couette chamber). In the Couette chamber, the shear rate and shear stress are constant all across the gap on condition of stationary rotation of the bob. Rotation of the bob causes the suspension flow, which orients the RBCs so that their axes of symmetry become parallel to the illuminating laser beam. The concentrations of the particles in suspension usually are chosen very small so that single light scattering condition in the gap is met. If the shear rate is small, the laser beam diffraction pattern (DP) has an axial symmetry and represents a system of concentric dark and light rings. The rings radii and brightness depend on the particles sizes and shapes as well as on the hemoglobin concentration inside the particles. An increase in shear rate results in elongation of deformable RBCs and consequent deformation of the DP in the direction, which is perpendicular to direction of the suspension flow in the Couette chamber. In case of shear rate the isointensity lines in the DP can be very well approximated by a system of dark and light ellipses on a screen. This testifies to the particles deformation by shear stress. Deformability index (DI), which quantitatively characterizes the ability of RBCs to deform in shear flow is calculated as the ratio between the difference of large and small axes of an ellipse to their sum. The DI dependence on the shear stress is a measure of the RBCs deformability.

For correct interpretation of the measurement results one needs a theoretical model, which relates the experimentally measured parameters (size and shape of the DP isointensity curves) with the parameters of particles. In this paper, we present a straightforward theory of laser diffractometry on the basis of anomalous diffraction approximation. We have obtained the analytical expressions for laser diffraction by a set of transparent elliptical discs mimicking RBCs.

In this paper, we show that a distribution of RBCs in sizes affects the visibility of the DP. Our analysis shows that the visibility of the DP can reach unity in the case of plane wave diffraction by a homogeneous (monodisperse) ensemble of particles. On the contrary, the real ensemble of RBCs can be inhomogeneous (polydisperse) that should lead to a decrease in the DP visibility. We have estimated the effect of the dispersion of the particles sizes on the visibility of the DP observed with the laser diffractometer. For example, the 8% dispersion of the relative sizes in the particles ensemble reduces the visibility of the DP to 0.5.

Acknowledgements: This work was partially supported by the RFBR grants № 08-02-92002-HHC_a and 10-02-01416-a.

References:

1. S. Nikitin, A. Lugovtsov, A. Priezzhev, "On the problem of the diffraction pattern visibility in laser diffractometry of red blood cells" Quantum Electronics, Vol. 40(12), 1074-1076 (2010).

P-10-BP

FIBER OPTIC DEVICE WITH ELECTRONIC SYSTEM OF COOLING FOR CONTACT INTERSTITIAL IRRADIATION OF TUMORS AND METASTASES

P. Grachev, G. Linkov, B. Loschenov
Prokhorov General Physics Institute, Russian Academy of Sciences, Moscow, Russia
p.v.grachev@gmail.com

Hyperthermia and photodynamic therapy are the methods of tumors and metastases treatments. These methods are based on the interaction of laser radiation with biological

tissues. Although the IR-radiation penetration depth in biological tissues is greater than the visible range radiation penetration depth, it is necessary to treat deeper layers of tissues in clinical practice without damage of subsurface layers. Increase of laser radiation intensity is the way to achieve deeper penetration of therapeutic effect. But it leads to enlarge the subsurface layer temperature. At the skin temperature of 43°C a patient feels pain, and irreversible damages of normal tissues occur [1]. Solution of this problem is to decrease temperature of subsurface layers. The aim of this work is development of cooling device for contact irradiation of interstitial tumors and metastases.

Theoretical calculations illustrate that under cooling laser treated surface hyperthermia temperatures can be achieved without damage of normal tissues. That is why the main task of the device is to dissipate heat effectively from irradiating area. Material of contact surface of the device must be optically transparent and possesses a high thermal conductivity. Sapphire is an appropriate material. Sapphire window is located in contact with an irradiated surface and is cooled by the Peltier electronic element. Laser radiation is delivered through quartz-polymer 600μm optic fiber from the light source to the cooling device. Fiber's aperture is 0.31.

Theoretical dependencies of temperature from the penetration depth were calculated for different tissues (human skin, muscle). The fiber optic device with electronic system of cooling has been developed. With use of the developed device experiments with muscle tissue were carried out and temperature profiles of muscle surface during hypothermia were obtained. The effect of hyperthermia in the depth of tumor localization has been achieved with use of the fiber optic device with electronic system of cooling.

References:
1. A.L. McKenzie, "Physics of thermal processes in laser-tissue interaction", Phys. Med. Biol., 1990, Vol. 35, No 9, 1175-1209

P-11-BP

COHERENCE DOMAIN IMAGING USING RASTER SCANNING AND AVERAGING

S. Proskurin, K. Galeb, A. Potlov, S. Frolov
Tambov State Technical University,
Sovetskaya 106, Tambov, Russia
spros@tamb.ru

We have applied a compact low power rapid scanning Optical Coherence Tomography system to monitor subcutaneous human blood vessels *in vivo* and velocity profiles in a flow with complex geometry using superluminescent diodes (SLD) in the wavelength range of 1.3-1.5nm. Optical clearing of skin tissues has been utilized to achieve depth of OCT images up to 1.7mm. Current approach enables applying low power (0.4-0.5mW) and low noise broadband near infrared light sources-SLD, obtaining structural images with spatial resolution down to 12μm. Two-dimensional time-domain OCT images of a complex flow velocity profiles in a phantom are presented. The effect of optical clearing on in vivo images is demonstrated and discussed.

Conventional OCT-systems provide structural images of tissue from synthesis of a series of one-dimensional reflectivity scans, so-called A-scans. The intensity of the backscattered

probing radiation recorded for each A-scan is proportional to the leap of the refractive index on the internal boundaries of the tissue.

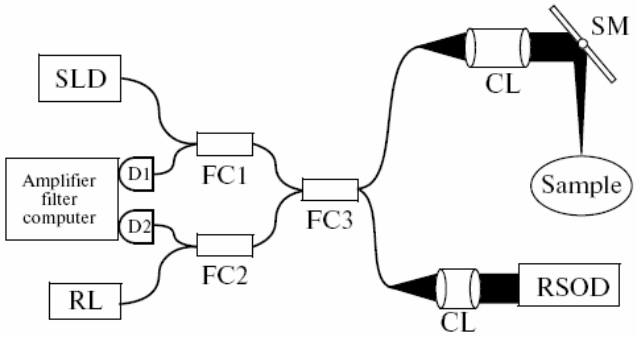


Fig. 1. Schematic presentation of the experimental setup based on single mode fiber optic Michelson interferometer: SLD-superluminescent diode; FC-fiber couplers; D1 and D2-balanced detectors; RL-pointing red light diod laser, can be switched with another SLD; CL-collimating lenses; SM-sample scanning mirror; RSOD-rapid scanning optical delay line.

We apply raster scanning of the sample arm and raster averaging in computer processing of adjacent A-scans [1, 2].

References:

1. Bonesi M., Proskurin S.G., Meglinski I.V., "Imaging of subcutaneous blood vessels and flow velocity profiles by Optical Coherence Tomography", *Laser Physics*, Vol. 20, No. 4, p. 891-899, 2010.
2. Proskurin S.G., Wang R.K., "Human subcutaneous blood vessels visualization by increasing coherence probing depth", *Quantum Electronics*, Vol 34, No.12 p.1157-1162, 2004.

P-12-BP

MICROSCOPIC CONTROL OF MESH EXPLANTS SURFACE HETEROGENEITIES

Valery P. Zakharov[1], Vladimir I. Belokonev[2], Ivan A. Bratchenko[1] and Pavel E. Timchenko[1]
[1] Samara state aerospace university, Samara, Russia
[2] Samara State Medical University, Samara, Russia
zakharov@ssau.ru

The influence of chemical composition, topology and surface heterogeneities of mesh explants on the process of their encapsulation is investigated with a help of confocal laser microscopy system. This system was designed on the basis of invert optical microscope Olympus IX71 with Yokogawa® CSU-X1 scanning unit working on the principle of Nipkow disk. DPSS lasers module ALC-400 with fiber acousto-optic control were used for excitation on wavelengths of 488 and 561 nm. Image registration was carried out with the use of EMCCD Andor iXONEM camera and Andor iQ software. This system provided recording of up to 2000 optical slices per second in the transverse and longitudinal resolution of 800 nm.
The microscopic analysis of tissue samples with mesh explant shows significant impact of the state of implants surface and weaving defects on the relapse probability in transplantation process. The encapsulation zone is qualitative changes with increasing of size, number and

density of implant microdefects forming "free play area". Examined explants types are shown in the table.

Explant	Type, composition	Density (g/m^2)	Porosity (%)	Average defect size (μm)
Prolene Ethicon	Isotactic crystalline polypropylene stereoisomer, diameter 115 μm	56	60	2..3
Mersilene	Polyethylene terephthalate monofilament, diameter 130 μm	66	68	15..25
Vipro	Composite fibers - prolyl-vicryl	93	73	5, 40
Esfil light	Monofilaments of polypropylene mesh, consisting of two fibers, diameter 90 μm, thickness 380 μm.	34	92	15..20
Esfil standard	Polypropylene monofilament, diameter 120 μm, thickness 500 μm.	62	85	30..40
Uniflex	Polivinilidenftoridnye monofilament, 120 μm diameter. Thickness - 480 μm	160	85	< 10
Ftorex	Lavsan complex fibers with fluoropolymer coating, 420 μm diameter	48	88	20..25
Optilene®Mesh	Polypropylene monofilament, 160 μm diameter	60	89	40

Acknowledgements: This work was supported by the federal target program "The scientific and scientific-pedagogical staff of Innovative Russia" for 2009 - 2013.

P-13-BP

BIOPHOTONICS OF THE EXTRA MEMBRANE LIGHT HARVESTING COMPLEX (PHYCOBILISOME) IN CYANOBACTERIA: NEW FLUORESCENT APPROACH IN ENERGY TRANSFER AND PHOTOPROTECTION MECHANISM STUDIES

Fedor I. Kuzminov[1], Maxim Yu. Gorbunov[2], Marina G. Rakhimberdieva[3], Irina V. Elanskaya[4], Navasard V. Karapetyan[3], Victor V. Fadeev[1]
[1] *Physics Faculty, Moscow State University, 119991 Leninskie gory 1-2, Moscow, Russia*
[2] *Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Road, New Brunswick, NJ 08901, U.S.A.*
[3] *A.N. Bakh Institute of Biochemistry RAS, 119071, Leninsky prospect 33-2, Moscow, Russia*
[4] *Biology Faculty, Moscow State University, 119991 Leninskie gory 1-2, Moscow, Russia*
fedor.kouzminov@gmail.com

The way, in which light harvesting is organized in cyanobacteria, differs from this process in algae and plants. In addition to chlorophyll (Chl) antenna, which transfers excitation to the reaction center, there are additional extra membrane light harvesting complexes – phycobilisomes (PBS), - which absorb light in 500-650 nm region. PBS consist of several phycobilin proteins and are organized in a way that light absorbed by shorter wavelength pigments (phycoeretrin or phycocyanin) is transferred to a longer wavelength pigment (allophycocyanin) and then to the Chl molecules. Excess energy is dissipated from PBS via

special photoprotection mechanism. Both processes involve interaction between large numbers of molecular complexes. A relatively high quantum yield of fluorescence of phycobilin proteins gives us an opportunity to study the process of exciton transfer and photoprotection mechanism using various fluorescence techniques.

Here we report our studies on the process of energy transfer and light protection mechanisms in cyanobacteria *Synechocystis* sp. PCC 6803 using highly informative techniques – Nonlinear Laser Fluorimetry (NLF) and two types of variable fluorescence techniques: Pulse Amplitude Modulation (PAM) and Fluorescence Induction and Relaxation (FIRe). Using NLF we define the molecular photophysical parameters (excitation cross-sections, times of linear relaxation and maximal rates of singlet-singlet annihilation) of different phycobilin proteins in PBS and suggested a possible pathway of exciton transfer between them. Performing kinetic measurements (using variable fluorescence techniques) of fluorescence quenching in wild type cyanobacteria *Synechocystis* and its mutants we determine the rates of transformations between different states of the system involved in the process of excess energy quenching and propose a multistep model of the formation of a quenching center.

P-14-BP

MONITORING PLASMAFERESIS BY THE METHOD OF BLOOD PLASMA LASER FLUORESCENCE

M.B.Tetukhina [1], V.A. Khomenko[2], A.G. Kuzmina[3], F.A. Batyrov [1], G.P. Kuzmin[4], O.G. Gaponenko[2]

[1]*7 tuberculosis city clinical hospital, 117014, Barbulina, 3, Moscow*
[2]*Central TB Research Institute of the Russian Academy of Medical Sciences, 107564, Yauzskaya alley,2, Moscow*
[3]*First Moscow State Medical University by I.M.Sechenov, 119992, Mochovaya, 11, Moscow*
[4]*Prokhorov General Physics Institute of the Russian Academy of Sciences, 119991, Vavilov 38, Moscow*
kuzmin@kapella.gpi.ru

The plasmaferesis use as the efferent therapy method in hard endotoxicosis treatment of various genesis in intensive therapy and urgent surgery is accepted as defining in disease prognosis and allows getting positive treatment results and lethality level decrease authentically.

Hard endotoxicosis stages demand to carry out repeated procedures which efficiency is necessary to estimate either clinically or on the authentic physics-chemical parameter basis. This monitoring is possible to implement with laboratory-diagnostic device "Spectrolux-MB" developed for laser fluorescent microbe nature disease diagnosis by blood plasma /1/.

He-Ne laser radiation with wavelength 633 nm supplied to the investigated sample with the dual-channel light-guide. After laser radiation interaction with the sample there is either reflected from its surface radiation or laser-induced fluorescence /LIF/. This second radiation is captured by adoptive light-guide fiber and directed to the dispersion knot and multi-channel photo-detector. Given data are displayed the computer monitor as a spectrum. 10 test tube time processing with blood plasma is 25 minutes. By blood plasma radiation on wavelength 633 nm the main spectral response is given by porphyrins/microorganism metabolism products/. While each microorganism type gives its own typical spectrum view which allows gaining spectrum data bank by micro-biological analysis results. Laser-induced fluorescence

method advantages are defined by getting fast analysis results compared with micro-biological.

There has been the research of 50 patients with various tuberculosis forms complicated by expressed intoxication. There was the initial plasma analysis at the moment of patient checking in at the hospital, research after plasmaferesis carrying out exactly and 5 days after plasmaferesis. Fluorescence indicator change allows thinking over patient treatment dynamics. As fluorescence decreases, there is adequately carrying out plasmaferesis session, the increase evidences about therapy inadequacy and intoxication increase. Therefore, due to fluorescence analysis method it is possible to estimate treatment efficiency in tight schedule and identify statement for the repeated plasmaferesis session.

References:

1. Alexandrov M.T., Kuzmin G.P., Gaponenko O.G., Khomenko V.A., Khokhlov E.M., Tikhonevich O.V. and Vasiliev E.N. Laser fluorescence spectroscopy and factor analysis in diagnostics of microbial diseases. Laser Physics, 2007, v.17, N3, p.p.290-295.

P-15-BP

ADJUNCTIVE DENTAL THERAPY FOR THE REDUCTION OF PLAQUE AND GINGIVITIS WITH LIGHT EMITTING TOOTHBRUSH: PILOT CLINICAL STUDY

Elina A. Genina[1], Vladimir A. Titorenko[2], Valery V. Tuchin[1,3], Georgy V. Simonenko[1], Alexey N. Bashkatov[1], Gennady M. Shub[2], Alexander V. Lepilin[2], Gregory B. Altshuler[4]
[1]*Saratov State University, Saratov, 410012, Russia*
[2]*Saratov State Medical University, Saratov, 410012, Russia*
[3]*Institute of Precise Mechanics and Control of RAS, Russia*
[4]*Palomar Medical Products, Burlington, MA, 01803, USA*
eagenina@yandex.ru

The main cause of inflammatory disease of periodont is vital functions of conditionally pathogenic microflora of oral cavity. Gingivitis is an inflammation of the gums caused by plaque and bacteria accumulation [1]. Antimicrobial phototherapy is successfully used for treatment of various inflammatory diseases [2,3]. Low-intensity light irradiation would be alternative therapeutic technique of treatment of for the patients who have contra-indications to the use of medicaments. In the past few years the development of light emitted diodes (LEDs) has advanced them to a stage where their use in phototherapy is possible [4]. We proposes the use of low intensity light diode toothbrush with irradiation at wavelength 405 nm as new aid of individual hygiene. The goal of the pilot studies is estimation of the efficacy of the treatment of inflammatory disease of gum mucosa with tooth brushing in combination with phototherapy.

Sixty subjects from 17 to 39 years old of both sexes with light to moderate gingivitis were enrolled. I group included the volunteers, who were treated by blue light emitted toothbrushes (LETBs) (405 nm), II group was control one and included the volunteers, who treated by standard manual toothbrushes. Clinical evaluation of changes in gingivitis compared with the baseline was visually assessed using five standard dental indices.

In the both groups there were improvement in gingivitis associated with improvement of indices of plaque, gingival bleeding and inflammation. However, in the first group addition

improvement of studied indices was clearly seen which was considered as caused by anti-microbial action of blue light on gum tissue. The use of LETB has a multifactor therapeutic action on oral pathological microflora: mechanical removal of the bacteria and suppressing action on microorganisms due to photodynamic reaction.

Acknowledgements: The authors are grateful to Palomar Medical Technologies, Inc. (Burlington, MA, USA) for funding this work. The research described in this paper was also supported by grant № 224014 PHOTONICS4LIFE of FP7-ICT-2007-2 (2008-2013) and Governmental contract 02.740.11.0879.

References:

1. Oral Hygiene Indices/WHO Oral Health Country/Area Profile Programme Department of Noncommunicable Diseases Surveillance/Oral Health WHO Collaborating Centre, Malmö University, Sweden: www.whocollab.od.mah.se/expl/ohiintrod.html (2011).
2. C. M. Cobb, "Lasers in periodontics: A review of the literature", J. Periodontol., 77 (4), 545-564 (2006).
3. S. Parker, "Lasers and soft tissue: periodontal therapy", British Dental Journal, 202 (6), 309-315 (2007).
4. L. Brancaleon, H. Moseley "Laser and non-laser light sources for photodynamic therapy" Lasers Med. Sci., 17, 173-186 (2002).

II. OPTOACOUSTICS

P-1-OA

OIL CONTAMINATION PHOTOACOUSTIC SENSOR SYSTEM

Mihaela Albu[1,2], Lars Duggen[1], Michal Radziwon[1],
Thomas Zwieg[2], Morten Willatzen[1], Horst-Günter Rubahn[1]
[1] *NanoSYD/Mads Clausen Institute, University of Southern Denmark, Sønderborg, Denmark*
[2] *PAJ Systemteknik, Sønderborg, Denmark*
albu@mci.sdu.dk

An important requirement in many industries is clean compressed air. In particular in critical production processes of the chemical and pharmaceutical industry, in food production and surface coating, the analysis and control of compressed air quality is a crucial factor. The aim of this work was to develop an online sensor system for the detection of the oil vapour contamination in compressed air according to ISO 8573 using the principle of photo-acoustics.

The investigations have been focused on the photo-acoustic detection of gaseous n-heptane in synthetic air (SA, 5.5) at room temperature and atmospheric pressure. The experiments were performed using the experimental setup which schematic diagram is presented in Figure 1. A distributed-feedback (DFB) infrared laser diode (1725 nm) has been used as light source. A modulated irradiation of the gaseous sample in the photoacoustic (PA) cell causes periodic pressure variations (i.e. sound) that can be detected by a microphone and measured using a lock-in technique [1]. The photo-acoustic resonator operates in its first longitudinal mode. The PA spectrum of n-heptane in synthetic air (for various concentrations: ~30 ppbV - 100 ppmV) at atmospheric conditions was recorded by scanning the stimulus laser modulation frequency between 1300 and 1800 Hz. The maximum signal was plotted versus different concentrations of n-heptane in synthetic air showing a good linearity of the PA sensor across the investigated concentration range.

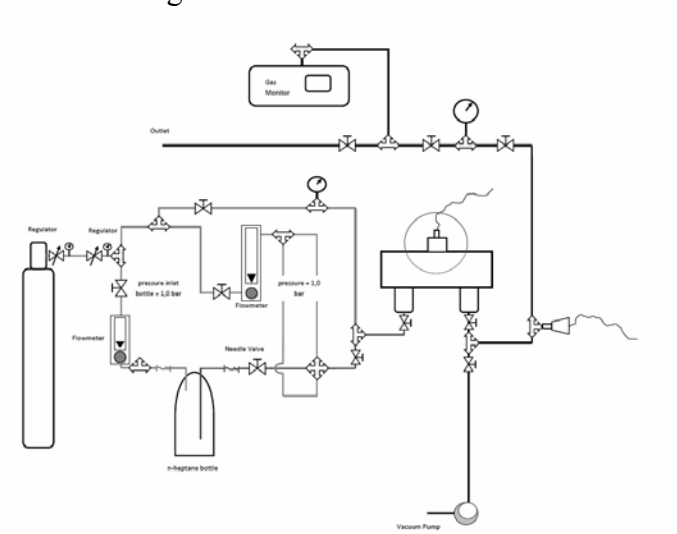


Fig.1: Schematic diagram of the experimental setup.

Acknowledgements: Financial support for this work by the Danish National Advanced Technology Foundation is gratefully acknowledged.

References:

1. W. Demtröder, "Laser Spectroscopy", Springer-Verlag, Berlin (2002).

III. LASER DIAGNOSTICS

P-1-LD

UV-VIS-IR PASSIVELY Q-SWITCHED σ-POLARIZATION COMPOSITE YVO_4 - Nd:YVO_4 LASER FOR MEDICINE APPLICATIONS

A.A. Sirotkin
Prokhorov General Physics Institute of the Russian Academy of Sciences,
119991, Vavilov 38, Moscow, Russia
saa@kapella.gpi.ru

UV lasers are widely used in technological, scientific, and medical applications. One interesting application in biology and medicine is the action of low-intensity UV radiation on various microorganisms. Medical treatment of patients suffering from fibrous-cavernous pulmonary tuberculosis is still difficult and urgent problem in modern medicine. Further experiments with laser radiation at the wavelength 266 nm show higher efficiency of the action of this radiation on microorganisms. Thus, it seems reasonable to create low-cost and simple UV laser medicine systems for further development of the treatment of patients suffering from tuberculosis and other diseases.

Here, we present a novel UV source based on passively *Q*-switched composite *a*-cut σ-polarization YVO_4-Nd:YVO_4 lasers with Cr^{4+}:YAG saturable absorber.

We have experimentally investigated the operation of diode-pumped passively *Q*-switched composite YVO_4-Nd:YVO_4 lasers based on *a*-cut (π- and σ-polarization) with Cr^{4+}:YAG saturable absorber with following conversion into visible and UV spectral ranges.

By using the natural birefringence of an *a*-cut YVO_4-Nd:YVO_4 crystal, we experimentally investigate laser operation under different light polarizations (π- and σ-polarized emissions) and compare their performance. The laser performance is further compared with a diode-pumped *c*-cut Nd:YVO_4 laser of the same parameters. It is known, that too large emission cross-section of vanadate crystals is a shortcoming for Q-switched lasers, because it limits their energy-storage capacity, leading to smaller pulse energies. Usial methods to avoid this drawback are to use *c*-cut crystals or mixed vanadates $Nd:Gd_xY_{1-x}VO_4$.

We have shown experimentally that the best passively *Q*-switched performance obtained in our experiments is from the *a*-cut σ-polarized laser, which gives the narrowest pulse of 1.5 ns with the highest peak power of 17 kW. In addition *a*-cut σ-polarized vanadate crystals have the polarized radiation. High peak power and beam quality of the IR lasers are required for efficient conversion of the radiation into visible or UV spectrum range by means of nonlinear crystals.

The average power of visible and UV radiation up to 340 and 24 mW has been obtained in the case of extracavity conversion of the laser radiation in crystals KTP and BBO, respectively.

We have demonstrated , for the first time, a low-cost, compact, high-efficiency passively Q-switched UV-VIS-IR laser medicine systems based on the *a*-cut σ-polarized Nd:YVO_4 laser with Cr^{4+}:YAG saturable absorber crystal.

Acknowledgements: This work partially supported by *ADVANCED ENERGY TECHNOLOGIES, LTD.*

P-2-LD

PHOTOLUMINESCENT PROPERTIES OF PARTIALLY CRYSTALLIZED SILICON AND SILICON CARBYDE LAYERS UNDER LASER EXCITATION

I.V. Mirgorodskiy, V.Yu. Timoshenko, D.M. Zhigunov
Physics Department, M.V. Lomonosov Moscow State University, 119992 Moscow, Russia
mirgorodskij@physics.msu.ru

Today light-emitting devices based on silicon nanocrystals (nc-Si) are intensively investigated due to observation of strong light emission in systems of nanocrystals in SiO_2 matrices [1]. However quantum efficiency of such devices is still low for practical applications. Also there are difficulties in exciting of nanocrystals by electric current because of large band gap of surrounding matrices. So, the main task of this work consists in investigation of new types of system based on silicon nanocrystals in semiconductor matrices possessed efficient and stable luminescence. Such objects are quite good candidates for application as electroluminescent devices and also solar energy applications.

In this work three types of samples were investigated by means of photoluminescence spectroscopy and Raman scattering spectroscopy. Samples of the first type were prepared by rapid thermal annealing of amorphous silicon layers (a-Si:H) and subjected to stain etching in hydrofluoric acid solutions in order to passivate surface of nc-Si. Samples of the second type were prepared by the same method but amorphous silicon carbide layers (a-SiC:H) were used as initial films. Samples of the third type were prepared by silicon ion implantation in layers of hexagonal silicon carbide (6H-SiC) and following furnace annealing.

So, first of all it was shown that nc-Si can be prepared by rapid thermal annealing and stain etching of a-Si:H and a-SiC:H layers. The mean size of 3-8 nm and volume fraction of 40-90% of nc-Si in annealed films were estimated by means of Raman scattering spectroscopy. Measurements of photoluminescence (PL) spectra and PL kinetics were carried out by using Ar^+ laser with wavelength of 364 nm and N_2 pulsed laser with wavelength of 337 nm, respectively. PL of nc-Si/a-Si:H layers showed strong emission in region of 600-900 nm. The PL intensity and lifetimes of obtained films were similar to those of porous silicon formed by electrochemical etching.

The PL spectra of nc-Si/a-SiC:H also showed emission in region of 600-900 nm. Analysis of lifetimes revealed that there are two fast processes in obtained films with typical time of 13 microsec and lower than 0.6 microsec. These lifetimes are considerably lower than lifetimes are known for silicon nc-Si in dielectric matrices and porous silicon. Such behavior may indicate the presence of charge transport between nc-Si and amorphous matrix. But it also can be connected with radiative recombination on structural defects. Also PL measurements did not reveal any remarkable changes in PL spectra of initial 6H-SiC samples and samples of third type. Together with very small lifetimes in these samples this behavior indicates that there was no efficient nc-Si formation under used annealing conditions.

In conclusion, the obtained results indicate new possibility for preparing luminescent films that may be used as base for electroluminescent devices.

References:

1. M.E. Castanga, S. Coffa, M. Monaco, L. Caristia, A. Messina, R. Mangano, C. Bongiorno, "Si-based materials and devices for light emission in silicon", Phys. E, 16, 547-553 (2003).

P-3-LD

STUDY OF GOLD NANOPARTICLES BEHAVIOR IN MODEL SOLUTIONS OF BLOOD SERUM BY DYNAMIC LIGHT SCATTERING

Gibizova V.V., Sergeeva I.A., Petrova G.P.
[1]*Department of Molecular Physics, Faculty of Physics, M. V. Lomonosov Moscow State University, 1, building 2, GSP-2,Lewinsky Gory, Moscow, 119991, Russian Federation*
gibizova@physics.ru

More attention is paid to the development of nanotechnologies in modern medicine. Quite promising object of the research became gold nanoparticles with plasmon resonance (PR) because of their possibility of adjustment to spectral position and PR amplitude and their ability to transfer energy from absorbed light to thermal [1]. Due to it, they can be effectively used as markers for cancer cells visualization and also for oncological diseases treatment.

The most widespread way of nanoparticles address delivery to the diseased cells-the transporting of them by blood system. Gold nanoparticles are characterized by their biocompatibility and small toxicity, however, it is considered more detailed to investigate their interaction mechanism with the basic components of blood serum [2].

The research of behavior of a proteins mix of albumin and γ-globulin at their various mass parities [3] with addition of gold nanoparticles [4] was conducted in this work:

a) normal parity of proteins in serum of "healthy" blood;
b) parity of proteins in serum of "unhealthy" blood;
c) risk area.

For all three cases had been received concentration dependences of translation diffusion coefficient by dynamic light scattering.

On the basis of the received results the following conclusions can be pointed out:
1) there is no interaction between albumin and gold nanoparticles,
2) probably there is an interaction between investigated particles with γ-globulin and the sorption of γ-globulin on gold nanoparticles is observed.

Acknowledgements: Thanks to PhD, associate prof. A.V. Priezzhev for the given materials and for valuable pieces of advice.

References:

1. N.G. Khlebtsov, "Optics and biophotonics of nanoparticles with a plasmon resonance" Quantum Electronic, Vol. 38 (6), 504–529 (2008).
2. G.P. Petrova, Y.M. Petrusevich., A.N. Evseevicheva, "Optical Diagnostics of Toxic Heavy Metal Ions Effect on Plasma Blood Proteins", Proc. SPIE Vol.4263, p.150-160 (2001).
3. G.P. Petrova, A.V. Boiko, K.V. Fedorova, I.A. Sergeeva, N.V. Sokol, T.N. Tichonova, "Optical properties of solutions consisting of albumin and γ-globulin molecules in different ratio modeling blood serum" Int. Conf. Advanced Laser Technologies "ALT-08", Laser Physics, Vol.19, p.1303 (2009).
4. G. Frens, "Controlled nucleation for the regulation of the particle size in monodisperse gold suspensions" Nature Phys. Sci., Vol.241, p.20-22 (1973).

P-4-LD

THEORETICAL CALCULATIONS AND EXPERIMENTAL EVIDENCE OF PHOTOLUMINESCENCE ENHANCEMENT IN ULTRATHIN LAYER WITH SILICON NANOCRYSTALS

D.M. Zhigunov[1], S.A. Dyakov[2], A.V. Emelyanov[1], N.V. Shvydun[1], V.Yu. Timoshenko[1], A. Hartel[3], D. Hiller[3], M. Zacharias[3]
[1] *Faculty of Physics, M.V. Lomonosov Moscow State University, 119991 Moscow, Russia*
[2] *Trinity College Dublin, Dublin 2, Ireland*
[3] *Albert-Ludwigs-University Freiburg, IMTEK, 79098 Freiburg, Germany*
dmzhigunov@physics.msu.ru, zhigunov@mail.ru

Most of prospective applications of silicon nanocrystals (Si-NCs), such as active media for optical waveguides, amplifiers and lasers, or basis for light-emitting diodes, or absorbing ultrathin layer for the third generation photovoltaic devices, imply utilization of thin films containing Si-NCs. Therefore, the control of optical properties (including theoretical calculations) of such films is of current importance. However, small optical thicknesses of the films (which are often much less than characteristic wavelengths) and complicated multilayered structure make certain difficulties for the ordinary estimations using standard formulas. We present a model, which enables one to prognosticate the optical response, for example, photoluminescence (PL) intensity of multilayered structure containing, among others, emitting layer with Si-NCs. Thus, using theoretical predictions we experimentally observed PL intensity enhancement of ultrathin (4 nm thick) film with Si-NCs for optimally chosen silicon dioxide (SiO_2) buffer layer thickness (Fig. 1a). Moreover, our model enables one to explain nonmonotonic dependence of PL intensity from Si-NCs layer on its thickness (Fig. 1b).

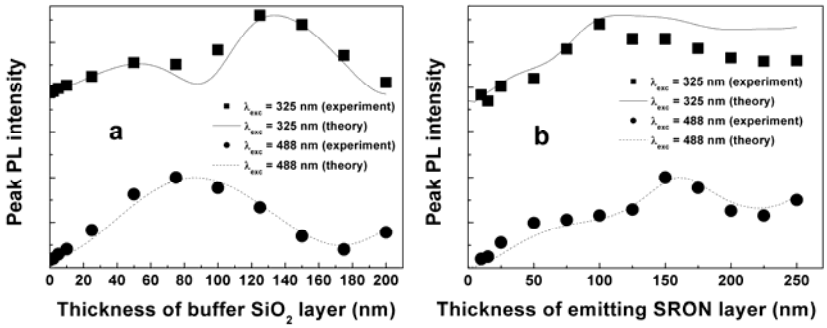


Fig.1. Comparison of experimentally measured and theoretically calculated dependences of peak PL intensity on thickness of buffer SiO_2 layer (a) or on thickness of emitting SRON layer (b) for SiO_2/SRON/SiO_2 triple-layered structure for two different excitation wavelengths

Alternating layers of stoichiometric SiO_2 and silicon rich silicon oxynitride (SRON) were deposited on Si substrates using PECVD system. Subsequently, all samples were annealed for 1 h in high purity N_2 atmosphere at 1100 ^oC in order to form Si-NCs in SRON layers. Triple-layered structures consisting of buffer SiO_2 layer, emitting SRON layer and capping SiO_2 layer were fabricated. For the first set of samples the thickness of buffer layer was varied from 0 to 125 nm, while the thicknesses of emitting and capping layers were fixed. On the contrary, the second set of samples is characterized by variable thickness of emitting SRON layer, while the thicknesses of other layers were constant. PL intensities were calculated using 2x2 transfer matrix method. The PL process is approximated by radiation of chaotically oriented oscillating electrical dipoles. The amplitude of oscillation is proportional to the electric field of excitation light at the position of dipole.

IV. LASER-MATTER INTERACTIONS

P-1-LM

A MULTIPARAMETRIC STUDY OF LASER ABLATION SYNTHESIS OF SILVER NANOSTRUCTURED FILMS

A.V. Bulgakov[1], S.V. Starinski[1,2], A.B. Evtushenko[1], Yu.G. Shukhov[1], V.I. Zaikovskii[3], L.S. Kibis[3], A.I. Boronin[2,3]
[1]*Kutateladze Institute of Thermophysics SB RAS, 1 Lavrentyev Ave., Novosibirsk, Russia*
[2]*Novosibirsk State University, 2 Pirogova St., 630090 Novosibirsk, Russia*
[3]*Boreskov Institute of Catalysis SB RAS, 5 Lavrentyev Ave., 630090 Novosibirsk, Russia*
bulgakov@itp.nsc.ru

Silver-based nanostructured materials are considered to be very promising for numerous applications due to their unique optical, catalytic and bactericidal properties. Pulsed laser ablation (PLA) has proven to be an efficient technique for nanomaterial synthesis. Although PLA is widely used for generation of silver nanostructures, both in the form of thin films and nanoparticles, their formation mechanisms are still poorly understood. In this work, PLA of silver in vacuum and ambient gases by 7-ns, 532-nm laser pulses and PLA-produced nanostructured films are studied using a variety of diagnostic methods. Data on the absolute ablation rate as a function of laser fluence in the range 1-10 J/cm^2 are obtained by mass loss measurements. The PLA plume composition and expansion dynamics are investigated using time-of-flight mass spectrometry. The angular distributions of the plume particles are studied by quartz crystal microbalance. The size, structure and composition of the deposited nanoclusters are investigated by STM, HRTEM, and XPS methods. A theoretical analysis of silver PLA based on the thermal model has been performed which demonstrates that surface vaporization is the main ablation mechanism at fairly high laser fluences, above ca. 5 J/cm^2 (the ablation threshold is ~1 J/cm^2). It is found that the main ablation products under these irradiation conditions are Ag atoms and the obtained nanostructures are formed on the substrate. We show that the average nanocluster size can be efficiently controlled in the range 2 -10 nm by varying the background gas pressure (Fig. 1). At lower fluences, a considerable part of the ablated matter is ejected in the form of silver microdroplets as demonstrated by a comparison of the experimental and theoretical results on the ablation rate as well as by STM images. The interplay between the size of the produced nanostructures and ablation conditions is discussed.

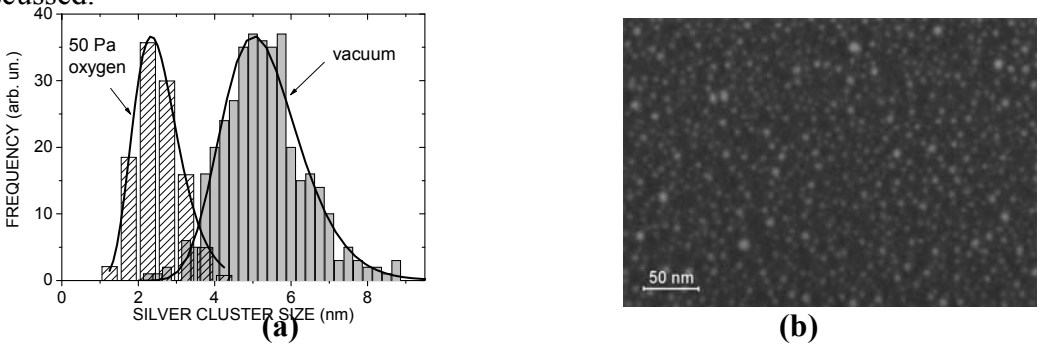


Fig. 1. (a) Size distributions (histograms) of Ag nanoclusters produced on Si substrates by PLA at 7 J/cm^2 in vacuum (grey bars) and in ambient O_2 at 50 Pa (shaded bars). The lines are fits with log-normal distributions resulting in average sizes of 5.2 ± 1.8 nm and 2.5 ± 0.4 nm, respectively. The corresponding STM image of the film obtained in vacuum is shown in (b).

Acknowledgements: This work was supported by the RFBR (projects No. 10-03-00441).

P-2-LM

PHOTON STATISTIC MEASUREMENTS OF SURFACE PLASMON EXCITATION

Dániel Oszetzky, Attila Nagy, Attila Kerekes, Aladár Czitrovszky
Research Institute for Solid State Physics and Optics
Konkoly-Thege u. 29-33, 1121 Budapest, Hungary
odani@szfki.hu

Surface plasmon oscillations (SPOs) [1] are in the centre of interest within an increasingly broad scientific community. SPOs are wave like density fluctuations of conduction electrons on metallic surfaces coupled with a p-polarized electric field in a dielectric material above the surface. They propagate along the metal surface and have a dispersion relation that is significantly different from that of "ordinary light"; the diffraction limit does not apply to them and they may be localized to nano-sized metallic irregularities or particles.

In this study we present the results of our measurements on photon statistic distributions of the light emitted by surface plasmon oscillations [2-4]. Both visible and near infrared lasers have been used for generation of surface plasmons. The experiments were performed in the Kretschmann geometry using both gold and silver layers at several laser pumping powers. We used different type of photo detectors in the photon counting regime to measure the statistical properties of the light generated by surface plasmons. Photon statistics have been measured by different methods. Time interval statistics, photon-number distribution, auto-correlation and cross-correlation functions of the generated light were determined and compared to those of the exciting laser. Correlations between statistical properties of the light emitted by decaying surface plasmons and the exciting laser source have been studied.

References:

1. H. R. Raether, "Surface Plasmons on Smooth and Rough Surfaces and on Gratings", Springer, New York (1988).
2. N. Kroó, A. Nagy, A. Czitrovszky, D. Oszetzky, H. Walther, "Surface plasmons and photon statistics", Journal of Modern Optics 53, 2309 (2006).
3. N. Kroó, S. Varró, Gy. Farkas, D. Oszetzky, Nagy, A. Czitrovszky, "Quantum Metal Optics", Journal of Modern Optics 54, 2679 (2007).
4. N. Kroó, S. Varró, Gy. Farkas, P. Dombi, D. Oszetzky, Nagy, A. Czitrovszky, "Nonlinear Plasmonics", Journal of Modern Optics 55, 3203 (2008).

P-3-LM

Au-COATED ZnO NANOSTRUCTURES FOR SERS APPLICATION

A.Og. Dikovska[1], N.N. Nedyalkov[1], S.E. Imamova[1], G.B. Atanasova[2], P.A. Atanasov[1]
[1]*Emil Djakov Institute of Electronics, Bulgarian Academy of Sciences,*
72 Tsarigradsko Chaussee, Sofia 1784, Bulgaria
[2]*Institute of General and Inorganic Chemistry, Bulgarian Academy of Sciences,*
Acad. G. Bonchev Str., bld. 11, 1113 Sofia, Bulgaria
dikovska@ie.bas.bg

Surface enhanced Raman scattering (SERS) has become a widely applied technique in the study of molecules at extremely low concentrations. Because of its great sensitivity, SERS

has tremendous potential in chemical and biosensing applications. However, the development of a SERS-based sensor requires an efficient SERS substrate that not only provides high enhancement factors, but is also stable, and easy and relatively inexpensive to fabricate.

One-dimensional ZnO nanostructures have attracted enormous interest due to their potential application in nanoscale electronics and photonics. Among the various synthesis methods, pulsed laser deposition (PLD) has been proven to be a simple and effective catalyst-free method for preparation of nano-scale materials. Several studies have been reported dealing with ZnO nanostructures growth by PLD and exploring a wide range of experimental parameters, such as choice of substrate, substrate temperature, background oxygen pressure, etc. The use of a buffer ZnO layer as a possible way of supplying growth nuclei for the subsequent growth of ZnO nanstructures has also attracted current interest. It was demonstrated that, once a buffer layer is introduced, the subsequent ZnO nanostructures growth can exhibit different morphologies.

In the present work, we report a study on nanostructured ZnO films fabrication by PLD and the measurements of the SERS characteristics of these samples after Au-coating. The experimental conditions used for preparation of the samples were chosen to obtain different types of ZnO nanostructures. Rodamine-6G (R6G) was used as a SERS active molecule pumped at 785 nm. The influence of the surface morphology on the Raman response of the samples at a fixed R6G concentration was investigated. An enhancement factor of approximately $10^6 \div 10^7$ was evaluated for all Au-coated ZnO nanostructures with R6G.

Acknowledgements: This work was supported by the Bulgarian Ministry of Education and Science under Contract DO 02-293/08.

P-4-LM

DIAGNOSTIC OF MELT-FLOW AT GAS-ASSISTED CUTTING OF STEEL BY CO_2 LASER

Alexander V. Dubrov, Vladimir D. Dubrov, Yury N. Zavalov, Vladislav Ya. Panchenko
Institute on Laser and Information Technology of Russia Academy of Science,
Shatura, Moscow Region, Russia
Zavalov_Yuri@yahoo.com

The measurements of melt temperature during CO_2 laser-cutting are carried out. Using of optical sensors for on-line monitoring of the roughness of the cut edge in laser cutting technology was suggested in [1-2]. In [3] development of this method and adaptive control system for laser cutting was described. The line of [Hamamatsu] K1713-05 photo-detectors were used in our experiments. This type of detector incorporates an infrared transmitting Si photodiode mounted over an InGaAs PIN photodiode along the same optical axis, which allowed us to calculate local brightness temperature of melting in area of laser radiation action.

Measurements have been performed of fluctuations of local brightness temperature in the operating zone in the process of cutting sheets of mild steel of 3 mm, 6 mm and 10 mm thickness. The results are presented for different velocities of laser beam travel across the sheet surface and pressures of oxygen used as an assist gas. The noise spectra of the local temperature fluctuations have been obtained, which are related to local pulsations of the removed material melt surface under heating by laser radiance.

The root-mean-square amplitude of temperature fluctuations is in excess of ±10 K up to the frequency of 7 kHz in effect of laser radiance above 1 MW/cm^2. The boundary between capillary-wave turbulence and hydrodynamic turbulence is shown to pass in the region of 1.5 to 4.5 kHz depending on the material thickness. An estimation of the threshold of thermocapillary effect of anomalous absorption reasoning from the experimental data is near of 1 MW/cm^2.

The results of calculation of the threshold of the formation of thermo-capillary waves will be presented in dependence on the wavelength of laser light. The estimation of range generated capillary waves will be presented. The local temperature gradient along the surface of the melt is also estimated on the basis of experimental data.

Acknowledgements: The authors wish to thank the Russian Foundation for Basic Research for financial support (grant 11-08-01094-a).

References:
1.P. Sforza, V. Santacesaria «CO_2 laser cutting: analytical dependence of the roughness of the cut edge on the experimental parameters and process monitoring» In: SPIE Proceedings "Laser Materials Processing: Industrial and Microelectronics Applications" 2207, pp. 836-847 (1994).
2.Heyn H., Decker I., Wohlfahrt H. «Tools and requirements for in-process quality control in laser beam welding» In: SPIE Proceedings «Laser Materials Processing: Industrial and Microelectronics Applications», 2207, pp.381-391 (1994).
3.J. R. Duflou1, E. Fallahi Sichani, J. De Keuster1, J.-P. Kruth «Development of a real time monitoring and adaptive control system for laser flame cutting» In: Proceedings of the 28th International Congress on Applications of Lasers and Electro-Optics, November 2-5, 2009 - Orlando, Fl, USA, 102, 527-536 (2010).

P-5-LM

INDUCED CHANGES IN REFRACTIVE INDEX AND NEAR-IR SPECTRUM OF POLYCARBONATE-SIO_2 THIN FILMS BY VIS-IR LASERS

H.Ehsani[i].A, M.Ghoranneviss[2]
[1] *Departman of physics,Islamic Azad University,Nor Branch, Iran*
[2]*Plasma research center, Islamic Azad University, Science and research branch,Tehran ,Iran*

In this work, we have investigated the effects of visible lasers irradiation in polycarbonate-Sio_2 refractive index in 400-800nm region .Then we have studied the changes in near-IR spectrum in irradiated samples created by VIS-IR lasers. One of the most usual methods to evaluate the refractive index of thin films from transmittance data is the method proposed by Swanepoel [1, 2]. Based on this method the refractive index of films as a function of wavelength can be calculated by

$$n(\lambda)=\left[\left(\frac{2s(T_M(\lambda)-T_m(\lambda))}{T_M(\lambda)T_m(\lambda)}+\frac{s^2+1}{2}\right)+\sqrt{\left(2s\frac{T_M(\lambda)-T_m(\lambda)}{T_M(\lambda)T_m(\lambda)}+\frac{S^2+1}{2}\right)^2-S^2}\right]^{\frac{1}{2}} \quad (1)$$

Where, s is the refractive index of the substrate.
The changes in near infrared spectrum of irradiated samples were interpreted by using the overtones and local mode approximation. According to this method the frequency of an overtone transition out of the ground state $\nu_{0\to\nu}$ is [3, 4].

$$\nu_{0\to\nu} = \nu\omega - (\nu^2 + \nu)\omega x \qquad (2)$$

Where ω and ωx are, respectively, the pure normal mode frequency and anharmonicity.To compare the effects of lasers beam on the refractive index and NIR spectrum the incident dose was considered as a key factor. The transmission spectra of the samples after irradiation at 50.33 J/cm^2 energy density and dispersion of refractive index at the same energy density have been shown in fig1(a and b)

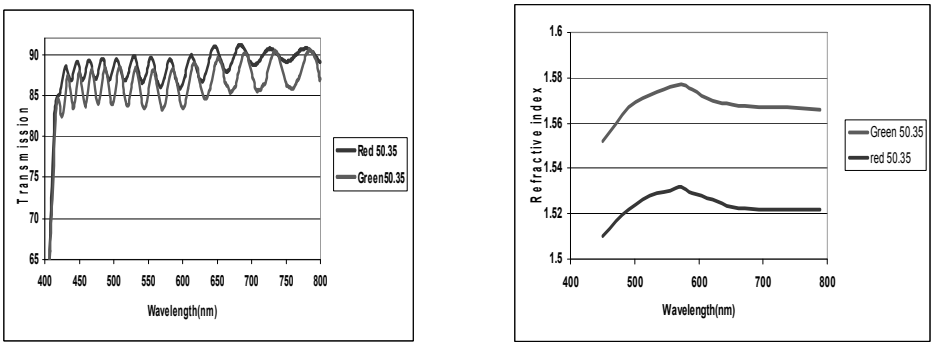


Fig. 1a) Transmission spectra of irradiated samples by visible laser at 50.35J/Cm^2
b) Dispersion curve

The refractive index first increases, and then it decreases and stabilizes with increasing wavelength. These behaviors of refractive index suggest the presence of absorption band at wavelength below 450nm. In NIR region, the presence of overtones and combination bonds in wavelength areas 1420-1450nm, 1200-1370nm and 1100-1200nm [5] leads to some changes in intensities of absorption peaks and their locations. For example in Fig. (2) the changes in absorption intensity in the wavelength range1200-1370 nm have been compared for index and irradiated samples at 50.35J/cm^2 energy density. Regarding to this figure it is deduced that irradiation of lasers have two important effects: increasing the intensities of absorption peaks and shifting their locations toward shorter wavelength. These effects are more considerable at higher photon energy of lasers and higher energy density and can be attributed to transition between the trans-trans and cis-trans conformations of carbonate group in diphenyl carbonate (DPC).

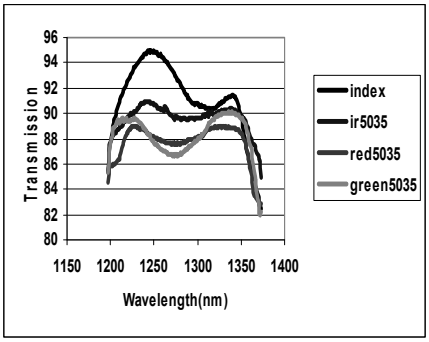


Fig. 2: Induced changes in Mid-IR spectrum after irradiation by Vis-IR lasers at 50.35J/Cm^2

Acknowledgements: The authors would like to thank Dr. Azima for his scientific support and also IAU, science and research branch for providing us with well-equipped labs.

References:

[1] D.Poelman , P.fredreic smet , j. D: Appl.phys. 36, 1850, 2003.
[2] G.Gomes , O.M.ozkendir, H.kavak, y.ufuktepe, opt. adv. Mat. 8, 299, 2006.
[3] M.L. Sage and J.Jorther, Adv.Chem.Phys.47, 293, 1981.
[4] M.G.Sowa, B.R.Henry,and Y.Mizugai, Phys.Chem.20.7659.1991.
[5] C.R.Malyan and A. Skumanich, Chem.phys.letters. 174, 139, 1990

P-6-LM

OPTICAL BISTABILITY IN PHTALOCYANINE FILM

Alexey Karpo[1], Vitaly Krasovskii[1], Victor Pushkarev[2], Larisa Tomilova[2]
[1]*A.M.Prokhorov General Physics Institute, Moscow, Russia*
[2]*M.V. Lomonosov Moscow State University, Department of Chemistry,Moscow, Russia*
karpo-ab@yandex.ru

Phtalocyanine compounds possess high nonlinearities and short relaxation times due to broad two-dimensional system of 18 delocalized π-electrons. Phtalocyanines enable to tune absorption spectra and nonlinear optical properties by means of the modification of the chemical structure. These compounds are well suited to the transition to constructing on the molecular level.

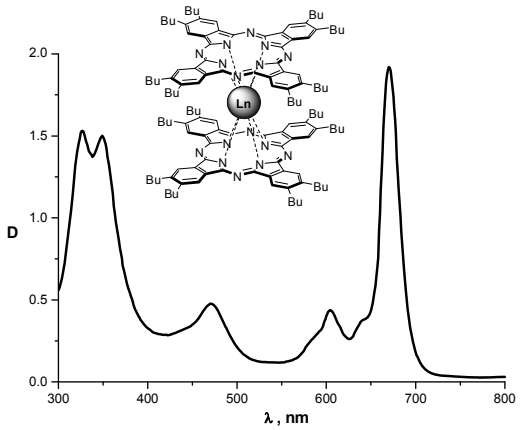


Fig.1. a) Absorption spectra of homoleptic phthalocyanine, b)structure

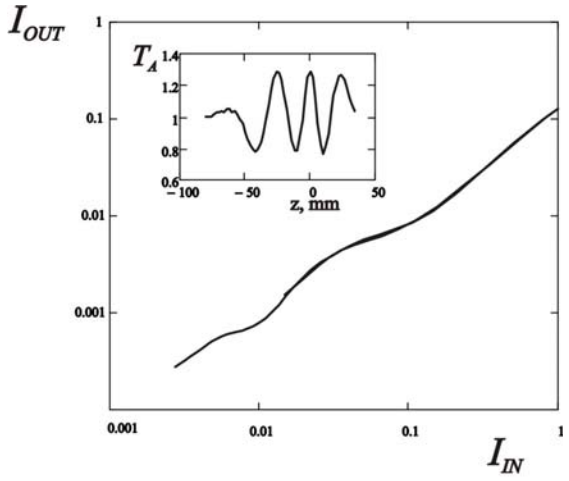


Fig.2. a) Dependence of I_{OUT} vs I_{IN} and b) transmittance with aperture

In this work the results of the experimental study of all-optical switching in erbium butyl-substituted diphtalocyanine [1] films of 5mm thick placed on the glass plate are presented. The experiment was carried out using the z-scan geometry [2] with aperture on the wavelength of 0.53 μ with the 300 ps pulse. The measured transmittance as a function of sample position and corresponding dependence I_{OUT} vs I_{IN} are presented on fig. 2.

The obtained data were interpreted within the phase bistability model [3] in the Fabry-Perot interferometer as the result of the competition of electronic and thermal mechanisms of nonlinearity [4].

References:

1. V. E. Pushkarev, A. Yu. Tolbin, A. V. Ryabova, L. G. Tomilova. Preparation of nanosized sandwich-type structures based on planar binuclear phthalocyanines // Mendeleev Commun. V. 19. No 1 (2009).
2. M. Sheik-Bahae, A.A. Said, T.H. Wei, D.J. Hagan, and E.W. Van Stryland, Journal of Quantum Electronics, QE-26, 760-769 (1990).
3. D.A.Miller, IEEE Journal of Quantum Electronics, V.17, No.3, 306-311 (1981).
4. A.A. Isaev, A.G. Vitukhnovskii, V.S. Lebedev, Russian Nanotechnologies 3, № 11/12 (2008).

P-7-LM

FAR AND NEAR FIELD OPTICAL PROPERTIES OF GOLD NANOPARTICLE ENSEMBLES

N.N. Nedyalkov[1], I. Dimitrov, P. A. Atanasov[1], R. A. Toshkova[2], E. G. Gardeva[2], L. S. Yossifova[2], M. T. Alexandrov[2], A. Dikovska[1]
[1]*Institute of Electronics, Bulgarian Academy of Sciences, Tzarigradsko shousse 72, Sofia 1784, Bulgaria*
[2]*Institute of Experimental Pathology and Parasitology, Bulgarian Academy of Sciences, G. Bonchev Street, bl. 25, Sofia 1113, Bulgaria*
nnn_1900@yahoo.com

Theoretical and experimental results on the far and near field optical properties of two- and three dimensional gold nanoparticle ensembles are presented. The system under consideration consists of spherical gold nanoparticles with different diameters in the range of 20 to 200 nm forming 2D or 3D clusters in water. The configuration of the nanoparticle ensembles are reproduced from the real experiments of gold nanoparticle deposition onto cancer cells and tumor tissue. The absorption and scattering cross-section spectra for the proposed nanostructures were obtained using the generalized multiparticle Mie-solution. This approach was applied to studying the properties of the far-field spectra as a function of the cluster size, particle dimensions, and incident radiation properties. Finite difference time domain simulation is used to describe the characteristics of the electromagnetic field in the close vicinity of the structures.

The results obtained can be used in defining the nanoparticle arrays optimal parameters in view of applications in biophotonics, bioimaging and photothermal therapy.

P-8-LM

LIGHT-INDUCED PHYSICOCHEMICAL PROCESSES IN HETEROGENEOUS SYSTEMS WITH NANOSCALE OBJECTS

V.V. Levdansky[1], J. Smolik[2], V. Zdimal[2]
[1]*Heat and Mass Transfer Institute NASB, 15 P. Brovka St., Minsk 220072, Belarus*
[2]*Institute of Chemical Process Fundamentals AS CR, v.v.i., Rozvojova 135, 165 02 Prague, Czech Republic*
vlev5@yahoo.com

Transfer phenomena and physicochemical transformations in the systems with nanoscale objects are of interest for many branches of nanotechnology. The resonance (e.g., laser) radiation leading to excitation of internal degrees of freedom of gas molecules can essentially change the character of the interaction between gas molecules and the object surface. This can lead to a change in such parameters as the sticking (condensation) coefficient and desorption (evaporation) energy of molecules as well as the rate constant of a heterogeneous chemical reaction. The paper deals with a theoretical study of transfer processes and physicochemical transformations in nanosystems in the field of resonance radiation.

The possibility to affect surface processes by resonance radiation allows one to change a number of physicochemical processes in particular to evoke a resulting mass flux in the

initially equilibrium system. The influence of radiation on heterogeneous systems can lead to the light-induced gas flow in porous membranes with nanoscale pores and to new components of the phoretic force acting on aerosol nanoparticles. Resonance radiation can also affect the gas molecule incorporation into condensed phase that leads to a change in growth rate and composition of nanoparticles (clusters). Radiation-induced mass transfer in the nonporous membrane in excitation (or dissociation) of gas molecules by resonance radiation near one side of the membrane is also discussed.

The influence of resonance radiation on homogeneous gas-phase nucleation is considered. The effect of radiation in this case can be related to a change in the critical cluster size due to a difference in the condensation coefficients of excited by radiation and unexcited molecules. It is shown that in the case, when the excitation of vapor molecules leads to a decrease in the condensation coefficient, the critical cluster size increases and the rate of nucleation decreases. In the case of heterogeneous nucleation resonance radiation can affect the activation energy for surface diffusion of atoms (molecules) and their adsorption time that leads to a change in the rate of heterogeneous nucleation. The joint effect of thermal and resonance effects on the rate of homogeneous and heterogeneous nucleation is discussed.

Thus, it is shown that resonance radiation allows one to control a number of physicochemical processes in the heterogeneous systems with nanoscale objects, e.g. aerosol systems with nanoparticles (clusters), porous membranes with nanopores and so on.

Acknowledgements: This work was supported by GAAVCR projects IAA400720804, IAA200760905 and GACR project 101/09/1633.

P-9-LM

DYNAMICS OF PICOSECOND PULSED LASERABLATION OF SILICON TARGETS

P.A. Perminov[1], A.I. Alekhin[2], P.K. Kashkarov[1,2]
[1] *National research centre "Kurchatov institute", 1 Kurchatov sq., Moscow, 123182 Russia*
[2] *M.V. Lomonosov Moscow State University, 1/2 Leninskie Gory, Moscow, 119991 Russia*
pavlikap@mail.ru

Laser ablation is one of the most promising approaches used for production of nanoparticles. No chemical precursors are required. This approach expands the range of materials which can be used in nanostructuring. Short pulsed laser ablation (femtosecond and picosecond pulses) offers a significant potential advantage over nanosecond pulsed laser ablation: the ability to deposit energy into a material in a very short time, before thermal diffusion can take place; the lowering of threshold ablation fluence by a factor of about 10 compared to nanosecond pulses. There are a lot of studies of laser ablation, but physical processes are not fully understood. That's why researchers are interested in the investigation of the processes occurring during and after the interaction of short laser pulse with matter.

Dynamics of picosecond pulsed laser ablation of crystal silicon (c-Si) and porous silicon (por-Si) wafers has been studied by the elastic light scattering. We have observed two peaks ("slow" and "fast" components) in the kinetics of elastic light scattering on laser ablation products. We suppose that "fast component" is scattering on the particles which vapour from the surface of the target, "slow component" is scattering on the clusters which vapour from deeper atomic layers of the target due to thermal diffusion processes. Experimental

dependences of laser elastic scattering on distance between probe laser radiation and surface of the target and on laser pulse fluence are presented in this work. Also we have obtained the corner diagram of elastic light scattering. The scattering has the non-Rayleigh nature.

Thus the investigation of elastic light scattering on the laser ablation products reveals some information about the dynamics of the processes occurring at the interaction of laser pulse with solid targets.

Acknowledgements: This work was performed at User Facilities Center of M.V. Lomonosov Moscow State University.

References:

1. R.F. Wood, J.N. Leboeuf, K.R. Chen, D.B. Geohegan, A.A. Puretzky, "Dynamics of plume propagation, splitting, and nanoparticle formation during pulsed-laser ablation", Applied Surface Science, 127–129, 151–158 (1998).
2. W. Marine, L. Patrone, B. Luk'yanchuk, M. Sentis, "Strategy of nanocluster and nanostructure synthesis by conventional pulsed laser ablation", Applied Surface Science 154–155, 345–352 (2000).
3. Y.Wang, X. Xu, L. Zheng, "Molecular dynamics simulation of ultrafast laser ablation of fused silica film", Appl Phys A, 92, 849–852 (2008).

P-10-LM

EFFECT OF HIGH-TEMPERATURE ANNEALING ON THE PHOTOLUMINESCENT AND OPTICAL PROPERTIES OF NANOCRYSTALLINE SiC FILMS

A. V. Semenov[1], A. V. Lopin[1], V. M. Puzikov[1], O. M. Vovk[1], I. N. Dmitruk [2], V. Romano[3]
[1]*Institute for Single Crystals, National Academy of Sciences of Ukraine, Kharkiv, Ukraine,*
[2]*Institute of Physics, National Academy of Sciences of Ukraine, Kyiv, 03680 Ukraine,*
[3]*Bern University of Applied Sciences, Engineering & Information Technology, Burgdorf CH-3400, Switzerland*
semenov@isc.kharkov.ua

Photoluminescent and optical properties of nanocrystalline silicon carbide (nc-SiC) films of cubic polytype and effects of annealing in oxygen at 850-950°C on them were studied in the present work. The nc-3C-SiC films with nanocrystal size 10-15 nm were obtained by direct ion deposition method [1]. The films contain >80% (at.) of nanocrystalline silicon carbide, with nanoparticles linked by regions containing homo- and hetero-bound silicon and carbon, as well as oxygen admixtures. In this study, to clarify the effects of the boundary regions on the properties of nc-SiC films, two sets of films of cubic polytype 3C-SiC were prepared, differing in composition and structure of the boundary regions. In the first set the initial SiC films were used as deposited, while the second set consisted of the same films annealed after deposition in oxygen at 850-950°C with the aim of modifying the structure and composition of boundary regions.

For the nc-SiC films with different state of boundary regions, optical absorption spectra were measured using a Perkin-Elmer L-35 spectrophotometer. The photoluminescence (PL) spectra in the UV range were measured at helium temperatures under excitation of the electron subsystem by the third harmonic λ_{excit} = 266 nm (E_{exc} = 4.66 Ev) of a titanium-sapphire laser

(pulse duration 1 ns). IR luminescence spectra were measured at room temperature using a DUETTO4 laser system with a USB4000 monochromator; the excitation energy was 3.49 eV (λ_{excit} = 355 nm), pulse duration 10 ps, and the average pulse power was varied within 0.15-1.5 W. The radiation spot diameter on the sample was 0.5 mm.

It has been established that annealing the nc-SiC films in oxygen at 850-950°C results in weaker absorption in a broad spectral range and increases the optical band gap from 1.8 to 2.2 eV. In annealed nc-SiC layers with nanocrystal interfaces that have a high contrast, IR photoluminescence bands M1 (1.52 eV), M2 (1.56 eV), M3 (1.63 eV) were observed, not present in the initial nc-3C-SiC films. The secondary emission in the IR range is unambiguously related to radiative optical transitions involving surface states in the SiC nanocrystalline [2]. The edge UV photoluminescence bands at 2.2-2.4 eV in the as grown and annealed films were similar. Measurements of luminescence intensity in maximums M1, M2, M3 as function of excitation power showed non-linear character of this dependence, which can be due to stimulated emission or random lasing [3] effect in the nanocrystalline silicon carbide.

Acknowledgements: The work was supported by the SNSF project IZ73Z0-128088/1.

References:

1. A.V. Semenov, V.M. Puzikov., M.V. Dobrotvorskaya, A.G. Fedorov, A.V. Lopin, Thin Solid Films, 516, 2899(2008).
2. L.J. Brillson, S. Tumakha, R.S.Okojie, M.Zhang, P.Pirouz, J. Phys.: Condens. Matter. 16, S1733-S1754 (2004).
3. X. H. Wu, A. Yamilov, H. Noh, H. Cao, E. W. Seelig, R. P. H. Chang, J. Opt. Soc. Am. B, Vol. 21, No. 1, p.159 (2004).

V. LASER SYSTEMS AND NEW LASER MATERIALS

P-1-LN

SINGLE FREQUENCY MOPA SYSTEM WITH NEAR DIFFRACTION LIMITED BEAM QUALITY

Danail Chuchumishev, Alexander Gaydardzhiev, Ivan Buchvarov
Department of Physics, Sofia University, 5 James Bourchier Blvd., BG-1164 Sofia, Bulgaria
ivan.buchvarov@phys.uni-sofia.bg

Compact and reliable laser systems providing both high-energy (in the tens of mJ range) and high-peak power (>10MW) pulses at kilohertz repetition rates with diffraction-limited beams find applications in new materials synthesis, remote imaging, chemical sensing and high efficient nonlinear conversion. Passively Q-switched microchip lasers are simple, miniature and robust sources that can provide single-frequency, high-repetition-rate, and sub-nanosecond pulses with diffraction-limited output in the near infrared [1]. However, the small gain volume limits the amount of energy that can be stored in the active medium, thus microchip lasers can reach only very modest output energy, typically up to hundreds of micro joules. In order to overcome this deficiency complicated amplification geometries have been developed and up to 5.7 W (0.2 mJ) and 0.4-MW at 500-ps were achieved [2]. Recently, a Nd:YVO_4 bounce geometry was used for amplification of a passively Q-switched laser with energy up to 0.545 mJ and 577-ps pulse duration [3]. However, in the vast variety of the existing kHz laser systems the output pulse energy is substantially smaller than 10 mJ while, on the other hand, the repetition rate of the 10-100 mJ systems does not exceed 100 Hz.

In this work we report on the amplification of a near diffraction limited, single frequency, passively Q-switched Nd:YAG laser (240-μJ, 830-ps at 0.5-kHz) up to 9.5-mJ in a two stage diode pumped amplifiers, whilst preserving pulse duration, beam quality and linear polarization. We use a passive Q-switched Cr^{4+}:YAG/Nd:YAG laser, with mirrors coated on the YAG element as an master oscillator emitting up to 240 μJ at 0.5 kHz with 830 ps pulse duration and diffraction limited beam. The signal from the oscillator is amplified in two stage amplifier in double pass configurations of each stage. Using an input energy of 240 μJ (into the first amplifier stage), and 200-μs pump pulses (at a total of 82.8 mJ pump energy into the amplifier head), we were able to produce up to 2.12 mJ pulse energy at 0.5 kHz, with near-diffraction-limited beam quality. With this energy level as an input of the second stage and the same pump conditions for the laser head we achieved maximum output energy of 9.5 mJ, corresponding to 4.75 W average power and above 10 MW pulse power. The amplified pulse duration is the same as the pulse duration of the microchip oscillator, i.e. 830 ps. The output from the oscillator and the amplified pulse duration were measured by a 1-GHz oscilloscope and an InGaAs photodiode with detection system pulse response (350 ps). The beam quality of this master oscillator power amplifier (MOPA) system was measured with a commercial CCD based beam-analyzer at the output of the oscillator (Mx2 x My2=1.38 x 1.31) after the first stage (M_x^2 x M_y^2=1.39 x 1.33) and at the output of the second stage of the amplifier (M_x^2 x M_y^2=1.4 x 1.35). The results show lack of considerable beam quality deterioration after the first as well as the second stage of the amplifier.

Acknowledgements: We acknowledge support from project DO/02/134/2009 funded by the Bulgarian ministry of education, youth and science.

References:
1.Zayhowski J. J., "Passively Q-Switched Microchip Lasers," in Solid-State Lasers and Applications, A. Sennaroglu, ed. (CRC Press, 2007), p. 1-76.
2. S. Forget at all, "A new 3D multipass amplifier based on Nd:YAG or Nd:YVO4 crystals"Appl. Phys.B 75, 481-485 (2002).
3. A. Agnesi, P. Dallocchio, F. Pirzio, G. Reali, "Sub-nanosecond single frequency 10-kHz diode pumped MOPA laser", Applied Physics B 98, 737-741 (2010).

P-2-LN

SIMULTANEOUS COMPENSATION OF THERMAL POLARIZATION AND PHASE DISTORTIONS IN GGG-BASED CRYOGENIC FARADAY ISOLATOR

V. Starobor, S. Zheleznov, V. Palashov
Institute of Applied Physics, 46 Uljanov Street, 603950 Nizhny Novgorod, Russia
astarobor@mail.ru

Intense development of laser technique and average power enhancement of CW and pulse-periodic radiation demand reduction of thermal effects appearing in different optical elements due to laser radiation absorption. The main important Faraday isolator' (FIs) characteristic - the isolation ratio - is determined by thermally induced depolarization, because of strong absorption ($\sim 10^{-3} cm^{-1}$) of its magneto-optical elements (MOE).

Cooling FI to cryogenic temperatures (T <100K) is a way to decrease the thermally induced depolarization. The magneto-optical figure-of-merit *M* (it characterizes the medium impact on the FI isolation degree at high average power) [1], increases by cooling, which leads to a reduction of thermal effects. Application of traditional media terbium-gallium garnet (TGG) for cryogenic FI (CFI) is limited due to depolarization, arises because of inhomogeneous distribution of the angle of rotation of polarization plane caused by the temperature dependence of the Verdet constant. Therefore, in paper [2] gadolinium gallium garnet (GGG) was proposed as a MOE for CFI.

In present work CFI with MOE made of GGG with thermally induced depolarization compensation was theoretically and experimentally investigated. We had chosen new scheme of compensation, introduced in [3]. The idea was to add to FI outside magnetic field a compensator consists of 2 optical elements: quartz rotator and additional optical element (AOE). Compensation effect bases on the principle that radiation passing through depolarizing element and quartz rotator partially compensates in another element. GGG at 80K has parameter of optical anisotropy $\xi \sim 1$ that makes effective using of glass as AOE, so GGG crystal and optical glass Schott FK51 were chosen as media for AOE. FK51 has the opposite sign of *dn/dT* relative to GGG, so it can partially compensate not only the thermally induced depolarization but also the thermal lens.

Experimentally at a temperature of 100K at laser power 260W 1.3-fold compensation of thermally induced lens with glass FK51 was obtained, which agrees well with theoretical calculations. Also simultaneous compensation of depolarization respect to the total depolarization in the GGG and the DOE of the FK51 in ~ 2.8 times was achieved and respect to depolarization in the GGG in ~ 2 times. It should be noted that we used for experiment AOE with nonoptimal parameters and MOE with high absorption coefficient (6.10^{-3} cm^{-1}).

In the case of an optimal compensation maximum operating power of isolator should be about 1.5 kW. Using GGG crystal with low absorption of 10^{-3} cm^{-1} will raise the maximum power 6

times, and provide the degree of isolation of 30 dB, with incident power ~10 kW. And using glass with optimal properties as AOE will also compensate the thermal lens.

References:

1. E.A. Khazanov «Faraday Isolators for High Average Power Lasers», Advances in Solid-State Lasers: Development and Applications, INTECH, Croatia (2010).
2. A. V. Starobor, D. S. Zheleznov, O. V. Palashov, and E.A. Khazanov "Magnetoactive media for cryogenic Faraday isolators", JOSA B Vol. **28**, Iss. 6, pp. 1409–1415 (2011).
3. I. Snetkov, I. Mukhin, O. Palashov, and E. Khazanov, "Compensation of thermally induced depolarization in Faraday isolators for high average power lasers," Opt. Express 19, 6366-6376 (2011).

P-3-LN

RESEARCH OF THE SEMI-CONDUCTOR LASER ON HETEROSTRUCTURES BY MEANS OF A COMPLEX OF THE PRECISION MICROSCOPES

Noman Mustafa A.A., Prokoshev V.G., Abramov D.V., Kutrovskaya C.V., Khorkov K.C.
Vladimir State University, 600000 Vladimir, Gorky str., 87
awraam@mail.ru

Semiconductor lasers are important elements of systems of modern optoelectronics and photonics. Lasers on heterotransitions are basically used now. Lasers on double heterostructure $Al_xGa_{1-x}As$-GaAs with various width of the forbidden zone in *p*- and *n*- areas have the greatest application. Complex researches of structure of laser diode layers and their geometrical characteristics are necessary for definition of the reasons of disorder of parameters of semiconductor lasers and development of technologies of their manufacture. Modern methods and means of scanning probe microscopy and scanning electron microscopy give such possibilities.

The results of researches of the semiconductor laser LLD-20 by means of scanning electron microscope Quanta 200 3D and probe nanolaboratory Integra-Spectra are presented in report. Separate structural layers of the semiconductor laser have been registered despite small differences. Layers are made of the materials different only molar concentration Al and degree of an alloying. The difference of molar concentration Al in the next layers of heterostructure is 20 %. Concentration of an alloying impurity didn't exceed 10^{19} sm^{-3} and differed in the next layers on one order. The registered structural layers of the laser diode are presented on Fig. 1.

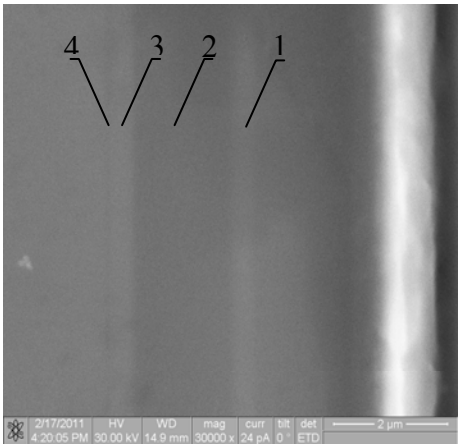


Fig.1. SEM images of structural layers of the semiconductor laser.

The right edge of the registered semiconductor structure adjoins positive contact of the diode. It is insulating layer which passes in a contact layer from p^+-type GaAs (1). The contact layer is alloyed Zn. Concentration of an alloying impurity is 10^{19} sm^{-3}. A thickness of a layer is 300 nanometers. Further the p-emitter (2) of $Al_{0,5}Ga_{0,5}As$:Zn is located. It thickness is 1500 nanometers. Concentration of an alloying impurity is 10^{18} sm^{-3}. Following structure is waveguide layer (3) from not alloyed $Al_{0,3}Ga_{0,7}As$ with thickness of 300 nanometers. The active area (4) from not alloyed $Al_{0,1}Ga_{0,9}As$ with thickness 10 nanometers is registered on SEM image as a thin dark strip. Layers of n-type and p-type are located by symmetric concerning active area. Unfortunately n-type layers are not registered as separate structures because of the low contrast caused, possibly, their raised relative negative charge. More exact definition of structure and geometrical characteristics of registered layers was carried out on the basis of the maps of Raman spectra which were obtained by means of probe nanolaboratory Integra-Spectra.

P-4-LN

RESEARCH ON THE ONLINE DIGITAL CONTROL TECHNOLOGY IN HIGH POWER LASER SYSTEMS

Jianqiang Zhu, Junyong Zhang, Yanli Zhang, Baosuan Chen, Dean Liu, Fang Liu,Xuejie Zhang,Zhaoyang Jiao, Yan Zhang, Pingping Sun, Jie Miao
Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, No. 390, Qinghe Road, Jiading District, Shanghai 201800, China
jqzhu @shcnc.ac.cn

For the precise targeting in Inertial Confinement Fusion (ICF), the requirements for beam transformation, beam shaping and beam control are harsh. The online digital control technology is used to realize automatic calibration, automatic fault diagnosis and feedback control of the laser system. After several times of repeated correction and feedback, 192 beams with stable output and precision balance control between beams are achieved on NIF device. Nowadays, PROP, Frensel, and Miró, etc. are common softwares abroad, while in our country, SG99 is more popular. SG99 is developed to do flow analysis and is the first set of software package with all-optical simulation of high-power solid-state laser systems during the whole process. Based on previous research, control parameters, physical models, propagation and feedback algorithm involved in the online digital control technology are described in detail in this paper. The physical models include linear/non-linear propagation, laser amplification, frequency conversion, and feedback algorithm used to achieve a variety of these models. Moreover, to develop the other cell technologies, a correlation algorithm analysis is established, including the vector diffraction propagation of light fields, the phase recovery based on iterative algorithm, and the FDTD analysis of micro- and nano-devices.

References:

1. Wade H. Williams, Jerome M. Auerbach, Mark A. Henesian, etc, "Optical propagation modeling for the National Ignition Facility", SPIE, Vol.5341, 66-72(2004).
2. Michael Shaw, Wade Williams, Ken Jancaitis, etc, "Performance and operational modeling of the National Ignition Facility", SPIE, Vol.5178, 194-203(2004).
3.Michael Shaw, Wade Williams, Ronald House, Chris Haynam, "Laser Performance Operations Model (LPOM): A tool to automate the setup and diagnosis of the National Ignition Facility", SPIE,Vol. 5867,1-12(2005).

4. B J LE Garrec, O Nicolas, "Laser Performance Operation Model and its application to LIL energy and power balance", Journal of Physics: Conference Series 112, Vol. 032019, 1-5 (2008).
5. Pingping Sun, Dean Liu, Yanli Zhang, Xiaoyan Li, Yan Zhang, and Jianqiang Zhu "Evolution of low-frequency noise passing through spatial filter in high power laser system" SPIE,Vol, 7789, 778910 (2010).

P-5-LN

CHARACTERIZATION OF ZNO:P FILMS FABRICATED WITH PLASMA PRODUCED BY EXCIMER LASER

L. S. Parshina, O. A. Novodvorsky, V. Ya. Panchenko, A. A. Lotin, D. A. Zuev, O. D. Khramova, Ye. A. Cherebilo
Institute on Laser and Information Technologies, Russian Academy of Sciences (ILIT RAS), Shatura, Moscow Region, Russia
ParshinaLiubov@mail.ru

The investigation of the ZnO films properties is nowadays the subject of a large body of research. This is due to the necessity of producing the high-quality doped ZnO films to be used in the short-wave optoelectronic devices. Modern tendencies in microelectronics demand creation of qualitative films of nanometer thickness, requirements to uniformity and smoothness of a surface of received structures constantly rise. The zinc oxide, having band-gap zone 3.4 eV, it is characterized record exciton binding energy (60 meV) at room temperature, possesses high stability an irradiation, it is pliable to chemical etching and it is rather cheap, that does its attractive to application in microelectronics. The method of pulse laser deposition (PLD) is applied to creation of thin-film structures on the basis of ZnO. This method favorably differs wide possibility of management process of the growth, in the lowered epitaxy temperature and the simplified technology of controllable entering of doping impurity that allows to grow up ZnO film with set crystal, electrical and optical properties. The PLD method provides congruence evaporation of targets of any composition and deep effective vacuum during of deposition owing to high density of particles in a plume.

Films series have been received under various deposition conditions and methods of introduction of phosphorus in a film during deposition. For ZnO:P films has been lead thermal annealing. The films resistance has been measured before and after annealing. During of annealing the photoluminescence spectra of films were received. During of annealing there was an activation of acceptor the centers of phosphorus, and changed PL of films in UV areas, and dependence of amplitude and position of peak of a photoluminescence on a level annealing a film by phosphorus was observed. Passage through a maximum of intensity PL depending on time high-temperature annealing was observed. Dependences of PL intensity on time high-temperature annealing and from temperature annealing are received. We had been investigated dependence of a photoluminescence epitaxial ZnO:P films from concentration of doping by phosphorus. The dependence of the amplitude and the ZnO films photoluminescence peak position before and after annealing from the films P doping level has been established.

P-6-LN

EFFECT OF THE MAGNETOOPTICAL ELEMENT MAGNETIZATION ON THE ISOLATION RATIO OF FARADAY ISOLATORS

E.A. Mironov, A.V. Voitovich, O.V. Palashov, D.S. Zheleznov, A.V. Starobor
Institute of Applied Physics RAS, 603950, 46 Ulyanov street, Nizhny Novgorod, Russia
miea209@rambler.ru

Faraday Isolators (FIs) are very important elements of many laser systems. Their main characteristic is the isolation ratio. It is determined by several depolarization factors, particularly, by a nonuniformity of the magnetic field inside the magnetooptical element (MOE).

Magnetoactive media with high value of the Verdet constant are most promissory for using in FIs, because MOE fabricated from these materials can be made short-length. That allows reducing the absorption of transient radiation and diminishing size and cost of isolator. Popular terbium gallium garnet crystals (TGG) and some kinds of magnetoactive glasses can exemplify this sort of material. These media also have a significant value of the magnetic susceptibility, therefore accounting of effects associated with the MOE magnetization become important. Our theoretical investigation shows that the MOE magnetization can exert appreciable influence on a nonuniformity of the magnetic field inside the MOE. This nonuniformity appears even through the magnetic field of the magnetic system is absolutely uniform. This implies the appearance of new kind of depolarization γ_F, which can significantly worsen the isolation ratio. γ_F depends on length-to-diameter ratio and on magnetic susceptibility of MOE. Our estimates show that γ_F and depolarization determined by other factors can be comparable in cryogenic FIs and in traditional wide-aperture FIs based on TGG crystals.

We made series of the magnetic field nonuniformity measurements in cryogenic FI and in traditional wide-aperture FI and proved our theoretical calculations. Obtained results for γ_F value were in good agreement with performed estimations.

P-7-LN

STABLE OPERATION AND PRECISION SYNCHRONIZATION OF PICOSECOND PULSED DIODE-PUMPED LASERS

V.B. Morozov, A.N. Olenin, D.V. Yakovlev
International Laser Centre and Physics Faculty of M.V.Lomonosov Moscow State University, Moscow 119992, Russia,
morozov@phys.msu.ru

High-peak-power mode-locked picosecond lasers are used in high precision laser micromachining, time-resolved spectroscopy, soft X-ray generation, laser photo injection, laser ranging etc. Systems based on pulsed oscillators have definite advantages in comparison with cw ones: high pulse energy at the oscillator output, energy consumption efficiency and thermo-optical effect reduction, relative simplicity and compactness. For Nd-doped materials, pulsed regime can be considered as preferable up to several kilohertz repetition rates. Generation process in each laser shot arises from spontaneous fluctuations, and synchronization technique typical for cw lasers can not be applied. Time position of output

laser pulse can be controlled, to some extent, through active rapid phase changing of voltage applied from high-frequency generator to the electro-optical modulator. In that case, minimal jitter, determined by driving electronics can be made less than 10 ps. Significant advantage of this approach is a possibility to precisely synchronize high-peak-power laser pulse with the phase of periodic high-frequency signal in an arbitrary delay range.

In the present paper, we discuss results on jitter investigation with pulse diode pumped picosecond Nd:YAG laser. Stable operation and effective pulse shortening are provided by combination of electro-optical active mode-locking and negative feed-back and passive mode locking based on semiconductor absorber mirrors. The resulting jitter is determined by the combined action of various generation parameters. Experimental results on jitter measurements and generation process modeling will be presented.

Longitudinal pump geometry is very attractive for diode-pumped lasers since it provides efficient amplification of lowest cavity mode and, as a result, output beam excellent spatial quality. At the same time, focused pump beam produces essentially inhomogeneous intensity distribution in radial direction inside active medium. It results in forming aberrational thermolens and inhomogeneous amplification even at low repetition rates.

Using pulsed pump approach usually involves the accumulation of energy during pump pulse and subsequent fast amplification process of nano/picosecond pulse. Round trip amplification in this case is relatively high in comparison with case of cw lasers. As a result, relation between transversal size of pumped region and laser mode diameter in active medium determines not only pump power transfer efficiency, but also laser mode profile. In a previous work [1] we discussed conditions for stable operation of picosecond laser taking into account non-parabolic part of aberrational thermolens. This approach allows estimation of average pump power limit for laser operation with respect to aberration-induced diffraction losses. In the present paper we discuss criteria for stable operation, which connects parameters of pump geometry and resonator configuration with output pulse energy and beam quality taking into account inhomogeneous amplification profile.

Acknowledgments: The work is supported by Russian Foundation for Basic Research (10-02-01277-a).

References:

1. V.B. Morozov, A.N. Olenin, V.G. Tunkin, and D.V. Yakovlev, "Operation conditions for a picosecond laser with an aberration thermal lens under longitudinal pulsed diode pumping" Quantum Electronics, 41(6), 508-514 (2011).

P-8-LN

MOBILE LASER TECHNOLOGICAL COMPLEXES BASED ON FIBER-OPTICAL LASERS

A.V.Rodin, A.G.Krasyukov, S.T.Durmanov, G.V.Smirnov, N.U.Turkin
State Research Center of Russian Federation "Troitsk Institute for Innovation and Fusion Research" 142190 Russia, Moscow reg., Troitsk, RSC TRINITI
rodin@triniti.ru

Elaboration of powerful fiber-optical lasers in STU "IRE-Polyus" made the revolution in laser technique and led to the creation of new generation of mobile laser complexes in SRC RF TRINITI (MLTK-2, MLTK-3 and MLTK-20).

The main advantages of fiber-optical laser are as follows: completely solid-state execution; absence of any moving elements and units; resource up to 30 000 hours without maintenance; high efficiency (up to 30 %); the best weight - dimension characteristics among all existing lasers (less than 100 kg/kW and 0.3 m^3/kW).

The 2 kW laser complex MLTK-2 was created by request of the State Corporation "Rosatom" for conducting the works on deactivation of polluted concrete and metal constructions as well as the works on remote laser cutting. The Complex consists of 2- block-container, each block has the dimension of 2x2x2 m, the total weight of the Complex does not exceed 2 tons. It allows cutting of metal sheets up to 20 mm thickness at the distance up to 100 m from the block-container and up to 6 m from the output optical head. The MLTK-2 successfully demonstrated the reliable functioning both in the field conditions and in the commercial applications such as laser cutting of metal sheets up to 14 mm in thickness.

The complex MLTK-3 consists of three 1 kW laser sources with its own chillers of cooling system, the system of laser beam formation and positioning as well as the technological equipment. The weight of each block does not exceed 100 kg. Each block can operate independently. The Complex is successfully used in the works on building constructions dismantle.

The newest elaboration is the complex MLTK-20 created by SRC RF TRINITI and "Gasprom" Ltd in collaboration with STU "IRE-Polyus", Vavilov Optical-physical laboratory GOI, and other Russian companies. The Complex equipment was displaced in four block-containers (the dimension of each block is 2x2x2 m, the weight of each block does not exceed 2 tons). Each of three blocks contains the 8 kW CW Yb laser with chillers of a cooling system. The radiation from each of these blocks was transferred with the 90 cm long optical fiber to the fourth block-container including the three-channel formatting telescope with systems of pointing, positioning and control of whole Complex operation . Just near the forth block-container the operator was situated who directed the laser beam to the fixed zone of the cutting metal object located as far as 20-70 meters from the forth block-container.

Technical advantages of MLTK-20 complex are as follows: transportation can be carried out by all kinds of land, air and water transport; the total weight of the four block-containers does not exceed 8 tons; the time of deployment of the Complex in field conditions is not more than 0,5 hours; the thickness of a metal sheet for cutting is more than 50 mm; the cutting rate is up to 2 m/hour; the operation time is not limited. Successful Complex operation is possible in the temperature range from -45 up to 40 C. Two operators are quite enough for work; special conditions include a burning oil and gas fountain, smoke content, high temperature.

P-9-LN

RESEARCH OF SYNTHESIS AND SPECTRAL LUMINESCENT CHARACTERISTICS OF SUBMICRONIC FLUORIDE $NaYF_4$:Yb:R (R – RARE-EARTH ELEMENTS) POWDERS.

S.V. Kuznetsov, A.V.Ryabova, D.S.Los`, P.P.Fedorov, V.B.Loshchenov, V.V.Voronov, R.P.Ermakov, V.V.Volkov, V.V.Osiko
A.M. Prokhorov General Physics Institute Russian Academy of Sciences
kouznetzovsv@gmail.com

Inorganic fluorides have a unique set of physical and chemical properties, thus perspective in various fields of photonics: to create a promising source of white light, 3D displays, and in biomedicine application.

In this work synthesis and spectral luminescent characteristics of submicron powders investigates in the aspect of fluorescence diagnostics and photodynamic therapy of cancer are represented.

There are various methods of submicronic fluoride powder synthesis. The method of coprecipitation from water solutions was used. Polyethylenimin addition was used for prevention of agglomeration in a synthesis series.

Synthesized submicron $NaY_{1-X-Y}Yb_XR_YF_4$ (R=Er, Tm, Ho) powders have been investigated by SEM, TEM, EDX, DLS and X-ray powder diffraction methods.

It was established that the single-phase powders with cubic fluorite structure, as well as two-phase samples containing both cubic and hexagonal phase are mainly deposited. At use polyethylenimin, synthesis conditions for single-phase sample as cubic, and hexagonal phases are defined.

For the synthesized powders up-conversion luminescence spectra have been registered at semi-conductor laser with 974 nm wavelength excitation. Energy quantum yields in visible spectral region were derived for various ratio Y:Yb:Er for $NaY_{1-X-Y}Yb_XEr_YF_4$ compositions.

The promising compound with nominal composition in the initial solution $NaY_{0.60}Yb_{0.30}Er_{0.10}F_4$ was identified, which energy quantum yield was 0.54% at therapeutic doses of laser irradiation.

VI. NON-LINEAR OPTICS MATERIALS AND DEVICES

P-1-NL

NONLINEAR REFRACTIVE INDEX MEASUREMENT OF NEW MULTICOMPONENT GLASSY MATRIX POSSESSING VARIABLE NONLINEAR SUSCEPTIBILITY BY USING Z-SCAN METHOD

G. Yankov[1], I. Stefanov[2], B. L. Shivachev[3], H. Yoneda[4], T. Petrov[1]
[1] *Institute of Solid State Physics, Bulgarian Academy of Sciences, 1784 Sofia, Bulgaria;*
[2] *Faculty of Physics, Sofia University "St. Kl. Ohridski",*
[3] *Institute of Mineralogy and Crystallography, BAS, 1113 Sofia, Bulgaria*
[4] *Institute fo Laser Sciences-University of ElectroCommunication, Chofu-shi, Tokyo, Japan*
mennefer2@abv.bg

The synthesis of every new solid state material for the laser application and optical telecommunications is an extensive research and provoke a broad scientific response. Multi glassy matrix possessing variables nonlinear optical properties are an example for that.

The second harmonic generation is observed in samples of glassy matrix TeO_2-GeO_2-Bi_2O_3 (TGB), which have been treated by high dc voltage, 3-5kV. This is so-called poling process in which has formed a layer of nanocrystals in the glass matrix, closely to the anode. The state of the poled glass can be change by external optical or electric field, high temperature and others. Such mediums are interesting in the cases of optical switchers and optical memories.

TGB was the beginning of numerous of synthesis and studies of new multicomponent glassy matrix possessing variable nonlinear properties.

In the presented work we are reporting the z-scan method for non-linear coefficient measurement of the synthesized glasses. The methodology is based on the transformation of phase shift into amplitude shift, and being used the effect of Kerr. It is possible to get the nonlinear absorption (NLA) and nonlinear refraction (NLR), by the obtained data. The used setup has been checked, the nonlinear optical coefficients of fused silica, have been measured and compared with the known data from scientific literature. Full coincidence is observed.

P-2-NL

INVESTIGATION OF NONLINEAR OPTICAL PROPERTIES OF 535-4TBA/AU NANO PARTICLES PREPARED BY LASER ABLATION METHOD

A.Granmayeh.R[1], K.Madanipour[2], A.Koohian[3]
[1]*Roudehen Branch, Islamic Azad University, Roudehen, Iran*
[2]*Optical Measurement Lab,Amir Kabir University of Technology, Tehran, Iran*
[3]*Faculty of Physics, Tehran University, Tehran, Iran*
granmayeh@riau.ac.ir

Flexible Dye-Sensitized Solar Cells (DSSCs) [1] are new generation of nano structured photovoltaic solar cells that biomimetic the natural photosynthesis process [2]. These cells work by absorbing photons on an inexpensive thin-film composed of dye molecules attached to a titanium oxide layer on a plastic substrate [3].One of the dyes using to fabricate of this

solar cells is 535-4TBA dye. Fig .1 shows the chemical structure of 535-4TBA molecules. In this study, colloidal Au synthesized by laser ablation of Au target in 535-4TBA by using Nd:YAG laser with 1064nm wavelength and nonlinear optical properties of Au nanoparticles in 535-4TBA were investigated by z-scan technique. Under 15mW continuous-wave He-Ne laser (λ=632.8nm) illumination the magnitude and sign of second order refractive index (n_2) and nonlinear absorption coefficient (β) of 535-4TBA/Au nanoparticles were measured.UV-visible absorption spectroscopy, Transmission Electron Microscopy (TEM) and scanning electron microscopy (SEM) have been used to characterize the 535-4TBA dye/Au nanoparticles.

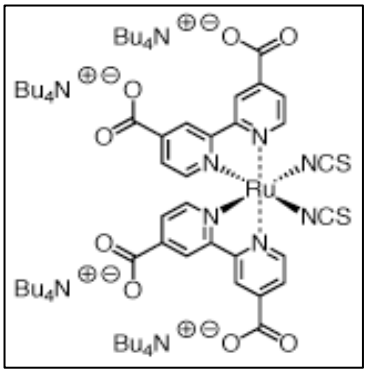


Fig.2. Molecular structure of Ruthenium 535-4TBA dye.

The DSSC utilizing in this work consists of a dye covered(535-4TBA/Au), nanoporous TiO2 (titanium dioxide) layer and an electrolyte containing a redox mediator (I-/ I3 -) encapsulated between two glass plates .On the surface of the TiO2, a monolayer of dye molecules is adsorbed. The huge nanoporous surface allows for an adsorption of a sufficiently large number of dye molecules for efficient light harvesting.

References:

[1] B. O'Regan and M. Grätzel, A low-cost, high efficiency solar cell based on dye-sensitized colloidal TiO2 films, Nature **353,** pp. 737–740(1991).
[2] A.F. Nogueira et al. / Coordination Chemistry Reviews 248 ,1455–1468(2004).
[3] Weiwei Tan & Jinmao Chen & Xiaowen Zhou & Jingbo Zhang & Yuan Lin & Xueping Li & Xurui Xiao J Solid State Electrochem ,13:651–656(2009).

VII. TERAHERTZ SPECTROSCOPY AND APPLICATIONS

P-1-TH

ROLE OF THE FIELD IONIZATION IN GENERATION AND POLARIZATION OF BROADBAND TERAHERTZ RADIATION FROM OPTICAL BREAKDOWN PLASMA

A. V. Borodin[1], M. N. Esaulkov[1], I.I. Kuricyn[1], I.A. Kotelnikov[2], A.P. Shkurinov[1]
[1]*Moscow State University, Moscow, Russia,*
[2]*Budker Institute of Nuclear Physics, Novosibirsk, Russia*
borodin_msu@mail.ru

Generation of Terahertz pulses in laser-induced plasma still raises theoretical and practical interest since it offers the most broadband spectrum and high peak electric field (up to hundreds kV/cm). The most efficient THz generation occurs under two-color plasma excitation using both first and second harmonics of optical pulse.

In this work, we focus our attention on the process of field ionization in case of two-color excitation beam. We apply a semi-classical Imaginary Time Method (ITM) approach to calculate the ionization probability and the electron momentum acquired in a two-color ionization process. It is found that the second harmonics field plays two different roles in formation of photocurrent. First, it modulates the probability of photionization according to the cosine law. Second, it results in formation of a nonzero average momentum acquired by the electron during the optical pulse, including the initial momentum it receives while leaving the parent atom or molecule. The momentum also has the dependence on ω to 2ω phase ψ and angle between polarizations θ.

This approach introduces the ability of accurate control of initial electron momentum and for modulation of ionization probability (thus the plasma density), through variation of ω to 2ω phase.

We observe the change in the probability of photoionization experimentally by recording the fluorescence intensity at 391.4 nm vs the phase ψ between ω and 2ω (see fig. 1). The modulation of the initial electron momentum manifests in rotation of the emitted THz wave polarization if the ω beam is slightly elliptic. Observation of this fact is visible on fig. 2.

The low-frequency radiation emission of the photoelectrons has a dipole-like character and thus most of energy is emitted in forward direction.

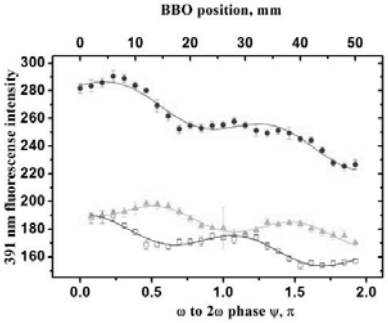


Fig.1. Fluorescence intensity of the first negative band of N_2^+ (proportional to plasma density) at different points of plasma column vs phase shift between ω and 2ω

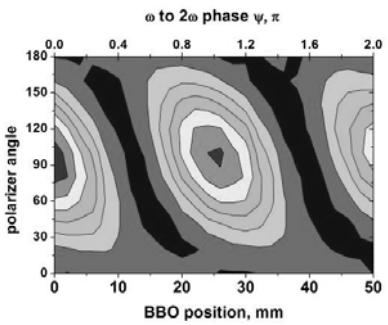


Fig.2. Measured THz radiation intensity as a function of polarizer angle and ω to 2ω phase

However, the experimental investigation shows somewhat different direction pattern. A 320x240 microbolometer detector array [2] is used to obtain the spatial profile of terahertz radiation intensity. The radiation formed a ring structure when the detector plane was moved behind the focal plane of the parabolic mirror. This equals the fact that Terahertz radiation is directed into a cone.

To confirm this conclusion, we investigate the spatial profile of the Terahertz radiation using an iris diaphragm placed behind the plasma filament and a time-domain technique.

We find that the emitted Terahertz spectrum has a strong angular dependence and confirm a cone-shaped Terahertz emission pattern for lowest part of the spectrum.

References:
1. *Kim, K. Y., et al.* Terahertz emission from ultrafast ionizing air in symmetry-broken laser fields // Opt. Express. 2007. V. 15, No. 8. P. 4577–4584.
2. *Demyanenko, M. A., et al.* Microbolometer detector arrays for the infrared and terahertz ranges // *J. Opt. Technol.* 2009. V. 76, No. 12. P. 739–743.
3. *D`Amico C, et al.* Forward THz radiation emission by femtosecond filamentation in gases: theory and experiment // *New Journal of Physics.* 2008. No. 10. P. 1–18.
4. *Balakin, A.V., et al.* Terahertz emission from femtosecond laser focus in a two-color scheme// *J. Opt. Soc. Am. B.* 2009. V. 27, No. 1. P. 16–26.

P-2-TH

STRUCTURALLY SENSITIVE CHANGES IN TERAHERTZ ABSORPTION SPECTRA OF CORTICOSTEROIDS

O. P.Cherkasova[1], A.V. Kargovsky[2], M.M.Nazarov[2], I.N.Smirnova[2], A.P.Shkurinov[2], E.V. Fedulova[2]
[1]*Institute of Laser Physics SB RAS, Lavrentyeva 13/3, Novosibirsk 630090, Russia*
[2]*Departament of Physics and International Laser Center, M.V.Lomonosov Moscow State University ,Leninskie Gory, GSP-1, Moscow 119991, Russia*
chrom@laser.nsc.ru

The corticosteroids carry out the most important regulatory functions and influence on many physiological processes. These hormones have similar general structure and differ only by the position of OH-group in steroid basis resulting in essential changes of hormone-receptor recognition and DNA interaction. This type of molecular structure has four rings providing conformational flexibility which is expected to have a number of low-frequency motions. It is these motions that show themselves in the terahertz (THz) frequency range. Because of their biological importance and their interesting metabolism we do study of corticosteroids along the metabolic steps from progesterone to cortisol. All the molecules under study are aggregated into the molecular crystals with the same orthorhombic space group ($P2_12_12_1$) with fours molecules in a cell of a similar volume. Thus, it may be supposed that the influence of a crystal lattice motions on the THz spectra can also be analyzed and the spectral features associated molecular motions can be highlighted. The aims of this work were THz time-domain spectroscopic (THz-TDS) study of the above mentioned molecules in the temperature range from 20 to 300 K and the assignment of the observed bands using DMol^3 simulations.

We used the substances in the form of poly-crystalline powders purchased from Koch-Light Laboratories Ltd, UK. For THz-TDS measurements the cylindrical pellets of thickness 0.4

mm and diameter 5 mm were formed. The description of the THz-TDS apparatus is given in [1].

It was obtained that THz absorption spectra of progesterone have several narrow absorption bands at 0.87, 1.25, 1.65 and 2.16 THz. The crystal unit cell of progesterone has maximal molecular packing among studied substances that is typical for the hydrogen bond free molecular environments. The biochemical synthesis from progesterone to cortisol proceeds by addition of hydroxyl groups at C^{17}, C^{21} and C^{11} of the steroid nucleus. This leads to the formation of hydrogen bonds between neighboring molecules in the crystal, and an increase in unit cell volume. Successive transformation of the molecular structure qualitatively affects the dynamics of the three absorption bands at 1.25, 1.65 and 2.16 THz. These absorption bands have unusual temperature dependence.

Thus, THz absorption spectra of corticosteroids have several intensive characteristic lines, which are uniquely determined by a hormone structure, the presence and quantity of hydrogen bonds.

References:

1. N.N. Brandt, A.Yu. Chikishev, A.V. Kargovsky, M.M. Nazarov, O.D. Parashchuk, D.A. Sapozhnikov, I.N. Smirnova, A.P. Shkurinov and N.V. Sumbatyan, "Terahertz Time-Domain and Raman spectroscopy of the sulfur-containing peptide dimers: low-frequency markers of disulfide bridges", Vibrational Spectroscopy, Vol. 47, pp 53–58, 2008

VIII. ULTRAFAST LASER TECHNOLOGIES AND APPLICATIONS

P-1-UF

TAUTOCHRONISM PRINSIPLE AND GRATING DISPERSIVE DELAY LINES

Andrey Gitin
Max-Born-Institut für Nichtlineare Optik und Kurzzeitspectroskopie,
Max-Born-Str. 2 A, 12489 Berlin, Germany
agitin@mbi-berlin.de

Duration of ultrafast pulses depends on optical media and systems dispersion. Dispersion delay lines (DDLs) are used for correction of the dispersion.

A waveform of the ultrafast laser pulse can be described by its frequency spectrum $\tilde{U}(\omega)$, where $\omega=2\pi/T$ is the angular frequency for oscillation period T. A DDL transforms the input frequency spectrum $\tilde{U}_{in}(\omega)$ to output frequency spectrum $\tilde{U}_{out}(\omega)$ by the formula [1]

$$\tilde{U}_{out}(\omega) = \tilde{U}_{in}(\omega) \cdot \exp[-i\varphi(\omega)], \quad (1)$$

where $\varphi(\omega)$ is the phase-advance function of a monochromatic wave. The monochromatic wave propagation can be described by the wave-fronts and by the orthogonal trajectories to the wave-fronts, the so called light rays. The phase-advance function can be calculated by the formula

$$\varphi(\omega) = \omega t. \quad (2)$$

Here t is a time required for light to travel along the light ray between input and output wave-fronts of the monochromatic wave. This phase time delay t can be calculated by the formula:

$$t = \frac{1}{c} \int_{ray} n \, \mathrm{d}\ell, \quad (3)$$

where n is the index of refraction for the medium under consideration, c is the speed of light in vacuum.

Note that the correct determination of the phase time delay is based on the tautochronism principle [2]: in an optical system consisting of refracting and reflecting elements the phase time delay *t* between any two wave-fronts is the same for all rays. But for a diffraction grating this principle does not valid: the phase time delay between the wave-fronts of incident and diffracted waves for different light rays is different.

It might seem that the marked ambiguity in the calculation of the phase time delay t and the phase-advance function $\varphi(\omega)$ makes it impossible to use diffraction gratings in the DDL. However, fortunately, a pair of diffraction gratings can be combined so that the input and the output wave-fronts of the system still satisfy the tautochronism principle. There are only two of such schemes: Treacy's compressor [3] and Martinez's stretcher [4].

References:

1. A.V. Gitin, "Application of the Wigner function and matrix optics to describe variations in the shape of ultrashort laser pulses propagating through linear optical systems", Quantum Electronics, Vol. 36 (4), 376-382 (2006).
2. A.V. Gitin, "Geometrical method for calculating the group velocity dispersion of stretcher taking into account the influence of optical system parameters", Quantum Electronics. **38** (11), 1021-1026 (2008).
3. E.B. Treacy, "Optical pulse compression with diffraction gratings", IEEE Jornal of Quantum Electronics, Vol. QE-5 (9), 454-458 (1969).

4. O.E. Martinez, "3000 Times Gratig Compressor with Positive Group Velocity Dispersion: Applicatiom to Fiber Compensation in 1.3-1.6 μm Region", IEEE Journal of Quantum Electronics, Vol. QE-23 (1), 59-64 (1987).

P-2-UF

SYNTHESIS OF ALN FILMS IN NITROGEN AMBIENT BY PULSED LASER DEPOSITION TECHNIQUE: FILM STRUCTURE AND SURFACE MORPHOLOGY

A. Szekeres[1], A. Cziraki[2], G. Huhn[2], K. Havancsak[2], G. Varga[2], E. Vlaikova[1], G. Socol[3], C. Ristoscu[3], I. N. Mihailescu[3]
[1]*Institute of Solid State Physics, 72 Tsarigradsko Chausse blvd, 1784 Sofia, Bulgaria*
[2] *Eotvos Lorand University, Department of Materials Physics, 1117 Budapest, Hungary*
[3]*National Institute for Lasers, Plasma and Radiation Physics, PO Box MG-54, RO-77125, Magurele, Ilfov, Romania*
a.cziraki@freemail.hu

The structure and properties of Aluminium nitride are of increasing interest due to high potential of its applications. Thin films of AlN are promising for various technological applications, such as electroacustic and optical devices, protective coatings and insulating layers. Also AlN films deposited onto Si substrates offer important advantages for nitride devices with the view of integrating nitride optoelectronics into the well-established Si technology. In the last decade, the main accent has been placed on development of new deposition techniques and optimization of the growth conditions of AlN films. One of the most efficient and versatile techniques is Pulsed Laser Deposition (PLD) having many advantages like the ability to grow polycrystallline thin films with good stoichiometry at relatively low temperatures. There is still no straightforward theoretical or experimental model of the processes during pulsed laser deposition and the resulting film properties.

Here we present results on the study of the structure and surface morphology of AlN films synthesized on (100) Si substrates by PLD technique. The ablation of polycrystalline AlN target was performed using a COMPEXPro 205 pulsed KrF* (λ=248 nm) excimer laser source (pulse duration 25 ns, pulse repetition rate 3 Hz and 10 Hz, incident laser fluence 4.8 J/cm^2) under nitrogen atmosphere at a dynamic pressure spread from 0.1 to 10 Pa. During deposition the substrates were heated at 800^{o}C, a temperature high enough to promote the crystalline growth of AlN. The film microstructure were studied by means of X-ray diffractometry (XRD), while the surface morphology of AlN films were examined by recording atomic-force-microscopy (AFM) and scanning electron microscopy (SEM) images.

It has been established that the films deposited at low nitrogen pressure are predominantly "XRD amorphous". By increasing the pressure up to 5 Pa the structural ordering increases and nano-sized crystallites appear in the amorphous matrix. Further increase of the nitrogen pressure to 10 Pa leads to deposition of films with "XRD amorphous" structure. Most probably they also contain nano-sized crystallites, however their amount and size are too small to be detected by XRD measurements. The average surface roughness values are within 0.2-3 nm, depending on nitrogen pressure and have a tendency to decrease with increasing the nitrogen pressure to 1 Pa. Increasing further the nitrogen pressure up to 10 Pa the surface roughness starts to increase. Smaller roughness values are observed in case of deposition with lower laser pulse repetition rate (3Hz). These results show a good correlation between structure and surface morphology of pulsed laser deposited AlN films.

P-3-UF

STRONG SHOCK WAVES DRIVEN ON SOLID SURFACES BY INTENSE (SUB-PW/CM^2) FEMTOSECOND LASER PULSES

Sergey I. Kudryashov, A.A. Ionin, S.V. Makarov, L.V. Seleznev, D.V. Sinitsyn
P.N. Lebedev Physical Institute, RAS, 119991 Moscow, Russia
sikudr@sci.lebedev.ru

We report generation of strong shock waves on aluminum, graphite, copper, titanium, silicon surfaces in a single-shot mode by intense IR femtosecond laser pulses in a broad laser fluence range, with their basic parameters (pressure, velocity) acquired by means of a non-contact ultrasonic technique. At moderate laser fluences formation of dense, strongly-heated supercritical phases of the materials, which expand on a fluence-dependent picosecond timescale via point-like three-dimensional explosion driving a multi-GPa shock wave both in ambient air and the solid target, was revealed. At higher laser fluences critical electron-ion plasmas are formed instantaneously during the pump pulse, initiating a TPa-level shock wave. These results are in good agreement with those of previous contact solid-state studies, while the developed non-contact ultrasonic measurement technique is of interest for material science of shock-wave phenomena and high-pressure physics.

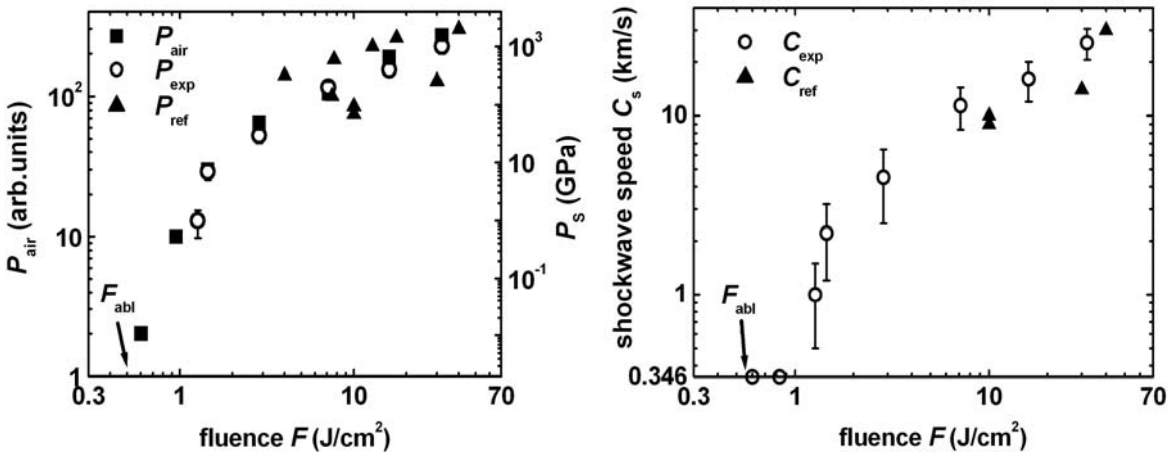


Fig.1. (left) Fluence dependences of measured air shock-wave amplitude P_{air} (left axis, dark squares) and calculated initial shock-wave pressure P_S (right axis): P_{exp}–this work, P_{ref} – literature data (right). Calculated initial shock-wave speeds C_S versus fluence F: C_{exp}–this work, C_{ref}–literature data. The arrow shows the ablation threshold $F_{abl} \approx 0.5$ J/cm^2.

Acknowledgements: This work was supported by Russian Foundation for Basic Research (projects nos. 10-08-00941-a, 11-02-01202-a and 11-08-01165-a).

References:

1. A.A. Ionin, S.I. Kudryashov, L.V. Seleznev, Near-critical phase explosion promoting breakdown plasma ignition during laser ablation of graphite, Phys. Rev. E **82**, 016404 (2010).
2. A.A. Ionin, S.I. Kudryashov, S.V. Makarov, L.V. Seleznev, D.V. Sinitsyn, Generation and detection of ultrastrong shock waves during ablation of aluminum surface by high-intensity femtosecond laser pulses, JETP Lett. 94(1), July issue (2011, in print).

IX. LASER APPLICATIONS IN MATERIAL SCIENCES

P-1-LA

PULSED LASER DEPOSITION OF THE $Si_{1-X}Mn_X$ FILMS RECEIVED WITH DROPLET VELOCITY SEPARATION TECHNIQUE

Khaydukov[1] E.V., Rylkov[2,3] V.V., Rocheva[1] V.V., Nikolaev[2] S.N., , Khramova[1] O.D., Aronzon[2,3] B.A., Novodvorsky[1] O.A., Panchenko[1] V.Ya., Semisalova[4] A.S.
[1] *Institute on Laser and Information Technologies of RAS, 140700 Shatura, Russia*
[2] *National Research Centre, Kurchatov Institute, 123182 Moscow, Russia*
[3] *Institute for Theoretical and Applied Electromagnetics, 127412 Moscow, Russia*
[4] *Lomonosov Moscow State University, 119991 Moscow, Russia*
khaydukov@mail.ru

The results of structural and transport properties studies of 60 nm $Si_{1-x}Mn_x$ films with various Mn (x = 0.33-0.5) content are presented. Films are received by the pulsed laser deposition method (PLD) with using of the deposited particles velocity separation [1]. The method [1] allows to avoid hitting of droplets on the growing film which presence is a primary factor of film quality loss in PLD. The deposition was carried out on Al_2O_3 (0001) substrates at the 340 ^{0}C with the rate of 1.5 nm/min.

The atomic-force microscopy analysis of the films has shown their high quality - the surface roughness is about 1 nm.

It is revealed that films demonstrate ferromagnetic properties in the anomalous Hall effect (AHE) at sufficiently high temperatures ($T \geq 200$ K) and possess essentially nonmonotonic dependence of resistance on Mn content (Fig.1). The R_{xx} film resistance initially falls and then grows at the Mn concentration increase. At that the temperature behavior of R_{xx} changes its character from metal type to dielectric one. Under these conditions the AHE dramatically falls – more than in 100 times at x = 0.5 in comparison with x = 0.36 and changes the sign (Fig.1). The possible reasons of unusual behavior of the transport properties are discussed.

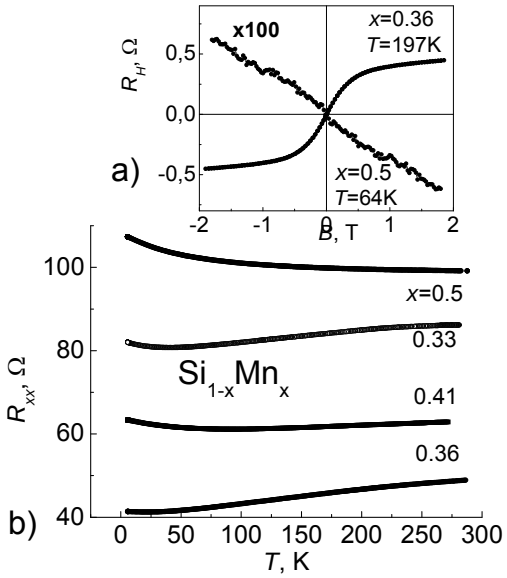


Fig.1. a) Dependences of the Hall resistance on magnetic field for the samples with x=0.36 at T=197K and x=0.5 at T=64 K (R_H is magnified in 100 times).
b) Temperature dependences of the resistance in $Si_{1-x}Mn_x$ films.

The work is partially supported by RFBR (grants 10-07-00492 and 11-07-00359).

References:

1. O.A. Novodvorsky, A.A. Lotin, E.V. Khaydukov, Utility model RF patent 89906, Published 20.12.2009, bulletin 35.

P-2-LA

LASER DISPERSING OF CARBIDE POWDERS IN THE LIGHT METAL ALLOYS FOR WEAR RESISTANCE ENHANCEMENT

Rafał Jendrzejewski
Photophysics Dept., The Szewalski Institute, Polish Academy of Sciences
Fiszera 14 , 80-231 Gdansk, Poland
rafj@imp.gda.pl

Functional materials of markedly enhanced wear resistance can be produced by dispersion of the ceramic, hard particles in light metal alloys [1]. Such metal matrix composites (MMC) are of interest for numerous applications ranging from the power plant, aircraft and automotive industries to the medical one.

In this work, the formation of MMC surface layers on the titanium-based Ti-6Al-4V and aluminum-based Al 6061 alloys by means of laser dispersing of the SiC, WC and TiC powder particles was investigated. In the process, the substrate surface was locally melted to the depths up to about several hundreds μm by the slightly defocused high power cw CO_2 and/or diode laser beam. Simultaneously, powder particles of irregular or spherical shape and average size of about 100 microns were injected into the molten material by means of specialized, lateral nozzle (Fig. 1).

The single traces as well as surface layers consisting of several consecutive traces were produced. The influence of the process parameters, such as: laser beam intensity, scanning speed, powder feed-rate and substrate preheating temperature, on the properties of the composite layer is analyzed and discussed. Moreover, the applicability of the 10.6 μm laser in the treatment of Ti-alloy was confirmed.

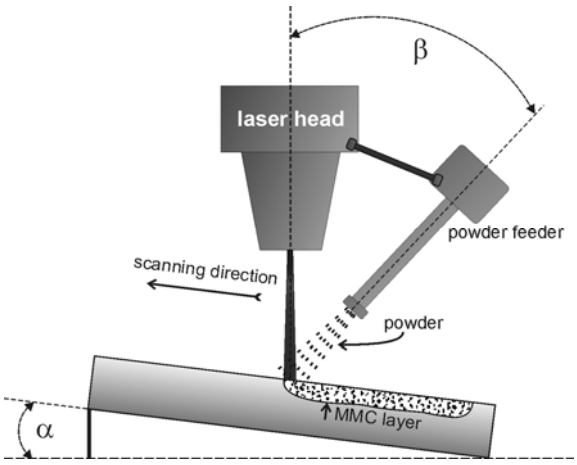


Fig.1. Scheme of the laser dispersing process.

Acknowledgements: This work is sponsored by the Polish Ministry of Science and Higher Education under contract 4884/B/T02/2010/38. Author appreciates the technical support of M. Piskulski.

References:

1. R. Jendrzejewski, K. Van Acker, D. Vanhoyweghen, G. Śliwiński, "Metal matrix composite production by means of laser dispersing of SiC and WC powder in Al alloy", Applied Surface Science, 255, 5584-5587 (2009).

P-3-LA

MIXED LASER WELD JOINTS AND LIBS-STUDY OF THEIR COMPOSITION

T.N. Sokolova, E.L. Surmenko, I.A. Popov
[1] *Saratov State Technical University, 77, Poytechnicheskaya st., Saratov, 410054, Russia*
sokolova@pribor-t.ru

Weld joints are characterized by significant changes of structure, physical properties and, in particular, elemental composition of welded substances in processing zones. The type of components redistribution depends on welded materials and welding modes. Variation of impurities, in turn, influences physical, mechanical and operational properties of materials.

We studied redistribution of impurities and alloying elements in weld joints in depth and in horizontal zones of joints. Weld joints of well-known metals and some special alloys were researched. Also, some mixed weld joints with different substances and type of welding were studied.

Elemental composition of weld joints was studied by laser induced breakdown spectroscopy (LIBS). Sampling from joints was implemented by consequent deepening into one point from both sides of the pieces. The horizontal redistribution was also observed by sampling from cross-section of joints.

The results showed that alloying elements migrate preferentially to the superficial layer of the weld joint, but there are extrema in distribution in depth (see Fig. 1 - example for Ni). The central line of the joints is enriched by impurities. Different elements choose different surfaces for migration. Character of migration depends on the type of welding and on the welding speed.

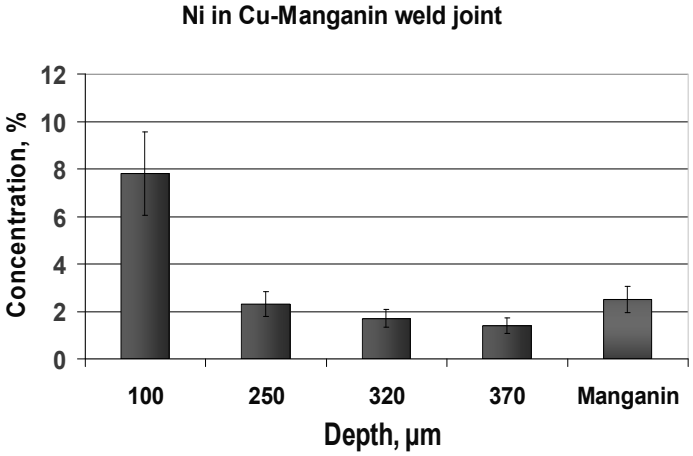


Fig.1. Redistribution of Ni through the weld joint copper-manganin.

Acknowledgements: The work is supported by Grant of the Russian Federation President MK-8473.2010.8. The experiments were implemented on the equipment of VCCU "Laser & Optical Technologies" under the FTP «Research and development in priority directions of scientific and technological complex of Russia for 2007-2013».

P-4-LA

LASER FORMING OF EMITTING STRUCTURE OF METAL-POROUS CATHODES

T.N. Sokolova[1], A.V. Konyushin[1], Yu.V. Chebotarevsky[1], E.L. Surmenko[1], I.A. Popov[1], G.V. Sahaji[2]
[1] *Saratov State Technical University, 77, Poytechnicheskaya st., Saratov, 410054, Russia*
[2]*FSUE "Almaz", 1, Panfilova st., Saratov, 410033, Russia*
sokolova@pribor-t.ru

Metal-porous cathode is an electrovacuum EHF device, providing a high density of emission current. The emitting surface of the device is usually obtained by ion etching. The emitting layer is made of a porous sponge of a refractory metal, usually tungsten. Through the pores of the sponge alkaline earth metals and their oxides are delivered to the emitting surface. One of the most important parameters of the cathode is a uniformity of emission, depending on regularity of the location of pores.

We describe a method of laser modification of metal porous cathode surface, instead of traditional ion etching. The preferences of laser etching are uniformity of pores, absence of deformation of surface, opportunity to specify the necessary size of the pores and the distance between them. Laser structuring of the cathode surface was implemented by laser micrograving. The resulting structure is a field of pores, diameter 5-6μm, with spacing of 20μm (see figure below).

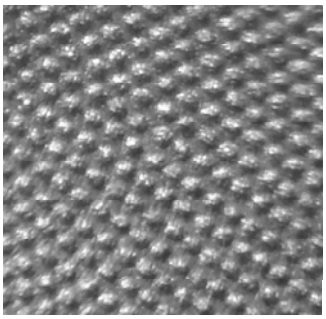


Fig.1. Emitting surface of metal porous cathode processed by laser radiation.

Acknowledgements: The work is supported by grant NK-566P/8(5), within the framework of the FTP «Scientific and Pedagogical Staff of Innovational Russia» 2009 - 2013. All the experiments were implemented on the equipment of VCCU "Laser & Optical Technologies" under the FTP «Research and development in priority directions of scientific and technological complex of Russia for 2007-2013».

P-5-LA

PLD OF ITO THIN FILMS AND THEIR CHARACTERISTICS

D.A. Zuev[1], A.A. Lotin[1], O.A. Novodvorsky[1], O.D. Khramova[1], L.S. Parshina[1], Ph.N. Putilin[2], I.A. Petukhov[2], A.N. Shatokhin[2], A.M. Gaskov[2]
[1]*Russian Academy of Sciences, Institute on Laser and Information Technologies, Moscow Region, Shatura, Russia*
[2] *Moscow State University, Moscow, Russia*
zuewda@yandex.ru

Transparent conductive oxides (TCO) have been widely used in manufacture of optoelectronic devices - LCD displays, light emitting diodes, thin-film solar cells, sensors, etc. Tin-doped indium oxide (ITO) is one of the most used in this class of materials due to its

high transparency in the visible region and good conductivity. Investigation of low-temperature methods of synthesis of ITO films, which do not require subsequent heat treatment and produces films of good quality, is an important problem. In this study, we have conducted experiments to study the optical, electrical, morphological and structural properties of films of ITO, obtained by the method of pulsed laser deposition.

ITO thin films have been deposited by PLD on quartz substrates. The experimental setup has been described elsewhere [1]. The targets have been prepared of powders In_2O_3 and SnO_2. The set of ceramic targets ITO containing Sn in ratio of 2,5,8,11 at%. has been used. During deposition, the substrate temperature has been varied within (25÷400) C°. The pressure of Oxygen background gas introduced into the chamber during deposition has been ranged within (5÷20) mTorr after the initial evacuation to 10^{-7} Torr. The growth rate of ITO films has been determined by optical interferometer MII-4 (λ=543nm), surface morphology has been studied by atomic force microscopy (AFM) DME DualScope 2401. Optical properties (T%) have been measured by spectrophotometer Cary-1950 (Varian), the electrical properties have been investigated by Hall technique using an automated setup HSM 3000, the structural characteristics of the films were studied by X-ray diffractometer DRON-3M.

The conditions of ITO films deposition have been defined, which allowed smooth films with a surface roughness of less than 3 nm. Having a good conductivity ($1\text{-}2\times10^{-4}$ Ohm • cm) and high transparency in the visible region (> 90%).

References:

1. A.A. Lotin, O.A. Novodvorsky, V.Ya. Panchenko, L.S. Parshina, E.V. Khaydukov, D.A. Zuev, V.V. Rocheva, O.D. Khramova, K.D. Sherbachev, "Ternary alloys $Cd_yZn_{1-y}O$ and $Mg_xZn_{1-x}O$ – materials for optoelectronics", Physics of the Solid State, 53(3), 438 – 442 (2011).

X. ACTIVE OPTICAL SENSING AND METROLOGY

P-1-AO

METHOD FOR CALIBRATION OF CCD-MATRICES PHOTOSENSITIVITY SPATIAL DISTRIBUTION

S. E. Stukachev[1], I. E. Kozhevatov[2]
[1] *IAP RAS, 46 Ul'yanov Street, 603950, Nizhny Novgorod, Russia*
[2] *Radiophysical Research Institute, 25/12a Bolshaya Pecherskaya Street, 603950, Nizhny Novgorod, Russia*
sergio_vshopf@mail.ru

The high-precision measurement of the optical wave intensity distribution is required for various research and technical applications: wavefield recording, digital imaging, astrophysics and industry. The most conventional devices for light intensity recording are CCD-cameras [1,2]. The main defect of all the CCD-cameras is that the pixels of the CCD-matrix have different values of the photosensitivity**.** Inhomogeneity of the photosensitivity limits the accuracy of the light intensity distribution measurements. The problem of the measurement of CCD-matrices photosensitivity spatial distribution remains very important.

We propose the novel method for calibration of CCD-matrices photosensitivity spatial distribution. The idea of the method is similar to the principles of absolute calibration of reference plates for interferometry [3]. The method is based on the several measurements of the intensity distribution of the steady light beam in different relative positions of the light beam and CCD-matrix.

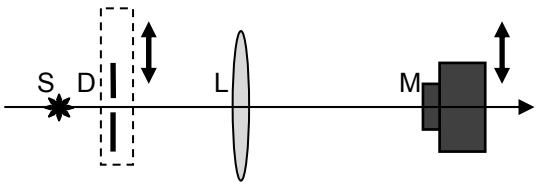


Fig. 1

The optical scheme for realization of the method is shown in Fig. 1. S is the steady light source, the lens L forms an image of the light beam of the incident beam in the plane, where the CCD camera M is placed. The camera can be displaced in the directions perpendicular to the optic axis of the system. Forming the image of the diaphragm D inserted in the scheme enables to control the displacement of the camera.

The results of five measurements of the intensity distribution in different relative positions of the light beam and CCD-matrix determine the system of equations. We can reconstruct the photosensitivity and intensity distributions solving the system numerically.

The numerical modeling of the experiment based on the proposed method is done. The results of the modeling supported theoretical studies of the method. It's shown that the new method provides the considerable increase of the accuracy of the intensity distribution measurements.

The setup for experimental testing of the method was designed in IAP RAS. The results of the experiment proved the efficiency of the new method. We consider the described method as an effective technique for high-precision optical measurements.

References:

1. W. S. Boyle and G. E. Smith, "Charge Coupled Semiconductor Devices". *Bell Sys. Tech. J.* 49 (4): 587-593 (1970).
2. G. F. Amelio, M. F. Tompsett, and G. E. Smith, "Experimental Verification of the Charge Coupled Device Concept". *Bell Sys. Tech. J.* 49 (4): 593-600 (1970).
3. E. A. Rudenchik, I. E. Kozhevatov, N.P. Cheragin, E. Kh.Kulikova, and E. G. Bezrukova, "Method for Absolute Calibration of Reference Plates for Interferometric Inspection of surfaces", *Opt. Spektrosk.*, 90, No. 1, 127 (2001).

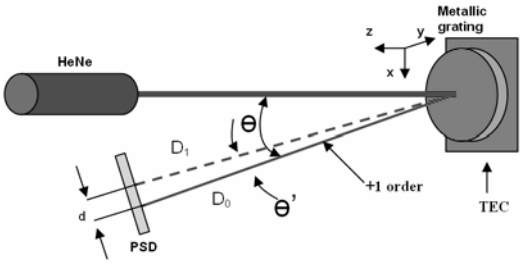
P-2-AO

HIGH FORCE TRANSDUCER AT NANOSCALE

T. Vasile, F. Garoi, I. Iordache, D. Apostol
National Institute for Laser Plasma and Radiation Physics,
Bucharest Romania MG36 Magurele
dan.apostol@inflpr.ro

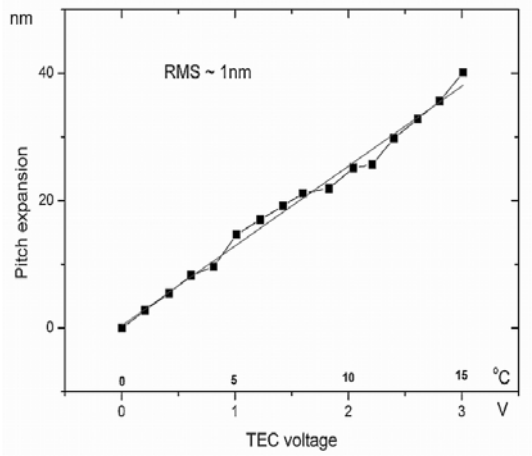
We have designed and experimented with a grating controlled actuator at nanometer resolution. The proposed actuator consists of diffractive and thermoelectric components. The structure of the actuator and the principle of its motion are described. Small displacement and high force are achieved by expanding a metallic diffraction grating. When the metallic diffraction grating, mounted on the thermoelectric cooler, will expand/contract, its pitch will increase/decrease and the diffracted laser beam will move on the position sensing detector (PSD) surface.

A PSD is a position sensitive detector able to sense micrometer displacement of the diffracted beam at the diffraction grating.



The experimental data are intended to emphasize the linearity and the sensitivity of the actuator, rms being as small as 1nm.
Actuator force approximation:

$$F \cong 117 \cdot 10^{9}\, {}^{N}\!/_{m^2} \cdot 4.9 \cdot 10^{-4} m^2 \cdot 17 \cdot 10^{-6}\ C^{-1} \cdot 15C \cong 15000N$$



References:

1. M. Tormen et. al., „Deformable MEMS grating for wide tunability and high operating speed", Journal of optics.A, Pure and applied optics, Vol. 8(7) (2006).
2. D. Apostol, P. C. Logofatu, S. Florea, V. Damian, I. Iordache, M. Bojan, "Accurate calibration of grating pitch" J. Optoelectron. Adv. M, Vol. 10(2), 352-355 (2008).

XI. LASER SPECTROSCOPY

P-1-LS

APPLICATION OF LASER-INDUCED BREAKDOWN SPECTROSCOPY (LIBS) FOR INVESTIGATION OF ANCIANT METAL AND CERAMIC OBJECTS

G. Malcheva[1], K. Blagoev[1], M. Grozeva[1], P. Zahariev[1], S. Karatodorov[1], P. Penkova[2], T. Hristova[2], D. Vasileva[2], S. Neikova[2], P. Leshtakov[2]
[1] *Institute of Solid State Physics, 72 Tzarigradsko Chaussee, 1784 Sofia, Bulgaria*
[2] *National Institute of Archaeology with museum – BAS, 2 Saborna Str., 1000 Sofia, Bulgaria*
bobcheva@issp.bas.bg

The technological development of laser sources and detectors after the 80-ies of the XX-th century allows to utilization of new scientific methods in different disciplines. One of the laser methods, used widely for elemental composition of ancient objects, is Laser-Induced Breakdown Spectroscopy (LIBS).

In the last years LIBS is a preferred analytical method because of a number of characteristics that make it competitive to the other commonly used methods: the comparative simplicity of the equipment, the possibility to reach high spatial resolution, the high degree of non-invasiveness of the method, the fast implementation of the analysis, the need of little or no preliminary preparation of the sample and versatility of the experimental setup for investigating different types of objects – inorganic and organic, solids and fluids, located in various environment – air, gas or liquid [1].

In this work, we present preliminary results from study of various ancient pottery fragments and metal objects from different time periods.

The experimental set-up for LIBS analysis is specially designed for investigation of archaeological objects and consists of a pulsed Q-switched Nd:YAG laser operating at the fundamental wavelength $\lambda = 1064$ nm. The duration of the laser pulses is $t \approx 10$ ns. The energy of the laser was reduced to 10-12 mJ, using variable attenuator. The laser beam is guided toward the sample by a set of mirrors and a focusing lens. The light emitted by the plasma is collected by an optical fiber and detected by Eschelle spectrometer (type Mechelle 5000) and a multi-channel detector (ICCD) having 1024 x 1024 pixels. The spectrometer was calibrated by W/De lamp for intensity and by Hg/Ar standard lamp for wavelength. The laser and the detector are synchronized and in this way we can fix the time interval for spectrum registration and the delay between laser pulse and registration.

The results, obtained by LIBS, give information about the elemental composition, the different types of surface treatment used in the antiquity and for ancient smelting technique. XRF analysis was also performed to verify the results, obtained by LIBS.

Acknowledgements: This work was financially supported by the project "Laser diagnostics in archaeology", ДО02-274/2008, financed from the Bulgarian National Science Fund.

References:

1. A. Giakoumaki, K. Melessanaki, D. Anglos, " Laser-induced breakdown spectroscopy (LIBS) in archaeological science-applications and prospects", Analytical and Bioanalytical Chemistry ***38***, 749-760 (2007).

P-2-LS

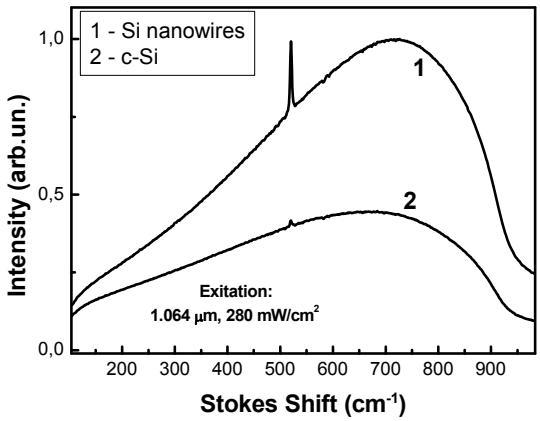
LASER DIAGNOSTICS OF SILICON NANOWIRE ARRAYS

K.A. Gonchar[1], L.A. Golovan[1], V.Yu. Timoshenko[1], V.A. Sivakov[2], S.H. Christiansen[3]
[1]*Lomonosov Moscow State University, Physics Department, 119991 Moscow, Russia*
[2] *Institute of Photonic Technology, D-07745 Jena, Germany,*
[3] *Max Planck Institut für die Physik des Lichts, D-91054 Erlangen, Germany*
k.a.gonchar@gmail.com

It is known that time of photon interaction with matter can be increased after multiply reflection from heterogeneity of the refractive index. This effect can lead to light localization, which is promising with point of view of fundamental physics as well as for practical applications in low threshold lasers, optical switching, sensorics etc. Our work is devoted to investigations of the light localization phenomenon in photoluminescence and Raman scattering in silicon nanowires.

Si wires with diameter of 10-50 nm were grown on crystalline Si (c-Si) substrate. The samples were prepared by etching process of silicon wafers using a sequence of two solutions based on $AgNO_3$/HF and H_2O_2/HF [1]. The optical excitation was done by cw radiation of a YAG:Nd laser at 1.064 μm.

The photoluminescence and Raman scattering intensities were found to increase strongly for the samples with Si nanowires in comparison with corresponding values of c-Si substrate (see Fig).



This effect can be attributed to increasing the excitation intensity of Si nanowires because of the light localization in inhomogeneous optical medium. These experimental results can be interpreted as an increase of the time of light-matter interaction in Si nanowire arrays. The interaction time is estimated to be about 6 ns for the sample with 20 nm layer of Si nanowires, which significantly longer than that for c-Si substrate (32ps). It manifests possibilities to enhance the laser-matter interaction in disordered silicon nanostructures.

References:

1. V.A. Sivakov et al., "Realization of Vertical and Zigzag Single Crystalline Silicon Nanowire Architectures" J. Phys. Chem. C, 114, 3798-3803 (2010).

P-3-LS

INFLUENCE OF SI <100> POROSITY ON LOW FREQUENCY SPECTRA

Z.V. Lavrukhina, A.V. Pavlikov, D.A. Sapozhnikov, V.Yu. Timoshenko
Physics Department, Moscow State University, 119991, GSP-1, Leninskie Gory, Moscow, Russian Federation
zinalavrukhina@gmail.com

Silicon, being the basic material for most electronic devices, remains a promising object under investigation for researchers. By structurally or chemically modifying silicon substrates one can obtain a material that will possess properties different from those of the initial material. One of the most promising methods of modifying silicon surface is electrochemical etching, which enables to obtain porous silicon with different extend of porosity [1].

This work compares spectral properties of crystalline and porous silicon samples. The crystalline silicon <100> under investigation was prepared using Czochralsky method. 10-100 μm films of porous silicon were synthesized by applying electro etching to p-Si <100> substrates doped with boron. Depending on the electrical current density during the etching and the conductivity of the substrate, films of different porosity were obtained. The measured dependencies of the amplitude of the radiation passed through and reflected from the samples on the frequency in near and far infrared range provide information on the vibrational modes present in the samples.

The terahertz spectra obtained for crystalline silicon in the temperature range of 50-18 K enable us to observe a specific narrow absorption line at 29.3 cm^{-1}. This line accounts for Si-O-Si modes which are present in crystalline silicon due to impurity oxygen atoms sited between two neighboring silicon atoms [2].

References:
1. L.A. Golovan', V.Yu. Timoshenko, P.K. Kashkarov, "Optical properties of porous-system-based nanocomposites" Uspekhi Fizicheskikh Nauk, 50, 595–612 (2007).
2. D.R. Bosomworth, W. Hayes, A.R.L. Spray and G.D. Watkins, "Absorption of Oxygen in Silicon in the Near and the Far Infrared" Proc. R. Soc. Lond. A, 317, 133-152 (1970).

P-4-LS

INTENSITY-INTENSITY CORRELATIONS OF SURFACE PLASMON LIGHT

Sándor Varró, Norbert Kroó, Dániel Oszetzky, Attila Nagy and Aladár Czitrovszky
Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences
1525 Budapest, POBox 49, Hungary,
varro@mail.kfki.hu

Intensity-intensity correlations of light signals, coming from spontaneous surface plasmon decay, have been studied both experimentally and theoretically. The surface plasmon oscillations (SPO) were excited in the Kretschmann geometry by a He-Ne laser beam, which was directed onto a gold film of thickness 45nm. Since the photon number rate was controlled in the range from 20000 to 200000 counts per second, and the estimated life time of the SPOs

is on the order of 100 femtoseconds, these experiments, in fact, have been performed in the single-photon regime. In the first experimental arrangement the auto-correlation functions of the reflected light and of the light emitted by the SPOs on the opposite side of the metal layer have been measured (see Fig. 1). In the second arrangement the light stemming from the SPOs was split by a beam splitter, and the cross-correlation function has also been measured.

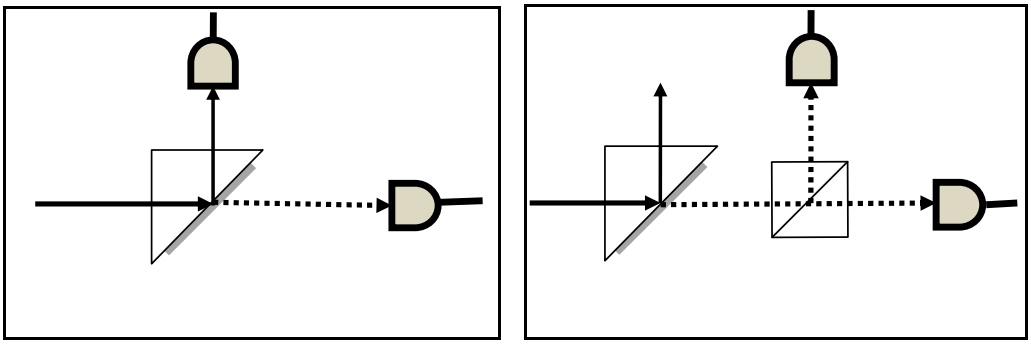


Fig.1. Illustration of the arrangements used for measuring count number correlations in split beams. The light stemming from surface plasmon decay is symbolized by dotted arrows.

The measured deviations from the shot noise level of the normalized joint counts were on the order of few percents, or even less. In spite of the modest effective resolution of our system, besides the photon anticorrelation effects, the transition from antibunching to bunching has also been observed. We have also developed a theoretical description of the counting statistics for very large gate durations, and received reasonable agreement with the experimental data.

Acknowledgements. The present work has been supported by the Hungarian National Scientific Research Foundation, OTKA Grant No. 73728.

TABLE OF CONTENTS