International Conference

“Fundamentals of Laser Assisted Micro– and Nanotechnologies” (FLAMN-10)

ABSTRACTS

July 5-8, 2010

St. Petersburg – Pushkin, Russia

International Conference
“Fundamentals of Laser Assisted Micro– and Nanotechnologies”
(FLAMN-10)

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ITMO

RFBR

GPI RAS

State Hermitage Museum

State Museum "Tzarskoje Selo"

July 5-8, 2010

St. Petersburg – Pushkin, Russia

INTERNATIONAL CONFERENCE

Fundamentals of Laser Assisted Micro– & Nanotechnologies
(FLAMN-10)

July 5-8, 2010, St. Petersburg – Pushkin, Russia

- Section Laser-Matter Interaction (LMI)
- Section Laser-Assisted Micro-and Nanotechnologies (LAMN)

Associated events:

- Workshop "Photophysics of Nano-scale Systems" (W1)
- Workshop "Terahertz Radiation Interaction with a Matter" (W2)
- Workshop "Laser Cleaning and Artworks Conservation" (W3)
- Seminar "Industrial Applications of Fiber Lasers" (S1)
- Seminar "Computer Simulations of Laser Technologies" (S2)
- School for young scientists and engineers (YSS)

Dedicated to 50th anniversary of lasers and laser technology and 110 anniversary of National Research University of Information Technologies, Mechanics and Optics

Organizers:

- St. Petersburg State University of Information Technologies, Mechanics and Optics (ITMO), St. Petersburg, Russia
- General Physics Institute of Russian Academy of Sciences (GPI RAS), Moscow, Russia

in cooperation with:
Laser Association & D.S. Rozhdestvensky Russian Optical Society

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* Russian Federation Ministry of Education and Science,
* St. Petersburg State University of Information Technologies, Mechanics and Optics (ITMO),
* Russian Foundation for Basic Research (RFBR),
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* General Physics Institute of Russian Academy of Sciences (GPI RAS),
* Foundation "Dinasiya",
* "Laser Track" Ltd.,
* Company "Lasers & Apparatus TM",
* CE "Lasertech" Ltd.,
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* "Mobile Laser Technologies" Ltd.,
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* TRIZ Centre "Tvortchestvo" Ltd.,
* Company "LaserVarioRakurs"

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GENERAL INFORMATION

CONFERENCE VENUE

The FLAMN-10 Conference will be held from July 5 till July 8, 2010
at the Manager Training Center ("Kochubey Mansion")
Radishcheva 4, Pushkin, St. Petersburg, Russia
Tel: +7(812) 465-3910

ARRIVAL & REGISTRATION

Members of the Organizing Committee will meet the participants at Pulkovo airport on July 4, 5. Transportation for foreign participants will be provided from the airport and the terminals to the place of registration.

To ensure that you will be met please inform the Organizing Committee of the exact time and place of your arrival in St. Petersburg by e-mail: flamn10org@gmail.com.

Registration will take place at the Manager Training Center ("Kochubey Mansion") in city Pushkin, Radishcheva street 4, tel. (812)465-3910. The place of registration can be reached from Saint-Petersburg by local train from Vitebsky railway terminal ("Pushkinskaya" or "Zvenigorodskaya" subway station) or from Kupchino railway station ("Kupchino" subway station) to Pushkin and then by bus numbers 376, 378, 381, 382 from Pushkin Railway Terminal till bus stop "Parkovaya ulitsa".

The Registration Desk will be open for participants on:

Sunday, July 4: 15.00-19.00
Monday, July 5: 8.00 - 19.00
at "Kochubey Mansion"

The Conference Program, Book of Abstracts and other information will be given at the Registration Desk.

ACCOMMODATION

A sufficient number of hotel-rooms will be reserved in the hotel of MTC "Kochubey Mansion" at the same location as the conference center.

TECHNICAL SESSIONS

The Conference sessions will include oral and poster presentations.
The time for invited talk is 30 min. including 5 min. for questions and discussion.
The time for oral presentation is 15 min. and 5 min. are given to answer the questions. Overhead, media and slide projectors will be available.
During the poster sessions (see time schedule) presenters remain in the vicinity of their posters for informal discussion and explanations.
The maximum poster size is: vertical 1.0 m, horizontal 1.0 m
Tape to stick the posters will be provided by organizers.

LANGUAGES

The official language of the Conference is English.

TIME

Moscow time is used throughout the program. Moscow time is 3 hours ahead of Greenwich time and 2 hours of central European time.

WEATHER

The weather in July usually unstable in Saint-Petersburg with the temperature in the range of +15°C...+25°C. Rains are possible.

SOCIAL PROGRAM

A number of excursions both at Saint Petersburg and at Pushkin are planned. The complete information concerning the social program will be available at the Registration Desk at the beginning of the Conference.

Conference Executive Director**: *A.A. Allas***
Conference Secretariat:

Phone: +7(812) 233–3406

from July 4:
Phone: +7(812) 465-3910

Conference Schedule

Monday, July 5

TIME	EVENTS
10.00-10.30	Opening ceremony
10.30 – 12.00	Special (historical) session (SS) [1]
12.30–14.30	Plenary session 1 (PL1) *
14.30-15.30	Lunch time
15.30-17.30	Plenary session 2 (PL2) (1/2) *
17.00-17.30	Coffee break
17.30-19.30	Plenary session 2 (PL2) (2/2) *
20.00	Welcome reception

Tuesday, July 6

TIME	EVENTS
9.00-12.00	Plenary session 3 (PL3) *
12.00-12.30	Coffee break
12.30-14.30	Plenary session 4 (PL4)
14.30-15.30	Lunch time
15.30-17.30	Session LMI1 (1/2) (Room 1)
17.30-20.00	Session LMI1 (2/2) (Room 1)
15.30-18.00	Session LAMN1 (1/2) (Room 2)
18.00-20.30	Session LAMN1 (2/2) (Room 2)
19.00-21.00	Poster session **PS1**

[1] ***Joint session of FLAMN-10 and School for young scientists and engineers***

Wednesday, July 7

TIME	EVENTS
10.00-14.00	Workshop “Photophysics of Nano-scale Systems” (Joint session of FLAMN-10 and Workshop)
10.00-14.00	Workshop “Terahertz Radiation Interaction with a Matter” (Joint session of FLAMN-10 and Workshop”)
10.00-14.00	Workshop “Laser Cleaning and Artworks Conservation” (Joint session of FLAMN-10 and Workshop”)
10.00-14.00	Seminar “Industrial Applications of Fiber Lasers”
10.00-14.00	Seminar (Panel discussion) “Computer Simulations of Laser Technologies”
14.00-15.00	Lunch time
16.00–18.00	Poster session **PS2**
20.00	Conference dinner

Thursday, July 8

TIME	EVENTS
9.30-11.00	Session LMI2
11.00-11.30	Coffee break
11.30-13.30	Plenary session 5 (PL5) (1/2)
13.30–14.30	Lunch time
14.30-17.00	Plenary session 5 (PL5) (2/2)
17.00	AWARDS CEREMONY
	Closing remarks

CONTENTS

SS-2 50 years of solid-state lasers

V.A. Serebryakov
Institute for Laser Physics, IFMO

The first Soviet solid-state laser, ruby, was launched on June 2, 1961 by L.D. Khazov in Vavilov Optical Institute. Over the past 50 years our country has become one of the world's leading centers in the area of lasers, and in the first place, solid-state lasers (SSL). Many made the country's research and development had drawn a wide response and a sizeable impact on the development of a number of directions in laser physics and technologies. And if in the 60 years the focus of our experts had processes in lasers themselves, then in 70-80 years, one of the most large-scale laser programs is laser confinement fusion (ICF), which was led by Nobel prize-winners N.G . Basov and A.M. Prokhorov. In its framework there have been realized SSL with a beam energy of tens and hundreds of kilojoules. In March 2009, at Lawrence Livermore National Laboratory (LLNL) USA, start up a National Ignition Facility (NIF) with an energy of 1.1 MJ. On the way laser with energy 1.8 MJ in France. The program Fast Ignition were created petawatt SSL's with pulse duration ~ 100 fs, and already to 2010 in Europe must be development exawatt-class laser ELI (Extreme Light Infrastructure) with attosecond pulse duration. ELI will be a new scientific infrastructure devoted to scientific research in lasers' field, dedicated to the investigation and applications of laser-matter interaction at the highest intensity level (more than 6 orders of magnitude higher than today's laser intensity).

A significant influence on the development of laser research program has "Star Wars" initiative push through by President Reagan in 1983. In the Soviet Union there were not the work of such level as in the U.S., but in a number of laboratories conducted the researches for the situation tracking. The most interesting works were devoted to studying the possibilities and ways of implementation, including the methods of nonlinear optics, extremely low divergence laser beam and its exact address, needed to follow the fast-moving objects. Today, practically all the complex laser-optical systems for precision guidance are used for realization of beam divergence near diffraction limited (DL) as line-adaptive circuit (correction of large-scale linear aberrations, visual fields matching) and phase-conjugate mirrors for correction of small-scale distortions.

Much attention and efforts had been placed on improving the SSL efficiency and reliability. In this connection it is worth mentioning the work to increase efficiency of SSL by improving pumping sources. The lamp pumping system, built on the principle of "optical boiler", allowed to raise the efficiency of high-power neodymium lasers up to 10% in continuous wave or free-running modes. More efficiency up to 40% can be achieved in the transition to a longitudinal diode pumping of relatively low-power watt-class lasers, or 20-30% for CW kilowatt-class disk- or slab-lasers. In the single-pulse mode with kilowatt average power the efficiency reaches >10% (≤ 3% for lamp-pumped).

And finally, we must note the work on the laser wavelength tuning by methods of nonlinear frequency conversion. If today's laser diodes cover discretely UV, visible and IR spectrum range, working in a CW or quasi-CW (hundreds of MHz) modes, the nonlinear SSL frequency conversion enables a discrete adjustment of the wavelength (harmonic generation) as well as fine tuning (parametric light generation), working in both continuous and pulsed modes. The SSL wavelength tuning has allowed to extend greatly them application in various fields of science and technologies.

SS-3 The "ROOTS" and "FRUITS" of laser micro- and nanotechnology

Vadim P. Veiko

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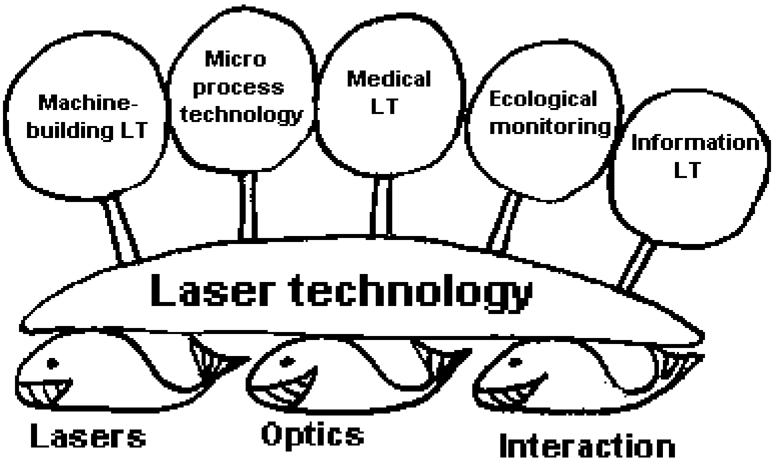
We believe, that "continent" of laser technologies with various concrete processes growth on it, is founded on three whales (see figure) — lasers, optics and physics of laser–matter interaction.



To develop a process in laser technology one should answer 3 questions:

1) **What type of laser source should be used** for the concrete task "A" decision (wavelength, mode of operation — continious or pulse repetition, power, pulse duration, coherence, cross–section energy distribution, monochromaticity, polarization, etc in consideration with safety demands, reliability, stability and cost effective ? And how to calculate and verify these parameters?

2) **What kind of beam–transporting and beam–shaping optical** (opto–mechanical, opto–electronic, etc.) **systems is necessary** for decision of the task "A"? As the laser beam is a working tool it should be organized in space and time in optimal style. Special optics, opto–mechanical, opto–acoustical, electro–optical and other modulators can provide the necessary time of action. Other optical systems: electromechanical, acousto–optical, opto–mechanical scanners and controlled diaphragm define the dimensions and shape (cross–section, energy distribution, caustic shape) of laser beam.

At the same time the tasks of transporting of laser energy (in free space or by optical fibers etc) and collimation, focusing or projection should be solved.

3) **Which kind of interaction (action) of laser radiation with (on) the object matter should be chosen** to reach the aim of action (resonance – nonresonance, scattering – absorbing, photo– or thermoabsorbing, exitation, heating, hardening, melting, softening, evaporation, decomposition, coagulation, etc.). Solving this question is probably the most important part of task "A". This knowledge should give the possibilities to make good–quality estimates and to decrease real expenses (because "the good theory is a highly profitable thing!").

Most impressive examples of the past applications of laser microtechnologies are remembered: diamond dies drilling, quartz generation trimming, mask saving etc.

The modern fields of LMNT – printing boards drilling, TFT panels annealing, solar cells treatment, high density optical recording, photonics devices laser technology are reviewed.

Actual tendencies of laser micro– and nanotechnologies are discussed.

1. S.M.Metev, V.P.Veiko. Laser–assisted Microtechnology. Springer–Verlag NY–Heidelberg, 1998.

PL1-1 High-power kw-class ns- and fs- slab lasers and their specific applications

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Ultrashort laser sources with pulse durations in the sub-picosecond regime enable a new domain of precision machining of various materials. Pulse durations shorter than the electron-phonon coupling time lead to minimum thermal load or even non-thermal ablation processes. Exploiting non-linear absorption processes, the absorption becomes nearly material independent when laser pulses of several micro joule energy and high beam quality are focused on the materials surface. Very small pulse energies and high intensities well above the vaporization threshold enable high-precision cutting, ablation and drilling of even weakly absorbing materials, multi-component and multi-layer systems. Additionally, focusing ultrafast laser pulses in the volume of transparent dielectrics allows localized modification of the bulk material. Specifically, defined refractive index changes in glasses and crystals can be utilized for wave guiding and beam forming applications. In addition, a combined approach of material modification followed by chemical etching provides the possibility to manufacture micro-channels or 3D-micro mechanical parts. The 3D-capability of the in-volume materials processing by selective laser etching “ISLE” originates from the non-linear absorption of light in the initially transparent material.

The potential of such processes is known for years, however only now the average power could be scaled up and thus leads to precision combined with power. In this paper we present compact laser sources with a high flexibility in pulse energy (μJ to mJ) and pulse repetition rate (kHz to ~100MHz), delivering an average power of more than 400W. Additionally, a broad range of application examples and parameter sets will be presented, from micro- and nanostructuring of various materials to volume processing of dielectrics.

PL1-2 The Road Ahead for Active, Controllable and Quantum Metamaterials

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The next photonic revolution will come from the development of active, controllable, nonlinear and quantum metamaterials.

Metamaterials, artificial media structured on a scale smaller than the wavelength of external stimuli, are fascinating international research communities. Existing materials derive an origin for their electromagnetic characteristics in the properties of atoms and molecules - metamaterials enable us to design our own 'atoms' and thus access new ground breaking functionalities such as invisibility and imaging with unlimited resolution. The next stage of this technological revolution will be the development of active, controllable and nonlinear metamaterials surpassing natural media as a materials platform for optical data processing and quantum information applications.

PL1-3 Nanoscale Imaging of Surface Plasmons via Photoemission

D.S. Pickard, V. Viswanathan, Ai Zhongkai
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The scientific community is witnessing increased research activity on Surface Plasmon Polaritons (SPPs). The potential applications of SPPs and plasmonic structures based on their control and manipulation are truly multi-disciplinary, spanning high speed nano-scale interconnects, meta-materials, chemical and biological sensing, sub-wavelength optics and waveguides, near-field optical trapping, high-density data storage, and the enhancement of nonlinear effects. Measurement of the localized optical field intensity is a critical component in validating physical models and characterizing plasmonic structures. The dominant technique employed for this task is the Scanning Near-Field Optical Microscope (SNOM) or Photon Scanning Tunneling Microscope (PSTM), whose contrast mechanism is based on measuring light scattered from the near-field with a probe. These techniques can provide high resolution images of the localized fields, but they are slow. Furthermore, tip-sample interactions can perturb the fields, yielding ambiguity between electric and magnetic fields and frustrating attempts at accurate optical characterization. One way to facilitate the advance of plasmonics is to develop new techniques for imaging and characterizing SPP behavior on the nanoscale.

Recent efforts employing photoemission to reveal the localized fields have demonstrated that this technique can provide both high spatial (~10nm) and temporal (fs) resolution when combined with a Photoelectron Emission Microscope (PEEM)[1-3]. The PEEM does not require a probe so the fields can be imaged without perturbation. It also provides a parallel image of the full field, so acquisition times are fast. We are expanding the capabilities of the PEEM to exploit a novel contrast mechanism which will broaden the spectrum of plasmonic devices observable.

We present our experimental efforts in this area, detail the underlying physics of the contrast mechanism and discuss how it can be controlled to enable unique spatial and temporal information on the propagation of SPPs within plasmonic structures.

1. M. Cinchetti, A. Gloskovskii, S. A. Nepjiko, G. Schonhense, H. Rochholz and M. Kreiter, PRL 95, 047601, (2005)
2. Atsushi Kubo, Ken Onda, Hrvoje Petek, Zhijun Sun, Yun S. Jung, and Hong Koo Kim, Nano Letters, 2005, Vol. 5, No. 6, 1123-1127
3. M. Stockman, M. Kling, U. Kleineberg, F. Krausz, Nature photonics, VOL 1, Sept 2007, 539-544

PL2-1 Novel carbon materials in laser technology

V.I. Konov
General Physics Institute, Moscow, Russia

Advanced carbon materials, such as CVD diamond, single wall carbon nanotubes and graphene, will be outlined. Advantages of laser – induced synthesis of diamond coatings in atmospheric air will be presented. The technology for production of micro and nanostructures both on the surface and in the bulk of diamond by ultra-short laser pulses will be demonstrated.

It will be shown that carbon can be a unique optical material. High quality CVD diamond diffractive optical elements for high power CO_2-lasers were fabricated by eximar lasers. It was found that materials (liquid suspensions, polymer films) “doped” with single wall carbon nanotubes can be effectively applied as saturable absorbers for mode-locking of various types of near infra-red lasers. Prospects of graphene in laser optics will be also discussed.

PL2-2 Photo-assisted amorphization of chalcogenide alloys: from curiosity to advanced applications

A.V. Kolobov

Nanodevice Innovation Research Center, National Institute of Advanced Industrial Science & Technology, Tsukuba Central 4, 1-1-1 Higashi, Tsukuba, Ibaraki, JAPAN

Photo-assisted amorphization in chalcognides alloys, from pure selenium to the prototypical phase-change memory material $Ge_2Sb_2Te_5$, has been studied experimentally using x-ray diffraction, Raman scattering and in-situ subnanosecond x-ray absorption spectroscopy as well as density-functional-theory computer simulations. Results of these studies are presented and the resulting implications for practical use are discussed.

1. A.V. Kolobov and S.R. Elliott, Reversible photo-amorphization of crystalline “lms of $As_{50}Se_{50}$, Journal of Non-Crystalline Solids 189 (1995) 297-300
2. V. Poborchii, A.V. Kolobov, and K. Tanaka, Photomelting of selenium at low temperature, Appl. Phys. Lett., 74 (1999) 215 - 217
3. P. Fons, A.V. Kolobov et al., Photo-assisted melting of $Ge_2Sb_2Te_5$ memory alloy (submitted)

PL2-3 Enhancement of secondary emission in metal-dielectric nanostructures

Sergey V. Gaponenko

B.I.Stepanov Institute of Physics, National Academy of Sciences of Belarus
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Nanostructures with characteristic surface relief of the order of 10…100 nm are known to modify spatial distribution of incident electromagnetic field. Local field enhancement results in enhanced absorption of photons by molecules or nanocrystals adsorbed at the surface. The effect is extremely pronounced in metal—dielectric structures because of surface plasmon resonance. A systematic application of the field enhancement in Raman scattering enhancement and in photoluminescence enhancement with respect to molecular probes is followed nowadays by application of the effect with respect to nanocrystals (quantum dots) adsorbed at metal-dielectric nanotextured surfaces. It is the purpose of the present paper to outline mechanisms of photoluminescence enhancement and Raman scattering enhancement and factors in the context of their application in novel luminophores and high sensitive spectral analysis [1-3].

We consider not only the local field enhancement in terms of excitation process but also photon density of states enhancement effect on photon emission processes with Raman scattering as a specific case of photon emission. In this consideration, scattering of light experiences enhancement as spontaneous emission does. Differences in scattering and luminescence enhancement are due to quenching processes which are crucial for luminescence and less pronounced for scattering. We consider ultimate experiments on single molecule detection by means of enhanced Raman scattering and photoluminescence enhancement of atoms, molecules and quantum dots and the approaches to efficient substrates fabrication for the purposes of ultrasensitive spectroscopy.

Mechanisms and experimental performance of photoluminescence and Raman scattering enhancement are considered in the context of their application in novel luminophores and high sensitive spectral analysis. So-called “hot spots” are treated as local areas in plasmonic nanostructures where high Q-factors develop both for incident light frequency and for emitted or scattered light frequency. Feasibility of 10- to 10^2-fold enhancement is highlighted for luminescence. Rationale is provided for 10^{14} enhancement factor for Raman scattering which has been claimed based on experimental observation but to date has never been reported in the theory.

1. S.V.Gaponenko. Phys. Rev. B 65, 140303(R) (2002); Izv. RAN, ser. fiz. 68, 116 (2004).
2. S.V.Gaponenko and D.V.Guzatov. Chem. Phys. Lett. 477, 411 (2009).
3. S.V.Gaponenko. Introduction to Nanophotonics (Cambridge University Press, 2010).

PL2-4 Laser methods of generation of high intensity terahertz pulses

*S.V. Garnov, V.V. Bukin, A.I. Ritus, A.A. Sirotkin, I.A. Shcherbakov, A.G. Stepanov**

A.M. Prokhorov General Physics Institute of Russian Academy of Sciences
*Institute for Spectroscopy of Russian Academy of Sciences

Among a variety of methods and techniques developed for generation of terahertz (THz) beams there are two of them which we discuss in the present talk. Aiming to reach a possibly higher THz pulse electric field (up to 106 V/cm) we studied and applied in the experiments: i) laser-induced gas plasma discharges – gas breakdown by femtosecond laser pulses in the presence of the external dc electric field, and ii) difference frequency mixing of laser radiation in nonlinear media – optical rectification of femtosecond laser pulses with tilted pulse front in lithium niobate crystals (LNb). The developed experimental setups, the THz radiation characterization techniques and the results obtained are described and discussed in details.

The 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.

PL2-5 Petawatt laser system of the “LUCH” facility

Belov[1] I.A., Buchirina[1] O.A., Voronich[1] I.N., Voronina[1] N.V., Garanin[1] S.G., Dolgopolov[1] Y.V., Zimalin[1] B.G., Kedrov[1] A.I., Koltygin[1] M.O., Litvin[1] D.N., L'vov[1] L.V., Manachinsky[1] A.N., Markov[1] S.S., Mecheryakov[1] M.V., Ogorodnikov[1] A.V., Romanov[1] V.V., Rukavishnikov[1] A.N., Rukavishnikov[1] N.N., Savkin[1] A.V., Senik[1] A.V., Sukharev[1] S.A., Trikanova[1] O.V., Tytin[1] S.V., Filatova[1] N.A., Chernov[1] I.E., Ginzburg[2] V.N., Katin[2] E.V., Kirsanov[2] A.V., Lozhkarev[2] V.V., Luchinin[2] G.A., Mal'shakov[2] A.N., Martyanov[2] M.A., Palashov[2] O.V., Poteomkin[2] A.K., Sergeev[2] A.M., Freidman[2] G.I., Khazanov[2] E.A., Shaykin[2] A.A., Yakovlev[2] I.V.

[1]Russian Federal Nuclear Center – All-Russian Institute of Experimental Physics (RFNC-VNIIEF), Sarov, Russia
[2]Institute of Applied Physics of Russian Academy of Science, N.Novgorod, Russia

The results of petawatt laser system development based on the parametrical amplification of broadband chirped laser pulses in the parametrical amplifiers made of DKDP nonlinear crystals [1] are presented. The factor of amplification 10^{11} is obtained in four cascades of parametrical amplifiers. The compressor of chirped pulses has been based on the single-pass scheme with four diffraction gratings in size of 240×380mm and 1200 l/mm. Energy on an output of the final parametrical amplifier being pumped up by radiation transformed to the second harmonic of the "Luch" facility channel [2] (λ_{pump}=527nm, E_{pump}≈1kJ, τ_{pump}≈2.5нс), was in the range of E_{signal}≈100J on λ_{signal}=911nm, that corresponds of laser radiation power at the compressor outlet P_{out} ≈ 1.2PW at τ_{pulse}≈50fs.

1. N. F. Andreev, V. I. Bespalov, V. I. Bredikhin, S. G. Garanin, V. N. Ginzburg, K. L. Dvorkin, E. V. Katin, A. I. Korytin, V. V. Lozhkarev, O. V. Palashov, N. N. Rukavishnikov, A. M. Sergeev, S. A. Sukharev, G. I. Freidman, E. A. Khazanov and I. V. Yakovlev, "New scheme of a petawatt laser based on nondegenerate parametric amplification of chirped pulses in DKDP crystals," Pisma v JETF 79, 178-182 (2004).
2. S. G. Garanin, A. I. Zaretskii, R. I. Il'kaev, G. A. Kirillov, G. G. Kochemasov, R. F. Kurunov, V. M. Murugov and S. A. Sukharev, "Channel of a high-power laser fusion Luch facility emitting 3.3-kJ, and 4-ns pulses," Quantum Electronics 35, 299-301 (2005).

PL2-6 Laser decontamination and cleaning methods for modern nuclear technologies

A. Semerok[1], P.-Y. Thro[1], F. Champonnois[1], D. Farcage[1], A. Leontyev[1], C. Grisolia[2]

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The development of high power high repetition rate lasers opens up new possibilities for their practical application for surface cleaning and decontamination in different fields of industry. Laser cleaning methods can offer remote handling decontamination without additional waste that is seen as a particular advantage for nuclear industry (contaminated paint or metal oxide removal, plasma facing surfaces detritiation in a future ITER installation). The process can be automated and provide a high capacity of surface cleaning without personnel attendance in the contaminated zone. The laser ablated matter can be collected on the filters of the aspirator system. The adequately chosen laser/surface interaction parameters can provide a selective surface cleaning without substrate damaging. This particular feature is regarded as very attractive for cleaning historical heritage monuments and art objects.

Laser cleaning methods for industrial application are seen as a complex technological problem. The adequate choice of a laser system, laser beam transport to the treated zone, laser beam surface scanning, ablated matter aspirator/filtration system were among numerous problems that have been under our laboratory study for the last few years. The development, optimisation, characterisation and the tests of the laser cleaning systems were the main aim of our investigations [1-3].

Laser cleaning devices based on high repetition rate solid state lasers (10-50 kHz, 20-200 W mean power, 1.06 μm wavelengths, 100 ns pulse duration), laser beam transport by optical fibers and rapid laser beam surface scanning systems will be presented. Laser cleaning performances (tokamak plasma facing surfaces detritiation and cleaning, contaminated paint removal from concrete wall of the dismantling nuclear plants) and the possible optimisation of the laser cleaning systems and laser devices will be discussed.

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2. C. Grisolia, A. Semerok, J.-M. Weulersse, F. Le Guern, S.V. Fomichev, F. Brygo, P. Fichet, P.-Y. Thro, P. Coad, N. Bekris, M. Stamp, S. Rosanvallon, and G. Piazza, In situ Tokamak laser applications for detritiation and co-deposited layers studies, Journal of Nuclear Materials 363-365 (2007)1138.
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PL2-7 Laser Technology in Museum Restoration

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Laser welding and laser cleaning of works of art became a common technique and in many countries it is successfully used for the restoration of masterpieces. Modern laser technologies enable restoring unusual objects, including those of precious metals. Four specific machines were designed for the Laboratory for Scientific Restoration of Precious Metals. The parameters thereof were adjusted to the restoration of precious metals: three machines are intended for welding precious metals, while one for cleaning precious metals.

The Laboratory is fitted with two types of machines – with fixed processing chamber, and with fiber-optic cable. The mobile laser cleaning system has wheels for moving, and a device for hanging up. The fiber-optic cable allows carrying out restoration work at a distance of 3 to 10 m from the machine. The machine removes the dirt from the surface of objects both by the direct light, and the light reflected by means of special mirrors.

While the laser cleaning process is still under development, the laser welding has taken a leading place in the restoration practice of the majority of museums.

The State Hermitage Museum has been the first of the museums in Russia, that used for the restoration the laser welding of the last generation, which meets all the museum requirements and allows to weld the most complex fragments (as from the delicate filigree to objects with thick sides). Due to the use of high technology the manufacturers could create the third generation inverter generator having more compact electronic module, better performance standards and energy efficiency. As a result they created a compact energy-efficient machine of high power. Laser technologies make it possible to avoid the use of solders. There is no welding cinder on joints. This machine provides high accuracy and clean surfaces welded, besides that the weld joints are polished by the system automatically pulsating. Localized heat allows welding above previously welded surfaces without damaging the earlier work. Appropriate parameters can be continuously adjusted while working with various metals. Laser welding does not change the weight of jewellery, which is extremely important for the museum practice.

The use of laser welding and laser cleaning in the museum restoration work obviously allow drastically decreasing the time of restoration, and essentially increasing the quality of work.

PL3-1 Plasmonic nanoparticles in biology

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In nanostructured noble metals, light induces localized surface plasmon resonance. This effect leads to absorption bands of particle solutions or peaks in the scattering spectra even of single particles. The dependence of this resonance on material, geometry and immediate environment exhibits the potential for various applications. The (auto) catalytic deposition of silver leads to particle growth enabling simple electrical and optical DNA detection schemes. The environmental influence enables sensoric applications because molecules binding to the particle surface change the spectral properties which can be detected. The coupling of light into the particles can even induce damages to the particle and also to the immediate surrounding resulting in nanoantenna-based optical manipulation with sub-wavelength precision.

PL3-2 Advanced nanostructured glassceramics for photonic applications

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Five types of nanostucturied glassceramics have been developed for photonic applications. These glassceramics exhibit good laser, photorefractive, non-linear, plasmonic, and ion-exchangeable characteristics in comparison with glassy and crystalline analogs. Different technologies for nanostructuted glassceramics preparation have been demonstrated – spontaneous thermal crystallization, laser-thermo-induced crystallization, electron beam-thermo-induced crystallization, ion exchange. Some examples of unique optical elements and devices based on the nanoglassceramics (amplifiers, Bragg gratings, sensors, limiters) have been demonstrated for photonics applications.

The first material presents a laser lead-fluoride nanoglassceramics doped with Er, Yb and Nd. It is shown that, rare earth ions play a role of nucleation centers and precipitate in crystalline phase, for example, $Pb_{(1-x)}$-$Er_{(x)}$-$F_{(2+x)}$. Spectral, luminescent and laser properties of the nanoglassceramics have been demonstrated and compared with fluoride crystals. Possibility of utilization of the nanoglassceramics in fiber laser and amplifiers have been discussed.

The second material presents a forsterite nanoglassceramics doped with tetravalent chromium ions. It was experimentally shown that tetravalent chromium ions are embedded in the forsterite nanocrystalline phase. It was found that the quantum yield of the luminescence of the forsterite nanoglassceramics is close to that for the forsterite single crystal. The results have demonstrated the possibility of synthesizing transparent nanoglassceramics doped with $Cr^{(4+)}$ ions whose spectral and luminescence properties are highly competitive with those of forsterite single crystals. In this work the polarized luminescence of four-valence chromium in glasses and glassceramics was revealed for the first time. It was shown, that the degree of polarization induced by light polarized luminescence can serve as a discriminator of valence state of transitional elements in matrix. It was demonstrated that the transparent nanoglassceramics can be used for drawing optical fibers. This offers new possibilities for designing broadband optical fiber lasers and amplifiers based on the use of transition metal ions.

The third nanoglassceramics exhibits good non-linear properties and presents a glass host with precipitated nano-dimensional crystalline phase of complicated composition (CuCl/Br/I or AgCl/Br/I). It is shown that an optical response appears in the materials when the energy density was 0.1–1 nJ/cm^2 while the appearance time of the response was less than 35 ps. The cause of the appearance of the nonlinear-optical response is the photogeneration of unstable color centers. These results can be used when developing nonlinear-optical media to control optical signals in integrated-optics systems, as well as for radiation limiters.

The fourth material presents a glass doped with highly concentrated silver metallic nanoparticles (3-7 nm) or precipitated nanocrystals of NaF-AgBr (20-30 nm) covered by silver metallic thin film. Several technologies have been used for creation of such structures – laser radiation or electron beam treatment, ion exchange and thermal treatment. Such structures possess a plasmonic resonance. Some plasmonic devices can be realized on the materials - plasmonic waveguides and switches, luminescent sensor and biosensors.

The fifth material - a new polyfunctional photo-thermo-refractive (PTR) glassceramics doped with erbium and ytterbium has been developed for the first time. The material combines itself three opportunities: fabrication of lasers or amplifiers, recording of volume Bragg gratings (VBG) or holographic optical elements (HOE), fabrication of planar waveguides or fiber. The nanoglassceramics can be classified as optical polyfunctional material. The polyfunctional PTR glassceramics exhibits good spectral, luminescent, and lasing characteristics, as well as photorefractive and ion exchangeable properties. The VBG or HOE recording is based on photo-thermo-induced crystallization process, when UV radiation and following thermal development result in growth of nanosize crystalline phase in the glass host. The VBGs/HOEs have high mechanical, chemical, and thermal durability. Optical characteristics of the VBGs/HOEs are stable over high temperature (up to 500°C) and under high power/energy laser beam. The diffractive efficiency of VBGs/HOEs archives 80-90%. Different HOEs and devices on the base of the polyfunctional PTR glassceramics have been developed for photonic applications. Some volume and waveguide elements and devices and their characteristics have been demonstrated. For example, supernarrow band spectral filters with a bandwidth of 0.1 nm and spatial selectors with an angular selectivity of 1 mrad. The polyfunctional PTR glassceramics is a promising candidate for development and design of a new generation of optical elements and devices.

PL3-3 Laser Ignition of Engines – a Status Report

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At Photonics Institute laser ignition of internal combustion engines has been investigated for the last 10 years. This talk will provide an overview on advantages and critical issues of laser ignition, different system concepts and technical solutions. Additional applications and trends for laser ignition are discussed.

PL3-4 High-Power Laser Propulsion

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In the report, we consider the development of new transportation system for launching of satellites and for space missions of vehicles, which is based on the use of high power lasers to create propulsion (HPLP). One of the principal advantages of HPLP is the avoidance of detachable parts or multi-stage rockets in the system. Other advantage of HPLP is the use of the atmosphere air or CHO-chemical materials as rocket fuel, which is ecological propellant. HPLP system can be also applied to orbital maneuvering of satellites and to interplanetary missions of space vehicles. At that, achievements of high energy efficiency of a thrust production as well as minimization of propellant consumption are considered as principal tasks at developing of HPLP.

The overview of experimental investigations on the interaction of laser pulses with CHO-chemical materials is presented too. The experiments are made by the use of pulsed Nd- and CO_2- lasers. Polymers and polycrystals of CHO-type are selected for the experiments. These materials have optimal properties at burning (combustion heat for the example) and ecological products of burning reactions such as CO_2 and H_2O, taking oxygen from the atmosphere. The theoretical model of the interaction is developed on the basis of this analysis.

PL3-5 Trapping and transport of nanoparticles in air with optical vortices

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Laser trapping and guiding of particles is traditionally associated with forces of radiation pressure and dipole-induced gradient forces in liquids, so called optical tweezers. However, stable trapping of absorbing particles in air was not realised due to the dominance of photophoretic forces stem from thermal interaction of the laser-irradiated particle absorbing light with the molecules of ambient gas. The major difficulty in utilizing the photophoretic forces for particle trapping is a finite time of thermal relaxation within the particle, which is sufficient for its stochastic motion. Nevertheless, it has been shown experimentally that using a vortex beam with a ring-shaped profile leads to a strong transverse confinement of absorbing particles at the *intensity minimum* on the optical axis. This is in contrast to laser tweezers where transparent aerosols trapped by radiation pressure and by gradient force at the *intensity maximum*.

We show here that by using *two counter-propagating vortices* in the dual-beam scheme we achieve a robust and fully three-dimensional photophoretic trapping of absorbing particles in air [1,2]. The on-axis longitudinal confinement was realised by a balance of the photophoretic forces induced by two vortex beams on the opposite sides of a particle. Our proof-of-principal experiments demonstrate stable positioning and guiding of agglomerations of carbon nanoparticles with the total size ranging from 0.1 to 100 micrometers, and for laser powers in the range from 1 mW to 100 mW. We have transported particles of various sizes in air backward and forward between the optical traps separated by a meter-long distance with the speed up to 60 mm/s.

These results demonstrate, for the first time to our knowledge, the ability of trapping and transporting particles over the distances limited only by a divergence of the laser beams. Our approach expands the applications of optical tweezers; it provides a necessary tool for experiments with absorbing aerosols, and allows simulating on the processes studied in atmospheric and planetary sciences in laboratory scales.

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PL3-6 Physical fundamentals and mechanisms, implementation and prospects for laser-induced reshaping and regeneration of biotissues

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Reshaping and regeneration of biological tissues under non-destructive modification of tissue structure and mechanical stress distribution are novel approach for laser application in medicine. The aim of the paper is to discuss the similarities between laser interaction with biological tissues and solids. We will show that a number of phenomena known for a long time for solids also occur in biological tissues, there include: (1) stress relaxation as a result of pore formation accompanied with the creation of new interphase surfaces (2) polygonization- stress relaxation due to reorganization of structural defectsin cartilage; chondrones play the role of structural defects like dislocations in crystals (3) the condition of plastic deformation (stress relaxation threshold) in cartilage can be defined with the well known von Mises criterium. A 5 minutes fragment of the TV telecast regarding new laser technologies and their medical applications will be presented.

PL4-1 Ablation by short pulse optical and X-ray lasers

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Short laser pulse in wide range of wavelengths, from infrared to X-ray, disturbs electron-ion equilibrium and rises pressure in a heated layer. A pulse creates two-temperature warm dense matter state and triggers a chain of hydrodynamic and kinetic processes: melting, expansion, stretching, creation of tensile stress and transition into metastable state. The case where pulse duration is shorter than acoustic relaxation time is considered in the paper. Acoustic time is defined as a time necessary to sound wave to travel along heat penetration depth. It is shown that this short pulse may cause thermomechanical phenomena such as spallative ablation regardless to wavelength. While the physics of electron-ion relaxation strongly depends on wavelength and various electron spectra of substances: there are spectra with an energy gap in semi-conductors and dielectrics opposed to gapless continuous spectra in metals. The paper describes entire sequence of thermomechanical processes from expansion, nucleation, foaming, and nanostructuring to spallation with particular attention to spallation by X-ray pulse.

PL4-2 Single Pulse Laser Interference: Principles and Applications

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A nanosecond laser pulse is split into several beams. These beams are then overlapped on the sample surface. The resulting interference pattern induces surface modifications. The physical principles which lead to surface modification are discussed for thin films and bulk materials. Periods achieved are below 200 nm, while the structure sizes could be much smaller. Besides the direct application for the generation of nanostructures, the method can be used as well to generate laterally modified chemical surface structures, which can be used in different applications.

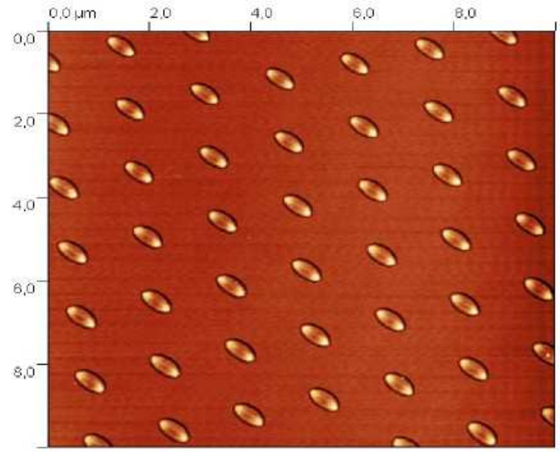

Fig. 1: Nanostructures on Si produced by single pulse 3 beam laser interference

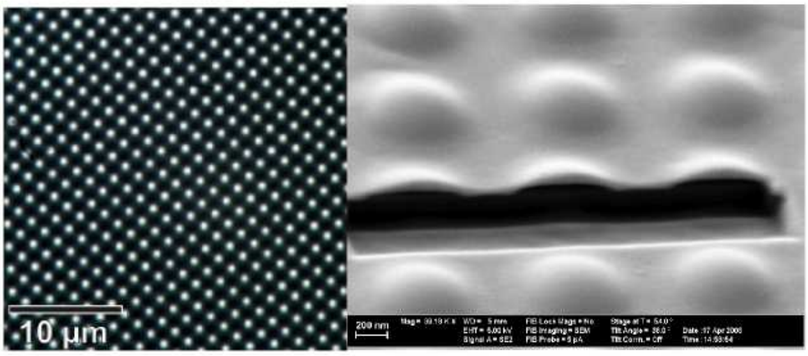

Fig. 2 Optical dark field image of nanostructures on Ta thin films produced by 3 beam laser interference (left). Electron microscopy of a focused ion beam produced cross section through the modified structure.

PL5-1 Laser assisted immobilization of organic biomolecules for very sensitive bio-catalyzers

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Matrix-assisted pulsed laser evaporation (MAPLE) has been shown to be a viable alternative to conventional pulsed laser deposition for polymers and other organic biomolecules. There are already a variety of important applications for thin organic films including biomedical, electronic, chemical sensing, and optical applications. In MAPLE, the targets submitted to laser radiation consisted of frozen composites prepared by dissolving or suspending the active biomaterials in appropriate solvents, to minimize the photochemical damage. The material to be deposited is dissolved in the solvent, usually 0.1–5 wt% concentration, and cooled below the solvent freezing temperature. The solid composite target is evaporated by a UV laser and the material is collected on a nearby substrate as a thin film. The vaporized solvent does not form a film and is pumped away.

1. ***Enzyme based biosensors*** represent one of the most recognized and widely studied classes of biosensors. They are the first choice as miniaturised detectors for medical diagnostics, due to their high amplification of biorecognition and selectivity. Special attention is paid nowadays to improve the enzyme immobilization. We report on the immobilization of urease in the form of thin films using laser techniques. An essential prerequisite for the development of enzyme based biosensors is to preserve the enzymatic activity after the biomaterial immobilization procedure. Therefore, the dependence of the immobilized urease films surface morphology, composition, structure, enzymatic activity, and storage stability on the target preparation and laser parameters was carefully investigated. The kinetic analyses indicated that under optimum deposition conditions the laser immobilized enzyme is active in breaking down urea.

2. We extended the laser ablation process to the deposition of ***extracellular matrix (ECM) proteins*** such as fibronectin (FN) and vitronectin (VN) on different substrates–to functionalize material surfaces with biomimetic peptides. The protein depositions were performed on biomedical titanium and hydroxyapatite covered titanium to investigate the cellular response of modified surfaces. The typical morphology and optimal spread were evidenced by fluorescence and scanning electron microscopy when human osteoblast precursor cells were cultivated on ECM protein modified surfaces. The cellular distribution, viability and morphology were evaluated by comparison with negative and positive controls.

PL5-2 Laser Ablation as a Technique of Nanoparticle and Nanostructure Formation: Mechanisms and Applications

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Laser-produced nanoparticles have found many applications in bio-photonics, medicine and in the development of solar cells. Many experiments have been performed demonstrating nanoparticle formation in vacuum, in the presence of a gas or a liquid. However, it is still difficult to control the properties of the produced particles. Therefore, numerical modeling is required to explain experimental results and to better understand the mechanisms involved. The developed models allow us to compare the relative contribution of several processes involved in the cluster production by laser ablation: (i) direct cluster ejection from a target under rapid laser interaction, (ii) condensation/evaporation; (iii) fragmentation/aggregation processes during cluster diffusion; and (iv) diffusion and coalescence if nanoparticles are deposited on a substrate. The calculation results of both hydrodynamic and molecular dynamics simulations demonstrate that an exposure of a target to a short or ultra-short laser pulse leads to an explosive target decomposition and to the ejection of nanoparticles. These cluster precursors are formed during rapid target expansion through both thermal and mechanical processes. Collisions with background species affect the cluster size distribution. The influences of the parameters, such as laser pulse shape, initial cluster temperature and size, background temperature and density, on the cluster evolution are analysed. Calculations performed for nanoparticle formation in the presence of a gas or a liquid show, furthermore, that the laser-generated plasma plume is strongly decelerated and confined. As a result, conditions for particle nucleation can be controlled. In nanosecond regime, where plume absorbs laser radiation, its temperature is high initially, so that nucleation and collisional condensation sets in only after a certain delay, followed by the particle coalescence. If femtosecond laser is used, the ejected clusters and ions can serve as nanoparticle precursors. These precursors disappear, however, if many pulses are applied with a short delay between them. Finally, additional diffusion-limited aggregation process plays a role. The latter process may last for a long time and can lead to a significant change in the size distribution. The obtained calculation results agree with recent experiments. In particular, our results explain the difference between nanoparticle formation in femtosecond and nanosecond regimes.

PL5-3 Laser heating of nonequilibrium electrons in transparent solids: computer simulation of avalanche laser damage mechanism.

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Computer modeling of nonequilibrium electrons heating with intense laser pulses was conducted aiming to describe the avalanche laser damage mechanism of transparent solids. The dependences of avalanche rate on laser electric field, so as the critical electric field on laser pulse duration, laser wavelength and lattice temperature, were obtained. The processes of phonon heating and their role in avalanche ionization mechanism were analyzed in details. It was shown that the use of Fokker-Plank type equations may lead to a noticeable discrepancy even though the ratio of laser quantum energy to the energy of material band gap is about of 0.1.

PL5-4 The potential of fiber lasers in PLD

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While diode-pumped solid state and very recently fiber lasers with tunable pulse energy up to millijoules, tens of kHz to MHz repetition rates and tens of W average output power are opening up new perspectives in industrial applications as reliable and flexible micromachining tools, their potential in pulsed laser deposition is far not explored yet. In this contribution we exemplify the peculiarities of high-repetition-rate fiber laser PLD by ablating graphite and PMMA targets with a train of pulses from an Ylia M20 fiber laser (1.06 micrometer, 100 ns, 20 KHz, max. 1 mJ/pulse) in vacuum. The reason of the apparent inconsistency between extremely efficient material removal and low growth rate is that deep ablation tracks are formed within seconds, setting thereby a geometrical constraint for film growth. The morphology of the films on micro- and nanoscale is characterised by optical-, scanning electron- and atomic force microscopy, while the chemical- and bond structure of the targets and the respective films is compared by using Raman- and FTIR spectroscopies, respectively. The results reveal that the ablation mechanism is thermal. The films are compact with bond structures strictly comparable to the target material. The corollary of the study is that - using fast enough beam scanning and/or target movement - fiber laser PLD is a viable alternative when high growth rate is required without the need for highly energetic film forming species.

PL5-5 Tissue Dissection with Ultrashort Pulse Laser using Extended and Multiple Foci

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Ultrashort pulse lasers are typically utilized for tissue dissection by sequential application of tightly focused beam along a scanning pattern. Each pulse creates a small (on the order of 1μm) zone of multiphoton ionization. At energies exceeding vaporization threshold cavitation bubble is formed around the focal volume. A continuous cut can be created if the rupture zones produced by sequential bubbles coalesce.

We present an alternative approach, in which an extended zone of tissue is cut by simultaneous application of laser energy in multiple foci. Simultaneous formation of multiple cavitation bubbles results in hydrodynamic interactions that can lead to significant extension of the rupture zone in tissue. Two simultaneously expanding bubbles compress and strain material between them, while simultaneously collapsing bubbles can produce jets towards each other. We calculated and experimentally imaged the flow dynamics of expanding and collapsing bubbles and obtained maps of tissue deformation. Based on the measured tissue threshold strain, the deformation map allows

predicting the rupture zone as a function of maximum bubble size and distance between the bubbles.

We also demonstrate an optical system producing 1 mm long dissection with a single laser pulse. Combination of a lens and an axicon produces a cylindrical zone of optical breakdown, with aspect ratio exceeding 250:1. The subsequent cavitation bubble has aspect ratio 100:1 at 100 ns after the laser pulse. Analyzing the dynamics of resulting cavitation bubble and using Fresnel diffraction theory we derive a beam intensity profile that creates a uniform axial intensity distribution in the breakdown zone, and minimizes the energy delivered into the sample. Such system can be advantageous in applications to linear and/or planar dissection of transparent materials, especially with moving targets. It might be useful for ophthalmic surgical applications including cataract surgery and crystalline lens softening.

PL5-6 Nonlinear Optical Lithography: Materials & Applications

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We present our investigations on the fabrication of three-dimensional nanostructures by direct laser writing using organic-inorganic hybrid materials that (i) have nonlinear optical properties, (ii) can be selectively covered with metal and (iii) are suitable for biomedical applications.

Direct laser writing by two photon polymerization (2PP) is a nonlinear optical technique which allows the fabrication of three-dimensional (3D) structures with a resolution beyond the diffraction limit [1]. The polymerization process is initiated when the beam of an ultra-fast infrared laser is tightly focused into the volume of a transparent, photosensitive material. Two-photon absorption takes place within the focal volume where polymerization occurs; by moving the focused laser beam in a three-dimensional manner within the resin, 3D structures can be fabricated. The technique has been employed successfully in the fabrication of nano-photonic structures and devices [2].

Here, we present our most recent work on the structuring of a series of hybrid organic-inorganic materials by two photon polymerization. These materials fall into the following categories:

(i) Silicon oxide-based sol-gels in which a nonlinear optical molecule has been chemically bound onto the photopolymer, potentially enabling the dynamic tuning of the optical properties of the fabricated structures. The sol-gels investigated include materials with second and third-order optical nonlinearity [3]. One example is shown in Figure 1, where the plasmonic waveguide pictured has been fabricated using a photopolymer incorporating the nonlinear optical molecule N-(4-nitrophenyl)-(L)-prolinol (NPP).

(ii) Composite sol-gels with metal binding affinity. These materials can be structured accurately and, due to the incorporated metal binding groups, can be readily metalized with silver and other metals by simple immersion in a metal bath, without the need to modify the surface of the structures or to use other, complementary techniques [4]. An example is shown in Figure 2, where the structure has been covered with silver. As seen, the silver coating is uniform and without blemishes (Figure 3).

(iii) Biocompatible materials that can be structured accurately without the need for compensation due to shrinkage. An example is given in Figure 4, where a 3D scaffold has been fabricated. Initial studies have shown that these materials are biocompatible and promote cell adhesion.

The combination of direct laser writing with specially designed, functional materials can lead to advanced applications in photonics, metamaterials and biomedicine.

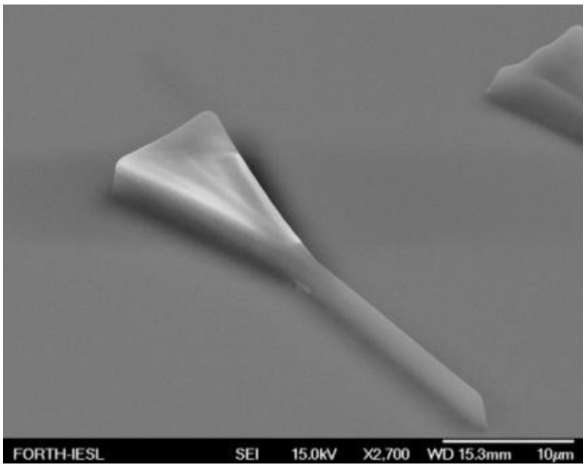

Figure 1: A plasmonic waveguide fabricated using a nonlinear optical silane

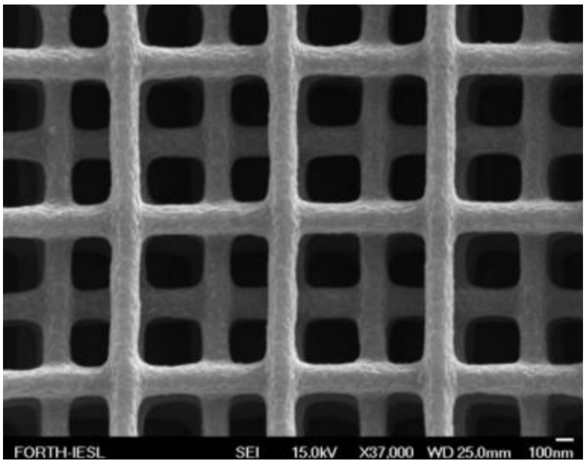

Figure 2: A 3D photonic crystal structure fabricated using a metal binding composite.

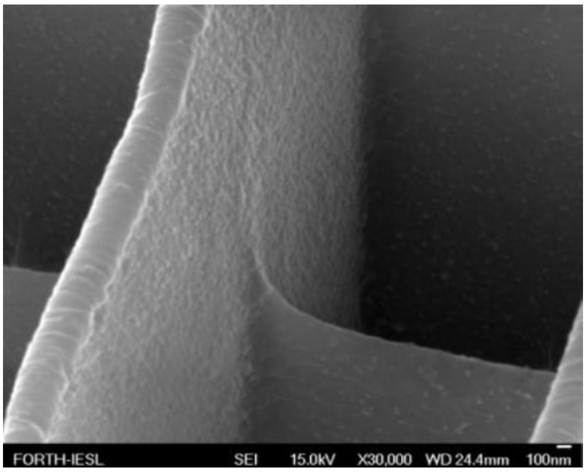

Figure 3: Detail from a silver-coated structure.

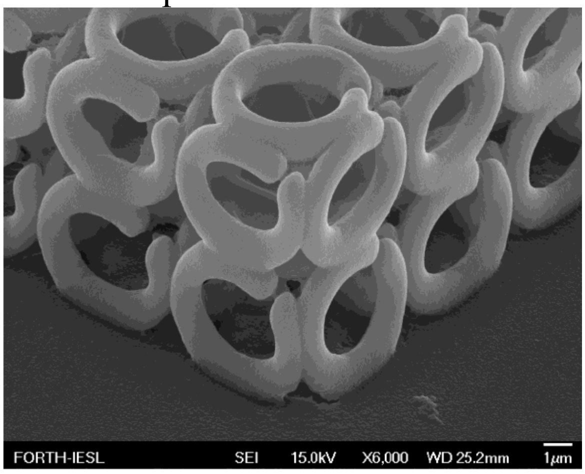

Figure 4: A biocompatible 3D scaffold

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PL5-7 Synthesis of nanometric iron and chromium oxide films by reactive pulsed laser deposition for photo-thermo sensors

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Films based on oxides of transitional metals have semiconducting properties that make them up-to-date materials for functional electronics. The reactive pulsed laser deposition (RPLD) allows the control of thickness and stoichiometry of deposits in order to obtain semiconductor structures with accurately tailored thickness and band gap. It is very important to study electrical, structural and optical properties of these semiconducting nanometric films, as sensing characteristics strongly depend on these properties.

We deposited iron oxide (Fe_2O_{3-X}; $0 \leq X \leq 1$) and chromium oxide ($Cr_{3-X}O_{3-y}$; $0 \leq X \leq 2$; $0 \leq Y \leq 2$) films on <100> Si substrate by RPLD using a KrF laser. The deposited nanometric films (thickness 50-200 nm) of iron and chromium oxides have large thermo electromotive force (e.m.f.) coefficient (S). The S coefficient of iron oxide films varied in the range 0.8-1.65 mV/K in the temperature range 210-322 K. The maximum value of the S coefficient (1.65mV/K) was measured in the temperature range 270-290 K. The S coefficient value depends on the band gap (E_g) of semiconductor films: the largest value of this coefficient was measured for films with $E_g \cong 0.70$ and 0.86 eV and the lowest one for films with $E_g \cong 0.43$ and 0.93 eV. But the largest photosensitivity (F) of iron oxides films was about 44 V/W for white light at power density (I) of about $6x10^{-3}$ W/cm^2 for films with $E_g \cong 0.43$ eV and the lowest value of F was about 23 V/W at the same I for films with $E_g \cong 0.86$ eV.

As regards chromium oxide films, the S coefficient varied in the range 0.30-4.5 mV/K in the temperature range 210-333 K, with the maximum of 3.5-4.5 mV/K in the temperature range 270-290 K. Also in this case the S coefficient value depends on the band gap: the largest value of this coefficient was measured for films with $E_g \cong 0.40$ and 0.71 eV and the lowest S coefficient was for films with $E_g \cong 0.32$ and 0.38 eV. The largest photosensitivity of chromium oxide films was about 2.5 V/W at $I \cong 6x10^{-3}$ W/cm^2 for films with $E_g \cong 0.32$ and 0.71 eV and does not practically depend on E_g.

Our results show that RPLD is a very simple procedure to synthesize of iron and chromium oxide nanometric films with variable stoichiometry and, consequently, with different values of their band gap result in variable the S coefficient and the photosensitivity. The deposited films present large thermo e.m.f. coefficient and high photosensitivity that make them up-to-date materials for photo-thermo sensors.

LMI-1 Interaction of ultrashort VUV laser pulses with semiconductors

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Irradiation of semiconductors with ultrashort laser pulses leads to an excitation of electrons from the valence band and deeper shells to the conduction band producing nonequilibrium highly energetic free electrons. We apply Monte Carlo simulation to trace the excitation and ionization of the electronic subsystem of a solid silicon target irradiated with a femtosecond VUV laser pulse. The temporal distributions of the density and energy of excited electrons are obtained. We demonstrate that due to the energy spent to overcome the ionization potential, the final kinetic energy of free electrons is significantly less than the total energy provided by the laserpulse.

We introduce the concept of an 'effective energy gap' for multiple electronic excitation, which can be applied to estimate the free electron density after high-intensity VUV laser pulse irradiation.The effective energy gap depends on properties of the material as well as on laser pulse parameters.

LMI-2 Novel multiphoton-avalanche mechanisms of prebreakdown laser excitation of wide-gap-materials

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New results on pre-breakdown optical excitation processes are presented. Emphasis is placed on such phenomena as the photon avalanche effect (PAE), optical trampoline effect (OTE), multiphoton avalanche effect (MPAE), and multiphoton (MP) absorption controlled by optical Stark effect.

The PAE occurs as a result of optical absorption from an excited state and Auger-type transitions. Typical threshold intensities for a PAE in systems of rare-earth impurity ions and quantum wells (QWs) are from tens to hundreds kW/cm^2. In deep QWs, the PAE allows a fast switching of the material between states with different optical and electrical parameters, with the times of 10^{-9}-10^{-11} s. The PAE makes it possible to derive emission at a wavelength 3-5 times shorter than the excitation wavelength [1, 2]. The last-mentioned result can be also achieved at higher excitation intensities via the OTE produced by optical transitions from the ground state and Auger-type processes involving a photon in the elementary event. The theory of the OTE was developed for semiconductors containing deep impurities and for deep QWs [3].

Analysis of the pre-threshold generation of electron-hole pairs (EHPs) in wide-gap materials shows that, under certain conditions, the MPAE [4, 5] plays a dominant role. Similarly to the PAE, the MPAE shows a well-pronounced threshold in excitation intensity and involves Auger-type processes assisted by several photons, along with the cascade of MP interband transitions. A specific feature of the MPAE is that there exists a region of light intensities j, in which a small increase in j yields a sharp increase in the EHP generation rate and, as a result, the breakdown of the material. A similar effect may result from MP interband absorption controlled by one- or two-photon optical Stark effect [6-10]. The energy band spectrum reconstructed by interaction of electrons with high-intensity light exhibits new van Hove critical points whose position in the Brillouin zone depends on the light intensity j. If j is changed so that such critical points approach the points of MP resonance between the upper valence band and lower conduction band, the EHP generation rate sharply increases.

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LMI-3 Non-paraxial approach to the problem of terawatt femtosecond pulse self-reflection from nonlinear focus and plasma in solids

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In this work the model adequate to solve the nonlinear backscattering problem of terawatt femtosecond pulses from photoinduced plasma and nonlinear focus in Kerr media has been elaborated. Application of the nonlinear eikonal related to the pulsed beam phase increment along the propagation axis allows us to reduce Maxwell equation to the set of two coupled equations of non-linear Schrödinger type for forward (incident) (FW) and backward (reflected) waves (BW). Backscattering process is investigated in dependence on the ratio α of input pulse power and critical one for self-focusing.

When the input pulse power exceeds the critical one it focuses in Kerr medium under propagation. Its intensity increases and its radius decreases achieving the value less than wavelength. This process is accompanied with the plasma formation via the multiphoton absorption or tunelling mechanisms. Near the nonlinear focus medium inhomogeneity becomes maximal. It's shown that the longitudinal gradient of medium refraction index is the origin of a backward wave as a result of forward wave self-reflection. At this, the reflection coefficient from nonlinear focus depends on the α value. If at $\alpha<20$ the backscattered wave intensity does not exceed 5% of the forward one, then at $\alpha>30$ it can reach 10% and more. For a threshold value of ratio $\alpha \sim 3.7$ minimal FW beam radius in the focal region is of order of the radiation wavelength λ. BW beam radius becomes minimal and the BW intensity is maximal at the distance $\sim 5\lambda$ from the focus. At larger distances from nonlinear focus the BW beam defocuses essentially. The extent of the BW beam defocusing depends on the parameter α. and its radius can be comparable with the radius of the FW beam at the sample input. If the propagation distance exceeds some diffraction lengths at $\alpha>20$, the multifoci behavior of the FW takes place. As for the self-reflection from plasma it arrests the FW pulse self-focusing at earlier stage then longitudinal gradient of refraction index. The minimal diameter of the FW pulse is about 7λ that is essentially larger than in aforementioned case. For $8<\alpha<20$ the reflection from plasma is 3 - 4 times more than the reflection from the nonlinear focus. If the FW intensity and its radius minimum is in the focus then the BW intensity maximum and its width minimum are shifted from focus, but, in difference from self-reflection from nonlinear focus, the BW beam width is minimal at the much shorter distance (about 0.05λ) from focus. At small distances from nonlinear focus the BW wave propagates in a waveguide formed by the FW pulse. Note the scenario of multifoci FW behavior is due to radial distribution of photoinduced plasma connected with the forward pulse form. In opposite case such scenario is impossible.

LMI-4 Femtosecond ablation of dielectrics : double pump-probe investigation of excitation mechanisms

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To satisfy the increasing demand in terms of resolution and reliability in laser induced processing of dielectrics, a better understanding of the mechanism at work in the processes of ablation, micromachining or modification of optical properties, is clearly needed. In this field of laser ablation of wide band gap materials by ultrashort laser pulses, there has been a long debate regarding the excitation and energy deposition mechanism. This is due to the lack of direct experimental investigations, which have been mostly limited to the measurement of ablation threshold. Indeed, the measurement of this single parameter, besides its technological importance, is clearly insufficient to understand a phenomenon as complex as laser induced breakdown. The complexity arises from the intricate evolution of the laser pulse propagation and the optical properties of the solid, due to the onset of a dense electronic excitation. If we consider only the very first step which is the electronic excitation, it is noteworthy to observe that one can still find advocate of different mechanisms such as tunnel [1], avalanche [2], or multiphoton [3] ionisation.

To investigate this problem, we use an original pump-probe interferometry technique [4, 5] which allows to measure the carrier density as a function of time, and to observe the initial relaxation mechanisms. We will show that, using a pair of excitation pulses with well chosen characteristics, it is possible to clearly identify the excitation mechanism at work at intensities when the breakdown threshold is reached. By using this approach on Al2O3 samples, , we have obtained original results showing that the breakdown mechanisms is not involving an increase of the density of carrier, as expected from the avalanche model, but rather from an efficient energy deposition mechanism, by linear and non linear absorption of photons by the previously excited carriers.

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LMI-5 Nanoplamsonics and its applications

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Recent advances in nanofabrication and subwavelength optical characterisation have led to the development of a new area of nanophotonics concerned with routing and conditioning of optical signals in scalable and integratable devices. In this context, plasmonics which is dealing with surface electromagnetic excitations in metallic structures, may provide a great deal of flexibility in photonic integration in all-optical circuits since with surface plasmons the problem of light manipulation can be reduced from three to two dimensions. Surface plasmon polaritons, the electromagnetic excitations coupled to collective motion of conduction electrons near a metal surface, are emerging as a new optical information carrier that enables signal manipulation and processing on the subwavelength scale. Plasmonic metamaterials play crucial role in the development of novel paradigms such as negative refractive index engineering, superlensing and optical cloaking. A variety of passive plasmonic elements such as mirrors, lenses, waveguides, resonators, etc. have been demonstrated. The development of active plasmonic elements capable of controlling light on the nanoscale dimensions with external electronic or optical stimuli is on the agenda. Here we discuss general principles of nanoplasmonics and overview various realisations of plasmonic components for integrated nanophotonic circuits with particular emphasis on the active functionalities such all-optical and electro-optical modulation and amplification of plasmonic signals and dispersion management. These functionalities facilitate possible applications of plasmonics in telecommunication networks, integrated photonics and lab-ona-chip systems.

LMI-6 Dephasing of the localized surface plasmon polariton resonance of gold nanoparticles: Mechanisms and correlations on the fs-time scale

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The optical properties of noble metal nanoparticles differ from those of the bulk and are dominated by localized surface plasmon polariton resonances (LSPPRs). Recently, the quantitative determination of the damping mechanisms of LSPPRs has gained increasing interest. In particular the essential damping parameter A, which quantifies the influence of the reduced dimension of metal nanoparticles on the homogeneous broadening of an LSPPR, was in the focus of recent studies. The reason is that for a precise description of the optical properties of metal nanoparticles, the damping parameter A has to be included in the Drude part of the dielectric function. Although theoretically well understood, the exact value of A is still an open question and measurements to determine the parameter A are urgently needed.

For this purpose gold nanoparticles were prepared by deposition of thermal atoms followed by subsequent diffusion and nucleation, i.e., Volmer-Weber-growth. Thereafter, systematic measurements of the dephasing time T_2 were carried out as a function of nanoparticle size, photon energy, and substrate material and the respective A parameters have been extracted. The three most essential among the numerous results are: First, different damping parameters between A = 0.20 nm/fs and A = 0.40 nm/fs have been extracted for gold nanoparticles with LSPPRs located between $h\nu$ = 1.40 eV and $h\nu$ = 2.15 eV. Second, a threshold energy for the chemical interface damping has been observed, which cannot be explained within the classical picture and, third, an unexpected high damping for gold nanoparticles with an LSPPR at photon energies in the vicinity of $h\nu$ = 1.85 eV was measured, which could be related to band structure changes.

The fundamental impact of the presented results on the general understanding of LSPPRs and their damping, as well as consequences of these measurements on the applications of noble metal nanoparticles will be discussed.

LMI-7 Plasmonic photo-catalytic chemical reactor

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Applications of plasmonic effects for photo-catalytic chemical reactor will be discussed in this talk. Plasmonic near-field optical interactions are considered to be the novel methods to achieve photo-catalytic chemical process. The localized and enhanced electromagnetic field of plasmonic nanostructures provides ultrahigh spatial resolution hot spots for achieving photo-catalytic chemical process. Responses of the local plasmonic nano-structures of the nano photo-catalytic thin films are found to be the key of the photo-catalytic chemical reactor. Measurement and analysis of the photo-catalytic process happened in the plasmonic photo-chemical reactors clearly demonstrate better efficiency of some photo-catalytic chemical process such as the decomposition of the Methyl Orange to carbon dioxide and water. Interesting and promising applications of the plasmonic nanostructures on photo-catalytic chemical reactor are demonstrated.

LMI-10 Actual principles of the simulation of state-of-the-art technologies of laser processing of materials

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Here we present the results of mathematical, numerical, and experimental simulation of the processes of interaction between the laser radiation and metals in the technologies of gas-laser cutting of thick-sheet materials and laser gas-powder cladding at the production of coatings and 3D objects by the DMD (Direct Material Deposition) method.

The peculiarities of jet 3D flows of the working gases in narrow channels which are geometrically identical to keyholes have been studied. It is demonstrated that at the supersonic flows of the gas typical for the stainless steel cutting, occurring local regions of separation flows at the cut front result in the worse carry-away of the metal by the gas flow; it increases the roughness and worsens the surface quality. The gas flow inside the cut may be improved significantly if a supersonic underexpanded jet is formed at the channel input. Under study were the boundaries of the effective application of supersonic gas-dynamic nozzles in the laser cutting of thick-sheet metals. At the subsonic jet flows typical for the oxygen gas-laser cutting of low-carbon steel, a vortex flow was found inside the cut; this flow causes slagging of the cut bottom edge. Simulation and visualization methods were used to determine the operation modes of a double coaxial nozzle which permits to avoid the vortex.

The processes running inside the laser cut at the cutting of fusible metals by the low-power radiation were visualized in the laboratory conditions. New impressions of the processes running inside the keyhole have been gained; also the explanations are offered on the mechanisms of roughness and other surface defects occurring at the cutting of thick-sheet standard metals on the automate laser technological complex.

We propose a mathematical model of the volumetric laser-powder cladding. The submitted results concern the numerical simulation of multi-layer flows of shaping and working gases with the gas-jet transportation of powder particles into the laser spot on the substrate. The purpose of is to study the peculiarities of such flows to control and increase the effectiveness of the transportation and local supply of the powder.

The performed theoretical and experimental researches enabled to find the fundamental regularities of the physical parameters influence; as well, some technical recommendations were formulated on how to improve the quality and increase the effectiveness of the laser processing of metals.

LMI-11 Laser-Assisted Nanotechnology in Ferroelectrics: Nanodomain Engineering in Lithium Niobate and Lithium Tantalate

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Nanodomain engineering ("domain nanotechnology"), which represents the creation of nanodomain structures and control of the domain structure periods with precision in nanoscale has formulated recently and becomes one of the most important subjects of ferroelectric science and technology. The spatial modulation of electro-optic, photorefractive and nonlinear optical properties introduced by creation of the precise periodic domain structure allows to manufacture devices with upgraded performance. The ultimate interest is the creation of the nanodomain structures with capabilities for nonlinear optical devices. We demonstrate the achievements in nanodomain patterning in single crystals of lithium niobate (LN) and lithium tantalate (LT) family by pyroelectric field during fast heating/cooling cycle induced by UV and IR pulse laser irradiation.

Different scenarios of nanodomain structure evolution and the rules of the nanodomain chain growth and formation of the self-assembled structures have been singled out. The analysis of 3D images obtained by scanning laser confocal Raman microscopy and in situ observations of the domain growth by optical microscopy allows to extract the unique information about the nanodomain structure evolution.

The unified approach to domain kinetics based on the nucleation mechanism has been formulated and studied by computer simulation. The correlated nucleation and anisotropic domain growth have been taken into account. It was proved that the proper scenario of the domain kinetics can be chosen by variation of the screening ineffectiveness.

The proposed method can be used for manufacturing of periodic nano-scale domain structures thus opening the new page in photonic applications of periodically poled LN and LT.

The research was made possible in part by RFBR (08-02-99082-r-ofr, 10-02-96042-r-Ural-a, 10-02-00627-a); by the U.S. CRDF BRHE and FAE (PhD Awards RNP 2.2.2.3.16019/ Y5-P-05-10); by Federal Agency of Education (Contracts P870 and P 2127); by Federal Agency of Science and Innovation (Contracts 02.74011.0171 and 02.552.11.7069).

LMI-12 Plasmon-enhanced optics and magneto-optics via the near field of a nanowire

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Plasmonic excitations are of principal importance for enhancing the optic effects in nanocomposites with noble-metal constituents. In this work, we developed a theory for surface-plasmon-enhanced near-field optics and magneto-optics and the related scanning nanoscopy operating via a linear nanoprobe. As a model, the boundary between a sample with embedded nanolayer and vacuum with a linear nanoprobe is considered, both nanoobjects being placed nearby the interface and parallel to it. The nanoprobe is thought of as a noble-metal cylinder nanowire which possesses long-lived surface plasmons, and so does the plane surface of noble-metal sample. Using the electrodynamic Green function technique, a resonant polarization response of the complex «probe+image» is treated self-consistently within a multiple-scattering approximation. The magnetization-linear magneto-optic scattering events are classified in terms of TM (*p*-polarized) and TE (*s*-polarized) waves, the polarization planes of incident and scattered waves coinciding in the case of a linear probe. The problem of resonant near-field magneto-optics with a linear probe is solved analytically for a nanolayer magnetized along its normal (polar magneto-optic Kerr effect). In varying the in-surface distance between the probe and nanosized in-layer dielectric or magnetic domain, a scanning near-field nanoscopy in scattering mode is considered. Polarization, angle and spectroscopy characteristics of the magneto-optic scatterings due to a nanowire are shown to differ principally from those studied for a quasi-point probe [1]. Resonant enhancement of scattering efficiency due to coupling surface plasmons of a nanowire and a sample is estimated.

The work was partly supported by the RFBR, grant No. 10-02-00783.

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LMI-13 Ultrasonic characterization of high-pressure, high-temperature transient thermodynamic states of matter during nano- and femtosecond laser ablation

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We report on our recent ultrasonic studies of nanosecond and femtosecond laser ablation of solids. Such ultrasonic measurements of peak transient ablative plume/plasma pressures enable rather accurate thermodynamic characterization of corresponding extreme high-pressure, high-temperatures states of the laser-induced “warm dense matter”. In the former case, nanosecond-laser ablated graphite demonstrates sub-critical phase explosion below its critical thermodynamic point (the critical pressure is about 2200 atm), while at higher laser intensities (> 1 GW/cm^2) optical breakdown and sub-critical plasma ignition occurred providing plasma pressures up to 20 kbar. Similarly, the transient thermodynamic states involved in femtosecond laser ablation of graphite were identified by means of this ultrasonic technique, which may be a useful, non-invasive and informative supplementary tool in diagnostics of extreme high-pressure, high-temperature states of “warm dense matter”.

S1_01 Interferometry of femtosecond laser plasma filament

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Experimental results of interferometric pump-probe diagnostics of femtosecond laser-plasma filament are presented. Spatial distributions of electron density in section of plasma channel are obtained. Dependence of filament parameters from time and parameters of pump pulse are presented. Interferometric technique used in our experiments has phase sensitivity better than $2\pi/1000$ rad, which allows us to register electron concentrations about 10^{16} cm^{-3} in 100 mkm diameter filament.

PS1_02 Investigation of femtosecond excitation conditions of surface polarisation TM- and TE- cavity in model structures

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A physical model of electron subsystem evolution in wide band-gap dielectric and semiconductors under intensive photo-excitation is presented. Dynamics of optical properties modification during femtosecond light pulse is studied taking into account different types of emission mechanisms. It is shown that intensive photo-excitation of surface results in establishing conditions for excitation of both surface plasmon-polaritons (partly longitudinal TM electromagnetic waves) and waveguide modes (surface TE electromagnetic waves). The proposed model explains experimentally observed surface modification in above media formed under femtosecond laser pulse.

The consideration develops an approach to experiment arrangement for more accurate testing of the proposed model through measurement of properties of plasmon-polaritons and wavegude modes being excited in multilayer structures, which simulate spatial distribution of dielectric constant predicted by the model for femtosecond action. The presented experimental results include investigation of excitation conditions and characteristics of plasmon-polations and waveguides modes in the model multilayer structures.

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PS1_03 Exciton-exciton Interaction in scintillators: from simulation to correction of images

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One of the important qualities expected from scintillating materials is the proportionality of its response to the flux of incident particles. It is well known that this is not always the case, but, more surprisingly, one can find in the literature different decay times, depending upon the type of particles, or photons used to study the characteristics of the luminescence. For instance, in $CdWO_4$, many different values of decay time have been measured, ranging from less than 1µs to 15µs: it is sometimes described as bi-exponential, without any explanation.

We have used intense ultra-short VUV pulses to study the response of $CdWO_4$, in well defined excitation conditions. A systematic study as a function of excitation density allowed us to demonstrate that the change of luminescence decay time is connected to interaction between luminescence centers (self-trapped excitons). Furthermore, we could develop an analytical model which takes into account the competition between the usual exponential decay and the non radiative recombination arising from this interaction which is time and space dependent. This model fully describes the experimental measurements, and these effects of non proportionality and change in decay times are completely explained for the first time. Finally, we show that this model, we can process the time resolved images of luminescence, and de-convolute the interaction effects that leads to erroneous measurement of high intensity beam profile, as can be now currently delivered by the new generation of synchrotron or free electron laser beams.

PS1_04 Nanosecond laser ignition of plasma in gases and condensed matter

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In this work we use optical transmission and contact broadband photoacoustic techniques to study micro-scale optical breakdown of pure water by intense nanosecond 248-nm KrF laser pulses. The breakdown has been identified as a sharp transmission drop coinciding with appearance of unipolar compressive acoustic pulses, both indicating a threshold-like rise of local intrinsic absorption in the micrometer-scale laser focal volume. The acoustic pulses, which are much broader than the exciting laser pulse and show a strongly reduced far-field diffraction effect, result from breakdown-induced millimeter-sized steam bubbles. The acoustic pulse amplitudes exhibit a sub-linear pressure dependence on laser intensity characteristic of sub-critical electron-ion plasma and demonstrating the avalanche enhancement of two-photon ionization above the breakdown threshold until appearance of the critical plasma. In the critical plasma regime, where the transmission and the acoustic signals slowly vary as a function of laser intensity, the main acoustic pulse is preceded by nanosecond and sub-µs pre-pulses, where the first one represents a GPa-level plasma-driven shock wave and the second one adjacent to the main pulse appears due to weak submillimeter-long heating of water surrounding the hot plasma by its bremsstrahlung radiation, indicating significant dissociation of water molecules in the plasma. These experimental results enable us to identify and characterize the breakdown and succeeding sub- and critical plasma regimes in terms of their thresholds, plasma pressures and densities, and relate them to specific breakdown features, such as a rise of bremsstrahlung plasma emission, an appearance of a shock wave and a steam bubble, demonstrating significant dissociation of water molecules in the near-critical plasma and surrounding water.

Likewise, optical breakdown in dense, hot ablative plumes resulting from laser-induced phase explosions on graphite surfaces were also studied in this work. Removal rate, air shock and ablative recoil pressure parameters were measured as a function of laser intensity during nanosecond laser ablation of graphite. Surface vaporization of molten graphite at low intensities < 0.15 GW/cm^2 was observed to transform into its near-critical phase explosion (intense homogeneous boiling) at the threshold intensity ≈ 0.15 GW/cm^2 in the form of a drastic, correlated rise of removal rate, air shock and ablative recoil pressure magnitudes. Just above this threshold – at 0.25 GW/cm^2 - the explosive mass removal ended up with saturation of the removal rate, much slower increase of the air and recoil pressure magnitudes, and appearance of a visible surface plasma spark. In this regime, the measured far-field air shock pressure amplitude exhibits a sub-linear dependence on laser intensity, while the source plasma shock pressure demonstrates a sub-linear trend, both indicating the sub-critical character of the plasma. Against the expectations, in this regime the plasma recoil pressure increases versus laser intensity super-linearly, rather than sub-linearly, with the mentioned difference related to the intensity-dependent initial spatial plasma dimensions within the laser waist on the graphite surface and to the plasma formation time during the heating laser pulse (overall, the pressure source effect). The strict coincidence of the phase explosion, providing high (kbar) hydrodynamic pressures of ablation products, and the ignition of ablative laser plasma in the carbon plume may indicate the ablative pressure-dependent character of the underlying optical breakdown at the high plume pressures, initiating the plasma formation. The experimental data evidence that the spatiotemporal extension of the plasma in the laser plume and ambient air during the heating laser pulse is supported by fast lateral electron and radiative heat conduction (laser-supported combustion wave regime), rather than by propagation of a strong shock wave (laser-supported detonation wave regime).

PS1_05 Atomistic-continuum modeling of short pulse laser melting of semiconductors

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A computational technique for description of the kinetics of melting followed by short laser pulse excitation on semiconductors is developed on the example of Si. The technique is based on the coupling of two different approaches: the laser light absorption, electron-phonon nonequilibrium followed by a short laser pulse, and fast heat transport due to free carriers are described with self-consistent model [1] in continuum, while the description of laser-induced nonequilibrium phase transformation processes is accounted for at atomic level with the molecular dynamics method. The hybrid atomistic-continuum approach combining the advantages of the two different computational techniques has been already proven as an effective tool to study the kinetics of short pulse laser melting, spallation, and ablation of metal targets under strong laser-induced nonequilibrium conditions [2]. In this work the combined model is applied to investigate the effect of temperature and pressure interplay on the kinetics of laser melting of semiconductors.

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PS1_06 Investigations of laser-induced plasma evolution using Rayleigh and Thomson scattering

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Laser-induced gas breakdown has many practical applications such as laser plasma igniters, ultrafast shutters, high intensity X-rays sources or it can serve as a spectrochemical analysis method. The characteristics of the laser-induced plasmas (LIP) can be extremely variable in space and time which makes LIP diagnostics a very complex task.

The use of passive optical emission spectroscopy (OES) for LIP studies is relatively common though there exist some intrinsic flaws. OES does not allow accessing the LIP at times shorter than about 100 ns due to the strong continuum emission which covers all transient characteristic lines. Spatially, the measurements are merely based on photons escaping from outer (thus cooler) regions, whereas the core photons are potentially self-absorbed. Besides, OES carries no information about non- emitting species which constitute the majority at later stage of the LIP evolution. Two active laser based methods, eg. Thomson and Rayleigh scattering, can be used as complementary ones in studies of the LIP dynamics. Both of them are of good spatial and temporal resolution and can be simultaneously applied using the same laser configuration.

In this work Thomson scattering was used to study electron density and electron temperature evolution in laser-induced gas breakdown plasma while Rayleigh scattering was utilized to investigate the plasma shock wave.

The plasma was generated focusing nanosecond pulses of Nd:YAG laser at wavelengths of 1064 nm, 532 nm and 355 nm inside the vacuum chamber which was operated at atmospheric pressure in various noble (He, Ne, Ar, Kr) and molecular (N_2, air) gases. Another nanosecond Nd:YAG laser at 532 nm was illuminating the LIP and its scattered light was imaged onto the slit of spectrometer and the signal collected by the intensified CCD camera.

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PS1_07 The creation of nanoclusters and periodic structures at the surface of silicates by action of CO_2 laser radiation

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The photochemical transformations caused by continuous CO_2 laser radiation (10^5-10^6 W/cm^2) and pulsed CO_2 laser radiation (10^7 W/cm^2) at the surface of the silicates (quartz-SiO_2, nepheline - Na[$AlSiO_4$], rodonite - $CaMn_4$[Si_5O_{15}], zircon - $ZrSiO_4$ etc.) have been investigated. The laser radiation falls on the low frequency side of inhomogeneously broadened infrared absorption line of valent Si-O-Si vibrations in these materials. That provides effective absorption of laser radiation. The action of laser radiation on these silicates results in the selective sublimation of silicon oxides and the enrichment of surface by the rest elements [1, 2].

The action of pulsed CO_2 laser radiation (10^7 W/cm^2) at the surface of this silicates lead as to increase of metal atoms content as to the creation of different kind of nanoclusters, such as Me-Me, Me-Si and Si-Si at the irradiated surface, where «Me» means the metal atoms. The appearance of photo reduced processes and nanoclusters formation has been confirmed by means of different spectroscopic and microscopic method of investigation of irradiated surface. The X-ray emission microprobe analyses, photoluminescence analysis as well as optical microscopic and atom fires microscopic analysis of irradiated surface have been used.

The photoluminescence spectra of laser irradiated zircon reveal the intensive line of complete form at the region of 400 nm. The specific form of spectra which contain zero-phonon narrow line ($\Delta\lambda \sim 10$ nm) at 360 nm and wide background confirms the formation of silicon nanoclusters at surface of samples. The appearance of superluminescence at the 360 nm also shows that the nanoclusters at the irradiated surface have been created.

The atomic force microscopic (AFM) images of irradiated surface of silicates show the appearance of nanoclusters with size approximately of 100-150 nanometers in dependence of type of silicate. The threshold of laser fluency for such nanoclusters formation has value close to 7-10 J/cm^2.

The image of laser spot at the surface made by means of high resolution optical microscope revealed the appearance of periodic structure at the irradiated surface with the period length close to wave length of laser irradiation.

We believe that all observed phenomena are connected with the selective breaking of the strong covalent Si-O bonds induced by resonant laser radiation and photo reduced processes in oxide matters. These processes lead also to creation of metallic and silicon nanoclusters and periodic structures at the surface of irradiated silicates. That gives the possibility to make the materials with novel properties applicable in integral optics, photonics, and other fields.

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PS1_08 Effect of electron emission on solids heating by femtosecond laser pulse

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The rapid development of femtosecond lasers over the last decade has stimulated study of ultra-short laser pulse interaction of with matter. However, theoretical and experimental investigations meets some difficulties, and computer simulation helps to avoid it. The aim of this work is calculation of temperature dynamics during interaction of short laser pulse with a solid body with the account for electron emission significantly affecting the temperature: the electrons take away a portion of energy stored in the electron gas and thus diminish the lattice heating.

The two-temperature model is used to calculate the electron and lattice temperature since laser pulse duration is less then electron-lattice relaxation time. Laser energy is absorbed by free electrons and then transferred to ions due to collisions, so the crystal lattice heating occurs after the end of the pulse.

During laser heating of metals, free electrons diffuse from the depth of the material to its surface, and then their emission occurs. Emitted "hot" electrons carry away portion of energy stored in the electronic subsystem thereby reducing its temperature, and eventually the temperature of the whole body. The change in electron concentration in the surface region leads to a change in optical characteristics of the material. The emissive layer thickness is limited by the electron mean free path and also depends on the electron concentration and the emission coefficient.

The temperature of the material during laser heating by femtosecond pulse can be calculated by solving the system consisting of heat-conduction equations for electrons and phonons (lattice) and the equation describing time variation of the electron concentration. Heat-conduction equations describe transport of energy inside the material and electron diffusion, their emission from the surface. Variation in the optical properties of metal are taken into account when calculating the free carrier concentration dynamics.

For the numerical solution of the heat conduction equation, which is a non-stationary differential equation in partial derivatives, the finite difference method is applied.

The developed simulation program in Delphi allows to vary the source data and thus explore the effects of laser radiation on metals at various conditions.

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PS1_09 A Novel Low-switching power (45 mW) optical bistability devise using Fiber Bragg Grating pair separated by a ytterbium-doped fiber

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A Novel Low-switching power (45 mW) optical bistability devise(OBD),using Fiber Bragg Grating pair separated by a ytterbium-doped fiber was proposed, which was to form a nonlinear Fabry-Perot cavity. The principle of this new OBD is described using the method of transfer matrix, and the two groups of transmitted and reflected optical bistability loops under different parameters are investigated symmetrically. Compared with the single fiber bragg grating switching, whose switching power is greater than 2kW, this new device has evident merits in reducing the switching power to less than 45mW.

PS1_10 Dynamics of picosecond pulsed laser ablation of silicon targets

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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.

PS1_11 Nanosecond laser ablation of Si: diagnostics and simulation

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Nanosecond laser ablation of silicon has been studied by optical pyrometry and numerical simulation methods. Crystalline Si wafers were irradiated with ruby laser single pulses. Pulse duration was 80 ns, irradiation energy density changed in the range of 1.8 ..9.5 J/cm^2. Thermal radiation of heated zone and products of ablation were detected by a pyrometry sensor. The dependence of thermal radiation intensity on laser energy density was investigated. Under the conditions of laser ablation (ablation threshold is ~ 7 J/cm^2) the drastic increase in thermal radiation intensity was observed.

Laser – induced processes were studied on the basis of a model developed. Thermal processes in samples were simulated with the use of heat conduction equation taking into account the formation of melted layer at the surface. The system of gas-dynamic one-dimensional equations in Euler forms was numerically calculated to describe the spreading and thermal ionization of evaporation products. The coefficient of light absorption in a gas due to photoionization and bremsstrahlung effect was determined on the basis of Kramers-Unsöld formular. The boundary condition for the heat conduction equation was specified by the necessity of the energy balance at the interface between condensed and gas phases. The mass balance condition at this interface defines the velocity of the evaporation front. Both of these conditions couple heat transfer and gas-dynamic equations. Gas-dynamic boundary conditions were formulated taking into account jumps of temperature and other hydrodynamic parameters in Knudsen layer. Energy dissipation due to bremsstrahlung was considered. The Hertz-Knudsen expression was used for evaporation rates.

We obtained numerical data about dynamics of pressure and temperature in evaporation cloud and ablation rates. The calculated values were compared with available experimental data. The conditions of nanoparticle formation due to condensation in gas phase were discussed.

PS1_12 Laser bleaching of Ti^{3+} centers in TiO_2 hybrid material

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Organic-inorganic hybrid materials based on TiO_2 gels [1] are promising for photonics applications [2]. They demonstrate high photosensitivity at the wavelength of the third harmonic of a Nd: YAG laser [3]. Irradiation at this wavelength results in formation of a broad absorption band from near UV to near IR in initially optically transparent material. This absorption is attributed to UV induced generation of Ti^{3+} centers [4]. The time of life of these centers at daylight conditions at the room temperature in air could be as long as several months. For applications, it is important to control the number density of Ti^{3+} centers. In the present communication, we study the laser induced bleaching of these centers. Earlier [3], the photochemical transition $Ti^{3+} \rightarrow Ti^{4+}$ was observed when irradiating the samples possessing Ti^{3+} centers at short enough wavelengths. The red border of this transition was measured to be about 450-500nm [3]. It is also known that molecular oxygen, diffusing through the sample, can bleach Ti^{3+} center.

We observe the bleaching effect when irradiating the hybrid materials by lasers at the wavelengths much longer than the photochemical red border. In all these cases, the bleaching was accompanied by laser heating. The examination of the dark bleaching in a furnace in air environment allows us to estimate the activation energy of this process to be 60-80 kJ/Mol. In order to study the effect of oxygen, we carry out the irradiation of 1mm thick hybrid sample in a vacuum cell with the quartz windows by the third harmonic of a Nd:YAG laser to form Ti^{3+} centers and afterwards, by the diode laser at the wavelength 660nm to annihilate them. The bleaching was examined by monitoring of the transmission of the diode laser radiation. Comparison of bleaching kinetics in vacuum (10^{-2} torr) and in air shows that the initial bleaching rate in vacuum is larger than that in air but after approximately two times increase of diode laser transmission signal the bleaching in air outruns the bleaching in vacuum. The simple model addressing both the pure thermal Ti^{3+} annihilation and the oxidation fits well to the experimental data.

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PS1_13 Transient electronic effects affecting photo-excitation and energy deposition of femtosecond laser pulses in semiconductors (GaAs)

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In this work femtosecond laser photo-excitation of GaAs is studied experimentally and numerically. The transient plasma densities photo-generated during the pumping IR fs-laser pulses along with ablation thresholds were evaluated using experimental data of time-resolved reflectivity measurements of transient bandgap shifts.

Theoretical modeling employing quantum kinetic formalism based on a generalized Boltzmann-type equation, including one/multi-photon photo-excitation, joule heating and free-carrier absorption, interband excitation, impact ionization, Auger recombination of electron-hole plasma, thermal exchange with the lattice, etc. is performed.

For the first time the effect of enhancement of ionization by transient bandgap renormalization (BGR) is considered both experimentally and theoretically. The energy spectra of the electron distribution function and the time dependence of the electron density are calculated and the key role of BGR in the transient electron-hole plasma dynamics is pointed out.

PS1_14 On the self-similar solution of laser ablated plasma expansion

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The expansion of plasma plume produced by a laser ablation is investigated using the self-similar approach. Based on the fluid model and the quasi-neutral assumption, the one dimensional expansion of an either partially or globally charged collisionless plasma is studied in the presence of electrons in thermal equilibrium. The uniqueness of the self-similar solution is questioned. Two different self-similar transformations for the ion density are proposed, one commonly used for free plasma expansion and the other corresponds to the expansion with diffusion. The density profiles and the self-similar parameter limit, corresponding to the end of the expansion, are found to be strongly affected by the transformation. A comparison is made with experimental results of a plasma produced by a nanosecond laser pulse interacting with a metallic titanium target in a vacuum. The time dependent solution obtained by Lagrangian approach is pointed out for the case of a spatially uniform electron temperature.

PS1_15 Selective Ablation of Xe on Silicon Surfaces: MD Simulation and Experimental Laser Patterning

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The ablation process during laser induced thermal desorption (LITD) of Xe adsorbed on Si(100) surface was studied employing molecular dynamics (MD) simulations. 5nsec long laser pulse at λ=337nm was applied to a Xe slabs at thicknesses of 16, 32 and 40ML. Evaporative and explosive ablation thresholds were reached at absorbed laser power of 12 and 16MW/cm^2 which corresponds to surface temperature rise of 500 and 658K, respectively. Selective ablation was studied, where only a fraction of the lateral dimension of the computation cell was actually ablated. Due to effective lateral dissipation among the Xe layers, the ablation threshold shifted to higher laser power as the fraction of heated area shrinks. Heated fraction (HF) less than 10% results in practically no ablation at laser power below substrate damage threshold (44MW/cm^2, exceeding surface melting at 1683K). Experimental assessments of the ablation threshold were performed as a test of the MD predictions. A 10nsec Nd:YAG laser pulse operating at λ=532nm was employed. It was found that for 80 and 160ML Xe thickness, full ablation was reached at laser power of 7.3 and 9.1MW/cm^2 which corresponds to surface temperature rise of 461 and 563K respectively. Line-edge resulting from laser induce desorption- coverage grating formation followed by metallic lift-off experiments were compared to the MD simulations of selective ablation, revealing a remarkable similarity.

PS1_16 Investigation of fs-laser-induced Phase transformations and atomic mixing in Au film – Cu substrate system

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Laser ablation and processing is known to change material properties, e.g. material hardening or alloying of heterogeneous samples can be achieved in this way. This has been experimentally demonstrated for CW and nanosecond pulsed lasers long ago e.g. [1-2]. Application of femtosecond lasers is a promising extension of this technique since this may be a key for producing alloys of immiscible compounds due to very rapid melting and solidification processes. Femtosecond laser pulses are absorbed in a thin layer and trigger quick sample heating with heating rate of approximately 10^{14} K/s [3]. A shallow layer of metal melt appears and mixing of the metals constituting the sample starts. After that a very rapid (with cooling rates of more than 10^{12} K/s) resolidification occurs under such conditions. Such a rapid quenching allows supposing that even immiscible solids will not separate and exotic alloys may be produced.

On the other hand such a quick melting and solidification results in a very short time window for mixing and the energy confinement of laser energy reduces the depth of the melt layer and limits laser fluence at which alloying happens without simultaneous ablation. This raises the question if surface alloying is really feasible by femtosecon laser processing.

Here, we present experimental and numerical study of surface metal mixing of Au/ Cu bimetal layers exposed to fs-laser pulses. Depth profiles are studied by means of X-ray photoelectron spectroscopy (XPS). We demonstrate formation of an internal, alloyed interface layer in a certain window of laser energies. As a second control parameter the number of shots per area is indentified controlling the depth of the mixing process. The results are compared with numerical TTM simulations.

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PS1_17 Features of modeling of pulsed laser action on condensed media

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Pulsed laser action is characterized by occurrence of fast phase transitions of the first order which velocity increases with decrease of duration and increase of intensity. High velocity of phase transformations creates conditions for the strong non-equilibrium of the process appearing in the form of metastable strongly overheated states during melting and strongly overcooled during solidification.

Mathematical modeling of nonequilibrium phase transitions demands explicit tracking of interphase boundaries which is a difficult computing problem.

Mathematical modeling with explicit tracking of interphase boundaries has allowed to determine the typical values of the overheating of solid at various duration of laser influence. In a nanosecond range the overheating of a solid is characterized by tens of degrees, and in picosecond range by thousands of degrees.

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PS1_18 Mathematical modeling of dynamics of phase transitions in two-dimensional statements

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Application of a method of dynamic adaptation for the solution of two-front Stefan problem in two-dimensional region with explicit tracking of interphase boundaries is considered. The method is based on the idea of dynamic adaptation of computational grid carried out by means of transformation to arbitrary nonstationary coordinate system.

The results of computing experiment for modeling of action of the concentrated energy flow on metals are presented.

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PS1_19 Simulation of Laser-Induced Phase Transformations in Semiconductors

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This work is devoted to discussion of three different approaches to the problem of modeling laser-induced processes in semiconductor materials. We restrict our study to the crystal-liquid phase transformation. Usually, the classical Stefan problem or a Stefan-like moving boundary problem is solved for these purposes. In the first case, the Stefan conditions are set at the interface. It is supposed that the temperature at the interface is constant and is equal to the equilibrium thermodynamic melting temperature, and the velocity of the moving interface is determined from the heat balance equation. However, under laser heating by short pulses (nanosecond or less duration) the phase transitions take place in substantially non-equilibrium conditions. In this case, the interface temperature and velocity are connected by an interface response function (Stefan-like problem). Another possibility here is to use the approach in which the processes of the new phase formation are described on the basis of the nucleation theory (kinetic approach).

The numerical solutions of one-dimensional nonlinear heat transfer equation with different interface conditions have been analyzed. In this analysis, particular attention was given to the study of the influence of nonlinear interface conditions since it is these conditions namely that have influence on the basic parameters of the processes that can be determined experimentally: temperature distribution and melt duration.

We carried out a comparison of the results obtained by the algorithms based on: 1. the classical Stefan problem; 2. a non-equilibrium model where the Wilson-Frenkel response function was used; 3. a kinetic model where the kinetics of nucleation is described on the basis of solving Kolmogorov's equation. The experimental data obtained on the melt duration and peak surface temperature under irradiation by ruby laser of Si and GaAs crystals have been compared with the results of our modeling in the three settings of problem. Properties and application conditions for the models considered have been analyzed.

PS1_20 4D relief reconstruction and analyze for task of laser matter interaction

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In the given work the experimental complex for visualization of area of laser radiation action on a material with an opportunity of a three-dimensional relief reconstruction of a surface is developed. Observation of a surface is carried out by the "laser monitor". The obtained images are registered on high-speed CCD-SMOS-camera. The developed technique allows to obtain images of area in the size from 50 μm up to 1mm with the resolution up to 3 μm. Speed of registration of dynamic images depends on the size of area of observation and will change from 500 up to 5000 frame per second.

The method of reconstruction of a three-dimensional relief of a surface on base one dynamic optical image is based on the law of reflection of radiation from a homogenous surface. In such approach it is possible to assume, that the initial surface will consist of some number of "simple" elements - "microplatform". As a first approximation brightness of separate pixel of the image depends on orientation of "microplatform" in space. The reconstruction a three-dimensional relief of a surface is possible with using of a set rules of an arrangement of "microplatforms" relative each other.

In now time the processes of laser radiation action on a surface of metals and carbons materials are investigated with use of the given method. For determination change of properties of three-dimensional reliefs of a surface during action, with use of methods of statistics of Hurst. The coefficient of correlation of heights in the area of action are calculated. It is shown, that the developed method allows to determine a conditions of a surfaces and to classify it into degrees of relative orderliness.

PS1_21 Variation of size distribution of NPs generated by laser ablation of a gold target in liquid with time-delayed femtosecond pulses

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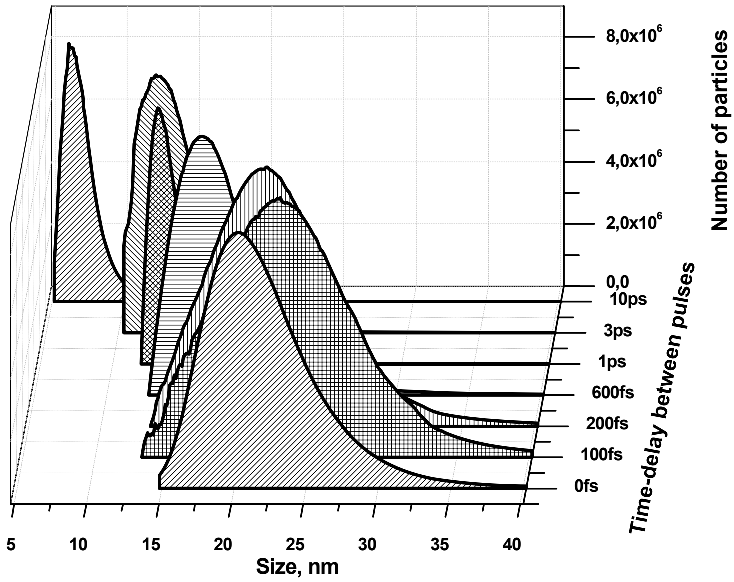
The influence of time - delay between femtosecond pulses on the properties of nanoparticles obtained via laser ablation of gold target in ethanol was studied. The morphology and optical properties of obtained nanoparticles were characterized using high resolution transmission electron microscopy and UV-Vis absorption spectroscopy respectively. These analyses confirmed that colloidal solutions contain Au nanoparticles of spherical shape.

The size distribution of nanoparticles was measured with the aid of a CPS centrifuge. It was noticed that the changes of time delay between pulses lead to the changes in size distribution, plasmon resonance position and speed of nanoparticles generation.



The family of normalized size distribution functions of Au NPs versus the time-delays between femtosecond laser pulses.

PS1_22 Mass quadrupole spectrometry and time-of-flight characterization of ZnO laser-generated plasma

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We have carried out a study of the laser ablation of a ZnO target, in vacuum, by using 3 ns Nd:YAG laser radiation at 532 nm wavelength.

Mass quadrupole spectrometry measurements allowed estimation of the atomic and molecular species emitted from the plasma. Measurements of ablation yields, crater profiles and fast CCD plasma imaging permitted to evaluate the plasma density.

Time-of-flight (TOF) measurements have been employed to monitor the ion emission from the plasma by using a special ion collector placed along the normal to the target surface. Ions show high directivity, charge state, current and energy. A Coulomb-Boltzmann-shifted ion energy distributions is obtained depending on their charge state.

The plasma temperature was evaluated by the ion energy distributions of the experimental data. A special regard is given to the ion acceleration process occurring inside the plasma, due to the high electrical field generated inside the non-equilibrium plasma.

ZnO plasma characterization and thin film deposition are correlated and discussed.

PS1_23 Femtosecond laser ablation and nano-structuring of Ti_6Al_4V

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Because of its excellent combination of mechanical and chemical stability properties, Ti_6Al_4V alloy is one of the mostly used titanium alloys in aeronautical and biomedical applications. Research of surface modifications of the material by laser beams, especially with ultra-short pulses, is a field of research with significant impact on its application in nano- technology and bio-mechanics. In this presentation, the femtosecond laser ablation of $Ti_6A_{l4}V$ will be reported. During these investigations the femtosecond Ti:sapphire laser (Clark CPA-2101) with variable pulse energy in interval from 5 to 250 μJ was applied. Experiment was conducted in air by a focused laser beam with 775 wavelength, pulse duration of 200 fs and at a repetition rate of 2 kHz. The surface of the sample was irradiated with the count of pulses varying from 1 to 200 at constant pulse energy. Two important parameters as the laser ablation threshold fluence (Fth) and the incubation factor (ξ) of the material were calculated. We compared them with the same parameters obtained in our experiments with the other titanium based materials. Besides ablation, the appearance of laser induced periodical nano-structures and micro-/nano- particles were registered and analyzed. Various analytical techniques were used for characterization of the samples before and after laser irradiation. The phase composition and crystallite structure of the alloy were determined by X-ray diffractometer. Surface morphology was monitored by optical (OM) and scanning electron (SEM) microscope. The SEM was coupled to an energy dispersive analyzer (EDX) for determining surface composition. Profilometer was used to estimate ablation rate and periodicity of laser induced periodical structures. Finally, the results were compared with our previous experimental results obtained with longer picoseconds laser pulses.

PS1_24 Analysis of Internal Crack Propagation in Silicon due to Permeable Pulse Laser Irradiation — Study on Processing Mechanism of Stealth Dicing

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Stealth dicing (SD) is an innovative dicing method developed by Hamamatsu Photonics K.K. In the SD, a permeable nanosecond laser is focused inside a silicon wafer and scanned horizontally. A thermal shock wave is propagated every pulse toward the side to which the laser is irradiated, then a

high dislocation density layer is formed inside a wafer after the thermal shock wave propagation. In our previous study, it was supposed that an internal crack whose initiation is a dislocation is propagated when the thermal shock wave by the next pulse overlaps with this layer partially. In the experimental result, the trace that a crack is progressed gradually step by step was observed. In this study, the possibility of internal crack propagation by laser pulses was investigated. A two-dimensional thermal stress analysis based on the linear fracture mechanics was conducted using the stress distribution obtained by the axisymmetric thermal stress analysis. The internal crack propagation was analyzed by calculating the stress intensity factor at the crack tips and comparing with a threshold of that. The results mainly obtained are summarized as follows: When the thermal shock wave of the next pulse propagates in part of a high dislocation density region formed by last pulse, it is considered that dislocation becomes a nucleus, and a crack propagates. It has been proposed based on a heat transfer analysis result previously presented. The validity of this hypothesis was supported by a crack propagation analysis. Also it was clarified that the internal crack is propagated by at least two pulses.

PS1_25 Study of surface chemical reactions induced by molecules electronically excited in the gas phase

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In a new experimental approach [1], based on application of total internal reflection phenomenon on an insulator surface, we localize laser photoexcitation in a narrow boundary gas layer just above the interface. Majority of the excited molecules can reach the surface before the relaxation. Approaching the surface, the electronically excited molecules will naturally experience strong acceleration and alignment. The energy of the excitation is likely to be converted to kinetic motion along the reaction coordinate for chemical adsorption. While recombination chemical reactions in a gas phase require participation of a third body, this strong limitation on the reaction rates is removed upon interaction with a surface.

The experiments are performed at high gas pressures, so that dense fluxes of the excited reagents can be readily produced. Products of chemical adsorption and/or chemical reactions induced within adsorbates are aggregated on the surface and observed by light scattering. Results of evanescent wave illumination are compared with those for laser beam propagating trough the interface. We will demonstrate how pressure and spectral dependencies of the chemical outcomes, polarization of the light and interference of two laser beams inducing the reaction can be used to distinguish the new process we try to investigate from chemical reactions induced by photoexcitation within adsorbed molecules and/or gas phase photolysis. High quantum yields for photochemical transformations are observed for some chemical substances (NO, SO_2). The experimental results may indicate an opening for investigations of a new, previously unexplored domain in photochemistry. The phenomenon observed and the experimental technique developed may have important perspectives for technological applications.

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PS1_26 Photo-ionization and modification of nanoparticles on transparent substrates by ultrashort laser pulses

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The objective of this combined experimental and theoretical research is to study the dynamics and mechanisms of nanoparticle interactions with ultrashort laser pulses and related modifications of substrate surface. We studied experimentally the response of metal (gold), dielectric (SiO_2) and dielectric with metal coating (about 30 nm thick) spherical particles deposited on glass substrate. Size of the particles varies from 20 to 200 nm. Density of the particles varies from very low (average inter-particle distance 100 nm) to high (with average inter-particle distance less than few nm). The nanoparticle assemblies and the corresponding empty substrate surfaces are irradiated with single 130-fs laser pulses at 775-nm wavelength and different levels of laser fluence (from 0.005 J/cm^2 to 1.5 J/cm^2). Large diameter of laser spot (0.5-2 mm) provides gradient variations of laser intensity over the spot and allows observing different laser-nanoparticle interactions. The interactions vary from total ablation of the particles (in the areas close to the center of the laser spot) to gentle modification of particle size and shape and totally non-destructive interactions. The removed particles frequently form specific sub-micrometer-size pits on the substrate surface at their locations. Special attention was paid to the processes of laser-induced ionization of the nanoparticles resulting in charging them positively.

The experimental study is supported by simulations of the nanoparticle interactions with high-intensity ultrashort laser pulse. The simulation employs specific modification of the molecular dynamics approach [1-3] applied to model the processes of non-thermal particle ablation following laser-induced electron emission. This technique delivers various characteristics of the ablation flow from a single nanoparticle including energy and speed distribution of emitted ions, variations of particle size and overall dynamics of its ablation. The considered geometry includes single isolated particle as well a single particle on a flat substrate that corresponds to the realistic experimental conditions. The simulations confirm existence of the distinct regimes of laser-nanoparticle interactions depending on laser intensity. In particular, implantation of ions departing from the nanoparticles towards the substrate is predicted.

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PS1_27 Coherent phonons and nonequilibrium transient state of fs-laser excited bismuth

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Observation of coherent displacement and atomic vibrations, which appear as oscillation of reflected light after excitation by an ultrashort laser pulse, gives access to study lattice dynamics in solids.1,2 We present here the results of time-resolved dual-probe reflectivity measurements at 800 nm of bismuth after the excitation by femtosecond pulses. The dielectric constant was recovered from the time-resolved reflectivities of two optical probes measured with an accuracy of ΔR = 10-5 with 40 fs time resolution (Fig.1).

The value of the complex dielectric constant of the transient state ε_{tr} = 17.9±0.2 was found to be out of the solid-liquid transition gap between the values of ε_{sol} = 22.4 and ε_{liq} = 30.9. This suggests that the excitation of coherent oscillations in Bi followed by a transition into a quasi-steady state, which lasts ~4 ns before recovering back to the solid Bi. The transient state does not lead to a disordered state of melting phase even at the absorbed excitation laser fluence as high as 4 mJ/cm2, supplying the energy into the skin layer more than twice above the energy density required for an equilibrium melting.

The transient state is characterised by lower conductivity, lower electron-phonon collision rate, and has higher electron effective mass than that in a solid. The data evidence that the transient state has less metallic character than both solid and liquid states of bismuth.

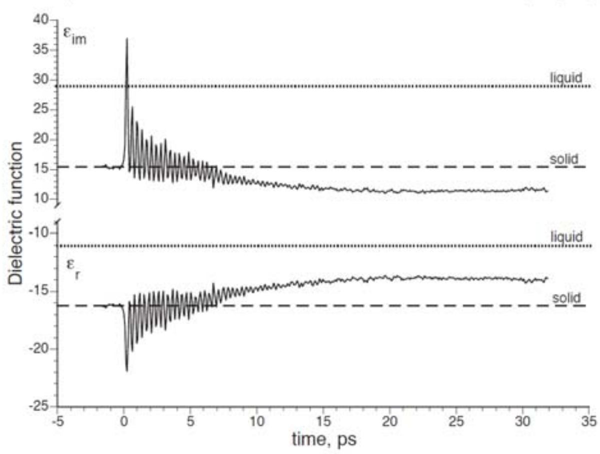

Fig. 1. Dynamics of real (bottom) and imaginary (top) parts of the dielectric function. Values for solid (dashed line) and liquid (dotted line) equilibrium states are also shown.

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PS1_28 Modeling of propagation of optoacoustic signals generated by laser radiation in metals and semiconductors

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The optoacoustic signal transformation in two materials is modeled during laser heating. The role of phase transformations in formation of the optoacoustic signal is investigated. Density in metal (Al) at the moment of phase transition "solid-liquid" is observed to step down, as well as at the majority of metals. In the semiconductor (Si) - to step up. The considered conditions were close to experimental data with laser impulses of the identical duration of $3*10^{-9}$ s and intensity varied within range 10^{8}-10^{11} W/cm^2.

Modeling has shown:

1. The melting of Silicon occurs at smaller laser intensity, than melting of aluminum, despite greater temperature of melting.
2. The signal characterizing the phase of heating, has greater duration in the aluminum than in the silicon. It is related to a smaller absorbing ability of aluminum.
3. Pressure jump which is related to melting, is positive at aluminum (dp> 0) and is negative at silicon (dp <0).
4. The optoacoustic signal which characterizes evaporation appears in silicon at greater laser energy. It is caused by greater heat of melting and evaporation in the silicon.

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PS1_29 Properties of a phonon and electronic Fermi gas at arbitrary temperature

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Integrals of Fermi-Dirac are used to define and present temperature dependences of the basic kinetic, thermophysical and thermodynamic properties of a phonon and electronic Fermi gas of metals at arbitrary temperatures Te and Tph. The calculation is performed on an example of the study of physical properties of two metals: monovalent copper and trivalent aluminum. The thermophysical properties of both subsystems are presented in the form of exact formulas and simple approximating functions with small number of input parameters. Temperature dependences of phonon gas are expressed through metal macroscopic parameters.

ACKNOWLEDGMENTS: This study was supported by RFBR grants: N10-07-00246-a, N 10-07-00246-ofi-m.

PS1_30 Diode pumped Er:YLF laser with tunable lasing spectrum

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Tuning the laser spectrum in 3 μm region can greatly change the parameters of laser radiation and biological tissues interaction what is very promising for medical applications. This paper presents the results of theoretical and experimental investigations of spectral and energy characteristics of diode pumped Er:YLF lasing in 3 μm region.

The theoretical model of Er:YLR multiwave lasing was developed. The model predicted sequentially change of lasing wavelength from shortest to longest during lasing pulse. For the nonselective resonator, pump power densities up to 2 kW/cm^2 and pump pulse durations more than 1.5 ms model predicted Er:YLF lasing on four wavelengths: 2.66, 2.71, 2.81 and 2.84 μm. For the pulse-periodical mode the theory predicted strong dependence of lasing spectrum from frequency and duration of pumping pulses: lasing on wavelengths 2.66 um and 2.71 μm stopped with increasing pumping pulses frequency and duration.

The most of theoretical results were proved experimentally. For the diode pumped Er:YLF laser with nonselective mirrors sequential lasing on wavelengths 2.66, 2.71, 2.81 and 2.84 μm was observed. The pump power was 340 W and current pulse duration was 2 ms. Pulse-periodical mode was investigated with pumping pulse duration 250 us when 2.84 um lasing were absent. With increasing of pulse repetition rate the lasing delay on wavelength 2.66 um increase and for repetition rates higher than 45 Hz lasing on that wavelength discontinued. When repetition rates were higher than 50 Hz lasing on wavelength 2.71 also discontinued and lasing was being gone only on wavelength 2.81 μm. For low pulse repetition rates (0-30 Hz) and pump pulse durations (30-100 μs) generation only on wavelength 2.66 um was observed. The investigated effects can be used for tuning laser spectrum without any additional devises in resonator or on the laser output.

PS1_31 Mathematical modeling of femtosecond laser action on metals

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Femtosecond laser action on metals is characterised by high velocities of a nonequilibrium heating and phase transformations. Results of modeling of the nonequilibrium phenomena in 3-valence Al and monovalent Cu are compared. In copper the appreciable separation of electron and phonon temperatures is observed at duration of a laser impulse $\tau \sim 1$ nanoseconds, and in aluminium - at duration of 0.1ns. The velocity of distribution of phase front of melting in both metals reaches velocity of sound during femtosecond laser action. This phenomenon accompanied by an overheat $10^2 - 10^4$ K of a solid phase.

ACKNOWLEDGMENTS: This study was supported by RFBR grants: №10-07-00246-a, № 10-07-00246-ofi-m.

PS1_32 Femtosecond laser micro-scale writing in bulk dielectrics for photonics and medical applications

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Structural modification of PMMA in the form of contrast micron-sized channels was produced at tight focusing of femtosecond laser pulses with its energy-dependent dimensions and fabrication mechanism characterized by optical microscopy and optoacoustic spectroscopy, respectively.

Point-by-point multi-shot femtosecond laser writing of micro-scale linear damage tracks and symbolic logo information was performed inside single-crystal natural diamonds in transversal writing geometry at variable basic operational parameters (numerical aperture of focusing optics, depth of focusing inside samples and peak laser pulse powers). The filamentary character of femtosecond laser writing of buried damage tracks in this material at the supercritical peak laser powers was revealed.

Micro-incisions were fabricated inside human cornea and sclera in vitro using single femtosecond laser pulses. In these experiments sclera was for the first time pre-cleared by means of a biocompatible and clinically safe (non-toxic) natural agent (refractive-index matching 40%-glucose solution in water), partially replacing water in the tissue comparing to its severe dehydration by previously used agents. Basic operational parameters of the corresponding microsurgical procedures are reported.

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PS1_33 Nonlinear optics of metal nanoclusters in dielectric matrices

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It is well known that many dielectrics have nonlinear optical properties. But this optics associated with nonlinear polarizability of atoms and moleculaes constracted these dielectrics. During the last years the new mechanism of nonlinearity in nanoplasma was discovered both theoretically and by experiment. The electron plasma in metal nanoparticles driven by laser field will oscillete. In the process of oscillation a small amount of electron plasma will be spillet out of ion core. The interaction of these electrons with core differs from inner electtrons. Therefore the oscllations are slightly nonlinear. As a resalt the harmonics of pump wave may be emitted. The theory and experiment existed will be presented and discssed.

PS1_34 Human hard tooth tissue cavities formation by the YAG: Er laser radiation with various spatial distributions

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In the literature devoted to the investigation of the laser interaction with hard tooth tissue, the multimode erbium laser systems with the size of a spot in a treatment area of 300-1000 microns are most often used. However, the multimode laser radiation does not allow the full realization of unique ability of the laser to form the extremely small light spots. The single-mode lasers with the Gaussian spatial distribution are used for creation of small light spots. In a number of cases the single-mode laser radiation can be focused in a beam comparable with wavelength of the laser radiation. Exactly the spatial distribution defines the angular divergence of a beam and accordingly the minimum size of a spot in the forming system focal plane. It is obvious, that the treatment process is especially locally and safely, when the spot size and divergence are less.

In the present paper a hard tooth tissue was treated *in vitro* by either the impact single-mode or multimode YAG: Er laser radiation. The spatial distribution of the single-mode and multimode YAG: Er laser was measured. The volume, diameter, depth, aspect ratio of the created cavities, and speeds of enamel and dentine removal by the single-mode and multimode radiation were measured. Influence of the focal plane position of forming optics concerning a hard tooth tissue surface on the parameters mentioned above was discussed.

It has been shown, that the aspect ratio of the cavities created by the single-mode YAG: Er laser radiation exceeds the aspect ratio of the cavities created by the multimode radiation of this laser. The focal plane optimum position of the forming optics concerning a hard tooth tissue surface was defined. The modeling explaining the received results was carried out.

LAMN-1 Fundamental studies of heat modification inside glasses by repeated irradiation with ultrashort laser pulses

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Femtosecond lasers have been used for microfabrication of tools in most transparent materials [1-4]. Recently, the heat accumulation during high-repetition fs laser irradiation has attracted considerable attention, because it is useful for fabricating low-loss optical waveguide [3] and for inducing precipitation of functional crystal [4] or micromodification of elemental distribution. The induced structure with heat modification has two circular boundaries; the inner one should be the boundary between the melting and non-melting material, but the origin of the outermost boundary has not been elucidated. In this study, we investigated the heat modification inside a sodalime glass by 250 kHz fs laser irradiation, and determined the temperature distribution during the exposure of laser pulses, the threshold temperature of the heat modification and the amount of generated thermal energy. [1]

The important findings in this study are (1) the threshold temperature depended on the laser exposure time, (2) the heat modification should be the result of the viscoelastic deformation of a heated glass under a stress loading due to thermal expansion, (3) the fast cooling dynamics after the stop of the laser exposure should determine the strain distribution in the heat modified region, (4) the generated thermal energy was about 40 % of that of focused laser pulses.

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LAMN-2 3D observations and control of laser-induced refractive index changes in optical glasses using spatio-temporal adaptive optics

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Ultrafast laser radiation shows increasing potential for 3D functionalization of optical materials by processing embedded refractive index changes. Consequently photonic functions were demonstrated in various glasses of optical relevance. The mechanisms are based on the nonlinear confinement of laser energy in small volumes and the subsequent thermo-mechanical and structural rearrangement of the dielectric matrix. However, the irradiation outcome depends on the material relaxation paths as well as on the spatio-temporal characteristics of the writing beam. It can result in both positive and negative index variations, the latter being detrimental for waveguiding applications. These facts impose specific limitations to the photoinscription process.

Additionally, if at low photon doses isotropic refractive index changes are induced via soft electronic alterations, in more energetic regimes corresponding to thermo-mechanical photoinscription effects, ultrafast laser radiation can generate an intriguing nanoscale spontaneous arrangement, leading to form birefringence and modulated index patterns. The formation dynamics of refractive index structures and the characteristics times of the driving factors can be visualised using time-resolved microscopy techniques. This determines a guideline for intelligently improving the irradiation outcome using tailored irradiation and regulated energy delivery.

From a practical view, building up on the above mentioned observations, recently, new beam manipulation concepts were developed which allow a modulation of the energy feedthrough according to the material transient reactions, enabling thus a synergetic interaction between light and matter and, therefore, optimal results. We consequently discuss the possibility of controlling laser-induced physical phenomena employing automated temporal pulse shaping. Examples of adaptive design of refractive index changes in “thermal” glasses will be shown as well as insights into 3D parallel writing techniques for complex structures utilizing wavefront engineering. Moreover, using the birefringence properties and the associated anisotropic light scattering properties characteristic to the ordered nanostructures, polarization sensitive devices were designed and fabricated. The polarization sensitivity allows particular light propagation and confinement properties in three dimensional structures.

LAMN-3 Synthesis and Optical Property of Nano-Structured ZnO Crystals by Nanoparticle-Assisted Pulsed Laser Deposition

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Zinc oxide (ZnO), a II–VI semiconductor, which has a direct wide band-gap of 3.37 eV at room temperature and a relatively large exciton binding energy of 60 meV, is one of the promising materials in UV optoelectronic applications. In addition, nano-structured ZnO crystals, such as nanowires and nanowalls, have attracted a great attention for next generation nanodevices because it has a superior crystalline quality, a better electrical/optical quality, a freedom to choose substrate and a large surface area to volume ratio.

In our study, we have been succeeded in growing nano-structured ZnO crystals by nanoparticle-assisted pulsed-laser deposition (NAPLD) without using any catalyst. Not only vertically aligned ZnO nanowires but also horizontally aligned ZnO nanowires have been successfully grown on the annealed c-plane and a-plane sapphire substrates, respectively. Besides, Depending on the PLD growth conditions and the composition of the target, ZnO nanowalls with thickness of tens of nanometers and dimension of several micrometers were synthesized. The room temperature photoluminescence spectrum of such a ZnO nanowall exhibited a strong intrinsic UV emission and a week defect-related visible emission. Synthesized ZnO nanowires could be applied to a heterojunction light-emitting diode and an UV photo-sensor. In addition, it was found that the ZnO nanowalls showed stable field emission properties with low threshold field and a big field enhancement factor.

In this presentation, the progresses of synthesis and optical property of nano-structured ZnO crystals by NAPLD using a multi-target changer system will be discussed.

LAMN-4 Deposition of transparent, conducting and magnetic films by pulsed laser deposition for spintronic applications

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In the emerging field of spintronics, information is carried by the electron spin instead of only its charge. Addition of the spin degree of freedom to conventional electronics, or ultimately using the spin alone, offers potential advantages for the development of new generation solid-state devices. For this reason in recent years a lot of research work has been devoted to deposit and study ferromagnetic materials and to induce ferromagnetism, by suitable doping, in materials which are paramagnetic or diamagnetic. In fact, very recently, both theoretical and experimental studies have suggested that degenerate wide band gap oxide semiconductors can be one of the most favourable host compounds for 3d transition elements to obtain dilute magnetic semiconductors (DMS) with high Curie temperature.

However, in order to use such materials as electrodes in spintronic devices, the deposited films, beside the magnetic character, must present other physical properties like good electrical conduction (properties) and transparency in the visible region. It is not so easy to obtain all these requirements for a single material.

In this paper we review the principal results obtained in this field with a particular reference to two different classes of materials deposited by laser ablation: ITO-Cr doped and $La_{0.7}Sr_{0.3}MnO_3$. In particular, for what about the latter, the effect of the Cr insertion into the ITO matrix on the modifications of the electrical and optical properties and the eventual magnetism induction will be reported. The optical, electrical and magnetic properties of $La_{0.7}Sr_{0.3}MnO_3$ films will be discussed in relation to the deposition parameters too.

LAMN-5 Effect of conical emission on micromachining by ultra-short pulses

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It has been shown, that precision micromachining of materials by ultra-short laser pulses, which is commonly anticipated due to negligible heat effected area, meets significant difficulties in ambient gases at high intensity of the incident focused beams, due to distortion of their spatial profile by sort of non-linear scattering [1]. This distortion results from a complex bunch of phenomena modifying refraction index of the ambient atmosphere at the leading edge of the laser pulse. The phenomenon is often referred as conical emission (CE), and is contributed by several mechanisms of ionization and the optical Kerr effect in atoms, molecules and components of the created micro-plasma [2]. The introduced this way complex spatial and temporal profile of refractivity in the vicinity of the beam waist causes noticeable expansion of the beam, destroys its homogeneity and results in spectral broadening via self-phase modulation. The effect was found and investigated mostly for large aperture beams making the main point of filamentation, while here, we concern features of CE peculiar for tight focusing of ultra-short pulses

Our work intended to clarify particular roles of the contributing mechanisms and, in the long run, aimed at elimination of scattering via optimization of the laser radiation parameters. Particular attention was paid to spectral and temporal dependences of CE [3]. To do that, parameters of conical emission were experimentally investigated at focusing of femtosecond and short picosecond pulses in several gases. A number of methods were used and specially developed for this task, allowing characterization: of the scattered and absorbed energy, of the intensity profiles and spectra in the scattered beams, and of the mechanisms contributing to ultra-fast modifications of the refraction index using time domain interferometry in the beam waist area. A new fast method of numerical simulations was proposed to evaluate the scattered energy, showing good agreement with the obtained experimental data. Combinations of experimental conditions (wavelengths of incident radiation, type of gas, pulse width) were found, which allows elimination of scattering in a wide range of the incident pulse energy, and opens a clear prospective for enhanced productivity and accuracy of micro-machining by ultra-short pulses.

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LAMN-6 Laser-assisted development and modification of lithium-ion battery materials on micro- and nanometer scale

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Laser-based process technologies for an advanced Lithium-ion battery concept with outstanding features with regard to safety and stability issues in high power and high capacity systems are presented. A combination of r.f. magnetron sputtering and subsequent laser annealing and structuring is applied for precise adjustment and tuning of material and surface properties of thin film electrodes. Additionally the laser-based synthesis of solid state electrolytes is promoted in order to have the option for an all-solid-state lithium ion battery.

The thin film electrodes were deposited by r.f. magnetron sputtering from ceramic targets onto Si and stainless steel substrates with varying working gas pressures and gas compositions. Laser micro- and nano-structuring of cathode and anode materials ($LiCoO_2$, $LiMn_2O_4$, SnO_2) was applied to improve the electrochemical cycling stability, especially for increased electrical discharge currents. The active surface area was increased by either direct laser micro- or nano-patterning or by selective laser ablation and material re-deposition leading to the formation of micro-sized cones.

The cone-formation can be controlled with respect to size, distance and orientation. Laser annealing was used to rapidly create the appropriate crystalline battery phase and to control the average grain size within a range of 20 nm-2 μm. The thin film electrodes were studied with regard to their chemical composition, crystal structure, morphology, topography and electrochemical properties.

As an alternative to conventional melt quenching a glass-ceramic solid state electrolyte based on $LiO_2 \cdot Al_2O_3 \cdot TiO_2 \cdot P_2O_5$ was fabricated by laser heating and rapid cooling. For this purpose an axially pressed powder compact with the appropriate composition was subjected to the radiation of a high power CO_2 laser. For the identification the glass- and crystallisation temperatures a detailed thermal analysis was performed. Ionic conductivity measurements were carried out at different temperatures.

LAMN-7 Ultrafast laser production of color inkjet printer nozzle plates

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In this presentation I will describe the process development of color inkjet printer nozzle plate production by picosecond laser milling technology. Comparison between short pulse and long pulse ablation is made. Details on parallel drilling process development will be given.

LAMN-8 Laser printing of functional materials

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Laser Induced Forward Transfer is a direct technique which enables the controlled transfer of a thin film in liquid or solid phase. In this paper we report our recent results on laser printing of organic functional materials employing Laser Induced Forward Transfer process (LIFT). The aim of our work is to use this alternative and very promising printing technique to directly fabricate biosensors, chemical sensors, and organic electronics. The LIFT experiments were carried out using a pulsed Nd:YAG laser (266 nm wavelength, 4 ns pulse duration) and a high power imaging micromachining system.

As an example, in the field of amperometric chemical sensors, laser irradiation of composite target materials such as Poly(acrylic acid)/CNT and Polyvinylpyrrolidone/CNT, enabled the dry deposition of well resolved composite pixels onto glass substrates. The LIFT technique was also employed for the accurate deposition of polymer/CNT composite pixels onto aluminium microelectrodes for the fabrication of chemical sensors based on polymer/CNT compounds. The deposited composite pixels present high electrical conductivity that makes these layers candidates for chemical sensing through amperometric measurements. The use of LIFT in the deposition of sensitive composite layers allows for great flexibility of both the composite material and the pattern size, which may vary between 10 and 250 μm. This simple and direct printing process can be applied for the deposition of a wide range of polymer/CNT composite materials and will help scientists to produce multianalyte chemical sensors and organic electronics based on the fascinating properties of CNTs.

LAMN-9 Trends in direct laser writing methods for fabrication of Diffractive micro- and nanostructures

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Fabrication of diffractive micro- and nanostructures with nonuniform complicated topology is rather difficult task. At the present time the fabrication technologies for diffractive optical elements with minimum zone period of up to 3-5μm for continuous-relief elements and 1μm for binary phase elements have been well tested. Most popular fabrication methods are following: direct writing by scanning electron or laser beam, diamond turning and photolithography. The methods of direct scanning writing are most universal and used for fabrication of both amplitude masks and phase structures. These methods are based on scanning of focused intensity-modulated laser or electron beam on substrate surface covered by recording layer. Writing beam is moved on given trajectory and exposes whole area of an element. Requirements of modern diffractive optics set complicated problems which demand accurate microstructuring of optical surfaces with minimal feature size of not less than 0.5μm in light field of up to 200-300mm. Absolute accuracy of element topology should in range of 1/4 - 1/20 of minimal diffractive zone period. Besides that profile shape of "blazed" diffractive structure can change from submicron to tens of microns depending on wavelength. Such requirements make difficult or sometimes impossible a usage of regular technological equipment produced for needs of microelectronics industry. In last year's a number of scientific institutions and high-tech companies developed specialized laser systems and technologies optimized for tasks of optical micro- or nanostructuring.

Several generations of circular laser writing systems (fig. 1) for fabrication of diffractive optical elements (DOEs) were developed in IAE SB RAS [1]. Creation of inhouse laser writing system allowed us to develop resistless technology of scanning direct writing of amplitude masks on chrome films (рис. 2) [2]. Given technology appeared optimal for synthesis of precision computer-synthesized holograms and DOEs, fabricated on large and heavy substrates which can not be spin coated by photoresist. Task of manufacturing high-efficiency DOEs with continuous relief was also successfully solved with application of laser technologies. We developed a number of materials (for example, a-Si films and LDW-glass) [3], which demonstrated change of optical transmission at heating by focused laser beam. This effect gave a possibility to write gray-scale masks (fig. 3) used in gray-scale lithography for formation of given exposure distribution in photoresist film which is converted after liquid development to 3D surface relief of diffractive or microoptical elements. This technology of single step printing permits to fabricate on fused silica and silicon substrates (рис. 4) the diffractive elements having diffraction efficiency of up to 95 %.

Fig. 1.

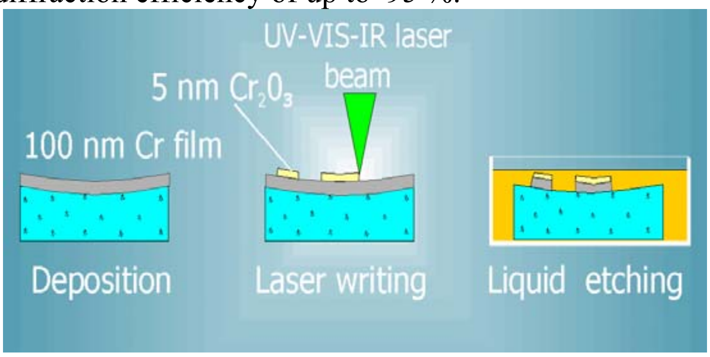

Fig. 2.

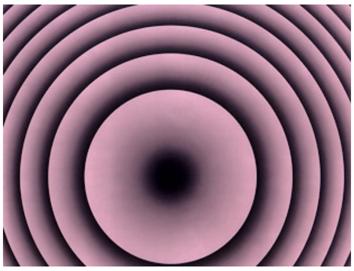

Fig. 3.

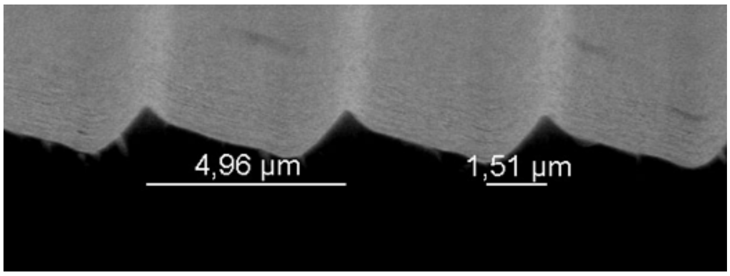

Fig. 4.

In spite of success reached in development of microfabrication technologies a further development of computational basis of diffractive optics in frame of rigorous diffraction theory results in necessity of creating technologies for optical surface nanostructuring. Considerable reduction of minimal feature sizes relates to new challenges in light control - modification of light beam polarization, synthesis of antireflection surface layers with sub-wavelength gratings, focusing of deep UV light. The new challenge led to renaissance of interference lithography which was widely used at the dawn of diffractive optics when there were no scanning laser and electron writing systems. At the new stage UV and deep UV lasers have been appeared. They allowed one to reduce minimal grating period to 100 nm. Success in development of precision scanning and replacement measurement systems resulted in appearance of scanning beam interference lithography. IAE also started to develop this technological direction [4].

Appearance of high intensity pulse lasers stimulated development of laser writing technologies on the base of two-photon and three-photon absorption. This technology and interference lithography made possible to synthesize volumetric 3D periodical structures – photon crystals. Duty to laser technologies the diffractive optics gets real third dimension.

Nevertheless, in spite of new trends in development of direct writing technologies for diffractive optics fabrication the real manufacturing practice is still mainly based on well-tested technologies of photolithography, diamond turning and single-point electron and laser direct laser direct writing.

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LAMN-10 Laser microprinting of liquids

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Laser direct-writing appears to be a very interesting tool for microfabrication, with applications ranging from the well established microelectronics industry to more emerging fields like lab-on-a-chip manufacturing. Although in most direct-writing techniques lasers are used for material removal, they can also be used for material addition. The best known additive laser-direct writing technique is possibly laser-induced forward transfer (LIFT). In LIFT, small amounts of material are transferred under the action of a laser pulse from a previously prepared donor thin film to a receptor substrate, placed parallel and at a short distance from the film. The application of LIFT to liquid donor films allows the deposition of complex and fragile materials in solution or suspension without compromising the integrity of the deposited material. In this case, LIFT acts as a microprinting technique, in a very similar way to inkjet printing, but with clear advantages over it, like a potentially higher resolution or a much wider range of printable rheologies.

In this presentation a review of our achievements on the LIFT of liquids is carried out. The performances and capabilities of the technique are explored through the systematic analysis of the morphology of deposited microdroplets at varying process parameters. In addition, it is demonstrated that the technique is feasible for printing fragile materials; this is performed through the preparation of biomolecule (DNA, proteins) microarrays which are perfectly functional, that is, the biomolecules preserve their biological activity after deposition. The study is not limited to technological aspects: the mechanisms responsible for liquid ejection and deposition are also investigated. Time-resolved studies allowed characterizing the dynamics of liquid transfer, which resulted in the discovery that the process was mediated by the formation of liquid jets with an extraordinary aspect-ratio which led to the formation of circular and uniform droplets when they contacted the receptor substrate.

Finally, the presentation ends with the development of a new printing technique which allows overcoming the main drawback of LIFT for its further implementation in an industrial process: the preparation of the donor material in thin film form. The principle of operation of this new printing technique consists in strongly focusing a very short laser pulse underneath the free surface of the liquid, which is contained in a reservoir. Subsurface absorption of the laser radiation results in the propulsion of liquid away the free surface, leading to material deposition on a substrate facing that surface. It is demonstrated that the technique results in the deposition of uniform circular droplets with excellent reproducibility and resolution, and that it is feasible for printing fragile materials without harm.

LAMN-11 Nanofabrication of GaN by femtosecond laser

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Gallium nitride (GaN) has attracted considerable interest over recent years because of a wide band-gap semiconductor that can be used for a variety of optical devices, including light emitting diodes (LEDs) and laser diodes (LDs) in blue or UV wavelength. Plasma etching or reactive-ion etching are widely utilized for the microfabrication of conventional semiconductors, such as Si and GaAs. High chemical stability and high hardness of GaN, however, obstruct the high-speed and high-quality microfabrication by these conventional techniques. By contrast, femtosecond (fs) laser ablation is a promising technique for high-quality and high-efficiency fabrication of hard materials due to its high repetition rate and ultrashort pulse width which minimizes formation of heat-affected zone around the processed region. For micro- and nanofabrication of GaN, we originally developed wet-chemical-assisted fs laser ablation in which the focused fs laser beam was directed on a GaN surface immersed in 35% hydrochloric (HCl) acid solution. Nanocrators with a diameter as narrow as ~ 200 nm (FWHM) were successfully formed on surface of a single-crystal GaN substrate using the second harmonic fs-laser beam (λ= 387 nm, 150 fs) focused by an objective lens with NA of 0.9. Nano scale ablation is responsible for two-photon absorption of the fs laser. The ablated craters exhibit higher quality and much less distortion with little debris deposition compared with those produced by fs laser ablation in air followed by etching in HCl (two-step processing method). The high quality ablation is presumably due to photochemical or photothermal reaction of HCl solution with ablated materials, resulting in complete removal of debris and in sharp edge and smooth surface of craters. Etch rate was estimated to be 20 – 80 nm/pulse dependent on pulse energy and the etched depth can be increased by increasing the number of pulses with almost no increase of the diameter of ablated craters. Finally, we have succeeded in fabricating a 2D array of periodic nanocrators on GaN surface by scanning the sample in x-y plane using a Piezoelectric stage. Formation of such a structure on GaN surface is crucially demanded to enhance the light extraction efficiency in blue LEDs.

PS2_01 Pulsed laser deposition CNx films and Carbon plume dynamic study

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Carbon nitride films were synthesized by a KrF excimer laser ablation of a graphite target in a controlled nitrogen atmosphere. The laser fluence was set at 10, 12 and 16 J/cm2. These thin films were deposited on <100> silicon substrate kept at room temperature and placed parallel to the target surface at both distances 3 and 4 cm. The pressure of nitrogen was varied from 0.1 to 1 mbar.

The deposited films were characterized with different diagnostic techniques. Scanning electron microscopy (SEM) and Atomic force microscopy (AFM) were used to study their surface morphology and to measure their surface roughness. The crystalline structure of the films was analyzed by X-ray diffraction (XRD). Film composition was investigated by Rutherford backscattering spectrometry (RBS) analysis. SEM observation indicates that CN_x films present a granular structure for all pressures used. Film structure evolves from amorphous to crystalline phases at 16 J/cm^2. These crystalline phases depend on nitrogen pressure.

The carbon plume dynamics was also investigated by fast imaging. This study was performed into 0.2 and 1 mbar nitrogen pressures. The light emitted by the plasma was observed along the perpendicular to the ejection direction through a fast intensified charge-coupled device (ICCD, Princeton Instruments PI-MAX, 1024 x 256 pixels). The expansion dynamics was distinghished by different regimes and several reflected shocks within the plume have been evidenced at 1 mbar pressure. Furthermore, emission of C_2 and CN were also imaged using interference filters. The CN radical is considered to be the mainly precursor to CN_x growth.

PS2_02 Modification of "FOTURAN" glass-ceramic material by ultrashort laer pulses.

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Glass-ceramic materials modification by ultrashort laser radiation is examined. Laser-induced crystallization and reverse amorphisation of "Foturan" is represented. An experimental results of "Foturan" interaction with picosecond laser impulses are observed. Development of optical memory based on phase changes induced by laser excitation in photosensitive glass-ceramics is proposed.

PS2_03 Reception of thin films from a liquid phase by means of laser radiation

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Thin films of various metals and their oxides have been deposition on metal and dielectric substrates by pulse-periodic radiation. As a target the colloidal solution nanoparticles copper oxide (CuO) and nickel (Ni) with carbon nanotubes in a liquid phase (glycerine) was used. For deposition metals nanoparticles, substrates were seated in a colloidal solution then action by pulse-periodic laser radiation (wave length 1.06 microns, a pulse length 100ns, repetition rate 20 kHz) various power was manufactured. Deposited films have good adhesion with a surface of a substrate and are homogeneous by the form. The width of the besieged layer was equaled to diameter of laser spot and made from 30 up to 60 microns. Research of samples was made on a raster-type electronic microscope (Quanta 200/3D) and an atomic force microscope (Ntegra Aura). Researches have shown that the characteristic roughness of a layer made 270nm at height of a relief about 2 microns . The offered method of deposition of metals from colloidal solutions by means of laser radiation is simple, inexpensive, and to substrates scaled to the big areas and length of the precipitated layer.

PS2_04 Micro-fabrication on surface of transparent body material

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There are two kinds of methods to laser processing for the glass. One is an internal processing and another is surface fabrication. A lot of papers or documents are seen about an internal processing and a surface fabrication is increasing.

When the focal point of the laser beam is focused on the surface of the glass of a mirror surface, it is difficult to process the surface of fused silica in generally. It takes time to fix the focus position. Moreover, the material surface should be kept clean, and requires noting for oil, dust, and dirt. The laser light beam reflects scatters or is absorbed to the surface of the glass by the surface of the finish such as mirrors, and weakens. And, it doesn't deeply reach the beam in surroundings of the material. Always doing such close attention to handle it causes a cost increase.

It has come to be required to be able to do a shaping processing on the glass surface freely. For instance, the dimple processing to mold the micro-lens etc. is so in the typical example. The method of giving free micro-fabrication to the surface of the glass is researched.

Besides reason to avoid complexity, a special surface-coating was employed for the converted into the thermal conduction type of laser processing by increasing the laser absorption rate on the material surface. It is to make the absorptive thin layer of the laser beam on the surface, and to accumulate the laser energy on the surface temporarily. A micro-fabrication on the surface was processed by the third high harmonic laser. As a result, a good processing result was obtained. To prove the result, it calculated.

PS2_05 Nanostructures optical parameters measured by spectroscopic ellipsometry

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There are analyzed the ellipsometrical measurement methods for using at technology processes of thin dielectric films production [1, 2]. Shown, that these metrological methods are very useful for study of uniform and gradient thin films parameters. Shown, that it can be measured dispersion functions of complex refractive index n(λ), k(λ) and thickness d with help of spectral many angles ellipsometrical method. For example it's shown the measurement results of thin films parameters from laser mirrors materials Ta_2O_5 before and after reoxidation. It can see from Fig.1 and Tabl.1 that mirror losses through film absorption can be lessen more than three times for λ=632 nm. This result was confirmed by another measurement method.

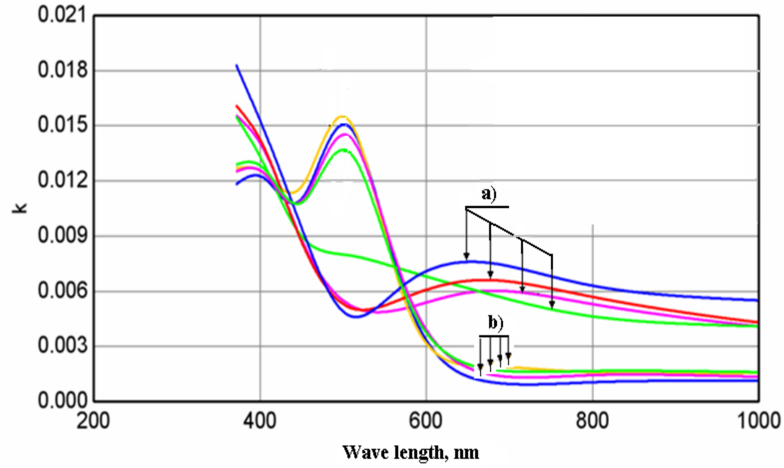

Fig.1: The dispersion functions k(λ) of four samples of Ta_2O_5 thin films before - a) and after - b) reoxidation.

Table 1.

The number of the samples	The thickness d, nm. Reoxidation		n (λ=632 nm). Reoxidation		k (λ=632 nm) Reoxidation	
	before	after	before	after	before	after
1	113	114	2.12	2.10	0.006	0.002
2	109	110	2.13	2.11	0.006	0.002
3	113	114	2.12	2.10	0.006	0.002
4	112..5	113..5	2.13	2.10	0.007	0.002

Also there are discussed the comparative parameters of three gradient thin films (Nb_2O_5 and SiO_2) in this work. It's shown that by moving the substrate between two targets Nb and SiO_2 into oxidized environment it can product the gradient films as with linear profile (see Fig.2 and Tabl.2 – sample 1) and more complicate profiles (samples 2 and 3) obtained in relation of the algorithm of the substrate movement [2].

There are shown that using of the spectral ellipsometrical metrology methods makes it possible to improve the technology process of thin films production.

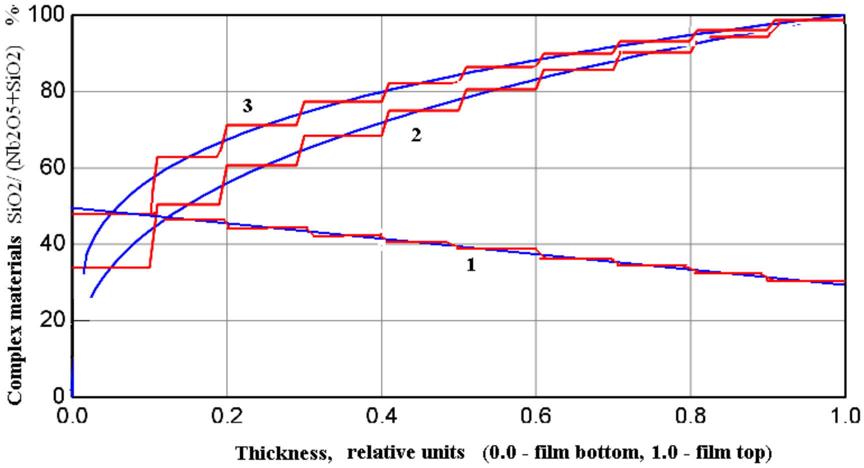

Fig. 2: The percentage of SiO_2 into complex materials Nb_2O_5 + SiO_2 across thin films thickness of the samples: 1, 2 and 3.

Table 2.

The number of the samples	The thickness d, nm.	n(λ=632 nm) - top	n (λ=632 nm) - bottom	k (λ=632 nm) - top	k (λ=632 nm) - bottom
1	57,2 ± 0,3	1,89	1,81	0,0033	0,0026
2	49,2 ± 0,5	1,52	2,34	0,0012	0,0282
3	48,0 ± 0,3	1,51	2,2	0,0003	0,0075

1. V.Azarova, Yu.Golyaev, G.Kolodnyi, M.Rasyov, N.Tikhmenev. Proc. SPIE, v.4350, 120÷125(2000).
2. O.Volpyan, A.Kuzmichev, Yu.Obod, P.Yakovlev. Proc.III IS-Techn.Conf. "Vacuum technique, materials and technology". Moscow, 42, (2008).

PS2_06 Pulsed laser deposition of Ni and Ni-Pd thin films

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Pulse laser deposition (PLD) of Ni films sets a wide spectrum of thin film states: amorphous Ni films (am-Ni phase), metastable hexagonal close packed (HCP) nickel (α-Ni phase) and stable face centralized cube (FCC) nickel (β-Ni phase). Transitions between these states, initiated by film annealing, are accompanied by structure, density and magnetic property changes.

Electron microscopy and electron diffraction investigation of film structure and morphology were performed in this work. It was established that transitions between am-Ni phase and β-Ni phase were accompanied by relative density increasing $\Delta\rho/\rho = 7.5\%$. For transitions between α-Ni phase and β-Ni phase $\Delta\rho/\rho = 18.5\%$. The orientation relations between α-Ni and β-Ni phases take place according to following scheme: (110) $[\bar{1}1\bar{1}]$ α-Ni // (110) [001] β-Ni and (110) $[\bar{2}2\bar{1}]$ α-Ni // (110) [001] β-Ni.

Possibility of formation of films of Ni-Pd alloy by the pulse laser sputtering of two-element metallic targets has been considered. In the case of alternate mode deposition of Ni and Pd laser erosion plasma on substrate with the temperature above 280 C films with FCC structure have been shown to be formed. The solid solution lattice parameter a_0 increases monotonically when the palladium content rises in the films. The positive deviation of the dependence of solution lattice parameter on the Pd content from Vegard's law takes place. The as-prepared Ni and Ni-Pd films do not reveal of magnetic moment. As a result of annealing the transition to ferromagnetic state occurs. The hysteresis was observed at magnetization reversal.

PS2_07 Laser produced plasma expansion across transverse magnetic field

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A one-fluid magnetohydrodynamic (MHD) model is used to investigate the dynamics of laser produced plasma expanding across a transverse external magnetic field into vacuum, just after the termination of the laser pulse. The plasma plume created in the framework of Pulsed Laser Deposition (PLD) process is assumed to be fully ionized containing electrons and single charged ions. The adiabatically expanding plasma is considered to be under local thermodynamic equilibrium, allowing all the charged particles to have same temperatures.

A self-similar analysis is proposed to describe the early stages of a one-dimensional expansion of the plasma satisfying ideal time-dependant MHD equations where charge quasi-neutrality is assumed to be valid. The evolution of the transverse magnetic field is supposed to follow Faraday law and the set of obtained differential equations is closed with an ideal equation of state.

The numerical results report the behaviour of the deduced plasma parameters like density, velocity and temperature as functions of the self-similarity variable for different increasing initial values of magnetic field.

We find that the interaction of the plasma with the transverse magnetic field may cause significant changes in the plume expansion dynamics, including confinement of the plasma leading to the increase of ions arriving on the substrate. Ion velocity increase is also observed due to the Lorentz force that accelerates the charges to move faster and further away from the target. The temperature of the plume is found to be larger compared to temperature in unmagnetized plasma, due to Joule heating and magnetic compression of the plume.

PS2_08 Researchs of the substitutional impurity influence on the viscosity of glasses

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Abnormal behaviour of glasses at laser heating is described in articles [1,2] and. Therefore the adequate model describing laser heating of glasses is necessary. At present there is no such model.

The work purpose is research of model LDVC (liquid – deformed vacancies crystal):

Modelling of fusion processes taking into account influence of impurity, within the limits of LDVC model

Theoretical calculation of viscosity as function from temperature and concentration of impurity

Comparison of theoretical and experimental results

Conclusions regarding consistency of model and development ways

Results:

Theoretical dependences of viscosity on temperature and concentration of an impurity with various modeling data were received.

Corresponding experimental results were received.

The selection of modeling data and check of results for a wide range of temperature and impurity for three structures of glass was made.

The good matching for an area with small concentration of an impurity for a wide temperature range.

In the course of work ways of possible completion of LDVC model have been revealed.

1. E.B. Yakovlev "Change of glass structure at laser influence", Optical Journal, No. 2, 1996, p. 5-9
2. E.B. Yakovlev "Abnormal behaviour of viscosity of glasses at laser heating", Izvestiya vusov. Priborostroenie, No. 6, 2001, p. 26-31

PS2_09 Calculating modeling of laser treatment process

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Laser treatment of materials is characterised

– not selectivity to a materials;

– high locality;

– absence of a worn out edge;

– simplicity of the operating program change that causes flexibility of applied technology, allows to change quickly the working task and to change of manufacturing object;

– high accuracy of beam position management;

–the small size of the focused spot (a processing zone) that allows to create images with the high resolution.

High accuracy of laser processing, along with a wavelength, a power, an impulse duration, the system resolution are defined also by cross-section beam power distribution, of power density threshold level and a spatial moving mode of a beam.

In work results of calculating modeling of material removal process with use of laser radiation are presented. In the calculating modeling the physical processes leading to removal of a material are not considered. In calculations parameters which can be measured experimentally before the manufacturing beginning are used:

– power distribution in a radiation spot (beam);

– radius of a radiation spot on level $1/e^2$;

– threshold power of radiation interaction with a material.

Processing calculations are spent as for a motionless beam (a punched hole), and for linear and raster movements of a zone of processing on a flat surface.

Calculation results are:

– the profile of a surface formed at processing;

– the power efficiency defined as a laser radiation energy part, spent for material removal.

Comparison of action of laser beams with various power distributions is made. For the most applied Gaussian type distribution influence of power density threshold level and spatial parameters of beam moving is considered.

Results of calculating modeling of laser treatment process and experimental laser processing are presented.

PS2_10 Conical and volumetric laser beams in nanotechnologies

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Some optical schemes for the production of conical beams with high cone angle and a quasi-uniform axial distribution of the intensity have designed and a elaborated method of laser power delivery in heterogeneous stream [1] are used for nanopowder production. Microparticles discharged from coaxial feeder are evaporated by conical beam and condensed nanopowders are drifted by gas stream to glassfiber filter. The results of investigation of nanoparticles characteristics and process efficiency are presented. Using conical beams SLC process has been modified . The efficiency and accuracy of the process of 3D-object production using conical beams is much superior to well known processes. The potential use of conical beams to improve the efficiency of some laser technological processes are discussed. Using conical beams Precitec create a optical eguipment for brasing on the base of fiber laser. More complex shapes up to 3D can be produced with high quality.

A laser systems schemes have been developed and theoretically justified for pulsed converging cylindrical and spherical laser beams production. These volumetric laser beams can be used in high intensity optical fields production, pumping a long active mediums and in laser plasma chemical reactors.

1. Chivel Yu // Technical Phys.Lett. V.31. PP.1-3. 2005

PS2_11 Temperature monitoring in selective laser sintering/melting

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In the present paper, development of a temperature monitoring systems adapted for SLS/SLM-process are discussed. The systems provide the possibility to measure spatial distribution of brightness temperature at two wavelengths, calculation of colour temperature and maximum temperature in focal spot. A combination of two type optical sensors – spatially resolving 2D sensor – digital CCD camera and single spot sensor- pyrometer which integrate thermal radiation emitted by a surface of certain size are used.

As is well known in modern SLS/ SLM machines mainly galvo scanner systems are used. The most-used interference scanner mirrors have a selective character of reflection depending of wavelength and angle of rotation , that must be take in account in deciding on a spectral range of temperature measurements. Also custom made F- teta lens are not achromatic usually. That cause image shift in coaxial set-up sensor positioning systems and errors in measurements. 2 D sensors are tolerant to such shifts and this is its major advantage over single spot sensors. But for the continuous control of melting process the measurement of maximum surface temperature in the heat affected zone is preferable through high time resolution. Principles of temperature measurement and special optical scheme have been designed to minimize image shift and have been using of two wavelengths pyrometer with time resolution 50 μs and spatial resolution ~100 μm.

The temperature monitoring make it possible to optimize SLS of powder body with high range of porosity through connection of particles by liquid bridges under Ti -particles surface melting during the action of pulse –periodic laser .

PS2_12 Near surface plasma formation under high intensity pulsed laser action

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The results of investigations of plasma formation thresholds dependences and the influence of the target surface state on the initial destruction of solids and plasma formation over a wide range of laser wavelengths and pulse duration are introduced. Experiments are carried out at atmospheric pressure and vacuum with the use of Nd – laser (λ= 1,06μm, τ = 40ns and 300ns), CO_2 – laser (λ= 10,6μm, τ = 1μs), rodamin laser (λ= 0,59 μm, τ = 10 μs).

Polished samples from pure aluminium A99, duralumin , Zn, Bi , In are used.

Conducted comprehensive measurements including surface temperature, the pressure in the irradiated spot , the dynamics of the scattered laser radiation, optical and electron microscopy allowed to explore the dynamics of destruction and evaporation of the target and plasma formation.

Local nature of the initial evaporation was identified caused by the presence of both the existing surface defects of micron size with the density ~ 10^6 – 10^7 cm^{-2} and the resulting explosive destruction of surface [1]. As a result of the overlap of individual clouds of vapor for a time in the future geometry of the flow of steam is determined by the size of the spot. The development of plasma in the vapor is strongly influenced by lateral rarefaction wave. In the transition from quasi (d <0,2 mm at τ = 300ns) to the two-dimensional expansion is an increase in the delay time of plasma formation and threshold power density.

It was determined that plasma formation has nonsteady character under the action of short (τ<1μs) laser pulses . Energy density E/S are criterion in this case and the time delay of plasma appearance agrees well with power dependence $t = \beta\, \tau^{0,5} / q_m$. Plasma formation has quasi-steady character on exposure to long pulse and power intensity q∗ is criterion. This is most pronounced at the action of laser pulse with echelon form of pulse edge.

1. Chivel Yu., Minko L. // Proc. SPIE, 4423, 232-237, 2000.

PS2_13 Laser induced metal ablation at high ambient gas pressure

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Laser-induced metal ablation are of considerable interest in connection with technological processes elaboration. The results of the investigations of quasi-continuous laser pulses action on metal targets in high pressure nitrogen are introduced.

Neodymium laser capable of generating quasi-continuous pulses with energies of up to 900 J, the total duration of 1.5 ms, and the leading-edge duration of ~300 μs was used . The targets from Al-alloy and Bi have been used.

Studies of dynamics of the plume formation shows that at enhanced pressures the initial emergence of vapor and the initial plasma formation in the plume occurs well later than that at atmospheric pressure. At 1,0 – 1,5 MPa the particles release is missed and mass removal is lowered by a factor ~ 100 . With growth of the ambient gas pressure up to 1.5-1.7 MPa. a character of the spectrum drastically changes and nitrogen ion lines are registered and laser absorption wave is formed. Qualitative assessment of gas plasma temperature on N ion lines excitation functions gives value of plasma temperature ~14-16· 10^3K. Calculated absorption coefficient of Al erosive and nitrogen plasma under P= 1,5 MPa equal to 2,7 $см^{-1}$, resulting in high level of surface shielding.

Numerical calculation according the model of heterogeneous laser ablation [1] shows that pressure in pores has a value 1,5-2,0 MPa. The ambient gas pressure like that inhibit the heterogeneous volume ablation and suppresses the particle release at initial stage of laser action. The transition of plasma front in ambient high pressure gas produce target shielding which reduce ablation at a later time.

1. Chivel Yu., Petrushina M., Smurov I.// Appl.Surf. Sci., 254 (2007) 816-820

PS2_14 Characterization of the electrical and optical properties of backside opened thin metal films

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The packaging density and the functionality of flexible electronic devices can be increased by using backside wiring. For fabrication of the required vias without damaging the thin functional films at the front side of the polymer substrate holes must be drilled into the flexible substrate for connecting of the functional layer with the backside wiring by a conductive adhesive for instance. For the selective removing of the substrate from the functional layer lasers are promising especially for low-density patterning processes, large-area applications, and flexible substrates [1]. However, it has been found that the contact resistance between a laser exposed metallic surface and a conductive adhesive varies very strong.

The exposure of different thin metal films, e.g. titanium, molybdenum, silver, deposited on polyimide foils were studied by laser ablation with a Nd:YAG picosecond laser applying different conditions. The surfaces of the laser-exposed thin metal films have been analyzed with optical microscope, SEM, c-AFM and XPS. The contact resistance between the laser-exposed thin metal films and a conductive adhesive has been measured to investigate the electrical behaviour of the interface. The results will be correlated with the analytical results and will be discussed on the basis of the used laser-exposure parameters of the thin metal films.

1. K. Zimmer, R. Böhme, T. Stephan et al., Appl Surf Sci 255(2009) 9869-9872.

PS2_15 Auto-organization and auto-shaping of laser induced periodic parallel structure

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A big progress in micromachining by femtosecond lasers has been made during the last years. In particular, a better control in shape and features with dimension less than beam diameter can now be achieved. In this work we will show that it is even possible to decrease the shape dimension down to wavelength and less. This process of self formation and self organization of surface structure in ablated area is known as Laser Induced Periodic Parallel structure (LIPPS). This structure may be the result of interference between the laser beam and electronic waves at the surface, which gives a modulation of intensity and modulation of erosion speed of the surface. However we believe that in most cases the mechanism at work are still to be identified. There are a number of aspects controlling this process: propagation and auto-modulation of absorption coefficient by ionization and laser induced defects, energy dissipation and evolution of the surface from pulse to pulse... Studying the space distribution and time evolution of electronic excitations is one of the tools that can answer for these questions and help to better control the ablation and nanostructuration process. For instance, not only a grating can be created on the surface, but also a matrix of nano-channels.

We will show results of our studies on quartz. For this material not only surface modifications have been observed, but also creation of periodic structure in volume is possible. A structure of oxygen defects can grow up to sets of bulbs and lines (channels). Structure shape in volume is also controlled by laser beam characteristics: wavelength and polarization.

PS2_16 Study and Simulation of the Growth of $MoSe_x$-Based Thin-Film Coatings Formed by Pulsed Laser Deposition

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Physical, chemical and tribological properties of the $MoSe_x$ and $MoSe_xC_y$ coatings for micromechanical applications grown by pulsed laser deposition in vacuum and in a rarefied inert gas (argon) atmosphere are studied. In a number of experiments a disk-shaped screen was used that is placed on the path of the expansion of laser plume in order to trap the droplet fraction. Upon deposition in a gas at a pressure of ~2 Pa, stoichiometric $MoSe_2$ coatings with improved antifriction properties as compared vacuum-deposited $MoSe_x$ (x<2) coatings form. However, a too strong increase in the argon pressure (to ~10 Pa) degrades the tribological properties of the coating. Structure formation in the $MoSe_x$ coatings grown by pulsed laser deposition on an unheated substrate is investigated. Deposition in vacuum or argon at a pressure of 2 Pa leads to formation of rather smooth coatings with a dense amorphous structure containing molybdenum nanoinclusions. Deposition at a high argon pressure results in a developed surface relief and a loose coating structure. Numerical experiments based on the combination of two computer models that describe physical processes on the atomic level using Direct Simulation Monte Carlo and Kinetic Monte Carlo methods are performed to reveal the factors that affect the thickness, chemical composition, and structure of the MoS_x-based coatings. The results of modeling the dynamics of the laser-induced atomic flux in a chamber without and with an anti-droplet screen are used to simulate the coating growth. The deposition of a scattered flux under conditions of surface bombardment by vapor particles incident to a negatively biased substrate is shown to substantially increase the coating density and to smooth away the surface relief.

PS2_17 Electrical Characteristics of Metal-Semiconductor Structures Formed on SiC Crystal by Pulsed Laser Deposition of Pt at Varied Conditions

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The features of platinum film formation on *n*-6*H*_SiC substrates were experimentally studied for different methods of pulsed laser deposition, i.e., by both the conventional method in vacuum and in an inert gas atmosphere. In the latter case, a disk screen was placed on the plume expansion axis between the laser target and substrate to protect the latter from micrometer and submicrometer particles. A numerical model of such a process based on Direct Simulation Monte Carlo method was developed, which makes it possible to predict the deposited film distribution over the substrate surface, energy and angular parameters of the atomic flow as laser plume properties, inert gas pressure, and screen position are varied. Simulation results were used to explain electrical properties of Pt/*n*-6*H*-SiC thin-film structures fabricated by different methods. Experiments showed that there is a pronounced dependence of electrical characteristics of such structures on energy parameters of the platinum atomic flux. Analysis of *I–V* forward portions showed that the energy barrier at the semiconductor–metal interface during deposition of Pt atoms without a screen (the mode of high-energy atom flow deposition) was lower than during deposition with a screen (the mode of low energy atom deposition) by 0.058 eV. The corresponding electron density at the surface levels could be lower by 10^{12} cm^{-2} at the general background of ~10^{14} cm^{-2}. The Pt/*n*-6*H*-SiC structures grown by pulsed laser deposition exhibited *I–V* characteristics with a rectification effect, which indicates their applicability for developing solid-state devices, i.e., gas analyzers, photodetectors, and detecting rectifier systems. The laser method attractiveness consists in the possibility of developing multilayer functional structures in a single technological cycle under conditions of flexible variation of chemical composition and properties of atomic flows used to grow such structures.

PS2_18 Adaptive control system for laser micromachining devices

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This paper proposes a variant of application of a decision support system (DSS) in order to form a set of laser micromachining system configuration parameters on the basis of previously created knowledge base. The efficiency of DSS tool depends upon the volume of knowledge base, the quality of its contents and the possibility of its effective update. The creation of such a base is usually a result of a continuous strenuous work of experts, hence the subjectivity of its contents and low update rates.

In order to create the knowledge base rapidly and objectively, we introduce an automated control module containing a high resolution camera, profilometer and spectrophotometer into a system of a laser micromachining.

To check the solutions proposed, the control module has been mounted in the laser micromachining device (with a 20 W disc laser) developed on the basis of complementary scanners [1]. The hardware basis of the module is a machine vision system consisting of a videocamera with a high resolution lens (3.4 Mpix, image plane resolution <1 micron). Electromechanical drive of the device enables to position the space under study of the micromachined object in the videocamera lens field. The videocamera visual field is considerably less than the laser writing field, hence a full image of object of writing is synthesized frame-by-frame. The implemented frame linkage algorithm enables us to obtain the image of the micromachined object with an error not greater than ±1 micron (within a 50 mm field). There at the geometrical deformations of objects caused by a distortion of the videocamera lens do not exceed ±1 micron either.

At the first stage of the work, an automated search of optimal adjustments of galvanometric scanning system for the vector mode micromachining has been implemented. Comparing the initial task (the vector image) with the result of laser machining obtained by means of a camera, a maximum length of microvectors (beam displacement velocity), the value of delays between the vectors, delays of switching on and switching off of the laser source are determined. A series of experiments has been carried out concerning vector machining with system parameters resulted from automated adjustment. They showed the increase of the velocity of micromachining, the quality of the latter being preserved. The optimum distance from the plane of the machined surface to the plane of the scanning lens focus has been also determined.

Thus, the controlling module has shown its ability to simplify and automate the process of data collection for DSS. The developed soft- and hardware elements allow to semi automatically adjust the system in order to solve a specific micromachining problems, to evaluate results of experiments and to store the resulting data in the knowledge base.

1. Goloshevsky N., Aleshin A., Bessmeltsev V. et al. Precision laser system based on complementary scanning principle for dielectric material microprocessing // Proc. SPIE, 2008, 6985

PS2_19 Continuous-Wave Laser induced Modification in Glasses

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We report on a permanent change in the physical properties inside glass that is rapidly heated and quenched with a continuous-wave (CW) laser beam. The absorption of the glass was enhanced by laser heating, and the heated spot moved by thermal radiation and conduction. To trigger the heating, an absorbent material was placed on the backside of a glass plate and irradiated through the glass. Laser illumination with a power of 11 W focused on the absorbent material induced a cylindrical modified zone along the laser beam with a length of up to 5.5 mm that was modified at a rate of ~ 130 mm/s. The characteristics of the modified silica glass were studied. The modified area consisted of two layers, and the diameters of the inner and outer zones were ~40 μm and ~55 μm, respectively. The inner zone was modified by laser heating. The fictive temperature was estimated to be ~1900 K. The etch rate and hardness of the modified glass increased owing to the increment of the fictive temperature. The outer zone was modified by tensile stress due to the densification of the inner zone. In the outer zone, the etch rate was increased and hardness was decreased.

The time-lapsed temperature distribution was investigated by simulation using the Finite Difference Method. The temperature distribution was roughly in accordance with the shape of the modified area observed in the shadowgraphs. It is possible to say that the radius of the modified area is dependent on the temperature attained in glass.

PS2_20 The investigation of the structure of thin metal films after pulsed laser irradiation

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The main requirment for all types of DOE is high spatial resolution. So, the general task of our investigation is increasing the resolution of thermochemical recording technology by reducing the duration of laser pulses.

The most simple method for structure controlling of irradiated chromium films is measurment the kinetics of etching. For investigation of the chemical composition of irradiated chromium films we used method of Raman spectroscopy. To study the change of the profile of irradiated films we used atomic force microscopy.

The report presents the experiments that can explain the sctructure of the exposured chromium films. It is shown that ultrashort pulses can provide the maximal resolution of the optical recording technology.

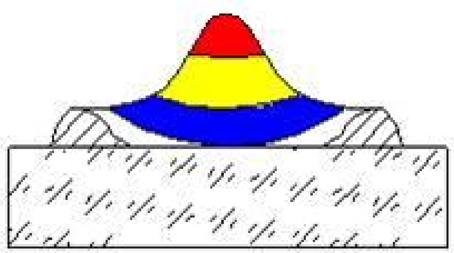

Fig. The structure of irradiated chromium film.

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2. Veiko V.P., Metev S.M. Laser-Assisted Microtechnology (Springer-Verlag, NY-Heidelberg, 1998) p.391. (Books)

PS2_21 Laser-stimulated thermal processes in In/CdTe thin `film system

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Laser doping as a method of p-n junction formation in CdTe has been studied. In the experiments we used the samples of CdTe with a thin (100 nm) In film formed by vacuum deposition. The samples were irradiated by ruby laser single pulses (wavelength 694 nm, FWMH 80 ns). Temperature regimes of laser processing are studied by means of optical pyrometry. The dependence of peak surface temperature on irradiation energy density is obtained. The threshold energy density for melting and destruction (film evaporation or ablation) are determined. Distribution of In after laser processing is obtained by SIMS. I-V characteristics of In/CdTe structures have been studied.

In order to clarify the experimental data, the numerical simulation of laser-induced transformations has been carried out. Temperature distribution was determined on the basis of numerical solution of Stefan problem. The reasonable agreement is obtained between calculated peak temperatures and experimental data from optical pyromery measurements. The threshold energy densities at which the onset of melting of the film and the substrate and the film destruction takes place are determined. Due to low meting temperature and meting heat of indium in comparison with the same for CdTe and low thermal conductivity of CdTe, the molten In film with solid CdTe substrate co-exists during several microseconds under irradiation conditions studied. The conditions of mass transfer and distribution of indium in CdTe after laser processing are discussed. The influence of temperature dependence of In reflectivity on laser induced processes are analyzed. Thermal elastic stresses are defined and their influence on mass transfer phenomena is studied. The properties of fabricated p–n junctions on the bases of In/CdTe samples are investigated.

PS2_22 Pulsed laser-induced forming of thin sheet metal

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The ability of contactless modification of the product shape as a result of the local laser heating can be used in various fields of technology. The advantage of laser technology is the ability of accurate control of energy, spatial and time characteristics of exposure with a result that a controllability of geometrical parameters of the produced elements would be widened.

The report is focused on laser bending of sheet metal elements of various shapes. In the present work two types of lasers have been used: q-switched pulsed Ytterbium fiber laser (average power 50 W, pulse duration 100 ns) and Nd: YAG laser (average power 200 W, pulse duration 0.1 - 10 ms). The following detail materials have been used: alloyed steel of various grades, brass and titanium. The detail thickness has been varied from 0,5 to 2,5 mm. For the formation of radiation area on the irregular shaped details we have used the programmable 6-axis robot Motoman SSF2000. The paper presents the results of laser bending of sheet details of different shapes and at different irradiation conditions. The comparison between the experimental data and known theoretical models of laser bending [1] has been made.

1. F. Vollertsen Mechanisms and models for laser forming. Manufacturing Systems Vol.24 (1995) No. 3

PS2_23 Laser-induced local transfer of glass-ceramic materials

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The devices based on various film elements have a wide distribution in the areas of micro- and optoelectronics. There is a necessity for forming of film depositions from the materials having specific properties in these areas now.

For this purpose, glass-ceramic materials, for example, sitalls are the interesting materials. Because of ability of glass-ceramic materials to exist in amorphous and polycrystalline phases which have different properties, possibility of their structural-phase modification, glass-ceramic films can find wide practical application, for example can be used for forming of microlenses, elements of optical memory, waveguides and other optical elements.

Laser-induced local transfer is used for forming of glass-ceramic films in the investigation. This method is available for forming of local film depositions because of its simplicity, universality, possibility of direct formation of film topology and using for a wide range of different materials.

Laser-induced local transfer of glass-ceramic films was carried out by 1,06 μm fiber laser for forming of polycrystalline glass-ceramic films about micron thickness on glass substrates in this work. Thickness of received films varied from 1 to 3 microns. Preliminary experiments have revealed necessity of pre-heating of acceptor substrate and donor material for avoiding their damage such as splitting. Spectral investigation of films has revealed similarity of spectral characteristics (reflection and transmission) of different glass-ceramic films and of initial glass-ceramic plate. Research of profiles of films surfaces has shown that the films have considerable thickness unevenness and roughness. It was shown necessity of the further investigation of laser-induced local transfer for process optimization and fabrication of glass-ceramic films of high quality.

PS2_24 The deposited particles energy spectrum control in the PLD method

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In the present work it is informed on engineering of the modified crossed-beam pulsed laser deposition method (CBPLD) which allows operating deposited particles energy in a wide range. Laser ablation was performed for the Si, Fe, Cr, Mn and Sn materials by the radiation of the first and second harmonics of the solid-state laser (1,06 μm and 0,53 μm) at the different power density on the targets. By the Langmuir probe technique ions time-of-flight curves (TFC) for the plasma beam formed by the intersecting plumes from two targets and the erosion plume from one target are received. The ions time-of-flight curves (TFC) are received at the probe-to-target distances in the 25-120 mm range. It is shown that ions TFC of the erosion plume approximate by the sum of one-dimensional Maxwell velocity distributions. It is demonstrated that the ions expansion velocity is in inverse proportion to root of ions mass. Ions concentration changing in initial plumes as a result of interaction is measured. For the first time the possibility of the ions energy spectrum control in a wide range at the crossed plumes method by means of angle changing between initial plumes axes is shown.

It is shown that the modified CBPLD method allows creating the Si-based multilayer periodical spin-tunnel nanostructures with atomic-smooth interfaces even to first laser harmonics using for ablation.

PS2_25 Laser-induced silicon surface structuring for solar cell application

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Creation of laser-induced morphology features of the crystalline and multicrystalline silicon at the influence of the 532 nm wavelength Nd:YAG laser and also at the influence of the 248 nm wavelength KrF eximer laser (LPX 200) nanosecond pulses in air and vacuum atmosphere was investigated at different power density and radiation dose. Distinctive feature of this work is application of the sufficient power lasers to the increasing of the spot size minimum on two orders than the characteristic sizes of the formed laser-induced structures. It allows to at carrying out of the structure analysis completely exclude nonuniformity effects of the intensity distribution at the spot edges and that is even more important, nonuniformity of the temperature distribution within the spot – factors which in practice cannot be considered completely in case of tightly-focused laser beams usually used in similar researches. The structured plate samples of the multicrystalline silicon of the

20x20 mm^2 size that sufficient for creation of the solar cells and studying of their photo-electric characteristics are received. The effect of laser influence modes on the morphological properties of the received by the laser method structures is investigated. The insensitivity to the borders presence between grains with various crystallographic orientations of the formed by the laser method structures has been shown and possibility of the uniform microtexturing of the multicrystalline silicon surface for high-performance solar cells creation is confirmed.

PS2_26 Study of microstructure topography and hardness evolution at direct laser writing on chrome films

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Thermochemical direct laser writing on chromium films is well-proved process for fabrication of high-precision diffractive optical elements, angular scales and limbs. Laser heating of chromium films causes build-up of a thin oxide layer which is stable in some chromium etchants [1]. This thermochemical effect allows the direct generation of patterns with spatial resolution better than 1000 mm^{-1}. The dynamics of the laser writing are chosen to build up enough oxide where the laser had scanned with minimal thermal broadening. After it is exposed, the pattern is developed by immersing the substrate in a caustic bath that dissolves the bare chromium much more quickly than the chromium oxide. After the development process, a pattern of chromium remains where the laser had exposed the surface and created the oxide layer. The writing is made on 50-100nm Cr films deposited on glass or fused silica substrates. Optimum intensity for thermochemical writing with green laser beam is 2 -12 MW/cm^2 and at scanning speed in range 0.1- 800 cm/s. The exposed films is developed in the etchant consisting of 6 parts of 25% solution of $K_3Fe(CN)_6$ and 1 part of 25 % solution of NaOH. Dependence of recorded line width on the writing power (in relative units) is shown in Fig. 1 for different scanning speed (1 - 4.4cm/s; 2 - 8.8cm/s; 3 - 22cm/s; 4 - 44cm/s; 5 - 88cm/s; 6 - 175cm/s) for 65nm thickness of sputtered Cr film. Spot size was 0.7µm. According to these data, the laser power during the writing process is controlled so that the lines of equal width are written at any radius. Fig. 1 demonstrates that a 1:40 change in scanning speed results in only a 1:2.3 variation of laser power required for writing 1 µm line. Typical ratios of maximum and minimum powers (dynamic range) does not exceed 5 for writing DOEs with diameters up to 300 mm. Writing in chromium films is very simple and an understandable method for the production of high quality amplitude DOEs and masks.

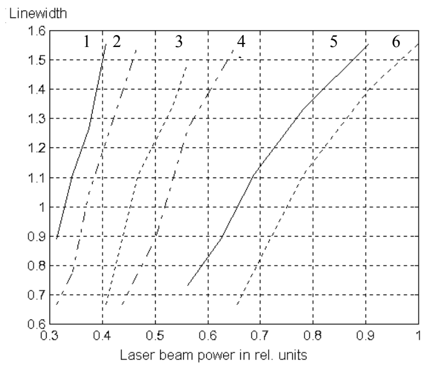

Fig. 1.

However up to now there are some unstudied problems in this technology. In the current paper we investigated an influence of thermochemical action of laser heating on hardness of the film. Using scanning nano-hardness tester Nanoscan-3D (FSI TISNCM, Russia) we investigated Cr films before and laser heating with different laser power. Preliminary measurement demonstrated that hardness increases by several times after thermochemical writing. It means amplitude mask written by our technique are more mechanically resistive and can be copied more times at contact printing.

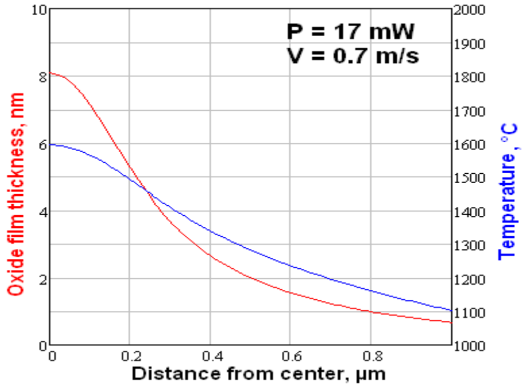

Fig. 2.

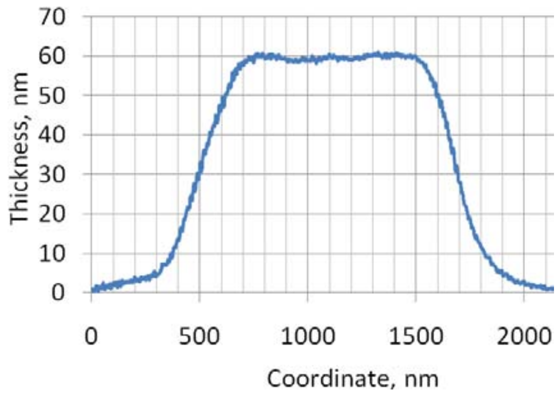

Fig. 3.

Another practical question is how Gaussian intensity distribution in the focused laser beam influences on a microstructure topography recorded by thermochemical writing. The form of edges of lines defines sidewall inclination of surface microstructure of phase diffractive elements fabricated by reactive ion etching through chromium mask. Fig. 2 depicts results of numerical simulation of temperature distribution and Cr oxide thickness at thermochemical laser writing on Cr film. Along distance from spot center the thickness of chrome oxide layer reduces faster than temperature. Nevertheless this reduction is quite gradual. After liquid etching the chrome oxide distribution is converted to Cr layer thickness distribution. This is not so linear process, because there is some volume modification of the film under laser heating. Unfortunately there is no reliable data about etching kinetics and therefore it is not possible to simulate it correctly. For the current research it is important to know how the Cr layer distribution is transferred to profile in fused silica substrate after reactive ion etching (RIE). Fig. 3 shows a profile of exposed Cr film after etching. It was measured by Nanoscan-3D in profilometry mode. Sidewalls on the plot have width about 400 nm. This profile was transferred to fused silica substrate surface by RIE system PlasmaLab80Plus (Oxford Technology, UK). Fig. 4 depicts a profile of binary structure in fused silica. For comparison fig. 5 demonstrate phase binary microstructure in fused silica formed by RIE process through masks fabricated by standard photolithographic process with photoresist. Both profiles have vertical sidewalls. Therefore thermochemical writing on Cr film can be used for fabrication of both amplitude masks for contact printing and final phase structures.

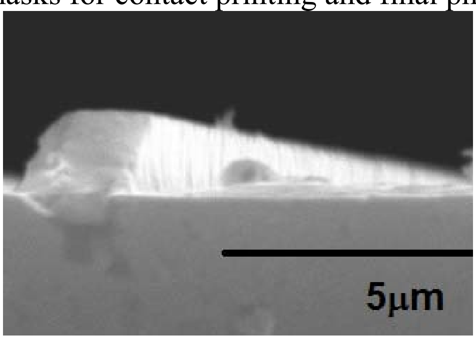

Fig. 4.

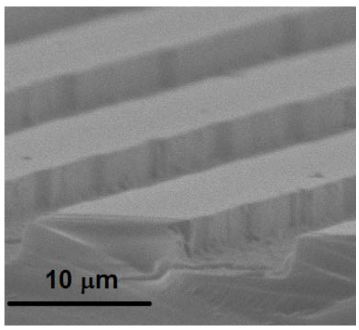

Fig. 5.

This work was partially supported by the Interdisciplinary Projects 54 and 55 of Siberian Branch of Russian Academy of Sciences, and RFBR project N 09-02-01065-a

1. V.P. Veyko, E.A.Shakhno, A.G. Poleshchuk, V.P. Korolkov, V. Matyzhonok, “Local Laser Oxidation of Thin Metal Films: Ultra-resolution in Theory and in Practice,” JLMN-Journal of Laser Micro/Nanoengineering Vol. 3, No. 3, 2008.

PS2_27 Femtosecond surface nanostructuring of electroformed nickel stamps in air or in various liquids

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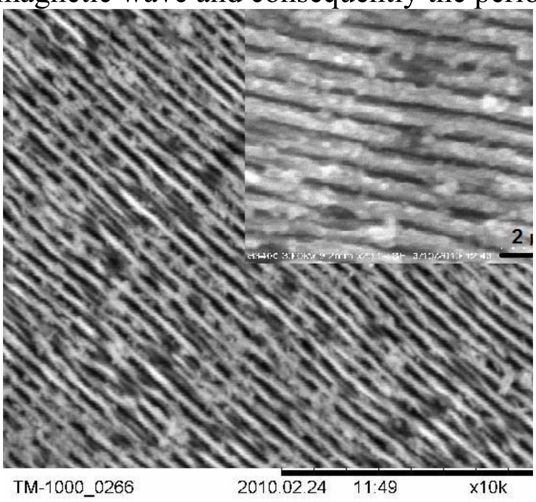
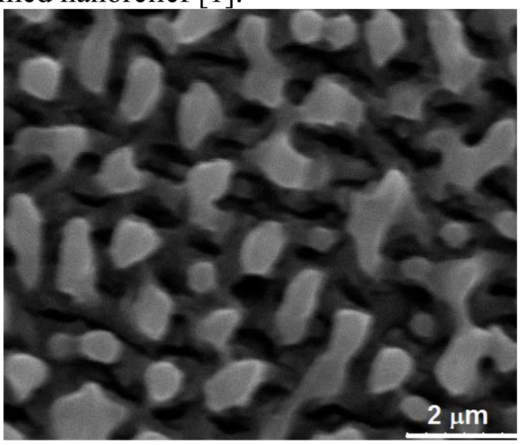
Effect of the femtosecond laser nanostructuring was actively studied theoretically and experimentally for the last five years. Experimental researches were conducted on polished bulk samples with polycrystalline structure. In the current work we investigated influence of powerful femtosecond laser radiation (744nm, 110fs, 5mJ/pulse, 10Hz, scan speed of 6μm/s) on electroplated two-layer Ni-Cu foil, which had been grown up on the polished optical surface. The irradiated top layer consisted of a layer of nanocrystalline nickel with thickness 5-20μm. We investigated the nanostructures formed at various laser parameters (energy density - 50-200 mJ/cm^2) and ambient environments (air, water and spirits) on a surface of samples under the influence of linearly polarized femtosecond laser radiation. The surface structure was analyzed by scanning electron microscope Hitachi S3400N. As a result, it was found out that under the action of the laser irradiation in air these nanostructures under certain conditions look like quasi-periodic linear grooves with the characteristic period of about 400-450 nm (Fig. 1a). At the same time after irradiation in liquids the linear shape of structures completely disappeared (Fig. 1b). Using the results of other researches [1-3], we can assume that as a result of an interference of falling and surface electromagnetic waves there is a periodic spatial amplification of influence on a material, because of which the observed structures appear. The frequency of such nanorelief depends on many factors, including the ambient mediun in which the exposure occurs. Thus, under the influence of laser pulses in air, non-equilibrium plasma formed on the surface of the sample, which involves its local oxidation. The latter factor affects the speed of propagation of a surface electromagnetic wave and consequently the period of formed nanorelief [1].



(a)



(b)

PS2_28 Influence of treatment on the properties of laser–densificated areas placed at the plates of porous glasses

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Experimental results of change geometry and optical properties laser–densificated areas placed at the plates of porous glasess different structures from time of treatment at temparature 870^0C are presented.

Investigation of change geometry rgese areas are made on the microscope Axio Image Zeizz with maginification $100–200^x$ in reflect, passing and linear polarization light between two crossed polarizers. Qualitattive value of change thermotension in process of treatment are reached by investigation laser–densificated areas between two crossed polarizers.

Optical technique measurement of focal length for plane–concave lense are used for investigation change of difference in reflective index of laser–densificated area (n_f) and the plate of porous glass (n_s).

It is defined that laser–densificated areas are presented, if time of treatment was less than 35–40 min. Experimental difference $n_f – n_s = 0.0150 \pm 0.0008$ has given evidence about it.

Increasing of time the treatment for all investigated glasses has put in reduction of thermotension both laser–densificate area and outside it.

PS2_29 Laser synthesis of metal-carbon nanostructurized complex

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The purpose of the given work is synthesis metal-carbon materials at action on the samples consisting of a mix crude multilayered nanotubes and metals nanoparticles.

Process of deposition of particles from a target on a substrate from laser-induced plasma has been realized on a method of back deposition, with application of the continuous fiber laser. In case of laser action (power of laser radiation – 3W) on a file carbon nanotubes, mixed with nickel nanopowder, is observed formation on a cold substrate of the homogeneous besieged layer as "scales" by the sizes 600 - 800 nm. It reminds structure of nanofiber, several tens formed at twisting nanotubes. At increase in power of laser radiation up to 5W, at the same focussing and constant time of action 5 s, it was possible to obtain more rarefied granular structures which form shows, that on a surface of a substrate the structure of a file nanotubes is copied: White spheres correspond to the caked particles of nickel, and strings between them are carbon nanofibers. Diameter of these spheres - 150-200 nanometers, and the radial size of strings - on the average 250 nanometers., similar structures are obtained at replacement in a mix nickel nanopowder on ferum oxide nanopartiles.

The carried out experiments on laser deposition of nanostructures on a substrate from an irradiated target show an opportunity of control of topology complex coverings from a mix metals nanoparticles and carbon nanotubes. This method allow to control of morphological and chemical-physical properties of creation complex structures.

PS2_30 Electroluminescence from *n*-ZnO/*p*-GaN/*c*-Al_2O_3 and *n*-ZnO/*i*-ZnO/*p*-GaN/*c*-Al_2O_3 heterojunctions light-emitting diodes grown by pulsed laser deposition

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ZnO is one of the most promising materials for shortwavelength light-emitting diode (LED) and laser diode applications. However, the application of ZnO to homojunction diodes has been limited due to the difficulties of highquality ZnO fabrication and *p*-doping on ZnO. As an alternative approach to utilize ZnO for optoelectronic applications, a ZnO film/GaN film heterojunction structure has been suggested. These GaN/ZnO LEDs exhibit the improved carriers confinement compared to homojunction, which leads to higher recombination and improved device efficiency. However, due to relatively lower carrier concentration and mobility of p-GaN compared with those of n-ZnO, the blue-violet electroluminescence (EL) of those reported GaN/ZnO heterojunctions usually originates from GaN layer, while UV EL related to ZnO exciton recombination is not observed. In our work, a thin semi-insulating ZnO (i-ZnO) layer with high resistivity was inserted between the p-GaN and n-ZnO layer, to form p-i-n heterojunction, which confined parts of carriers to recombine in i-ZnO region.

In this work, we report on the fabrication and characteristics of light-emitting diodes based on p-GaN/n-ZnO and p-GaN/i-ZnO/n-ZnO heterojunctions. The hybrid heterojunctions were grown on *c*-Al_2O_3 substrates. The *p*-GaN films were produced by MOCVD and the *n*-ZnO and *i*-ZnO films were grown by PLD. We present the materials characterization of this structure using x-ray diffraction, scanning electron microscopy and atomic force microscopy. In the p-GaN/n-ZnO heterojunction case was suggested that the high materials and interface quality obtained using pulsed laser deposition for the n-ZnO and growth and metal–organic chemical vapor deposition for the p-GaN were key factors enabling the injection of holes and the radiative near band edge recombination in the ZnO. The p-GaN/n-ZnO LEDs showed *I-V* characteristics confirming a rectifying diode behavior and a RT electroluminescence peaked at about 380 nm was observed. A good correlation between the wavelength maxima for the EL and PL suggests that recombination occurs in the ZnO layer and that it may be excitonic in origin. This also indicates that there is significant hole injection from the GaN into the ZnO layer. The *I-V* characteristics of *n*-ZnO/*i*-ZnO/*p*-GaN LEDs showed a rectifying diode behavior and a RT width electroluminescence (360 – 700 nm) with peak maximum at about 490 nm. The comparison of the film photoluminescence and diode EL are indicated that emitted recombination occurs as in the ZnO layer thus in the *p*-GaN layer.

PS2_31 Application of the optical biopsy system for breast cancer diagnostics

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Breast cancer is the most widespread female oncology disease. But being discovered in the early stage it may be successfully treated by combination of surgery, chemotherapy and radiation. Today X-ray mammography is number one among diagnostic methods but its high sensitivity leads to a large amount of false diagnosis, which requires additional invasive diagnostic procedure for tissue sampling. The most common are core and fine biopsy. But the fine biopsy's probability of false negative diagnosis is about 25-30% due to small amount of the cells in the sample. Core biopsy has greater specificity – 80-85%, but this procedure is much traumatic, because a column of tissue is cut by a thick needle and remained scars cause problems for future diagnostics. At all that the tumors are benign in the majority of cases and that means that the patients undergo unnecessary surgery and suffer from anxiety during the period of about a month while the results are prepared.

In the world science the diagnostic ability of optical spectra of biological tissue is widely studied. The shapes of the spectral curves have specific absorption bands, which are deformed when the disease progresses, and that allows differentiation of the tissues on types and conditions with high degree of accuracy.

Minimal invasive probe and the diagnostic system developed by Biotilligent (USA) and Russian Federal Nuclear Centre – VNIIEF are based on optical radiation spectra recording and analysis and seem to be a promising tool for early diagnostics of breast cancer. The suggested method has the advantages of automated on-line diagnosing and minimal tissue destruction and in parallel with the traditional diagnostic procedures provides the ground for decision-making.

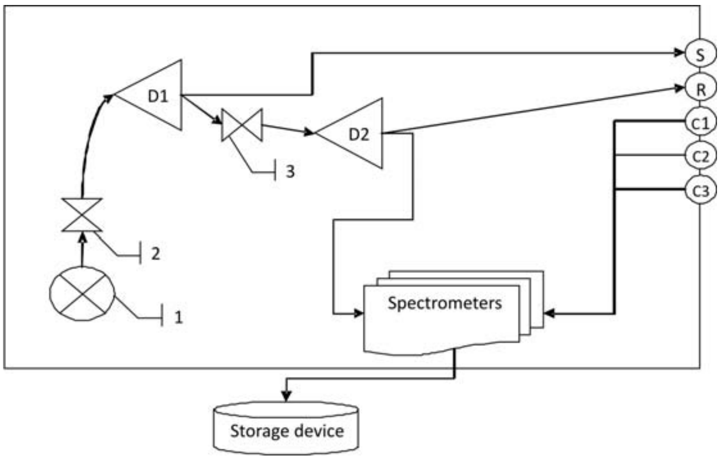

Fig. 1 Flow diagram of the diagnostic complex: 1 – xenon lamp; 2 – matching unit; D1, D2 – optical-fiber splitters; 3 - attenuator; S – white light source channel; R – reference channel for source spectrum measurement and calibration; C1, C2, C3 – scattered radiation measuring channels

The system consists of a source of light (Xe lamp), a measurement circuit and a unique probe with disposable needles containing optical fibers, and a computer for operation control and data recording. The flow diagram of the diagnostic system is presented in fig.1.

One of the fibers inside the needle emits white light, which interacts with biological tissue and then is collected by three other fibers located on the different distances (several microns) from the source. The needle diameter is 0.8 mm and the length is 50 mm, fiber diameter is 100 µm. A xenon lamp serves as a source of white light with continuous spectrum in the range of 370-750 nm.

Each record contains the data of a microscopic volume of tissue. The macroscopic representation of tissue properties is given by continues data acquisition during the whole period of probe movement. Recording frequency 100-120 Hz allowed spectral measurements each 100 µm along the trajectory of needle movement at the recommended rate 1 cm/sec.

The procedure of optical probing is similar to that of fine aspiration biopsy and may be used every time when fine biopsy is recommended. In addition to breast cancer investigation that is being conducted the optical probing may be applied to other organs: prostate, thyroid gland and other parenchyma organs.

To perform clinical studies a test protocol was developed and approved by the Ethical Committee of Nizhny Novgorod State Medical Academy of Ministry of Health of Russian Federation on scientific study with human participation as a subject of investigation.

In Semashko's regional hospital in Nizhny Novgorod a procedure room was equipped and about 200 tests were completed. Each procedure was supported by video filming and audio recording of the comments of the physician, who carried out the procedure. Independent diagnosis was obtained from the results of fine biopsy and sometimes of histology – when excision was required.

Fig.2 demonstrates the results of the clinical tests. The main difference in the 'benign' and 'malignant' curves behavior refers to the 'red' part of the spectrum.

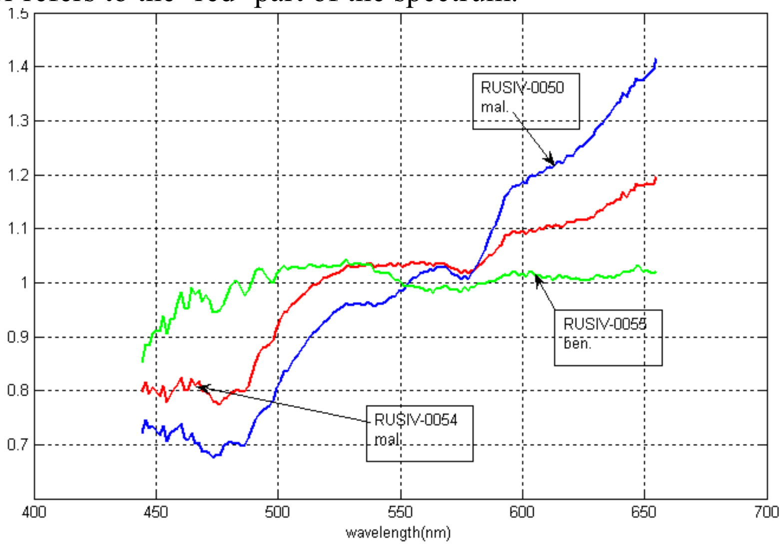

Fig. 2. The examples of the scattering spectra averaged over the time of needle being in malignant and benign tumors.

A method of automatic spectrum analysis was developed using wavelet decomposition and clasterization technique. Several main spectral types were found for malignant (4) and benign (3) tumors. The method demonstrated rather high efficiency parameters: specificity ~ 90% and sensitivity ~91%.

Large amount of information acquired in each procedure, fuzziness in criteria of 'cancer' family membership and data noisiness make neural networks to be an attractive tool for analysis of these data. To define the dividing rule between 'cancer' and 'non-cancer' spectral families a three-layer perceptron was applied. The learning and testing samples were composed only of the most reliable data. The model was tested over the sample of 29 'cancer' and 29 'non-cancer' cases and demonstrated total separation.

PS2_32 Laser forming of multichannel nanoprobe for SPM

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Introduction: Many studies are in need to define the different parameters of materials with nanometer resolution. Methods of scanning probe microscopy (SPM) can solve this problem. The analysis quality of the sample depends on the parameters of the probe.

Purpose: working out the technology of laser forming single-and multi-channel nanoprobes for SPM.

Main idea: nanoprobes formed by laser assisted stretching.

The microcapillaries are used as workpiece . Several metallic conductors can be placed inside the nanopipette.

Laser radiation heats the workpiece. It melts and breaks. We get two nanoprobes.

Intermediate results:

The current model of creating nanopipette is investigated through microcapillaries

The current model of creating metal-glass nanoprobes is investigated with the use of CO2 laser

Nanoprobes production modes are determined with the use of CO2 laser

The scheme for production of metal-glass nanoprobes using laser radiation with wavelength of 1.06 is worked out

Possibility of formation of nanoprobes using this scheme is researched

Scheme for production of metal-glass nanoprobes with simultaneous use of lasers with wavelength of 1.06 microns and 10.6 microns is worked out

Comparison of the methods of formation of metal-glass nanoprobes is carried out

Basic Results:

nanopipette laser forming modes that can be used us multifunctional SPM detectors production are determined

possibility of production metal-glass nanoprobes with one or multiple channels is shown

metal-glass nanoprobe laser forming modes that can be used for atomic force microscope, scanning tunneling microscopy and scanning ion microscopy detectors production are determined

PS2_33 Production of functionally reinforced gradient composite materials by surface laser treatment

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Surface modification is universal and economical method of increasing of working time of the sliding parts in machines. The possibility of surface modification of composite materials based on aluminium alloys ($AlSi_{12}Cu_2MgNi$ and $AlCu_4Mg_2$) reinforced with SiC particles by pulsed laser radiation was investigated in the present work. The effect of ceramic particles on welding pool dimensions was explored. It was found the parameters of surface modification which assured production of beads with a smooth surface and uniform distribution of reinforcement with the lack of reinforcing particles degradation. Using of surface treatment by laser melting leads to a significant dispersion of the initial matrix structure, microhardness of surface layers increases by 30-40%. The composite materials after modifying treatment are characterized by mechanical and tribotechnical characteristics superior source materials.

PS2_34 Patterning of $Ge_2Sb_2Te_5$ phase change material using femto-second laser-induced forward transfer

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The applications of phase change material have attracted much attention, because it has obvious optical and electrical contrast between the amorphous and crystalline states. It has been used as the recording layer of rewritable optical disks, as the core of the phase change memory, and as the resist layer of nanolithography. In this paper, we present a patterning of phase change material $Ge_2Sb_2Te_5$ (GST), which is a most popular one for its excellent physics prosperities, using laser-induced forward transfer (LIFT) technique. The as-deposited GST alloy films are deposited, after a femto-second laser pulse irradiation (wavelength is 800 nm, and pulse duration is 150 fs), the irradiated region are transferred to the receiver substrate. The separation of donor and receiver substrate is fixed at 100nm. The dots patterns are fabricated with different volume and height-width ratio by changing the laser fluence. The topography of donor and receiver substrates are studied by atomic force microscopy (AFM) and the transfer properties are analyzed. AFM measured information provided insights into the formation and structural features of dots pattern, and we found that the dot diameter is function of GST donor film thickness and laser fluence. The dot size is around 14 nm (thickness) x 500 nm (diameter). Under appropriate annealing process, the phase state transition of dots can be controlled. The ring-shape dots on the receiver are observed with thin $Ge_2Sb_2Te_5$ film. This technique provides a simple way to form arbitrary pattern and has potential in future production of optical components, MEMS and phase-change memory.

ACKNOWLEDGEMENT

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PS2_35 Oscillatory phase changes in glass-ceramics under near-infrared laser action

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Effect of oscillatory phase changes under continuously operated laser action is discovered in our works. It was observed while it was near–infrared YAG:Nd laser treatment for glass-ceramic ST-50-1. It exists at polycrystalline and amorphous phase, their optical and physical properties are differ. Possibility of glass-ceramic controllable phase changes under laser action was demonstrated early. YAG:Nd laser irradiation (wavelength 1.06 μm) is scattering in crystalline glass-ceramic due to equal sizes of microcrystalls inside volume, so absorption is situated, and it leads to fast heating of irradiated area. Opposite this, amorphous glass-ceramic doesn't have microcrystal, and this material is transparented for YAG:Nd laser radiation. That difference is the reason to oscillatory phase changes by continious laser treatment. YAG:Nd laser heating leads to melting, melted area don't absorb radiation, so melted area is some cooling. Thereby crystalline structures appears and grow, but in some interval they begin melt again because laser absorb again. That process may be oscillatory, and character of oscillation depends on laser irradiation parameters.

In our experiments character of phase changes in glass-ceramic ST-50-1 were detected by transparency measurements. On the one part amorphization are developed and transparency stays continuously high. But in other part melting area under continuously operated laser action tends to some ratio between amorphous and crystalline phases. That leads to establish any average transparency and stable temperature. It was determined transparency changes process can hold strong attenuation or can developed at aperiodic regime. Termovision measurements during laser action show that different parts of melting area have its own degree of cooling. It could explain some aspects of attenuation because crystalline structure can grow in certain parts of melting area. Oscillatory phase changes can take place when two phase of some material have different absorption by laser.

PS2_36 The color image formation during laser oxidation of metals

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Brief introduction. The statement of problem.

It is generally known that metals oxidises during heating at the atmosphere and thin oxides layers have different colours. Each colour of the film matches one of possible oxides of the metal. Laser impulse heating provides a unique opportunity to manage the geometrical structure (topology) and oxidation level of metal surfase. As a result it is possible to create the full-colour image on the surface.

One can use received results in the following cases:

the colour engraving and marking of products

in industry production (drawing of a colour logo of the enterprise on let out production for the purpose of an exception of possibility of a fake)

in advertising (souvenir production, cut always, tablets, signboards, panels of devices)

in jeweller manufacture

in decoration of applied art (creation full-colour laser production)

on the basic of this effect it is possible to create the device for the estimation of the incident light power on a metal surface.

The purpose of this work is to explore the laws of colour image formation on metal surface by managing or monitoring laser oxidation process. It is necessary to develop technology of the colour image.

The main result:

On the following stage the matching between key parameters (laser power, scanning speed and pulse repetition rate) and colours of forming films on an example of samples from a steel and the titan is established.

PS2_37 Shadowgraphy investigation of liquid phase laser induced forward transfer

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Laser induced forward transfer (LIFT) is widely used for the transfer of numerous materials such as metals, oxides, polymers and biomolecules. In particular, biologically active molecules in liquid phase can be also transferred using an intermediate metallic or polymeric layer as sacrificial dynamic release layer (DRL), which protects the material to be transferred from direct laser irradiation (damaging). Triazene polymers (TP) are good candidates as sacrificial layer because they decompose upon UV laser irradiation into gaseous fragments which transfer the soft material, with a minimum thermal load, to a receiver.

This approach was used to enable a precise positioning of liposome containing solutions with micro scale resolution for possible of developing applications such as biosensors and microarray chip devices. In order to understand and optimize the transfer process of biomolecules in liquid phase, shadowgraphy imaging was performed both on liposome containing solution as well as on a model solution consisting of double distilled water and glycerol.

We will discuss the transfer mechanism, the effect of laser fluence on the deposited patterns as well as advantages and limitations of the DRL assisted LIFT.

PS2_38 Formation of periodic surface structures on silicate glass by nanosecond CO_2-laser

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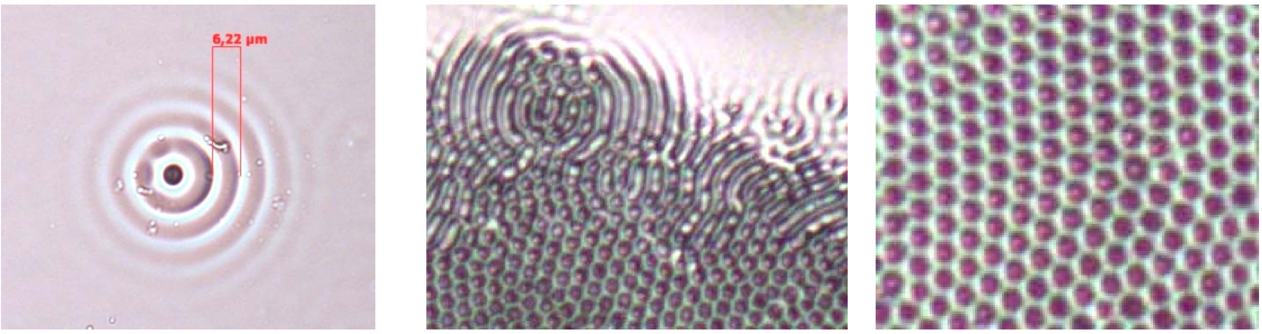
In the work the results of studying of the periodic surface structures on silicate glasses under the action of nanosecond pulsed CO_2 laser are presented (for the first time the similar structures were revealed in [1]). TEA CO_2 laser having nonpolarized radiation at wave-length of 10,6 microns and pulse energy of 0,1 J it has been used as an emission source. The microprojection optical scheme was used for the radiation zone formation, the size of radiation area was 3x3 mm. In the experiment the quartz glasses of marks КУ, К8 have been used.

After exposure on the glass surfaces the following structures have been revealed: the separate localized ring periodic structures fig. (a), structures formed by their overlapping Fig. (b) and hexagonal periodic structures Fig. (c). The period of the received structures makes about 6,2 microns.



a b c

Fig. Periodic surface structures

As a mechanism of the surface periodic relief formation we offer the interference mechanism of waveguide modes excited in the near-surface layer of glass and incident radiation.

Work is supported in partially by RFBR grant N 10-02-00208.

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PS2_39 Formation of angular elements for the output of optical radiation from waveguides

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At the present time the fiber-optic waveguides are actively engaged in numerous fields of information technologies, in particular, in development of the data transmission, receiving and processing devices.

In view of a sizeable waveguide bending having a radius lesser than its critical value the losses connected with radiation of light from the waveguide core to an adjacent environment occur. However, the waveguide destruction occurs at much greater bending radiuses which do not reach the critical values. So, critical values of the bending radiuses can be reached only at thermal action on a waveguide calling the heating of waveguide material to a softening temperature (for quartz waveguides this temperature makes more than 1400 C). Therefore, the best results can be expected with use of the laser-induced heating which allows regulating the spatial, power and time parameters in rather wide interval. In the present work a fabrication technology of the edgewise bend for a single-mode waveguide allowed to form the devices for output from a waveguide to 97 % of radiation in a narrow angular interval was studied. These devices having low production costs can be applied for the different fields, in particular, for development of the attenuators, fiber beam splitters and other components necessary for systems of transmission, receiving and processing of the optical information.

PS2_40 The use of thermal imaging and high-speed video camera in the technology of nanoinstruments laser extraction optimization

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Many studies need to determine the various parameters of materials with nanometer resolution. Methods of scanning probe microscopy (SPM) may solve this problem. The quality of analysis of the sample depends on the parameters of the probe. And for the high quality nanoprobes manufacturing it is necessary to optimize the mode of the exposure.

We used the thermal imager FLIR Titanium 520 M with 320x240 matrix. It allows to measure the temperature in the range from 20 °C to 2600 °C. The maximum refresh rate of the full frame is 380 Hz.

We also used the high-speed camera AOS High Speed Camera X-MOTION with the resolution up to 1280 x 1024 and the burst rate up to 32000 fps.

The results of the use of the speed camera and the thermal imaging for the regimes optimization for nanoprobes laser extraction are shown. The advantage of the speed camera is in possibility of detailed and accurate tracking of the nanoprobe's geometry during the manufacturing process. The thermal imager allows us to observe and analyze nanoprobe manufacturing temperature changes at all points of the investigated zone.

PS2_41 Localized phase separation inside glass by femtosecond laser-induced elemental migration

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The femtosecond laser has been recognized as an effective tool for microscopically and three-dimensionally modifying transparent materials such as glass. In femtosecond laser processing, the heat generated by laser irradiation has often been thought of as a disadvantage that contributes to low accuracy in processing. However, recently, a processing method that uses the heat accumulated during laser irradiation at a high repetition rate has attracted considerable attention. We will report on the space-selective phase separation inside a glass, which has a region of immiscibility in the phase diagram, by changing the glass composition locally from a miscible composition to an immiscible one by femtosecond laser irradiation at high repetition rate. Since the composition of the glass before laser irradiation was in a miscible region, the phase separation does not occur in the original glass and can be locally controlled by laser irradiation and subsequent heat treatment. The phase separation inside glass was detected with a confocal Raman spectrometer, and nanoscale co-continuous structure derived from phase separation was confirmed with scanning electron microscopy after heat treatment, polishing until the laser modified area was exposed and subsequent etching. We elucidated that during laser irradiation of soda-lime silicate glass, the temperature around the laser focal spot exceeds 1000 ºC and the temperature gradient is above several tens degrees per μm. Therefore, the change of compositional distribution is related to the thermomigration (Soret effect) which is the migration of atoms or ions by the temperature gradient. Application of this technique is to make the nanoscale structure in the microscopic area of the glass surface. We believe that this method can be used for other kinds of glasses and is useful for the fabrication of local catalyst supports, modification of micro flow devices, and so on.

PS2_42 Laser modification of thermal oxide films on silicon

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The aim of this work was the investigation of laser emission effects on electro physical properties of SiO_2-Si system.

The research was carried on thermal oxidized silicon substrates n-Si with ρ=4,5 Om·sm, orientation (100) and thickness of oxide 100 nm. Samples was irradiated with optical fiber YLP-laser (λ=1,06 μm) with 250ns pulse length.

The choise of irradiation mode was arised from two questions. Firstly, how interface SiO_2-Si electrophysical parameters are changing directly in region of laser irradiation. Secondly, how local is this influence. Investigation of conditios of irradiated zones under microscope showed the critical irradiation power. It is 5 kWt/sm^2 when local melting of silicon under the layer of SiO_2 begins. With this power or higher film of oxide was destroyed and measurment of capacity-voltage characteristic was unavailable.

With powers less than critical (2÷4 kWt/sm^2) oxide saved and it's c-v curve changed crucially. Firstly, c-v curve was shifted to positive voltage because of nearly total annealing of built-in charges on SiO_2. Secondly, value of capasity of MOS-structure was increased. The increasing of power caused encreasing of capacity. Thirdly, with woltages higher than +1V and less than -1V (c-v curve in inversion or enhancement mode) oscillation of capacity is observed. Increasing of capacity and oscillation of capacity can be caused by formation of silicon nanocluters in irradiated film of oxide. The presence of silicon nanocluster in film of oxide was proved with cathode luminescence in visible and IR spectrum.

PS2_43 Laser treatment of monolithic glass-carbon

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In many scientific centers all over the world including Russia development of autoemissive cathodes is being actively carried out. The main purpose of these researches is a study of cathodes performed on the basis of carbon micro- and nanostructures with high density of the emissive current. Such cathodes can be applied in all electrovacuum devices with the high density of electronic streams and a microsecond available time.

Paper describes a complex of laser technologies for glass-carbon plate processing. Laser scribing, milling, cleaning and structuring are applied for production of micropoint glass-carbon (graphyte) cathodes with high density of current emission. Also the process of impurity migration on a surface of plates is considered.

Scribing of a 2 mm monolithic glass-carbon plate allows breaking the carbon preforms. Laser milling is applied both for cutting of a cathode itself and for micropoints formation. Cleaning of a cathodes surface after laser milling (soot sedimentations removal) is carried out on the same equipment with changing mode. Laser structuring of a micropoints surface is carried out by laser micrograving. The elemental composition of glass-carbon plates is controlled by LIBS-method.

The produced structure represents a field of micropoints of the dome-shaped form with the sizes of the basis of one point 10×10 μm micron and from 15 μm height. On the tops of micropoints chaotically located groups of nanopoints are formed, improving emitting ability of structure and the cathode as a whole. The structure provides the average density of the current 1 A/cm^2.

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PS2_44 Redistribution of elements in steel weld joints studied by LIBS

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Laser weld joints are characterized by significant changes of structure, physical properties and, in particular, elemental composition of welded substances in laser processing zones. The distribution of alloying elements and impurities differs to initial after the termination of laser influence. 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 of fusion and in horizontal zones of joints. Weld joints of steel plates, 2 mm width, made by disc laser, Yb:YAG (λ=1.03 μm, P=1 kW) was considered as an example of the homogeneous material. The migration of steel impurities Al and Mn was considered after lap and butt welding on different modes.

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 workpiece. The horizontal redistribution was also observed.

The results show alloying elements migrate preferentially to the superficial layer of the weld joint. The central line of the joints is enriched by impurities. Different elements choose different surfaces for migration. In case of butt welding Mn "prefers" the front side of the joint, Al – the back side; in case of lap welding both elements migrate to the back side, and the subsurface extremums are observed. Character of migration depends on the type of welding (butt, lap) and on the welding speed.

The work is supported by the Russian Federation President Grant MK-8473.2010.8.

PS2_45 Characterization of mechanical properties and microstructural study of laser welded joints fabricated from carbon steel and 5754 aluminum alloy

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Joining dissimilar materials is a great technological and engineering challenge. Until today the joining of dissimilar metals was realized by mechanical ways of assembling: screwing, riveting, roll bonding or clinching. Welding of dissimilar materials such as aluminum to steel is difficult because of the differences in fusion temperatures, thermal conductivities and mutual solubilities. Brittle phases which formed at the welding interface would deteriorate the tensile strength of steel/aluminum alloy joint. The interest of laser welding is to limit the size of this layer. Laser welding of low carbon steel to 5754 aluminum alloy was studied in keyhole welding mode in steel-on-aluminum overlap configuration. Because of high heat input in continuous laser welding it was decided to use pulsed Nd: YAG laser. Effect of laser power, pulse duration and overlapping factor on intermetallic components formation, weld width, and penetration depth during laser welding was investigated. Tensile test was performed to identify the effect of each parameter on the weld. Effect of intermetallic components on tensile strength was then reported quantitatively. The phase composition was characterized by energy dispersive spectrometry and vickers micro hardness test and microstructure by optical and scanning electronic microscopes. Results obtained show that increasing peak power (in constant pulse energy), pulse duration (in constant peak power) and overlapping factor (in constant pulse energy and peak power) will increase percentage of intermetallic components (PIC). On the other hand, decreasing the mentioned parameters will cause destructive effects such as inadequate penetration depth, spattering and cavity formation. Improvement in the tensile strength was attributed to low values of intermetallic components in weld metal. Finally, an optimized peak power, pulse duration and overlapping factor were reported.

PS2_46 “Long-range action” effect under laser irradiation of SiO_2-Si system

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The aim of the given work is investigation of “long-range action” effect, which was detected in laser modification of thermal growth silicon oxide. This effect is shown in oxide charge changing in the region far from the region of silicon melting under laser irradiation. As a result, two questions appear. Firstly, how does non-irradiation oxides structure change depending on the distance from the center of irradiation region? Secondly, what is the radius of “long-range action” effect?

The research was carried on thermal oxidized silicon substrates n-Si with ρ=4,5 Om·sm, orientation (100) and thickness of oxide 140 nm. Samples were irradiated by 8000 picoseconds impulses of YAG-Nd-laser (λ=532 nm) with average power of impulse $7{,}13\cdot10^{12}$ Wt/sm^2. Oxide structure was analyzed by local cathodeluminescence method using microanalyzer Camebax in visible and infrared range of wavelength. Cathodeluminescence spectra were measured in different distances from epicenter of laser influence: 2, 5, 10, 20, 50 mm.

Cathodeluminescence spectrum in visible range from the region located very far from epicenter (50 mm) corresponds to typical cathodeluminescence spectrum of thermal grown oxide. In cathodeluminescence spectrum obtained in the region located in 2 mm from epicenter, the peak (2,2-2,5 eV) increased, but the main oxide peaks (1,9 and 2,7 eV) decreased. Spectral peak (2,2-2,5 eV) corresponds to silicon nanosize clusters. We suppose spectral modification is caused by reconstruction oxide structure with the assistance of intrinsic oxides defects (1,9 and 2,7 eV). Spectral peak 2,2-2,5 eV decreases with increasing of the distance from epicenter.

Cathodeluminescence spectrum in infrared range has permitted to define the size of silicon nanoclusters – 4-40 nm. Microphotography of irradiated region was obtained by transmission electron microscope. In microphotography one can see the decreasing of silicon nanoclusters density with increasing distance from Si-SiO_2 interface to the oxide surface.

PS2_47 Femtosecond laser recording on thin Cr films

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Laser oxidations of thin Cr films at the range of msec – psec pulses is a widely used method for digital optical recording. The important question now is how high optical resolution can be achieved by that way. One of the ideas which has been discussed lately is thermochemical amplification of thermal image resolution [1]. The other idea is to use the ultra short pulses action to solve this problem.

That is why a femtosecond laser action on thin Cr films has been studied at the power density range before melting point. The main peculiarity of our 100 fsec lasing regime was the 80 MHz repetition rate of femtosecond pulses. At those conditions the total time of action is much longer. The most important phenomena were waited at pointed parameters of laser source are : surface thermochemical reactions and change of a crystallization state of the film [2].

Tree main methods were applied to study the composition and the structure of irradiated zones were :

- Raman spectroscopy to study composition change – mostly to check the thermochemical reactions,
- optical microscopy – to identify external view, sizes and other geometrical parameters,
- AFM – to study the change of thickness of irradiated layers, an
- selective etching to understand difference in the structures in the sense of optical image development.

Finally two most important phenomena has been proved: oxidation and aggregative recrystallization. Both of them was detail studied (Fig). The conclusion is that aggregative recrystallization is able to provide the required difference at the etching rates with initial Cr-film, the highest sensitivity (lowest threshold) and the maximal resolution of the recording.

Fig. Water vapors condensation on irradiated (in the center) and non-irradiated zone.

Acknowledgements : this work was done by the support of RFBR 09-02-01065-a

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PS2_48 Research on the contrast of laser marks on precise surfaces of metals

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The most important operation in the contemporary production technology of sensitive elements for opto-electronical read-out systems is the creation of contrasting rasters with the necessary configuration.

Existing methods of rasters creation have deficiencies, e.g. the electrochemical method has lacks such as the structure friability, the unstable thickness of modified metal layers (from 1.5 to 2.5 μm) and the distortion of surface structure. The tolerance level for distortion has to be less then tenth parts of a micrometer.

The main goal of the research is to develop a technological process for the creation of contrasting rasters on metal surfaces by laser-marking: The developed technological process prevents the described lacks and thereby increases the productivity and the contrast level.

The research allows to determine the correlation between the optical properties and the roughness which influences the reflecting capability of the surface.

Further the dependences of the main characteristics of the contrast raster from the parameters of the laser-marking process are shown.

The future aspects for a practical application of the described technology in precise apparatus engineering are defined.

PS2_49 The new approach to optimization of laser microjoining processes by mathematical modeling of joints kinetic formation

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As a result of kinetics of computer simulation of soldered joints forming, practical investigations of soldering modes influence at the joints strength and analysis of micro section metallographic specimens fulfilled with the aid of electronic microscope, the possibility of three-five fold enhancement of soldered joints strength in comparison with manual soldering. Technological process and automated equipment are developed for laser soldering of electronic components with planar leads at the printed circuit boards.

By the development of modem radio electronic equipment the enhancement of soldered joints reliability is essential. The main indicator of soldered joints reliability is their strength towards mechanic influences. At Fig. 1 the cross-section of soldered joint of planar (surface-mounted) IC lead with copper contact land of printed circuit board (PCB). Soldered joint is formed as a result of filling of gap between PCB copper conductor and gold-plated planar IC lead with liquid solder (see Fig. 2).

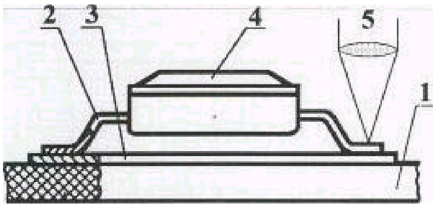

Fig. 1 Diagram of laser soldering of he IC planar leads to the PCB

1 - basis of printed circuit, 2 - planar lead of the IC, 3 - case of the IC, 4 - copper conductor 5 - laser beam

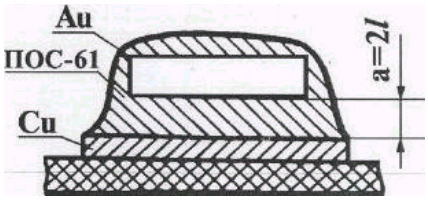

Fig. 2 Cross section of the soldered joint

The strength of soldered joints depends on the strength of melted solder structure in the gap and also on the strength of seals at the inter-phase boundaries.

It is known that by testing of soldered joints for break-away the dependence of their strength from the deformation rate is observed. Factual-account analysis registers plastic failure along the solder at low deformation rates and brittle failure along the intermediate layers at high deformation rates. Thus in order to enhance the joints' strength it is necessary to eliminate the conditions for forming of intermetallic compounds and to increase the strength of the solder within the gap.

In general case the interaction of solid and liquid phases by soldering passes three stages:

- fomiing of physical contact;
- moistening of surface with melted solder and forming of strong chemical bonds;
- mass exchange at the interphase boundaries (solution, hydro-diffusion) which lead to brittle intermetallics formation.

Depending on conditions and modes of soldering and also on relation of physical and chemical properties of soldered materials and solder, the seal, being formed between them, may have different structures. In dependence of soldering time the process of soldered joints formation may be finished as at the earlier stages, as well as at the later and deeper stages of interaction processes between solid and liquid stages. The composition and structure in the seal zone will change correspondingly. In order to obtain the strong joints it is most important to form solder joints with minimum development of diffusion processes or practically with their complete suppression, in order to avoid formation of intermetallic phases.

In order to make prognosis of optimal soldering modes it is necessary to calculate the main parameters of soldering process. It may be organised with the help of "Solution within the gap with account of boundary kinetics model, developed by the authors of this article. This model is the sistem of diflerential equations describing the conditions of mass balance in solid and liquid phases interphase boundary movement in dependence of mutual solubility at different stages of the process (see Fig. 3,) This model allows to analyse the time of boundary kinetics stage completion changing ot composition the moving boundary, diffusion zones width and liquid and solid phase concentration profiles, and also the interphase boundary position. Thus there is a possibility to estimate the limit parameters of soldering process which provide the acquisition of maximum strength of soldered joints.

The results analysis shows that optimum calculated soldering time of gold-plated IC leads with POS-61 solder V (gold solubility in the solder - 10-25 %) is in the limits from 0, 3 to 0, 4 sec (without account of moistening time, see Fig. 3). And the saturation stage is over during 2 to 4 seconds (Fig. 4). It is possible to provide this mode using laser soldering.

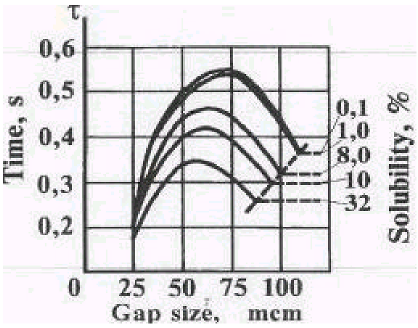

Fig. 3 Diagram of time of boundary kinetics (t) stage completion from the gap size from the different values of solubility dependence.

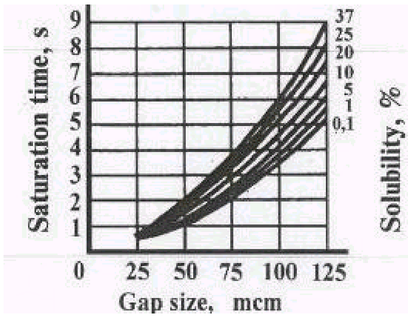

Fig. 4 Diagram of saturation time (t) from the gap size for different solubility values.

As the soldering process is fulfilled in the air and the oxidised surfaces take part in the soldered joint formation, then it is possible to anticipate that the activity of fluxes will essentially influence the strength properties at the short-time thermal influences, when the soldering time is comparable with the time of moistening.

With the help of meniscograph the measurement of moistening time of oxidised and tinned by POS-61 (using alcohol-rosin flux FKSp and flux 2MF, which are the components of soldering paste 1233 IES) solder surfaces of copper conductors was made. It was established that flux 2MF has more fluxing activity than FKSp. In the range of temperatures from 200° to 260°C the time of full moistening of oxidised surface for the first flux corresponds to 1, 2 s, for the second flux - 3 to 4 s; along the tinned surface 0, 3 and 0, 8 s correspondingly (Fig. 5).

Laser soldering modes optimisation made with the help of methods of experiments planning allows to make a conclusion that the optimum soldering time using 2MF flux (τ = 0, 4... 0, 5 s) is 2, 3 times less than for the flux FKSp (r = l, 0... 1, 1 s).-

Thus for realization of calculated soldering mode the more active flux is necessary. By laser soldering process of IC with planar leads at the PCB using solder paste 1233 1ES it is established that mechanic strength of soldered joints can be increased from 3 to 5 times compared with the results of manual soldering with the help of soldering iron. Break-away strength of the joints made with the help of laser using solder paste is 9, 4 ± 1, 3 N for one lead, in case of laser soldering with compact solder and alcohol-rosin flux FKSp - 5, 2 ± 1, 7 N, while by the manual soldering it is possible only to reach values of 3, 7 ± 2, 2 N.

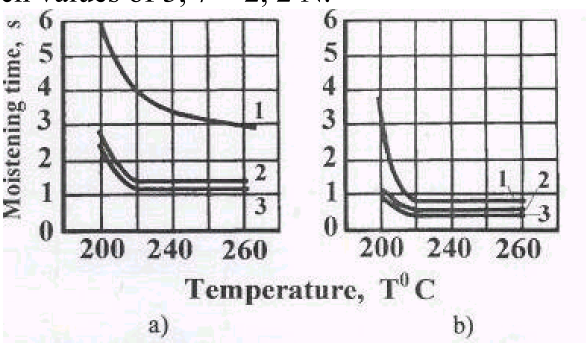

Fig. 5. Dependence of moistening time of copper by the POS-61 solder by using the following fluxes: 1 - FKSp (alcohol-rosin), 2 - OSPP-180 paste, 3 - 1233 IES paste a) samples without preliminary tinning b) samples tinned in advance

At the figures 6 and 7 the pictures of micro section metallographic specimens of soldered joints made with the help of scanning electronic microscope in different characteristic radiations. At the these pictures the front view of the specimen with indicatioh of photography site of solder structure within the gap, photographed in the reflected electrons (RE), in characteristic radiation: of copper - Cu, gold -Au, lead -Pb, tin -Sn.

By laser soldering with τ - 0, 5 s (Fig. 4) the gold coating begins to dissolve in the solder and the coating thickness is yet close to the initial one. By the increase of time of soldering up to 3 s the gold layer is completely dissolved. The copper dissolves rapidly as well.

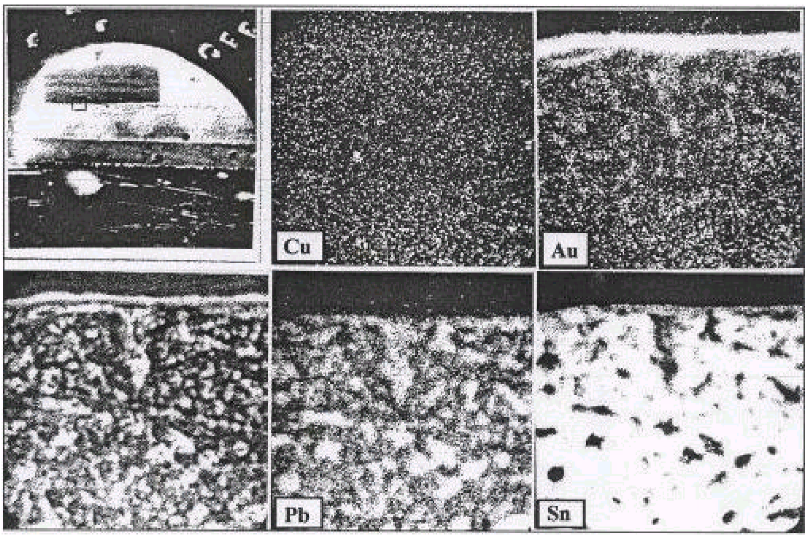

Fig. 6. Laser soldered τ =0, 5 s, T=260° C

By microsection metallographic specimens analysis fulfilled with the help of scanning electronic microscope, the finely dispersed solder structure, typical for laser soldering is observed in the gap and also the total absence of intermetallic interlayers. It is necessary to mention (fig. 6, 7) that by laser soldering in optimum modes the partial dissolution of the barrier gold coating at the IC leads, and the fixed width of the diffusion zone (10-15 mcm), while by manual soldering the gold is totally dissolved in the gap, forming inter metallic compounds with tin.

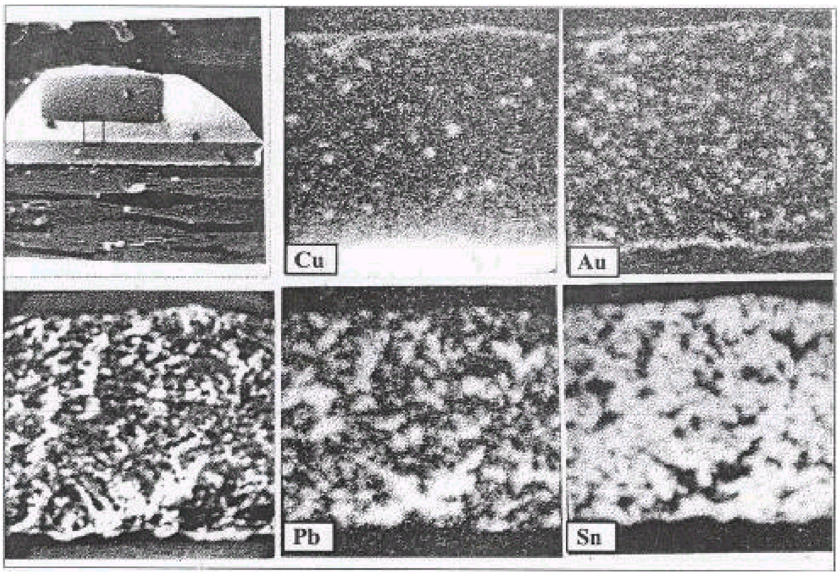

Fig. 7. Manual soldered T-3 s, T=240° C.

On the basis of investigations technological process and automated equipment were developed providing the solder paste measuring and laser soldering of IC leads at the printed circuit board.

W1-1 Nanoplasmonics: modern status and prospects

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Advances in the production and visualization of nano-sized clusters and other metal nanoparticles have given rise to nanoplasmonics [1], an important and fast-developing area of nanotechnology and nanooptics. Aimed at designing complex optical nanodevices, nanoplasmonics studies phenomena related to oscillations of conduction electrons in metal nanostructures and nanoparticles and how these oscillations interact with light, atoms, and molecules. Plasmon oscillations in nanoparticles differ substantially from surface plasmons [2] and are therefore called localized plasmons

What is most special about nanoplasmonics phenomena is that the strong spatial localization of the electronic oscillations is combined with their high frequencies varying from UV to IR ranges. The strong localization, in turn, leads to a huge enhancement of local optical and electric fields. Finally, the properties of localized plasmons are critically dependent on the nanoparticle shape, enabling their resonance systems to be tuned so as to effectively interact with light or with elementary quantum systems like molecules and quantum dots.

These most important properties of plasmon nanoparticles have already allowed a range of new effects to be detected. First and foremost, the huge local fields that arise near nanoparticles lead to an increase of 10 - 14 orders of magnitude in the Raman scattering cross section, conceivably making individual molecule detection possible [3, 4]. The presence of local fields can be exploited to design marker-free techniques for determining the structure of DNA [5]. Using the complex spectral structure of plasmon nanoparticles, it proves possible to simultaneously enhance their light absorption and light emission properties, giving rise to high- performance fluorophores and nano-sized light sources [6] and even to nanolasers [7]. Other than the above novel applications -ones that rely on plasmon nanoparticle physics-achievements in the field of nanoplasmonics can be used to improve the performance-to-cost ratio of, for example, solar batteries and LEDs [8]. Furthermore, the small size of metal nanostructures combined with optically fast processes occurring in them gives nanoplasmonics good promise for developing a new component base for computers and data processing devices [9]

In my talk I will discuss these and some other mainstream directions of investigations in nanoplasmonics [6, 10-15] and their applications to elaboration of operation principles of different nanodevices.

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W1-2 Absorption and scattering of light in detonation nanodiamonds

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Development of nanotechnology requires the production of dispersed particles of a material with characteristic sizes of a few nanometers. Artificial diamond particles produced by the standard high temperature - high static pressure method have sizes ranging from fractions of a micron to hundreds of microns. Detonation nanodiamond (DND) has a crystalline core of about 4 nm. They can be synthesized from carbon atoms of explosives during confined explosion.

The goal of presentation is to give a short review on technology and properties of diamond particles produced by detonation of carbon explosive materials discovered in USSR in the 60-s. The presentation based on the latest results of Ioffe nanodiamond group [1].

It has been recently shown by Ioffe group as well as other scientists the DND cluster consists of a diamond core (sp^3 hybridized carbon) covered by a carbon-onion shell (sp^2 hybridized carbon). It has been experimentally shown that the sp^3/sp^2 depends strongly on conditions of detonation synthesis and can be changed by heat treatment in different atmosphere.

It has been difficult to isolate the crystalline cores primarily because of the well-known high tendency for nano-sized particles to aggregate into clusters of submicron size due to the high specific surface area. DND usually forms a hierarchical fractal structure. However, it was recently suggested that stirred-media milling with micron-sized zirconia beads is an effective method for making from DND stable aqueous suspension of 4 nm particles. It was suggested that week-bounded π-electrons were formed on the surface of 4 nm diamond particles due to colliding at milling process. That was how unexpected black color and high viscosity of the suspension was explained for the first time [2].

The main attention is given to optical properties of light absorption and scattering of (DND) hydrosol. An analysis of experimental data and calculations based on the models taking into account detailed structure of single DND particle consists of diamond core covered graphite-like offers an explanation for some phenomena observed DND. It is shown the color of a DND hydrosol is determined by scattering of light from DND particles separated in size into a number of fractions. As result the analysis of spectra may shed light on the true nature of particle aggregation in hydrosols.

The research of Ioffe nanodiamond group has been supporting by the Federal Agency for Science and Innovations, Programs of the Russian Academy of Sciences and the Russian Foundation for Basic Research, Japanese organization NEDO and European FP7 program.

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W1-3 Light scattering by nonsphercal particles

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Light scattering (LS) by nonspherical particles is of a large interest in various fields of science and technology, including photophysics of nano-scale systems. Efficient solutions to most LS problems are known to be based on expansions of the electromagnetic fields in terms of wave functions. It can be obtained by three approaches – the separation of variables (SVM), extended boundary condition (EBCM) and point-matching (PMM) methods [1-3]. These approaches were earlier considered independently because of essential differences in the problem formulation: in the SVM unknown coefficients of the field expansions are derived from the boundary conditions written in a differential form and related to continuity of the tangential components of the electromagnetic fields at the scatterer surface, the EBCM is based on solution of surface integral equations associated with the Huygens-Fresnel principle, while the PMM solution applies least-square technique to satisfy the boundary conditions. However, the main feature of all the approaches is the use of the same field expansions and as a result expression of any optical characteristic of a scatterer is the same within the methods. Thus, they mainly differ in the way of determination of the unknown field expansion coefficients, which leads to different infinite systems of linear algebraic equations relative to these coefficients. Therefore, any analysis of the methods under consideration aimed at revealing their relations and applicability ranges is important. In this paper we perform such an analysis by applying techniques developed by us for the methods with spherical and spheroidal bases [3].

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W1-4 Shaping of surface nanostructures via non-thermal light-induced processes

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Non-thermal light-induced surface processes hold out hope for the development of new approaches to surface nanostructuring. Although they do not seem to be as flexible and universal as photolithography a number of niche application are waiting for a specific cheap and easy process. Light induced atomic desorption is a reliable tool to control the surface number density of the adsorbed atoms in the course of physical vapor deposition process. Strong enough illumination diminishes the number density of the adsorbed atoms below the threshold value needed for the beginning of the nucleation process. Hence, the deposition pattern reproduces the distribution of the illumination intensity over the surface. In addition, light induced surface diffusion stimulates the departure of the adsorbed atoms out of the illuminated region. In some cases plasmonic nanostructures are obtained via self organization of metal deposits on dielectric substrates. Their performance is severely hindered by broad size and shape distribution. Non-thermal light-induced detachment of surface atoms from the metal nanoparticles may be used to tune their size and shape. In particular, we find that a narrow dip in the shape distribution of the metal nanoparticles may be obtained by a laser treatment at the specific wavelengths. We present also experimental evidences of a new non-thermal light-induced process, namely, the light stimulated diffusion of the own atoms over the surface of a metal nanoparticle.

W1-5 Laser -Induced Quantum Adsorption of Atoms on a Surface

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The adsorption of an atom on a surface is a natural process of the trapping of the atom in a surface potential well (van der Waals interaction, formation of a chemical bond). The probability of trapping of the particle on the surface is determined both by the electronic structures of the particle and surface and by the thermodynamics of the collision of particles with the surface. In addition to the general physical interest in the process of the adsorption of particles on the surface, the adsorption of particles underlies the modern industry of micro- and nano electronics based on the methods of molecular beam epitaxy or gas phase epitaxy. For this reason, the investigation and control of elementary processes of the adsorption of particles on the surface are of both fundamental and large applied importance.

At present, one proposal on controlled loading of atoms into the surface potential well is known. It is based on the effect of the photoadsorption of the atom on the surface [1]. This process is similar to the photoassociation of atoms, i.e., the formation of a molecule from two atoms owing to the absorption of a photon at the instant of collision of these atoms. The effective light-induced pairing of atoms became possible after the development of the methods of the laser cooling of atoms, which made it possible to significantly increase the phase density of atomic ensembles. The probability of the photoassociation of particles can also be increased if one of the colliding particles is macroscopic. This is the case when the atom collides with the solid surface in the presence of a laser field. The photoassociation-induced loading of atoms into the surface potential well requires ultracold atoms and the efficiency of the process is low according to the theoretical estimates [1].

We propose and realize a new mechanism of loading atoms into the surface potential well (i.e., their adsorption) and demonstrate the implementation of this scheme for Rb atoms adsorbed on the surface of a YAG crystal [2]. The proposed mechanism of the loading of atoms into the surface trap is based on the energy-pooling effect, i.e., inelastic collision of two excited atoms followed by the transition of one of them to the ground state and the other one to the highly excited state. The defect of the internal energy is compensated by the kinetic energy of the atoms. When the atomic collision occurs inside the surface potential well, an atom can be trapped in this well.

The possibility of producing atomic micro and nano structures of arbitrary shape with the use of quantum adsorption has been also demonstrated.

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W1-6 Photo-induced processes at the interface of flat and nano-structured surfaces

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Photochemistry of various molecules caged within amorphous solid water can be viewed as model for such activity at interstellar space[1].

We have studied the photo-induced fragmentation of alkyl halide molecules caged within a thin (25ML) amorphous solid water (ASW) on top of Ru(001) and O/Ru(001) surfaces, under UHV conditions, following excitation by an excimer laser at 193nm (6.4 eV photon energy). Various fragments are formed, sensitive to the type of molecule, e.g. methyl vs. ethyl chloride, and the substrate – clean ruthenium, oxygen covered or modified by gold nano-clusters. Careful measurements suggest that the alkyl halide molecules are trapped and reside about 1.5 nm away from the surface. Typical cross section for photo-fragmentation on O/Ru(001) is $1.0 \cdot 10^{-20}$ cm^2.

The question arises to what extent the presence of gold nano-clusters at the vicinity of such photo-active center of caged molecules can modify and/or enhance the photo-activity. Gold clusters 3-7 nm in diameter were grown employing buffer layer assisted growth mechanism[2] over the clean and oxygen covered ruthenium surfaces. On top of these metallic clusters ethyl chloride molecules were caged in ASW, residing about 1.5nm above the clusters. Our measurements suggest that a significant enhancement of the basic photo-fragmentation event takes place due to the presence of gold nano-clusters. An order of magnitude larger photo-induced fragmentation cross section was measured over 7nm diameter gold clusters (on average). It is a remarkable observation considering that the clusters density is three orders of magnitude smaller than the substrate atom density.

This is probably the first report on *surface enhanced photochemistry/photo-fragmentation*, arising (tentatively) from surface plasmon resonance excitation.

This is a physical origin that resembles surface enhanced Raman spectroscopy (SERS), originally discussed more than 30 years ago.

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W1-7 Dynamics of excitonic transitions in semiconductor nanostructures in ultrashort pulse field

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The present work is devoted to detail analysis of the excitation induced dephasing (EID) and the excitation induced shift (EIS) effect on Rabi oscillation in dense ensemble of QDs. Starting with the case of the undamped system exposed to the monochromatic field under precise resonance conditions nonlinear dynamics of QD excitonic states can be described by Duffing model for anharmonic oscillator. At this Rabi oscillations strongly depend on the laser pulse intensity and the ratio of Rabi frequency and Lorentz one. If in the weak excitation field an inversion oscillations are practically harmonic, then with field increasing oscillations become strongly nonlinear. Further increasing of field intensity leads to bifurcation in Rabi oscillation. In the vicinity of the bifurcation Rabi oscillations are essentially anharmonic. This means that in the frequency domain the Mollow triplet (which characterizes the atomic Rabi oscillations) is transformed to a more complicated spectrum that contains satellites corresponding to higher orders of the Rabi oscillations frequency. The anharmonism in the Rabi oscillations disappears at the further increase in excitation field. In other words one can say that high intensity ultrashort pulse may suppress the local field effect.

Let's dwell on the excitation induced dephasing influence on the optical nutation signal. Like the EIS the latter results in multiple frequencies in the signal spectrum. In the field of long enough laser pulse the oscillation frequency is switched over to higher or lower one in dependence on Lorentz frequency. Moreover time switching is a function of the EID parameter.

W1-8 TR-photoemission electron microscopy - nanoscale spectroscopy with femtosecond resolution

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Improving the spatial resolution in time resolved experiments is of utmost importance for many applications of ultrafast laser spectroscopy. In a theoretical investigation a novel approach was approached to achieve simultaneously ultrahigh spatial and temporal resolution by the excitation of a nanostructure with polarization-shaped laser pulses [1]. The high sensitivity and lateral resolution of the two-photon photoemission electron microscopy technique is used to verify this experimental scheme for a simultaneous spatial and temporal control of nanooptical fields by means of femtosecond polarization shaped laser pulses. By this means the spatial origin of emitted photoelectrons and hence the optical near field distribution leading to the excitation of the nanostructure can be determined with approximately 50 nm resolution. A polarization-shaped pump pulse is used to excite a planar silver nanostructure that has been manufactured by e-beam lithography. The corresponding spatio-temporal excitation is probed by time-resolved cross correlation measurements between the polarization-shaped pulses and a simple circularly polarized probe pulse. Our experimental results show that by this means the local optical response in the vicinity of nanostructures can be manipulated in a very flexible manner on subdiffraction length scales [2]. Even more, time-resolved PEEM proofs that the highly localized optical fields can be switched on a time-scale as short as 400fs between different areas separated by some tens of nanometers within a single polarization shaped excitation pulse [3]. A simultaneous spatial and temporal control limited only by the spectral bandwidth of the coherent excitation light source is in principle possible.

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PS1_35 UV induced alteration of linear and nonlinear IR optical properties of dielectrics for photonics applications

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UV irradiation of polymeric PMMA films containing $HAuCl_4$ followed by annealing at 60-80^{0}C forms gold nanoparticles directly within the bulk of material [1,2]. Organic-inorganic hybrid materials based on TiO_2 gels demonstrate high photosensitivity at the wavelength of the third harmonic of a Nd: YAG laser [3]. Irradiation at this wavelength results in formation of Ti^{3+} centers [4]. In the present communication we show that both of these materials demonstrate significant UV induced alteration of linear and nonlinear optical properties in IR range.

Linear refractive index changes were demonstrated while UV recorded phase diffraction gratings were studied. Good efficiency of diffraction transformation was shown with visible and IR laser radiation. More complicated volume structures lead to multiplexing of laser beam. Obtained 3D-structures deep inside of samples are safe of surface damage. Materials have low optical losses in wide spectral range, so they could be widely adopted in real devices.

Highly sensitive method based on spectrally resolved two-beam coupling technique was used for detection of electronic optical nonlinearity in thin polymeric films in infrared spectral range. Our experimental setup possesses erbium doped fiber laser generating 100 fs pulses with high repetition rate on wavelength 1570 nm as the light source. Cross phase modulation during interaction of two beams with high and low intensity in focal area leads to large relative spectrum changes at the edge of the laser spectrum band. Thus, spectral analysis allows getting information about nonlinear optical properties of studied media. The nonlinearity activation time could be measured using time delay between pump and probe femtosecond laser pulses. High values of UV induced nonlinear refractive index and two-photon absorption coefficient owing to both the gold nanoparticles and the Ti^{3+} centers were obtained in studied materials. Small time of activation of nonlinear optical susceptibility proves the electronic mechanism of optical nonlinearity. Further studies will be carried out for optimization of the polymer composition and conditions of preparation for higher optical nonlinearities.

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PS1_36 Formation of self-organized nanostructures on titanium by its ablation with short laser pulses in liquid environment

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The process of nanostructures (NS) formation on bulk Ti immersed into either water or ethanol is experimentally studied under its exposure to short laser pulses. Two types of lasers were used: either a KrF excimer laser emitting at 248 nm with pulse duration of 5 ps or a Nd:YAG laser emitting 150 ps pulses at the wavelength of 355 nm. Nanostructures were characterized by Field Emission Scanning Electron Microscopy (FE SEM), X-ray Photoelectron Spectroscopy (XPS), and Raman Spectroscopy. Density of NS and morphology depends on both the number of pulses and laser fluence. It is found that the formation of NS on Ti surface under its laser ablation in various liquids is accompanied by its strong visible coloration, and the corresponding color correlates with the NS morphology. Such coloration can be attributed to the plasmon oscillations of electrons in the NS. Possible applications of nanostructured titanium in medicine and biology are discussed.

PS1_37 Nanowire as an optical resonator: Theory of Fabry-Pérot modes.

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The rigorous theory of electromagnetic modes of a cylindrical dielectric nanowire of finite length is developed. It assumes an arbitrary ratio between the nanowire radius and length and the electromagnetic field wavelength. The exact integral equation which determines the

electromagnetic field obeying the boundary conditions at the whole nanowire surface is derived by the use of fictitious electric and magnetic current sheets located at the nanowire ends. The solution has the form of the Fourier integral along the integration path in the complex plane of propagation constants. The nanowire Fabry- Pérot modes are defined as non-trivial solutions of the source-free equation. The approach is considered in more detail for elongated nanowires whose length is much larger than their diameter. The result obtained for a single-mode nanowire resembles the formula for classical Fabry- Pérot resonator if one introduces an effective wavelength-dependent phase shift which can be determined from the calculation of the nanowire response function. The developed approach can be equally applied to metal nanowires if one considers surface modes whose propagation length is comparable with or larger than the nanowire length. It is argued that among such modes only the TM0 mode dictates the resonance conditions in a metal nanowire Fabry-Pérot cavity.

PS1_38 Fabrication of V-shaped optical antennas

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Optical antenna based on metallic nanostructures is a new nano-optical element which is able to efficiently couple the energy of free-space radiation to a confined region of subwavelength size. Such elements are expected to find applications as probes for near-field optical microscopy and spectroscopy. Optical antennas can be fabricated by means of such method as focused ion beam milling or electron beam induced deposition with a precursor gas; however these methods require quite sophisticated equipment.

In this paper the possibility of V-shaped optical antenna fabrication has been experimentally demonstrated using the technique of electron beam induced deposition of carbon. The advantage of this method is that it can be implemented in any electron beam microscope. Fabricated structures consisted of pairs of closely-spaced carbon nanorods in the shape of the letter “V”. The carbon nanostructures were then coated with a 10 nm thick gold layer by means of sputter deposition. A set of V-shaped antennas of different size were fabricated: the length of the rods forming the antennas varied from 120 to 160 nm and the width of the gap between the rods ranged from 10 to 20 nm.

The fabricated nanostructures were theoretically studied using the finite-difference time-domain method. The modeling revealed that V-shaped antennas are able to create strong electromagnetic field in the gap between the nanorods while illuminated with visible and near-infrared light. The resonant wavelength of light redshifted with the increase of the length of the nanorods forming antennas. Field enhancement factor in the gap of antennas increases with the decrease of the gap width.

PS1_39 New holographic method for formation of 2D gratings in photorefractive materials by Bessel beam standing wave

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Materials with spatial periodic structure such as photonic crystals, are now finding applications in many fields of physics and optical device engineering. Among different methods of creation of spatially periodic structures the holographic technique remains one of a simple and promising method for fabrication of spatially periodic structures in photo-refractive materials.

In this report we present a new method for creation of 2-dimensional (2D) holographic gratings by Bessel beam standing wave in photorefractive materials. The intensity pattern of non-diffracting Bessel beams can be imparted into the photorefractive medium, being irradiated, via electro-optic effect, thus creating micro- and sub-micro-scale 2D refractive index gratings. The main idea of creation of 2D gratings by Bessel beam standing wave and schematic for creation of 2D grating by single axicon with back-reflecting mirror is shown in Fig.1a. Enlarged pattern of two neighbor planes with maxima of light intensities, separated by ~ $\lambda/2$, where the set of concentric rings are positioned, is shown schematically in Fig 1b.

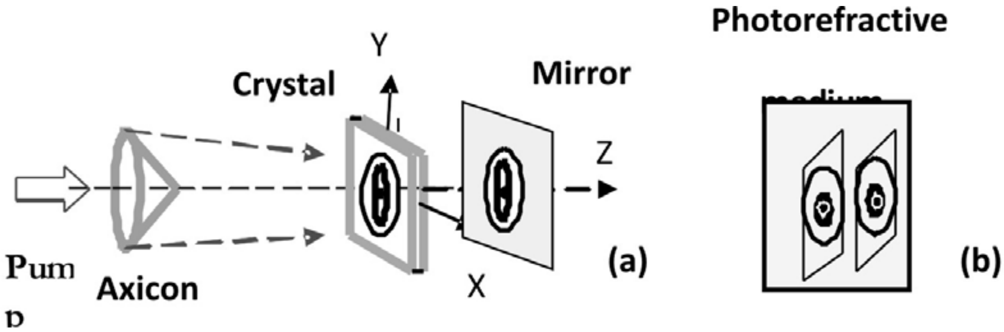
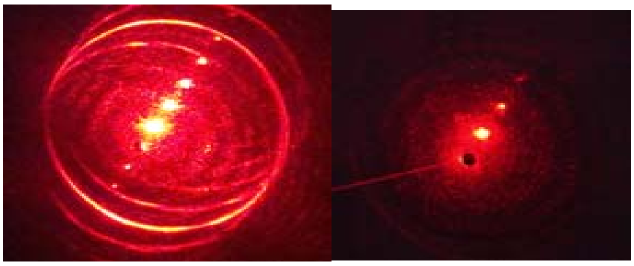


Fig.1. Main idea for creation of 2D gratings by Bessel beam standing wave in photorefractive medium.

The Bessel beams are formed by axicon being irradiated by single mode He-Ne laser beam at 633 nm and with 17 mW power and counter-propagating beam geometry is used for build-up the Bessel beam standing wave. The gratings are recorded in both Y and Z-cut lithium niobate crystals single doped by Fe and doubly doped by Fe and Mn, taking into account their high photorefractive properties and possibility of creating the permanent gratings. In series of experiments instead of using the separate mirror (Fig.1a) the output surface of the crystal was coated by nearly ~95% reflecting Al thin layer. The grating was tested by Gaussian beam observing the back-reflected diffraction pattern (Fig.2a), compared with the back-reflected beam patterns from the “clean” part of the crystal without recorded grating (Fig.2b).

The scheme allowing writing and reading of the written gratings by Bessel beam, as well as measuring the time evolution of diffracted beam power (Fig.3) and diffraction efficiency of the gratings is also realized. The gratings formed have the half-wave period of ~300 nm in longitudinal direction and ~10 μm period in radial direction and up to 10% diffraction efficiency.



a b

Fig.2(a) Diffraction pattern obtained by 633 nm Gaussian probe beam from the grating, written in Fe doped lithium niobate crystal with C-axis directed along the crystal surface.(b) back-reflected beam patterns from the “clean” part of the crystal.

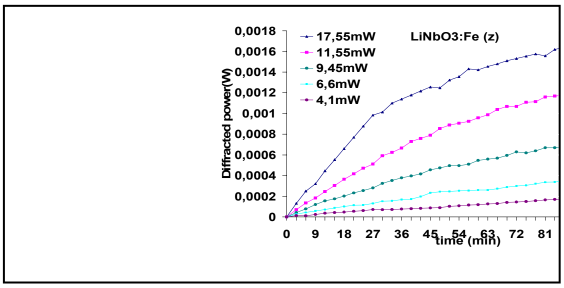


Fig.3. Time evolution of diffracted beam power for Fe doped lithium niobate crystal with C-axis directed orthogonal to the crystal surface.

PS1_40 Melting temperature of Ge nanoclusters in Si matrix

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The laser modification of nanostructures is of great interest. In order to study the interaction of laser radiation with nanocrystals embedded in a solid matrix it is important to know their melting temperature (T_m). It is well known T_m of nanocrystals depends on their sizes. In this work we considered the Ge/Si heterostructures with Ge_xSi_{1-x} nanocrystals (quantum dots) grown by molecular beam epitaxy. Our aim was to determine T_m of the quantum dots in dependence on their size, shape, composition and mechanical stresses.

We used two theoretical approaches for the description of size dependence of T_m. In the first approach T_m is determined by the entropy of thermal crystal vibrations. The entropy depends on nanocrystal size, shape and nanocrystal – matrix interface properties. The dependence of T_m for two different shapes of nanocrystals (hut- and dome- clusters) on size was obtained. In the second approach it is assumed that T_m is proportional to nanocluster cohesion energy. The data obtained by use of both approaches are compared. T_m increases from 1215K up to 1250K for Ge dome-clusters and from 1220K up to 1285K for Ge hut-clusters with reduction of base size from 50 to 5 nm.

The influence of lattice mismatch pressure can be estimated on the basis of Clausius-Clapeyron equation. Under the solid – liquid phase transition the Ge specific volume decreases about 5%. It indicates that T_m decreases with pressure increase. We obtained that the pressure due to lattice mismatch results in decrease of T_m on 90 K.

The effect of nanocluster composition on T_m can be estimated from equilibrium T-x phase diagram for Ge_xSi_{1-x} solid solution. At x=0.7 melting temperature increases on 150 K. Taking into account that the size reduction and pressure lead to opposite effects, the melting temperature of Ge_xSi_{1-x} nanoclusters is mainly determined by their composition.

PS1_41 Dynamics of formation and modification of silver nanoparticles in glass matrix

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The interest in composite materials containing metal nanoparticles has grown considerably because of their numerous potential applications in different fields of science and technology, such as optical elements, nanophotonic devices or novel nonlinear optical materials. Since linear and nonlinear optical properties of such nanocomposites are dominated by the surface plasmon resonance (SPR) of the metal nanoparticles, the key parameters determining their properties are size, shape and spatial distribution of the nanoparticles but also the properties of the surrounding matrix [1]. Laser-induced techniques represent a very powerful tool to control these parameters which has been proved in many experiments [2]. However, according to our knowledge, there has been no experiment in which optical properties of nanocomposite materials were studied during their formation.

In this work precipitation and modification of silver nanoparticles during nanosecond laser irradiation of silver ion-exchanged glasses is investigated by on-line measurements of optical absorbance.

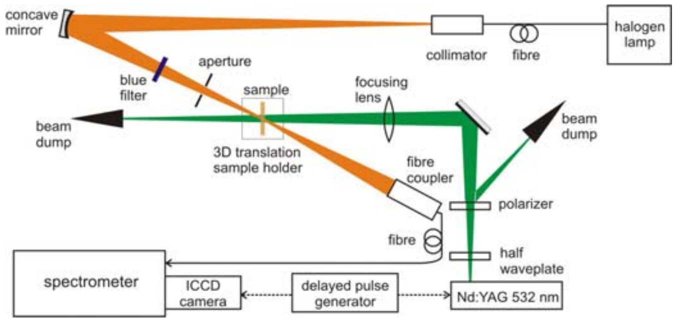

Fig. 1. Experimental setup.

In our experiment four sets of samples were prepared by immersion of the soda-lime glass slides in a molten salt bath of the 10% molar concentration of $AgNO_3$ in $NaNO_3$ at temperature of 300^0C. Such samples were then irradiated by nanosecond Nd:YAG laser pulses at wavelength of 532nm (Fig.1). The sample area irradiated by the laser was also illuminated by a white light beam from a halogen lamp. Transmitted light was coupled to the fiber and focused onto the slit of the spectrometer equipped with an image intensified CCD camera. In each single experiment a fixed number of 1000 laser pulses was deposited on the sample and its linear absorbance was measured 100µs after each pulse.

Suggested mechanism of variations of the absorbance curve is the formation and modification of silver nanoparticles [3]. For sufficiently high laser intensity silver ions can be reduced to atoms. Due to thermal diffusion in the ion-exchanged layer the silver atoms start to migrate and form clusters of different shape and size. These metallic nanostructures absorb light at some range of wavelengths due to SPR. Depending on the laser pulse energy we can further observe either slight increase or fast decrease of the absorbance. The latter is related to destruction of the formed nanoparticles in the process of laser ablation which is accompanied by plasma emission and results in bleaching of the sample.

The above-mentioned effects are studied with regard to the laser wavelength, its intensity and immersion time of the sample in salt bath.

Acknowledgments

We wish to acknowledge the support of this work by project d'Action Integrees - Polonium 836/R09/R10,7835/R09/R10 and partially by the Polish Ministry of Science and Higher Education grant NN202 031136.

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PS1_42 Direct comparison of large scale simulation of nanostructuring on metals with the experiment

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The process of short pulse laser nanostructuring on materials is currently a subject of active research interest from the side of rapidly progressive and promising scientific fields: IT- and BIO-technologies. The structures on sub wavelength scale obtained on metals [1] semiconductors [2] and insulators [3] exhibit unique properties from the point of both fundamental physics and possible technological applications. However, transient and nonequilibrium character of processes occurring simultaneously and on relatively wide time and spatial scales makes their experimental study limited and expensive on one hand and the applicability of the theoretical models difficult on the other one. In this work, the complete process of femtosecond laser nanostructuring of thin Au films on a substrate is modelled on the experimental scale, Fig., in a super-large scale simulation based on the atomistic-continuum approach [4]. In this model the laser energy absorption, the laser-induced electron-phonon nonequilibrium, and the fast electron heat conduction is treated in continuum with Two Temperature Model (TTM), and transient nonequilibrium phase transformations are accounted at atomic level with Molecular Dynamics (MD). The performed simulations based combined MD-TTM approach allowed for a direct comparison between simulations and experimental data.

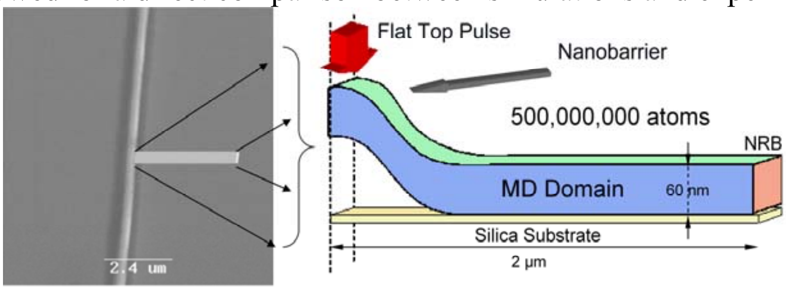

Fig. The model on short pulse laser nanostructuring on thin Au film is represented schematically (right). The computational technique allowed for a direct comparison of the results of simulations with the experiment (left).

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PS1_43 Sensitivity increasing of the EUV resists by the additional UV laser irradiation

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There are considered two methods of EUV positive polymeric resists sensitivity increasing. Both considered methods can operate in parallel.

The first of these methods provides the usage of a silicon-organic polymer as a EUV resist instead of the traditional organic polymers. The absorption coefficient at EUV wavelengths increases as a result of this replacement. The value of this increasing factor ranges up to about 10 times. The rise of the absorption is determined by the nature of non resonant influence of EUV radiation. Basically it is defined by the interatomic energy levels. And the absorbed energy fraction is proportional from 3⅓ to 5-th degree of the charge of nucleus Z. When used the silicon-organic polymers for which the silicon (Si) is a fraction of 20-25% (on mass), in the assumption of dependence $\gamma=0{,}2\bullet(Z_{Si}^5/Z_C^5)\approx10$. I.e. the carbon (C) (Z=6) replacement by the silicon (Si) (Z=14) gives a rise of sensitivity of an order of 10 times.

The second method of the sensitivity increase is applicable only for the positive resists. This technique assumes an additional non directed irradiation of the substrate's plane by the UV light, including the irradiation by the UV laser light. This UV light affects exclusively on the earlier formed macroradicals owing to coincidence of the spectral ranges. On the macromolecules without breakages this radiation does not effect. Thus under the influence of UV photons there is a reproduction of macromolecular breakages. So it is possible to increase the concentration of macromolecular breakages several times only in these areas, that earlier have been irradiated by the EUV radiation. In this case the linear resolution of the creating structure is persisting without essential deteriorating.

It has been developed a mathematical model. This model integrates all essential parameters descripting the process of EUV lithography. The analysis based on this model allows to define the optimum mode of the exposure of the EUV resist.

PS1_44 Femtosecond laser surface nanostructuring of solids

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We report on our recent femtosecond laser nanostructuring studies of diverse metallic (Al, Ti, Ni) and semiconductor (Si, C) surfaces in different ambient media (air, water, alcohols). We demonstrate the key role of ultrafast transient variation of optical constants of femtosecond laser-excited materials during their surface plasmon-driven energy deposition and resulting imprinting of nanoscale one- and two-dimensional surface gratings with spatial periods down to sub100-nm scale. Using various experimental techniques we thoroughly investigate very important accumulation effects during femtosecond laser nanostructuring of solids, resulting in eventual degradation and increasing disordering of the intermediate laser-induced surface nanostructures versus increasing laser dose. Some perspective applications of the femtosecond laser-written surface nanostructures and by-product nanoparticle sols are discussed.

PS1_45 Resonant diffusive reflection of light from rough interfaces of Bragg structures (photonic crystals)

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Surface (interface) roughness is one of the most important reasons for appearance of diffusive component of light reflected by a condensed medium. The spectrum and angle distribution of the light intensity are directly governed by the geometrical parameters (r.m.s. height and transverse correlation length) of roughness [1, 2]. Resonant elastic scattering of light from nanostructures with random interfaces is of great interest for the laser-assisted nanotechnologies It is particularly because such a scattering is significantly enhanced in exciting inherent resonant states as was demonstrated, e.g., for excitons [2,3]. For dielectric multilayers and semiconductor multiple quantum wells, the role of interface roughness becomes much more important. This makes actual to solve the problem for diffusive scattering of light from multiple rough interfaces under resonant excitation. Earlier the effect of this kind was not studied.

In this work, a theory is presented for resonant elastic scattering of light from Bragg structures (photonic crystals) with randomly rough interfaces between alternating dielectric constituents. For linearly polarized light waves, the spectra of diffuse scattering are analyzed in terms of statistical parameters of Gaussian interface roughness in comparison with the spectra of Bragg reflection. The scattering cross-section is found to be resonantly enhanced in the vicinity of the photonic stop-band edges. This effect allows one to observe a reliable resonant scattering signal from rather small roughness with the nanoscaled mean-square height. The scattering spectra are demonstrated to depend drastically on the depth location of a single rough interface along the axis of the Bragg structure. As well, an angle-dependent suppressing the reflection diffuse component in p-polarized light is found.

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PS1_46 Nondegenerate pump-probe spectroscopy of semiconductor quantum dots: interband absorption

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Knowledge of inter- and intraband energy relaxation rates of excited states of the quantum dot electronic subsystem is of significant interest to nanoscale physics and practical applications. In spite of the fact that a lot of efforts have been directed on obtaining of information about relaxation processes in semiconductor quantum dots, the currently available data are controversial. In this connection the additional systematic studies of the energy relaxation of quantum dot electronic states are required. It is well known that the pulse pump-probe method is the most promising optical method for finding of the energy relaxation rates of excited states in various systems from atoms to solid states. In this report a theoretical description of one of version of the method adapted to quantum dots, namely the transient interband absorption of energy probe pulse induced by the pump pulse, is proposed. It is assumed that the carrier frequencies of pulses are close to resonance with the different interband transitions of the electronic subsystem of the quantum dot (nondegenerate case) and the resonant excited states are connected by intraband relaxation process. This version of the method allows us to investigate not only the total energy relaxation rate of some state, but also the individual rate of intraband relaxation of electrons and holes. The conditions under which the dependence of the absorbed energy on the delay of probe pulse relatively pump pulse is exponential and the exponent is proportional to the relaxation rate of the investigated states are determined. The calculation results of differential energy absorption of the probe pulse for the strong and weak confinement regimes of the electronic subsystem of quantum dots are discussed.

PS1_47 Formation of nanosized particles (clusters) in resonance radiation field

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It is known that nucleation plays a significant role in formation of atmospheric aerosols and in production of nanoparticles by substance deposition from a gas phase. The rate of homogeneous nucleation depends on the free energy of critical cluster formation that is defined by the critical cluster size. Its value is found from the condition of the equality to zero of the resulting mass flux into the cluster. The critical cluster size is a key parameter in the nucleation theory. The paper deals with a theoretical study of the influence of resonance radiation on the formation of nanosized particles (clusters) in the presence of a foreign gas that can be adsorbed on the particles and affect physicochemical transformations on their surface. It is shown that in physical vapor deposition the critical cluster size and accordingly the nucleation rate can be affected by resonance radiation due to excitation of vapor and foreign gas molecules and a difference in the sticking coefficients of excited and unexcited molecules. In the case of chemical vapor deposition the excitation of molecules of the reactant gas by resonance radiation can lead to an increase in the rate constant of a chemical reaction and accordingly in the nucleation rate. The joint influence of heat and resonance effects on the critical cluster size and the particle (cluster) growth rate is discussed. It is shown that in some cases a maximum in the dependence of the particle growth rate on the radiation intensity can take place.

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PS1_48 Polariton model for nanostructures formation via femtosecond radiation interaction with condensed media

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Now it is a common place that process of ultrashort laser-condensed matter interaction on the time scales less than 1 picosecond occurred via interaction with electronic subsystems. The physical model of ultrashort polarized laser pulses interaction with dielectrics, semiconductors and metals

are considered based on laser-induced nonequilibrium phase transition into the metal state. Few variants of such transition realization are suggested, in particular with new boundaries formation having plane of cylindrical shapes. The phenomenon of laser induced periodic and ordered surface and bulk structures formation is considered in the framework of the universal polariton model of laser induced damage of condensed media.

The phenomenon of abrupt multiple change of structures period is interpreted using nonlinear model of one-dimensional unimodal logistic map and Feigenbaum universality, and Sharkovsky order.

The effect of period of laser-induced nanostructures lowering under the condensed matter boundary irradiation in water contact is discussed in framework of polaritonic model and effective cooling of irradiated zone.

The phenomenon of specific surface structuring and period d of nanostructures formation $d \ll \lambda$ is explained taking into account the cylindrical surface plasmon polaritons (CSPP) interference and their dispersion characteristics. Some effects are explained based on the CSPP interference, including the formation of arrays of equidistant nanovoids along the laser beam track inside transparent dielectrics.

It was shown that the cause of nanosructures formation having $\vec{g} \parallel \vec{k}$ ($d = \frac{2\pi}{|\vec{g}|} \approx 150\ nm$) under femtosecond pulses multifilametation inside 4H-SiC semiconductor is the interference of counterpropagating CSPP.

PS1_49 Silicon nanocrystals formation via laser ablation in liquids

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The nanoparticle formation by means of the laser ablation of solid state targets placed into different liquids has a set of advantages in comparison with the traditional laser nanofabrication at the laser ablation in gases: the nanoparticles are chemically pure, have the smaller size and spatial dispersion.

The aim of our work is the nanofabrication and the structural study of the silicon particles in various liquids with the different viscosities and temperatures.

As the buffer liquids we used the distilled water, the glycerol at 50 ºC and the liquid nitrogen. In first two cases the monocrystalline silicon targets were placed in a 15 ml cell filled by the liquid. The liquid intermixing took place by means of a magnetic stirrer. At the experiments with the liquid nitrogen the low-temperature liquid filled a thermos without outside mixing. All silicon samples were irradiated by focused pulses generated by a picosecond Nd:YAG laser. The irradiation went on from 30 to 60 minutes at 10 Hz repetition rate.

The atomic-force microscopy revealed the spherical shape of the formed nanoparticles with the typical size about 10 nm. Detailed analysis of the atomic-force measurement data allows obtaining the histograms for the silicon nanoparticle size distribution. The nanoparticles have the different peak size (from 7 to 20 nm) and the spatial dispersion depending on the buffer liquid.

Raman spectroscopy of nanoparticles revealed the line near 520 cm^{-1} corresponding to the crystalline silicon phase. Other Raman lines were not registered. So the formed nanostructures are the silicon nanocrystals.

We suppose the following mechanism of the nanocrystal formation. The ablated silicon atoms decelerate because of collisions with the molecular environment and agglomerate to the nanocrystals. The nanocrystal formation conditions (chemical composition, temperature, and viscosity) are various in the different buffer liquids. As a result we obtain the nanocrystals with the different sizes.

PS1_50 Stochastic fields in nanoscale vicinity of the ionic crystal surfaces at finite temperatures

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In perfect crystals, the charges of the lattice nodes create electric field that extends beyond the bounds of the crystal to within the lattice constant a and decays exponentially with the distance from the surface h.

Slight displacements ($l << a$) of ions from the ideally arranged lattice may destroy the charge neutrality within the distances exceeding the lattice constant. As a result, the fields extending over macroscopic distances beyond the bounds of the crystal may arise. In particular, polarization of a dielectric by an external electric field gives rise to a small, though coherent, displacement of ions producing a polarization field of macroscopic scale outside the dielectric.

Under thermal motion, even neighboring ions move in an uncorrelated way when the temperature is sufficiently high ($T > T_{Debye}$). In this case, the field of polarization, resulted from the thermal motion fluctuates. While the mean electric field is zero, its energy is nonzero. The type of correlation in thermal motion of the lattice ions depends on temperature. At low temperatures, the ionic displacements are small, and only long-wavelength phonons are excited. They create the charged areas that are large compared to a and, correspondingly, the fields that extend far away from the crystal.

In this contribution, we present the results of analytical study of the spatio-remporal behavior of the fluctuating electric field as a function of temperature of the model ionic crystal. We calculate the pair-wise spatio-temporal field correlators and show that the fluctuating field power density decays outside the crystals as $\sim h^{-3}$. At distances $h > 6a \sim 3$ nm, the fluctuating field exceeds the static field that decays exponentially. At these distances, the strength of the fluctuating field lies in the range of 10^6 V/cm. Typical values of the spatial and temporal variations of the fluctuating field are controlled by the crystal temperature. A characteristic correlation length for the field variation along the surface of the crystal at temperatures $T > T_{Debye}$ is of the order of h.

We also analyze the effects of the fluctuating electric field on atoms and molecules lying at nm-scale distances from the surface of the ionic crystal and consider manifestations of these effects in formation of nano-sized structures.

PS1_51 Changes in the equilibrium component composition and spatial reorientation of the molecular components of polymethine dye layers by photo- and thermal excitation

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Layers of symmetric di- and tricarbocyanine polymethine dyes were studied to evaluate the effect exerted by the molecular structure and thickness of a layer on its component composition. It was shown that the number of aggregated forms and the relative equilibrium concentration of the monomeric stereoisomers of various structures depend on the layer thickness, length of polymethine chain, and electron-donating ability of heterocyclic end groups (EGs). Thin layers contain cis-monomers of different structure as major form. The number of types of cis-isomers decreases and the relative concentration of the all-trans isomers increases with increasing thickness. As the electron-donating ability of EGs and the chain length grow, the width of the layer absorption spectrum increases owing to the increase in the number of types of stereoisomers. We studied change of the number of aggregated forms in a layer and irreversible spatial reorientation of its components by heating and a resonance laser excitation. The stereoisomerization mechanisms at photoexcitation and heating were ascertained. It was concluded that the intermolecular interaction and the interaction of a symmetric polymethine molecule with the substrate cause intramolecular electron density distribution in a chromophore to be asymmetric, which results in the appearance of stereoisomers of several types. Irreversible changes are due to the change in the asymmetry of the electron density distribution owing to irreversible spatial reorientation of layer components. The spatial reorientation of layer components is determined by all-trans→cis stereoisomerization upon rotations around the central bonds. It was shown that in the case of photoexcitation, the degree of rearrangement and the run of the orientation angle vs. the total excitation energy curve essentially depend on both the excited-state population and the temperature to which a layer is heated by absorbed radiation energy.

PS1_52 Fabrication of new perspective nanocomposite materials using femtosecond laser generated sols of nanoparticles

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New perspective photonic materials were fabricated using femtosecond laser-generated sols of corresponding metallic and semiconductor nanoparticles to dope inorganic matrixes. The content of dopant was controlled by means of optical transmission/reflection spectroscopy and other relevant physical properties were studied.

PS1_53 Electromagnetic response and near field enhancement of carbon nanotube bundles

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Electromagnetic characteristics of finite-length bundle containing both metallic and semiconducting single-walled carbon nanotubes (SWCNT) – absorption cross-section and field enhancement in the near zone – are theoretically studied in a wide frequency range from gigahertz to visible. The analysis is based on the impedance-type effective boundary conditions and the many-body integral equation technique.

The enhancement of electromagnetic response of finite-length SWCNTs bundles due to geometrical (antenna) resonance of surface waves was demonstrated. Strong local field enhancement is predicted to be inherent to bundle of SWCNTs in the near-field zone providing necessary mechanism for middle- and far infrared near-field optics. It has been shown, that near field intensity enhancement factor in middle infrared range can achieve 3000 for SWCNT bundle of length 100 nm and diameter 5 nm (the ratio of the number of semiconducting SWCNTs to the number of metallic SWCNTs in the bundle was taken to be equaled to 2). For bundle with only metallic SWCNTs the enhancement factor can achieve 10000.

A model for the effective conductivity of a dilute and disordered composite material containing randomly bundles of SWCNTs was formulated. The influence of aspect ratio and concentration of SWCNT bundles on effective conductivity of the composite was analyzed in wide frequency range from terahertz to visible range. The analysis presented in the report forms a basis for the design and development of SWCNT-bundle antennas and composite materials containing CNT bundles as inclusions.

PS1_54 Enhanced photoconductivity in sodium and silver nanoparticle ensembles owing to the excitations of localized surface plasmon polariton resonances (LSPPRs)

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Metal nanoparticle ensembles (MNEs) on transparent insulating surfaces have been studied for a long time, mainly from the viewpoint of their optical properties, associated with the excitation of the localized surface plasmon polariton resonances (LSPPRs). Such films are of great interest for a number of practical applications such as confocal microscopy, biosensoring, near field optics, informatics.

For the experiments, samples with various thicknesses of silver, and sodium nanofilms on quartz and sapphire substrates were prepared by Volmer-Weber-growth. Electrical as well as photoelectrical properties of the prepared nanofilms were investigated. The exponential temperature dependence of the conductivity in the nanofilms was obtained. Since $\ln I_c$ depends linear on 1/T in a temperature range between T = -8°C and T = 40°C, an activation energy concept of the conductivity can be applied. Activation energies of E_{act} = 0,17 eV for Na nanoparticles and E_{act} = 0,50 eV for Ag nanoparticles have been extracted. The photoconductivity of MNEs has been related to their extinction spectra. A clear evidence of the photoinduced conductivity of the metal nanofilms was obtained. Considerable enhancement of the photocurrent was observed for those wavelengths that are in resonance with plasmon excitations localized in the metal nanoparticles forming the nanofilm. The increased photoconductivity can be explained by the additional energy placed in the nanoparticles due to the excitation of an LSPPR. This additional energy can be used by the electrons to overcome the tunneling barrier between the nanoparticles.

PS1_55 Effective Light Scattering in Suspension of Silicon Nanocrystals Formed via Laser Ablation

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Miniaturization of silicon-based systems discovers new prospects for their use in modern optoelectronic, laser physic and biomedicine. One of the actual problems in this direction is fabrication of strongly scattered silicon nanocrystals and evaluation of their optical properties. Suspensions on basis of such particles assist to increasing the local electromagnetic field amplitude for transmitted light and decreasing the wave packet group velocity.

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

The measurements of the collimated transmission, total transmission and diffuse reflectance for the silicon-water suspension 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.

The prepared suspensions may be used as effectively scattered media for the design of random laser and devices for the control and “slowing” light. They also have potential as contrasting agents in optical biomedical diagnostics.

PS1_56 High harmonic generation in clusters irradiated by laser field of moderate intensity

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The process of HHG in gas is a well-known phenomenon. It is investigated both by experiment and theory. But the same effect in clusters has not been investigated in details. It was discovered only that in the cases investigated the HH intensity in clusterized gas is larger than in the gas with the same mean density of atoms [1, 2, 3].

In the present work we try to understand the difference in HHG process between gas and clusterized medium. We proposed that this difference is due to the new channel of recombination of ionized electron. This electron may recombine with its own ion. This channel is the same as in the gas. But there is another channel in cluster which may be important – the recombination with another ion.

In the work both channels in HHG are investigated by the use of Lewenstein model [4]. The parameters of the laser field and the cluster are chosen so that the oscillation amplitude of the electron in the laser field is much less than the cluster radius. In addition, the dipole approximation (which is excellent for infrared lasers) is used. It is supposed that the laser pulse is short enough to act before the Coulomb explosion of the cluster takes place. The intensity of the laser field is also limited by the condition that outer ionization, and thus the change of the self-consistent cluster potential, is slow. These requirements are usually fulfilled in experimental studies of high-order harmonic generation in clusters [1, 2, 3].

We investigate the process of HHG in a cluster in the frame of the single-active-electron model (SAEM). This means that we consider a single electron whose motion is governed both by the electromagnetic laser field and the electric field of the cluster itself. This model is applicable until collective effects become significant, which happens when the intensity is so high that a nanoplasma is formed at the leading edge of the laser pulse. The noble-gas clusters that we consider are of Van-der-Waals type so that their constituent atoms are well separated from each other. Hence, to a first approximation, each atom in the cluster may be described independently.

In the present work we have found that the yield of high-order harmonics emitted by a cluster consists of a coherent and an incoherent part. The former is generated by the recombination of the freed electron with its parent ion, the latter if it recombines with any neighbor ion. The former atom-like process is coherent for all atoms within the same cluster and may also be coherent for several clusters if the phase-matching conditions are satisfied; in this situation it forms a narrow angular distribution of the generated radiation. The latter crossing process is always incoherent, the corresponding angular distribution is wide (dipole-like). The spectrum generated by the crossing process differs significantly from that of the atom-like process: For fixed position of the neighbor ion, the cutoff is shifted from its standard value of 3:17 UP to a larger value by an amount that depends on the ion's position. Due to the spatial distribution of the neighbor ions, the net effect on the spectrum is that it extends to larger values and that the net cutoff becomes indistinct. Harmonics within a certain low-energy range are strongly enhanced. They are generated when the electron goes directly from its parent atom to the neighbor ion within a short time interval around a maximum of the laser electric field. The relative significance of the coherent and the incoherent part depends on the degree of ionization of the cluster. Calculations show, that the incoherent part becomes dominant if the ionization degree exceeds about 50%. In this case, for a not too small cluster, the spectrum is almost completely formed due to the incoherent mechanism. For a gas of clusters, if the coherent part is phase matched, the incoherent part should be well visible outside the phase-matching cone.

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PS1_57 Size and density dependence of photoluminescence and electrical properties of ZnO and TiO_2 nanoparticles

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In this work we report on ZnO and TiO_2 nanoparticles deposition with various size and densities on GaAs, Si, Ti/SiO_2/Si, and Cu grids by means of a novel nanoparticle source and the quadropole mass selection system. The metal Zn and Ti was used at targets in O_2 atmosphere with flow rate of 10 sccm for the ZnO and TiO_2 deposition respectively. The size, density, and crystalline structure of ZnO and TiO_2 nanoparticles were characterized by TEM. TEM bright and dark field micrographs of all samples showed that the diameters of ZnO nanoparticles were in the range of 6 nm to 13 nm, and their densities were in the range of 7.36×1010 cm^2 to 2.21×1011 cm^2. This indicates that the size and density of ZnO nanoparticles could be controlled by changing the deposition time. HRTEM micrographs exhibiting and (0002) lattice fringes indicate that the nanoparticles are single crystalline with no indication of stacking faults or dislocations. Photoluminescence (PL) measurements of all samples were performed at room temperature by a He-Cd laser with a line of 325 nm. The UV emission around 380 nm at room temperature is due to the recombination of excitons, and the green broad emission centered at 520 nm could be attributed to point defects such as oxygen interstitials.

W2-1 The propagation of a few cycle THz pulse: Methods of analysis and laws

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Few-cycle pulses of electromagnetic field with spectra in different optical regions are now experimentally feasible. Various prospects of their practical application are encouraging development of new theoretical methods to describe propagation and interaction of ultrashort light pulses with matter. New approaches have become necessary because the conventional treatment of slowly-varying envelope approximation ceases to be productive in case of few-cycle pulses.

In this report we consider two approaches that are actively applied in the theory of few-cycle optical pulses: field-based (or field approach) and spectrum-based (or spectral approach).

We discuss principles of construction of equations for the light field (rather than envelope) in different optical media. It is shown that the field approach is convenient in nonlinear optics of few-cycle pulses with paraxial transverse structure. It is demonstrated how to modify the slowly-varying envelope consideration for making it applicable to few-cycle pulses and getting predictions identical to those produced by the field equations. We illustrate the field approach by simulating generation of broadband Terahertz radiation in the process of plasma excitation in the field of two co-propagating femtosecond laser pulses with high intensities and different central frequencies.

Considering the spectral approach we demonstrate spectral analogs of Maxwell equations for dielectric media. It is shown to have clear advantages other the field approach in linear optics of pulses with ultrabroad temporal spectra as well as in nonlinear optics of non-paraxial waves with ultrabroad spatial spectra. The spectral approach is illustrated by the analysis of appearance of diffraction-defined pseudo-absorption bands of broadband Terahertz radiation in transparent media.

W2-3 Two-color diode-pumped vanadat lasers forTHz sources

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Terahertz-wave radiation has been wide used in THz spectroscopy, biomedical applications, DNA analysis and security applications. THz sources based on femtosecond Ti:Sapphire-laser and photoconductive antennas or nonlinear optical crystals which generate the THz radiation is extremely expensive and complex. One of alternative cost-effective and robust THz sources to use optical two-color light sources with THz converters. Difference frequency generation with photoconductive antennas or nonlinear optical crystals can be directly used to generate corresponding THz radiation. Such a two-color laser systems with THz convertors is probably the cheapest and the most compact sources for terahertz radiation.

Here, we present a THz source based on a novel two-color diode-pumped solid state c-cut Nd:$GdVO_4$ laser and the GaSe nonlinear optical crystals as convertor.

C-cut neodymium-doped vanadate crystals (Nd:YVO_4, Nd:$GdVO_4$, or mixed $YGdVO_4$) are efficient laser media and have a considerable potential to produce spectrally tunable radiation, two-frequency lasing and short pulse generation [1].

Two-color lasing has been obtained in the C-cut Nd:$GdV0_4$ and Nd:YVO_4 crystal at the spectral lines separated by 2.3 nm and 3.8 nm.

QW, mode-locking and Q-switching regimes with acoustic-optical modulators were realised.

Q-switching yielded 15-20 ns pulses with an average output power of 1.2 W at a repetition rate of 6-12 kHz. At 3 to 5 W of pump power the Q-sw - mode-locking laser produced a stable train of pulses with a pulse duration of about 30-40 ps FWHM and an output power of 340 mW at pulse repetition rate 140 MHz.

The use of GaSe crystal for the generation of pulsed THz radiation was demonstrated recently [2-3]. This crystal is excellent nonlinear optical element for difference-frequency generation (DFG). GaSe crystal has the lowest absorption coefficient in the THz spectral range and, furthermore, a large second-order nonlinear coefficient.

The two-color C-cut Nd:$GdV0_4$ and Nd:YVO_4 lasers served as an optical pump source. Laser emitted dual wavelength at 1063.2 nm and 1065.5 nm. After passing through lens the pump beam was focused in a GaSe crystal. The GaSe crystal is mounted on a rotational stage. The generated THz waves are combaned and separated from pump beams by two teflon lens and focused onto a piroelectric detector or an opto-acoustic detector. The THz signal from the detector is in turn low-noise voltage preamplifier SR560 and lock-in amplifiers SR830. A Si and black polyethylene plates are used to block the two pump beams.

Terahertz radiation with wavelength 436 mkm (0.56 THZ) was detected.

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W2-4 Superconducting terahertz hot electron bolometer mixers, direct detectors and infrared single photon counters based on ultra-thin NbN films

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We present new practical thin NbN film devices: Superconducting single photon detectors, Hot Electron Bolometers (HEB) and HEB-mixers, which took an important niche in the market of terahertz and optical technologies.

Terahertz superconducting Hot-Electron Bolometers (HEB) can be operated in either a direct detection mode (as a bolometer) or in a heterodyne mode (as a mixer). At frequencies above 1 THz NbN HEB and HEB mixers outperform their counterparts such as superconductor-insulator superconductor (SIS) tunnel junctions, and Schottky diodes. HEB mixers exhibit better sensitivity and wider IF bandwidth, which currently amount to 6 GHz. Best obtained value of the noise temperature is 750K at 2.5THz frequency. Being operated as direct detectors, HEBs demonstrate about 50ps response time and a noise equivalent power (NEP) of $3x10^{-13}WHz^{-1/2}$. HEB-detectors have already passed the stage of commercialization and are actively used as a basis for terahertz receivers in instruments for astronomical and atmospheric research, spectroscopy, materials and biological structures, study of terahertz sources.

A promising type of superconducting photon counters is a superconducting single photon detector (SSPD). In many ways SSPD exceeds existing single photon detectors of visible and near infrared range, such as avalanche photodiodes and photomultipliers. The SSPD is patterned from 4-nm-thick NbN film as 120-nm-wide and meander-shaped strip that covers a square area of 10 x 10 μm^2. SSPD quantum efficiency in this range (from visible to 1.3μm) is up to 30%, a level limited by absorption of the NbN film, with a negligibly small level of dark counts (at 2K dark counts of $2x10^{-4}$ s^{-1}) and time resolution (jitter) 20 ps. It provides NEP value of 10^{-20} $W/Hz^{1/2}$ at $\lambda \leq 1.3$ μm and 10^{-18} $W/Hz^{1/2}$ at 5 μm. SSPD can be efficiently coupled with a single mode optical fiber and thus can be easily integrated into a practical commercial dual-channel receiving system. The system has already found a number of practical applications in experiments on optical coherence tomography, detection of radiation from the quantum dots with high temporal resolution, as well as in quantum cryptography.

Further development of SSPD was to form it as parallel-connected strips. Such SSPD has a new quality: the ability to resolve the number of simultaneously absorbed photons, because the amplitude of the detector response is proportional to the number of incident photons. Simultaneously duration of the photoresponse decreased to 200 ps, enabling up to 1GHz counting rate.

In an effort to move into the middle IR we managed to develop a SSPD with a strip width of 54 nm while preserving the superconducting properties. These detectors show more than an order of magnitude higher sensitivity at a wavelength of 5μm and demonstrate single photon response at 10μm wavelength. These results open the way to the development of the practical mid-infrared single photon detector.

THz direct detectors and HEB mixers are used in a wide range of application ranging from THz imaging for security (observation of hidden drugs, explosives and weapons) and medicine (THz probing of human tissues) to radioastronomy observation of stellar formation and dark matter (space observatories Herschel and Millimetron). SSPD due to their high quantum efficiency and picosecond timing resolution has already been successfully applied for study of quantum dot luminescence and for quantum key distribution (recent result is 250-km-long distance).

W2-6 Using terahertz frequency range radiation for diagnostics and therapy of human and animals hard and soft tissues, and also study the complicated biomolecules

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Dependence of intensity terahertz radiations advancing from a thickness of healthy / pathological samples and from a scattering angle (an atherosclerotic plaque, a blood vessel, blood, a skin, an eye tissue, an adipose and nail tissue, dressing means) is received. Their basic optical parameters and spectra are defined.

At all stages of formation of atherosclerotic plaques, healing dermatitis, skin traumas, and eye pathologies it is necessary to carry out test diagnostics and therapy of the amazed area, to distinguish with the big accuracy healthy sites of tissue from damaged and to check efficiency of therapeutic procedures and preparations. The technologies developed now using terahertz radiation (THz) in a biomedical tomography and spectroscopy, strongly differ from modern methods of research. The new technology will provide not destroying control and not to demand removal of dressing means. Besides terahertz radiation is capable of early disease recognition. Oscillating-rotary transitions will arise after terahertz radiations influence on complicated biomolecules. These transitions are shown in their specific absorption spectra.

The modelling spent in given work, has shown that THz radiation of a range 0.3÷2 THz does not lose collimating at passage through the sample of fat in the thickness of 0.5 mm. The model of an atherosclerotic plaque in a blood vessel, and also models of an skin and nail tissue is created. In model the radiating antenna is optimized and visualization of objects is executed.

In the given work THz radiation was characterized by following parameters: a spectral range 0.05 ÷ 2.0 THz, average capacity 5 (10) μW, pulse repetition rate 50 (75) MHz, duration of an impulse 2.5 ps, the basic capacity is distributed on nine peaks on frequencies from 0.12 to 1 THz. It is experimentally shown that samples of biological tissues of blood, a skin, a nail tissue and lipids differ spectral structure in a range 0.1÷2 THz. Also they depend on water content. From the specified samples the best advancing the adipose biotissue possesses. Absorption spectra of a nail of the person and a skin of a turkey have an appearance similar each other, with peaks of absorption a little displaced on frequency. Such feature can be caused the general elements of a chemical compound of the specified samples. At increase in a thickness of a dressing from 0.1 to 0.3 mm (three layers of a gauze) THz radiation advancing decreases for 60 %. The spectrum of "the dried up blood" has characteristic peaks of absorption, unlike a spectrum of "fresh blood". In the dried up blood sharp peaks which correspond to blood components, such as leukocytes, erythrocytes and hemoglobin are visible.

Depending on a task in view of diagnostics of dermatological diseases are required various sources monochromatic THz radiation. So, for detection of the degrees of hydration of a biotissue use better sources on lengths of waves: 1.09; 1.16; 1.41; 1.69; 1.73; 1.81; 1.88 and 1.94 THz. For diagnostics in which water is the negative factor for diagnostics more preferably to use THz radiation in ranges: 0.1 ÷ 1.09; 1.16 ÷ 1.41; 1.41 ÷ 1.69 THz.

W2-7 Terahertz radiation emission by a single atom interacting with two-color laser field

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The process of non-linear interaction of atomic gas with the two-color laser field of frequencies ω and 2ω is an effective mechanism to produce the terahertz radiation. It is usually assumed that this specific non-linear transformation is mainly due to the plasma nonlinearities. Here we study the process of single argon atom interaction with the pulses of Ti:Sapphire laser at basic frequency (λ=800 nm) and second harmonic. In our computer simulations we have assumed that the intensity of laser field is below the ionization threshold. Nevertheless, the results of our study show that the terahertz radiation is effectively emitted under these conditions. The methods of control of conversion efficiency are discussed. They are based on the variation of relative orientation of polarization vectors of linear polarized laser pulses at frequencies of ω and 2ω, delay time between them, and their relative intensities.

In our computer simulations we have used the non-perturbative theory of light-atom interaction based on the exact eigenfunctions of the boundary value problem for the atom in the external field. This approach has been proposed in [1] and later developed for explanation of a number of specific features of high optical harmonic generation effect [2-4]. In the frame of this approach the spectra of atomic electrons in the final state (after action of laser pulse) are calculated analytically, therefore the threshold ionization intensity, which depends on the given values of laser pulse parameters and atomic energy level diagram, can be strongly defined. As a result, the input of the bound and free electrons to the atomic response can be exactly estimated.

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W2-8 Near-field terahertz probes based on metallic micro- and nanostructures

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Terahertz (THz) radiation offers an intriguing possibility for characterization of various classes of materials including biological tissues and semiconductors. Unfortunately the large wavelength of THz radiation does not allow direct imaging of single molecules or nanoelectronic devices due to the diffraction limit. However this limit could be overcome by means of near-field microscopy.

In recent years a number of new designs of near-field THz probes based on metallic micro- and nanostructures has been suggested. These metallic structures are able to effectively concentrate far-field THz radiation in a confined region of subwavelength size by means of surface plasmons.

In this report various structures which enable localization of THz radiation are reviewed. The review is completed with experimental results of fabrication and simulations of near-field THz probes based on metal/dielectric and periodically corrugated structures. The fabrication methods include various electron and ion beam assisted techniques, whereas simulations are performed by means of finite-difference time-domain method.

W2-9 On efficiency optimization of a terahertz waves generation from plasma induced by two-color laser beam

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Nowadays a problem of practical terahertz (THz) wave generation is significant and widely discussed due to a wide range of technology, medical and other applications for such radiation. One of key questions is a question of optimal method and conditions for THz generation in experimental setups. The most prospective way is generation in plasma induced in air by two-color laser beam that gives a most intensive THz wave output. A search of optimal conditions for such generation required a derivation of a theory for an interaction of intense femtosecond pulses with different frequencies exciting plasma in dielectric media.

This report presents results of a theoretical analysis of wide-range laser radiation generation in middle- and far-IR range, including THz waves, in plasma stimulated in air by a couple of intense femtosecond pulses with main and doubled frequency of Ti:Sa source. We show that generation of long-wave radiation in a strong field of such two-color beam can be described by a model of principally inharmonic oscillations of optical electrons, transferred from ground state to excited by cascade transitions. We demonstrate that generated infrared and terahertz radiation has a form of few-cycle pulse; a generation efficiency quasi-periodically depends on a length of area where two femtosecond pulses interact in condition of plasma presence. This allows an efficient solving a problem of terahertz wave generation optimization by controlling a properties of generator setup: a relative shift between interacting pulses; an interaction length; an initial beam duration and intensity. Presented theoretical dependencies can easily be transformed in practical recommendations for THz generator construction.

PS1_58 Study the influence of terahertz frequency range radiation for diagnostics of human and animals hard and soft tissues

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Last years the optics of femtosecond lasers is transformed from pure scientific direction to the applied innovative technologies, including medicine and biology. Appearance of accessible femtosecond laser sources promoted creation of new systems and devices, including coherent generators and radiation detectors in terahertz frequencies area.

The purpose of this work is the creation new methods and technologies of terahertz optics for early diagnostics of hard and soft human and animals biotissues pathologies.

Creation of biotissues diagnostics by terahertz radiation is an actual problem for the medical physics and technical appendices. In this project fundamental bases of pulse terahertz remote tomographies of biotissues and biological systems are developed. Such control can be used directly in clinical practice. More rapid reception and data storage opens possibilities for estimation of functional and physiological processes in blood vessels. It can be significant for the efficiency control of pharmaceuticals for atherosclerosis treatment.

Besides, at all stages of healing dermatitis it is necessary to carry out test diagnostics of the amazed area to check efficiency of therapeutic procedures and preparations. The new technology will provide not destroying control and not demand removal of dressing means. Thus, procedure of an estimation of medicines appointed influence for wounds treatment will simplified.

Terahertz diagnostics can detect early caries presence at layers of human teeth and distinguish them from areas with a low mineralization. Terahertz teeth diagnostics is important, in particular, for diagnostics of some diseases connected with change of the maintenance of water in teeth, for tracing of diffusion of medicines and movement tooth liquor in vivo. The developed system can work in a mode of real time, carrying out the control of biotissues and respectively reduce diagnostics time.

At all stages of formation of atherosclerotic plaques, healing dermatitis, skin traumas, and eye pathologies it is necessary to carry out test diagnostics and therapy of the amazed area, to distinguish with the big accuracy healthy sites of tissue from damaged and to check efficiency of therapeutic procedures and preparations. The technologies developed now using terahertz radiation (THz) in a biomedical tomography and spectroscopy, strongly differ from modern methods of research. The new technology will provide not destroying control and not to demand removal of dressing means. Besides terahertz radiation is capable of early disease recognition. Oscillating-rotary transitions will arise after terahertz radiations influence on complicated biomolecules. These transitions are shown in their specific absorption spectra.

The modelling spent in given work, has shown that THz radiation of a range 0.3÷2 THz does not lose collimating at passage through the sample of fat in the thickness of 0.5 mm. The model of an atherosclerotic plaque in a blood vessel, and also models of an skin and nail tissue is created. In model the radiating antenna is optimized and visualization of objects is executed.

In the given work THz radiation was characterized by following parameters: a spectral range 0.05 ÷ 2.0 THz, average capacity 5 (10) μW, pulse repetition rate 50 (75) MHz, duration of an impulse 2.5 ps, the basic capacity is distributed on nine peaks on frequencies from 0.12 to 1 THz. It is experimentally shown that samples of biological tissues of blood, a skin, a nail tissue and lipids differ spectral structure in a range 0.1÷2 THz. Also they depend on water content. From the specified samples the best advancing the adipose biotissue possesses. Absorption spectra of a nail of the person and a skin of a turkey have an appearance similar each other, with peaks of absorption a little displaced on frequency. Such feature can be caused the general elements of a chemical compound of the specified samples. At increase in a thickness of a dressing from 0.1 to 0.3 mm (three layers of a gauze) THz radiation advancing decreases for 60 %. The spectrum of "the dried up blood" has characteristic peaks of absorption, unlike a spectrum of "fresh blood". In the dried up blood sharp peaks which correspond to blood components, such as leukocytes, erythrocytes and hemoglobin are visible.

Depending on a task in view of diagnostics of dermatological diseases are required various sources monochromatic THz radiation. So, for detection of the degrees of hydration of a biotissue use better sources on lengths of waves: 1.09; 1.16; 1.41; 1.69; 1.73; 1.81; 1.88 and 1.94 THz. For diagnostics in which water is the negative factor for diagnostics more preferably to use THz radiation in ranges: 0.1 ÷ 1.09; 1.16 ÷ 1.41; 1.41 ÷ 1.69 THz.

PS1_59 The features of one oscillation terahertz pulse diffraction on the slit

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There are a lot of works by nowadays dedicated to the terahertz spectroscopy which lets to measure spectra in the frequency range of 0.2 – 2 THz or 6,6 – 66 cm^{-1}. It's very important for analysis of organic molecules containing hydrogen and carbon bonds [1]. In this work we show the results of computational modeling of the one oscillation terahertz pulse diffraction on the slit with a gap that's comparable with the size of the wave packet. It's indicated the diffraction of a broadband terahertz pulse can cause modulation of its spectrum which is possible to look like an absorption band in a resonantly absorbing media.

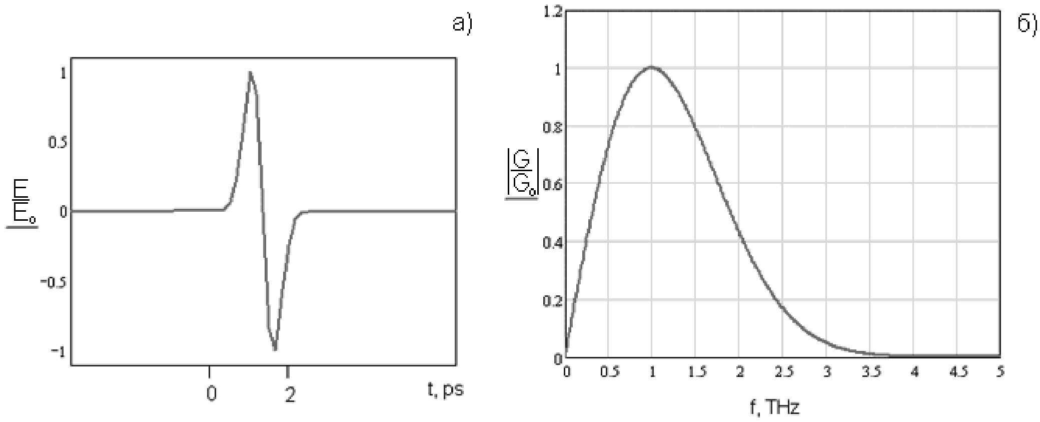
We took our calculation of the space-time spectrum of nonparaxial wave packet evolution after the diffraction on the slit basing on the spectrum equations [2]. We chose the gaussian transversely axisymmetric pulse as a boundary condition (when z = 0):

$$E(z,x,t)\Big|_{z=0} = \begin{cases} -4\frac{t}{\Delta t}E_0 \exp\left(-2\frac{x^2}{\Delta x^2}\right)\exp\left(-2\frac{t^2}{\Delta t^2}\right), & |x| \le d, \\ 0, \ |x| > d, \end{cases} \qquad (1)$$

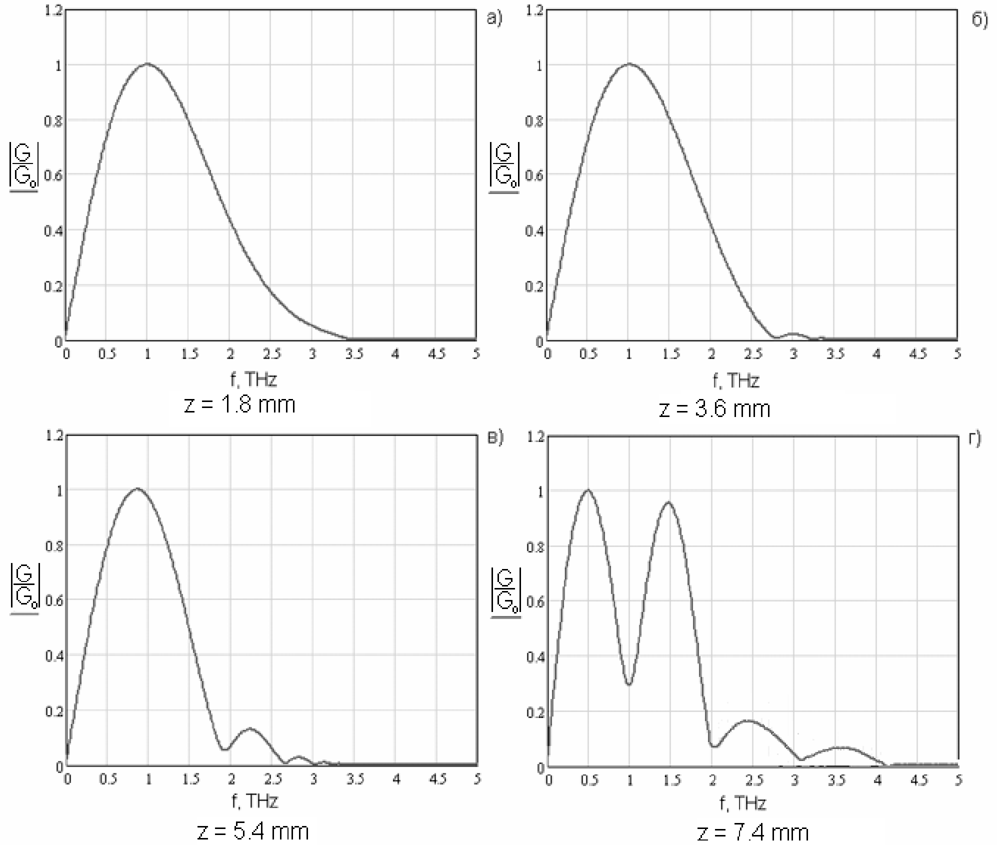
where z is the coordinate of the axis the pulse passes across, x is the coordinate of the transversal axis, t is time and $\lambda_0 = 300\,\mu m$ is the central wavelength of radiation. The scale-time size of the wave packet is $\Delta x = 10\lambda_0$ and $\Delta t = 1.2\,ps$. The slit's gap is $d = 10\lambda_0$. The index of refraction of air supposed to be [3]:

$$n(\lambda) = 1.000287566 + \frac{1.3412\cdot 10^{-18} m^2}{\lambda^2} + \frac{3.777\cdot 10^{-32} m^4}{\lambda^4}. \qquad (2)$$

In the picture 1 we show the initial pulse field's dependency on time and pulse spectrum, in the picture 2 we show this spectrum with different paths passed across the z axis in air.



Pic. 1. Normalized field and spectrum of the initial terahertz pulse.



Pic. 2. Normalized spectrum of the terahertz pulse with passed paths across the z axes: a) 1,8 mm; b) 3,6 mm; c) 5,4 mm; d) 7,4 mm.

As it's clear from these pictures, while the pulse is passing through air after the diffraction, the slit is seen as a different number of Fresnel zones, and it leads to the appearing of series of amplifications and decays of different spectral components of radiation (i.e. the modulation of the spectrum). The decays in the spectrum look closely like the absorption bands but, of course, they aren't absorption bands naturally. It seems to be necessary to take this effect into account while decrypting spectrograms received from particular spectrometers.

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W3-1 Contemporary art paintings: a study on the laser assisted removal of past and unsuccessful retouches

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The studies on the conservation/restoration issues of non-traditional paintings have been of particular attention and concern in the last years. The industrial formulations of the new paint media have enriched the application possibilities for the painters and conservators:, starting from modified oils as enamels, arriving to acrylic and vinyl binders in solvent and emulsion. Used leaving the correct idea of reversibility, sometimes, to remove the retouching realized using materials rather similar to the originals, can compromise the actual cleaning of these over paintings.

To study the laser assisted removal of these enriched paint materials a series of non-traditional painting films of industrial production have been prepared. The mock-ups (cotton canvases on stretcher) have been prepared using 12 commercial tube formulations made of two different colors, white and blue (titanium white and ultramarine blue or phthalocyanine blue) and six different binders (acrylic and vinyl emulsion resin, acrylic in solvent, oil-modified alkyd for artists and household, and alkyd with nitrocellulose) for a total of twelve products (6 white, 6 blue). Each of the six canvases was prepared with a white ground, over which a second layer was applied using all the combinations of binders and colors. These technical samples were subjected to comparative cleaning studies (chemical cleaning by solvents to test their solubility and selectivity and laser irradiation) with the aim to selectively remove the upper painting without compromising the underlying original layers. The investigated laser cleaning procedures were based on different laser systems with wavelengths ranging from the ultraviolet (248nm) up to near Infrared (1064nm) in various pulse durations.

Optical microscopy, micro-FTIR and micro-Raman analyses were employed to evaluate these tests and to show, in a first approach, the advantages and limits of the laser radiation as an alternative cleaning methodology. After treatments in particular optical microscopy has given information on both color homogeneity and surface morphology. The spectroscopic analysis of the irradiated surfaces by micro-FTIR and micro-Raman revealed residuals of the outer layer materials as well as alteration phases responsible for the color changes. The obtained results will be presented and discussed aiming to a comprehensive approach for the understanding the involved ablation phenomena as well as for the minimization of any side effects and the optimization of the working parameters.

W3-2 Application of laser in conservation and restoration of historical building

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The field of Cultural Heritage has many analytical and treatment needs both in the field of conservation than in restoration. For these reasons optical techniques, non-destructive or microdestructive and particularly in the field of historical monuments are present for many years. The laser therefore found a ready-made place in this area.

We find first the different application of laser cleaning. The LRMH was the initiative of creating the first field prototype used in the field for cleaning stone in particular. A tour of the Cathedral of France to test this method had been achieved in the early 90s. Then, many have phenomenological and physical studies were conducted to understand the mechanisms involved during the cleaning action. Different groups work to extend the domain of applicability to painting, gilding.

On the other hand, in analytical technology, LIBS (Laser Induced Breakdown Spectroscopy) is used for in situ identification of pigments, salts, metals or other materials. This laser technique present a lot of advantages: portability, analysis of light elements, stratigraphic analysis capability makes it an essential technique for this application. The LRMH was the first laboratory depanding from a ministry of culture to get the technology and to apply it systematically in situ (Notre Dame Cathedral, Saint Savin sur Gartemps abbey.)

In addition, more recently, a methodology for converting pigments by continuous laser was developed in the laboratory, thus extending the scope of the use of laser.

Many groups are now working on techniques Thz or OCT which also have their place in the cultural heritage field.

We will review these techniques and their application based on several studies that occur in our laboratory.

W3-3 Laser assisted removal of lining glues from easel paintings

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Since the 17th century several methods have been developed for the lining of canvas paintings: pasta glue or cerusa were mainly applied until the middle of 19th century. Different researches were lead in the second half of the 20th century to achieve an alternative method: polyvinyl acetate or acrylics have been applied. As glues age, paintings need to be retreated each ca 50 years. In order to remove the adhesive, current methods are limited to the use of chemical solvents or to scratch with a scalpel which leads to obvious damage to the original work. However, removal of the lining fabric (relining) is necessary/crucial. Laser technology may be a unique tool for the gentle removal of aged glue films as the whole cleaning process is well controlled and confined. Towards this, a systematic study was undertaken on mock-ups and real paintings to choose the laser parameters for a safe and efficient removal and to establish a reliable cleaning methodology. A series of laser irradiation tests spanning from UV to IR wavelengths were performed and their cleaning result on pasta glue, céruse (lead white and oil) and PVAc was assessed by microscopic observation. Furthermore, to ensure that this cleaning intervention does not affect the structure and integrity of the painting, digital holographic interferometric techniques were applied prior and after the cleaning tests. The results of this study will be discussed in detail with emphasis on the development of a safe and reliable methodology to remove past/unsuccessful lining films.

W3-4 Laser-induced breakdown spectroscopy. Application to the analysis of heavy metals in polluted soils

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Laser-induced breakdown spectroscopy (LIBS) appears to be a new promising technique for elemental analysis, especially useful to control the presence of contaminants and pollutants. We will present various results obtained by LIBS in the framework of the analysis of polluted soils. Both laboratory and on-field data will be discussed with a special emphasize on chemometrics, i.e. advanced multivariate methods of data processing.

Indeed, matrix effects appear to be very important and an advanced data treatment must be run in order to go further with LIBS quantitative analysis of soils. We will discuss how the Principal Components Analysis (PCA) is efficient for blindly sorting a set of unknown samples. Moreover, we will present some advantages and limits of the Partial Least Squares (PLS) regression and Artificial Neural Network (ANN).

Finally, we will discuss the results of in-situ LIBS analysis of polluted soils. A mobile LIBS system have been designed and constructed specially for this application. In this case, none of the quantitative methods based on calibration could be applied and only *relative data* have been processed in order to provide useful information allowing optimizing the on-field sampling protocol.

Thus, in this work, LIBS applied to the analysis of polluted soils has been firstly evaluated as an alternative method for laboratory quantitative elemental analysis and secondly as a kind of sensor providing semi-quantitative information for in-situ analysis and driving to smart sampling and as a consequence to save time and money.

W3-5 LIBS for ITER in situ tritium inventory

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During Tokamak operation and due to high energy and particle fluxes interacting with Plasma Facing Components (PFCs), wall materials are eroded, transported and redeposited in layers able to trap tritium. The accumulation of tritium in the vacuum vessel is limited due to safety constraint and the evaluation of the in vessel tritium inventory is of crucial interest. The spectroscopic analysis of the plasma produced by laser ablation of the PFCs and/or of the redeposited material, known as laser-induced breakdown spectroscopy (LIBS), is a promising technique to achieve this goal.

In the following paper, a parametric study performed to determine the optimised operational conditions for LIBS analyses with tokamak samples will be first described. The influence on the plasma properties of the irradiation conditions (laser wavelength and pulse duration) and of the gas pressure and nature are investigated. Using several experimental techniques, it will be shown that long pulse duration (>10ns) induced a too small plasma temperature for Tritium quantitative measurements.

Usually, quantitative LIBS analyses require calibration measurements using standard samples having compositions close to that of the material to be analyzed. Calibration during tokamak operation is always difficult due to the complex material supposed to be produced. For ITER application, it is proposed here to apply a *calibration-free* LIBS procedure based on the calculation of the spectral radiance of the plasma in Local Thermodynamic Equilibrium. These new procedure will be exemplified on the determination of the deuterium concentration on real Tokamak samples coming from the Tore Supra tokamak.

Then, the first experimental results obtained in Tokamak are recalled. It is observed that the complexity of the Tokamak environment leads to a complicated diagnostic especially if all the surface of the in vessel components must be analysed. The extrapolation of the LIBS diagnostic to ITER is then addressed with a special insight on embarked diagnostic able to scan the entire vessel walls.

W3-6 Laser cleaning: prospects for industrial applications

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Currency of laser radiation usage for cleaning of fabricated metals

Usage of removers and abrasives for surface treatment causes environmental issues. These methods are powerful and not always provide essential requirements for surface condition.

Laser cleaning is noncontact, nonabrasive, high-production and environmentally friendly technology, that can be used before painting, cladding etc.

Usage of pulsed fiber lasers enhances competitive advantages of laser cleaning

Cleaning efficiency depends proportionally on radiation average power and repetition rate.

Coupled with compactness and high electro-optical efficiency (wall plug efficiency) pulsed fiber lasers have laser spot intensity required for cleaning and high repetition rate up to 100 kHz.

Pulsed fiber laser with average power 50 W is estimated provide cleaning productivity 10 – 15 m^2/h

Features of heating with pulsed fiber laser emission in pulse length range 200 – 300 ns

There are three stages of laser radiation influence on material surface: 1 – heating of surface layer up phase transition temperature $T < T_m$, 2 – heating up $T = T_m$, 3 – heating over melting temperature $T > T_m$.

In the first case, the contaminations with vaporization temperature below melting point are removed, e.g. oil pollution, oxide films. Absorption coefficient of those contaminations is higher than the substrate coefficient, Fig 1a.

In the second case, the surface substrate material is melted. Melt is displaced to the border of the laser pulse spot under recoil vapor pressure forming freezing crater , Fig 1b.

In the third case, there is formed micro hole in pulse spot, Fig 1c .

All three stages can be realized by means of focusing whereas radiation parameters not vary. Point beam focusing causes formation of micro holes (stage 3). Focusing systems with long focus provide forming craters, long focal-length optics provide heating up phase transformation temperature (stage 1).

According to demands the exposure mode on metal and alloy can be changed by choosing optical system and by alternating laser radiation parameters.

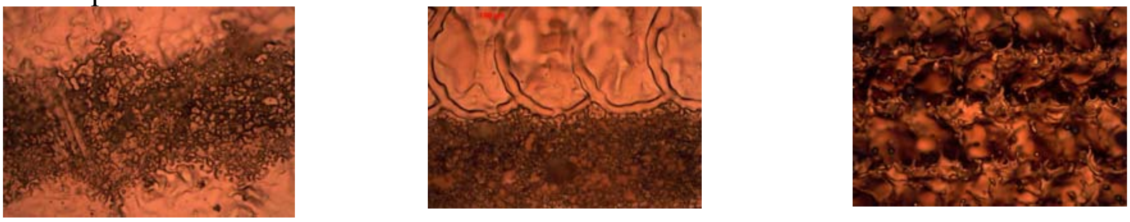
Thermo mechanical mechanism of laser cleaning from oxide films.

Removing of oxide films from metal surfaces using Q-switched AIG-laser occurs as a rule without melt formation.

Surface cleaning occurs remotely with usage of long focal-length optics F= 1…2 m, at peak power 10 MW and pulse duration 10 ns.

Surface material is heated under the influence of laser pulse in to a depth 1 mkm. Thermo mechanical tensions result tear of film large-dimension particles from substrate surface. The maximal dimension of particles reaches same millimeters.

That treatment process provides both forward transfer and back transfer of material with usage of films transparent at 1.06 mkm.



a в c

Fig 1

Shock mechanism of surface cleaning

A high-intensity laser beam with great peak power and short pulse duration induces optical breakdown under the surface and generates a mechanical shock wave into the depth.

The Laser Shock Peening is based on this effect. At the depth of some millimeters the crystal lattice structure is modified.

The treatment of corrode steel plates with laser pulse with energy 20-40 J and pulse duration 15 ns results removing of corroding films both from front, Fig 2a, and back site of the plate, Fig 2b. The cleaning region dimension on the back site is comparable with beam diameter.

This effect can be used for cleaning of closed hermetic volumes, where it is impossible direct action of laser beam on inside substance.

a в

Fig 2

Cleaning and micro structuring of structural steel surfaces and alloys.

Cleaning and micro structuring can be realized with pulsed fiber lasers.

Surface cleaning is usually applied for reprocessing, removing of consumption pollution, conservation, before cladding.

In the last case, high demands to surface adhesive characteristics have an considerable impact on the technology choice.

Research of laser radiation parameters influence on material physico-chemical characteristics

Ability to create microrelief on the structural material surfaces (metals and alloys) opens new industrial applications of fiber pulse laser technology.

Micro structuring treatment mode provides best adhesiveness and excepts usage of fat removal liquid reagents, Fig 3a. Laser surface cleaning results decrease of surface roughness that makes worse adhesiveness, Fig 3b.

50 W pulsed fiber laser provides micro structuring productivity 5 – 6 m^2/h.

Industrial applications examples of laser cleaning technology

Cleaning of cutting tool

Cleaning of railway carriages from old paint

Cleaning of critical items from multilayer paint-and-lacquer coating

Cleaning of metropolitan escalator steps

Laser decontamination of radioactive polluted parts of nuclear power plants

Cleaning of turbine buckets from consumption pollution

Cleaning of edges before welding

Cleaning heat exchanger interior surface

Cleaning from worn electroplate

Cleaning of aluminium alloy surfaces from oxide films before oleophobic coating

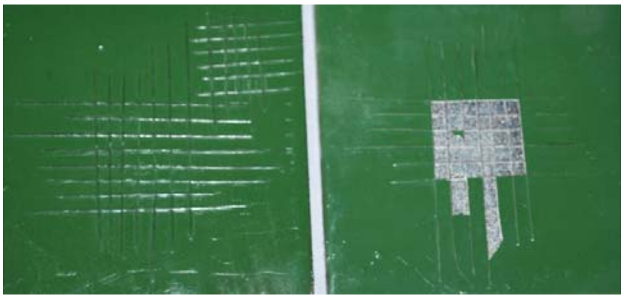


Fig 3

PS1_60 Laser rail cleaning for friction coefficient increase

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The problem of usage of a trailing weight of locomotives is actual for railroad communications with an intensive freight service as even at ideal weather conditions occurs wheels slip. It is bound to the significant surface contamination of rails (ground sand, the petroleum, the fall leaves, an icing etc.)

There are various modes of increase of a friction coefficient:

mechanical cleaning of rails (it is effective at speeds before 20 kphs);

depositions on a head of a rail of a even layer of ethyl compounds (at a lot of water on rails does not effective);

an electro spark treatment (produce an increase wear of surfaces of bindings and rails);

water usage under high pressure (it is effective at speeds before 30 kphs and positive temperatures);

sand increases a friction coefficient, however further becomes a constituent part of soiling lubricating film.

One of perspective directions of the decision of a problem is use of laser emission for cleaning of working surfaces of rails and wheel pairs. One of the important advantages of laser cleaning is the minimum additional deterioration of surfaces.

Are presented results of application of the laser for cleaning of various types of pollution and the economic efficiency analysis is made in the work. Samples of pollution have been taken and the analysis is made of their structure for an estimation of efficiency of laser cleaning. This pollution was put on a surface of a rail of mark P65 and a bandage. The friction factor was defined before and after laser cleaning at various pollution. In experiments, have been used following lasers: q-switched pulsed Ytterbium fiber laser (average power 50 W, pulse width 100 ns) and Nd: YAG laser (average power 200 W, pulse width 0.1 - 10 ms).

PS1_61 Basic physical processes during femtosecond laser cleaning of metals

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In this paper we report on our recent studies of femtosecond laser cleaning of nano- and microparticles from metallic and semiconductor substrates and underlying cleaning physical mechanisms. In our experiments we used a Ti:Sa femtosecond laser system including an oscillator, regenerative and multi-pass amplifiers, and providing at 10-Hz repetition rate 744-nm, 110-fs laser pulses with a maximum energy of 5 mJ in TEM00 mode. Alcohol solutions of nano- and microparticles were used to deposit these particles on copper and silicon substrates. Particle cleaning off the the substrates was performed in dry and wet modes via their raster scanning by femtosecond laser beam at different scan rates, pulse energies and focusing conditions. The underlying physical mechanisms were studied by means of time-resolved optical microscopy revealing picosecond displacements of these dry substrate surfaces due to transient acoustic deformation-potential ("electronic") and thermoelastic stresses. The main revealed femtosecond laser cleaning mechanisms are summarized.

PS1_62 Laser cleaning process investigation in the scope of laser decontamination

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Laser cleaning is a most innovative and advanced method of surface contamination removal. One of important laser cleaning applications is laser decontamination of radioactive polluted parts of nuclear power plants during its decommissioning or maintenance. This technology allows recycling of expensive constructional steels and alloys, and also reduces radiation exposures of power plant personnel [1].

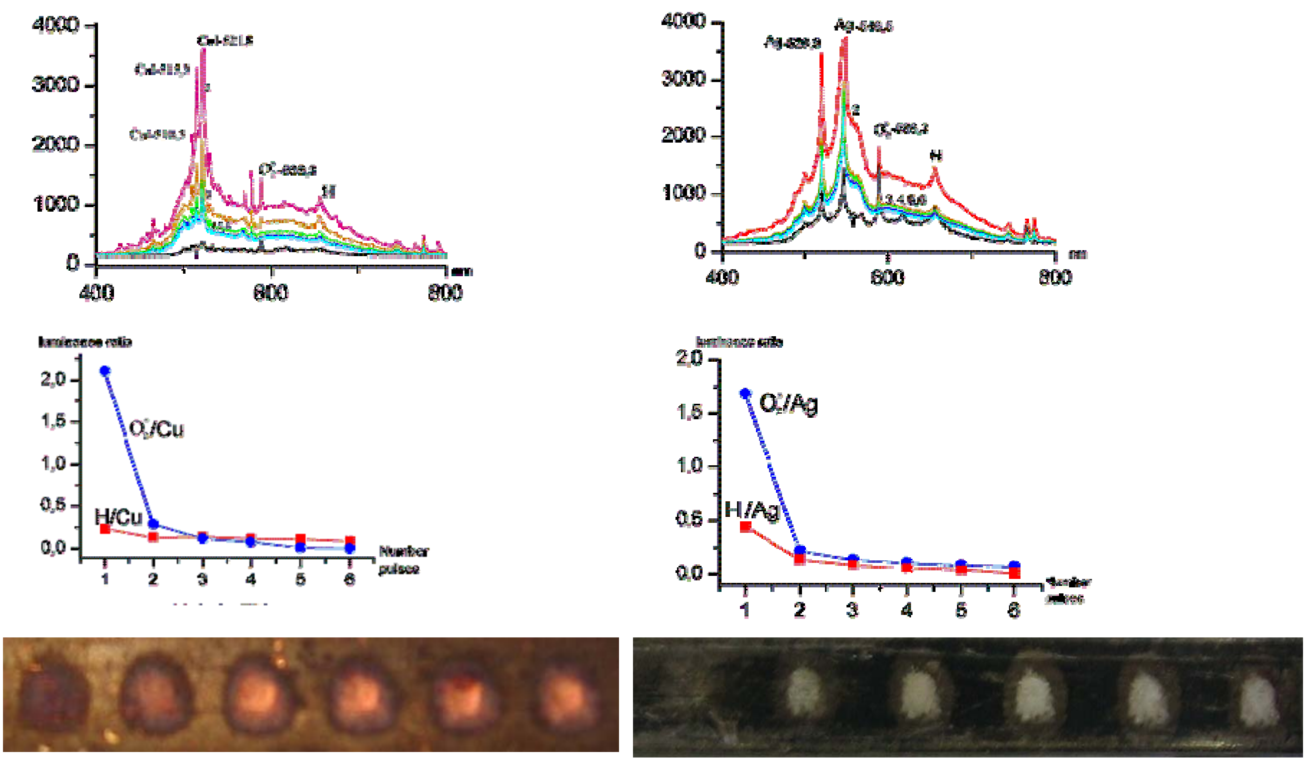
A promising scheme of decontamination process is presented in work [2]. In this scheme laser radiation on its way to the surface penetrates a thin transparent film. This film catches the cleaning products which fly apart from the interaction zone. This way the problem of cleaning products collection is beeng solved. To establish proper cleaning products collection one should know exactly the composition and speed distribution of flying particles. Measurements of these values using fast photocamera are described in this article.

It's very important to control the cleaning quality during the process. It is known that 95% of surface radioactive contaminations are contained within the thin oxide film [3]. So there are two tasks to be solved: first, a method needs to be developed for online cleaning quality checking; second, we need a strong and well-known correlation between oxide removal and radioactivity removal. In this work we offer a LIBS method for the control purpose. It supposes laser spark radiation online spectrum measurement. A model experiment with non-radioactive isotopes of the most common radioactive contaminants is also presented in this work.

To make an estimate of cleaning products expansion we made a photographic recording of the interaction process. A set of IR filters was used to avoid over-exposure by 1.07 um laser wavelength. Pulse fiber laser radiation was focused on the metal surface into a 100 um diameter spot. Fast galvo scanning system was used to make a string of pulses on the surface with near 300 um distance in between. Laser pulse frequency was 20 kHz, so during 1 ms camera exposure time we can catch 20 pulses with regular 50 us interval. This way a laser spark evolution was investigated. A set of conclusions has been drawn concerning cleaning products collector proper place and type.

Laser cleaning process supposes a laser spark, which emits light. This ligth spectrum carries information about the surface chemical composition. We may use this phenomenon to control a cleaning quality. The main idea is that pollution layer contains oxygen and base material contains no oxygen. To test this hypothesis we performed a set of spectroscopic measurements with nanosecond range Nd-YAG cleaning laser and prism specrometer. Spectra were registered during polluted surface cleaning and second processing of already cleaned surface. Significant drop of oxygen lines was detected during cleaning already cleaned surface (Fig. 1). This fact opens a perspective possibility to make a cleaning control system.

To reduce amount of experiments with radioactive polluted samples, we propose a method of decontamination rate measurement without dealing with radiation. We use the same contamination method [1] but with non-radioactive isotopes, for instance, ^{133}**Cs**. Presence of these isotopes on the surface can be controlled with spectromeric method.



old copper old silver

Fig.1. Laser–emitted spectra from old copper and old silver.

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1. Laser cleaning and decontamination of metal surfaces: physical processes and applications “Laser-Inform” № 1-2 (376-377), 01.2008 V.P. Veiko, T.Y. Mutin, V.N. Smirnov, G.D. Nikishin, E.A. Shakhno
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PS1_63 Laser graffiti removing

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One of the modern town problems is illegal paint drawn on architecture objects and sculptures like graffiti and vandal stain. So it is necessary to create methods for fast mobile removing of paint. Mechanical and chemical cleaning methods are widely used, but there are some shortcomings of these technologies, such as surface scratching and absorption of porous materials. Alternative method is laser cleaning. It is fast, noncontact and chemically clean method, it can provide remote cleaning of objects. Laser cleaning is investigated in this work.

YAG:Nd laser is traditionaly used for laser cleaning. For examples, this laser is used for art objects cleaning, removing of organic matter, removing of radioactive layer from metal surface. In our experiments we have used also other lasers: YAG:Er and CO2 laser. There was investigated removing of different paints, such as nitro paint, emulsified bitumen, permanent markers. Surfaces of widespread constructional materials like marble, granite, concrete, baked brick, steel were successfully cleaned. For each laser there were found the optimal regimes for every paint, by which the main material was not injured. YAG:Er fiber laser has small dimentions and weight, it needn’t for water colling (air colling is enough). These are reasons why its using for removing of paint allows to make our technology mobile.

Concrete ways for quality increasing of laser cleaning are proposed, for instance cleaning by double laser scanning, additional mechanical removing of burning products from the surface, etc.

PS1_64 Ultrafast lasers for conservation of heritage artefacts

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The use of laser technology for cleaning heritage artefacts is gaining increasing interest both in Australia and overseas. Laser cleaning is a dry and contact-free process, which selectively removes contaminating dirt or coatings (including hazardous contaminants such as radioactive and biological material), minimises mechanical and chemical disruption of historic surfaces and generates minimal waste.

The femtosecond pulses used by ultrafast lasers however, are too short to allow heat or shock waves to travel into the substrate. This allows highly controlled cleaning, which does not affect the substrate material. The main advantage of ultrafast laser cleaning is in the ability of treatment of extremely fragile or heavily altered surfaces which can not be treated by conventional techniques, such as, for example, over-painted gilded samples, fabric with pearls and/or gold threads, feather, etc.

Femtosecond pulses appeared to be better than longer pulses in terms of the spatial confinement of the beam and etching resolution – precision could be achieved down to 0.02 μm per pulse [1,2]. The cleaning efficiency with ultrashort laser pulses is less sensitive to the chemical composition of the contaminants than has been observed with nanosecond lasers. Moreover, working with low pulse energy and at high repetition rate allows the removal of a very thin layer of contaminant with each pass. This provides better control of the process and reduces the 'dot' effect, producing a smoother final surface.

The laser cleaning process was combined with real-time *in-situ* monitoring with Laser-Induced Breakdown Spectroscopy (LIBS) to analyse the ablated plume and provide a feedback to prevent damage to uncontaminated layers under the surface of an object. We demonstrate successful ultrafast laser cleaning of various objects from the heritage collections of the War Memorial in Canberra, Art Gallery of NSW, and ArtLab Australia in Adelaide.

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PS1_65 Laser cleaning of the metering rolls

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The main difficulty in procedure process of flexography is cleaning of metering (anilox) rolls. Due to its laboriousness and unproductiveness, it is very hard to automate present procedure using traditional ways of cleaning. Metering roll serves as ink transferring element, its surface is uniformly graded up to 150 micrometers in depth. Consequently, optical density of printed impression hardly depends from amount of ink on the roll. For readjustment of a printing machine for a new pressrun we need of clean anilox rolls quickly and qualitatively.

All of up to date traditional ways of cleaning are inefficient, because cleaning agents can't take away ink pollution from micronic halftone pattern of the roll and, also, they are ecologically destructive. Thus, the best way to deal with this problem is to develop technology of laser cleaning. To this end, a set of experimental studies was carried out. Fiber laser with 100 ns impulse time with adjustable pulse repetition frequency and radiation power was used. Also, the scanning system plays very important role in development of laser purification technology. In the present research system galvanic scanator was used.

Metering rolls, used in our research, had various microrelief dimensions. Thus, adhesive power and threshold values of the surface destruction on an anilox rolls face were determined experimentally. Also, different types of inks (spirit and ultraviolet) were tested

During the experimental study of dry and wet laser cleaning, we have determined relations between the effectiveness of cleaning process and some process parameters. Also, threshold values for both types of cleaning and for surface destruction of an anilox rolls were determined.

S1-1 Experience of industrial application of fibre lasers for metal processing

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The first fibre laser was created in 1963 on the basis of glass fibre conductor with neodymium ions. But only in the beginning of 70th this trend was developed because of receiving glass fibre conductors, alloyed with rare-earth elements with low optical loss.

Further structure of fibre conductors improvement and perfection of pumping systems on the basis of laser diods lead to expansion of diapason of power bar of fibre lasers with lenth of wave 0.9-2 mkm [1].

Heightened demand for fibre lasers is observed for last 10 years on the market of laser generators. In 2007 sales growth of fibre lasers was 40% and in absolute expression near 500 mln of US Dollars or more than 7% of market [2].

It is noticed the trend of replacement with fibre lasers of solid-state of traditional type, diod and gas in already existed market niches, including in industrial laser technologies of marking, engraving, cutting, welding, thermal treatment. [3].

Near 20 research and commercial centers in Japan, USA and Europe more that 15 years develop fibre lasers. Undeniable leader in this area is “IPG” that has Russian origin and controls 75-80% of sales this market segment. [4].

High competitiveness of fibre lasers can be explained with important technical-economical preference:

- High kpd – up to 30% (gas and solid-state – up to 7%);
- Low operational costs;
- Absence of external optical units;
- The best in comparison with gas and solid-state of traditional type lasers, parameter of ray BPP;
- High reliability and work resourse;

Soviet Union was one of the world leader in the area of creation and implementation of laser technologies of materials processing. For last 15 years our countries are substantiality behind form the level of developed countries in the level of practical using laser technologies and for present time are considered not as participant of foreign cooperations but as market area for delivery of laser product.

In the same time for Russia in period of establishment and development of process fields, existing of such equipment is very timely. Laser technologies are the necessary component of technological process during creation innovation product. Application of laser technologies raises of work efficiency, economize materials and energy resources, and come down cost price of production with the same rising of the quality and reliability.

Economic effect of the implementation laser technologies is 8-10 rubles for one ruble of costs; Duration of preparation of production is reduced in 3-5 times, reducing of laboriousness in 3-4 times, increase of using material coefficient for 30-40% [5].

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S1-2 Application of lasers with semiconductor pumping, generating in the green spectral range for laser stereolithography

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In the last years technology of rapid prototyping, based on the method of laser ste-reolithography, finds increasing application. This technology allows for the short-est period of time (several hours to several days) to produce plastic prototype of part any complexity from its computer model.

In Bauman Moscow Technical University for several years conducted work on replacement traditionally used in the technology of UV lasers for cheaper and more promising, with technical and operational point of view, solid-state lasers with semiconductor pumping, generating in the green spectral range. This change determined the development of photopolymerization composition with a new sys-tem of photoinitiation (FPC), capable to cure under the influence of green light.

Irradiation of the new FPC in the air may produce tracks with the minimum possible thickness of 15 microns. This makes it possible to grow three-dimensional prototypes with a thickness of polymeric layer of the same thickness (in the tradi-tional stereolithography minimum thickness is 25 microns). It is known that with decreasing thickness of the layer improves the surface quality and increases the resolution of the method.

The results also showed that the effectiveness of the photo process is somewhat lower than with traditional UV radiation is due to the lower energy of green light compared with UV. This disadvantage can be compensate by increasing of the ra-diation power, which technically easily realized in lasers green range.

Experience used to create apparatus for laser stereolithography using solid-state laser with semiconductor pumping, generating in the green spectral range. Laser beam moves on the surface of the liquid polymer in apparatus using a specially de-signed plotter system.

As a result of the research was designed apparatus of a new type, characterized the possibility of obtaining more precise details, increasing the worked area and lifetime.

S1-3 Diode pumped Er:YLF laser with tunable lasing spectrum

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Tuning the laser spectrum in 3 µm region can greatly change the parameters of laser radiation and biological tissues interaction what is very promising for medical applications. This paper presents the results of theoretical and experimental investigations of spectral and energy characteristics of diode pumped Er:YLF lasing in 3 µm region.

The theoretical model of Er:YLR multiwave lasing was developed. The model predicted sequentially change of lasing wavelength from shortest to longest during lasing pulse. For the nonselective resonator, pump power densities up to 2 kW/cm^2 and pump pulse durations more than 1.5 ms model predicted Er:YLF lasing on four wavelengths: 2.66, 2.71, 2.81 and 2.84 µm. For the pulse-periodical mode the theory predicted strong dependence of lasing spectrum from frequency and duration of pumping pulses: lasing on wavelengths 2.66 um and 2.71 μm stopped with increasing pumping pulses frequency and duration.

The most of theoretical results were proved experimentally. For the diode pumped Er:YLF laser with nonselective mirrors sequential lasing on wavelengths 2.66, 2.71, 2.81 and 2.84 μm was observed. The pump power was 340 W and current pulse duration was 2 ms. Pulse-periodical mode was investigated with pumping pulse duration 250 us when 2.84 um lasing were absent. With increasing of pulse repetition rate the lasing delay on wavelength 2.66 um increase and for repetition rates higher than 45 Hz lasing on that wavelength discontinued. When repetition rates were higher than 50 Hz lasing on wavelength 2.71 also discontinued and lasing was being gone only on wavelength 2.81 μm. For low pulse repetition rates (0-30 Hz) and pump pulse durations (30-100 μs) generation only on wavelength 2.66 um was observed. The investigated effects can be used for tuning laser spectrum without any additional devises in resonator or on the laser output.

S1-4 Status and Futures of Laser Marking and Engraving Industrial Application.

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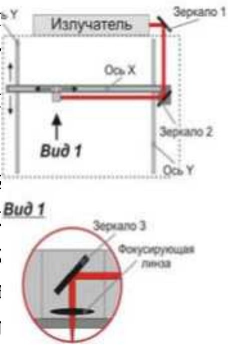
Today in spite of the fact that humanity has invented a lot of lasers [1], actually only 2 types of them are used for material processing. There are CO_2 lasers with 10.6 μm wavelength, and different solid state lasers with 1.06 μm wavelength. It should be noted, that the radiation of CO_2 lasers is quite difficult to time and space modification. It explains a using of CO_2 CW and pulse solid state laser resources for marking. Success progress of semiconductor and fiber technologies has achieved to significant overpatchings in producing of solid state lasers and appearance of compact, high reliable diode pumped fiber lasers. The fiber lasers have minimum overall size and weight. They are very reliable ar mporal characteristic of radiation.



The choice of ends on operating material. So far as various materials (metals, plastics, rubbe have different coefficient of absorption. Therefore some materials can be marked igths.

A material has l (heat, fuse, evaporate and etc.) under the effect of focused laser beam [2]. A st effect zone looking like graphical point. A combination of these points allows ical symbols and pictures. It is necessary the controlling of laser point in time a ting any graphical information. Basically, there are used scanning and plotter sys n control moving, see fig 1.

Also there are another ways of controlling laser beam. But all of them are quit exotic and don't have industrial application.

Laser marking depending on method of picture creating could could be classified on vector and raster mode. In raster mode a picture picture creates by drawing lines in turn, in vector mode - outlining a picture. Of cause may combination of these methods. Thereby any numerical, literal and symbolic information can be marked.

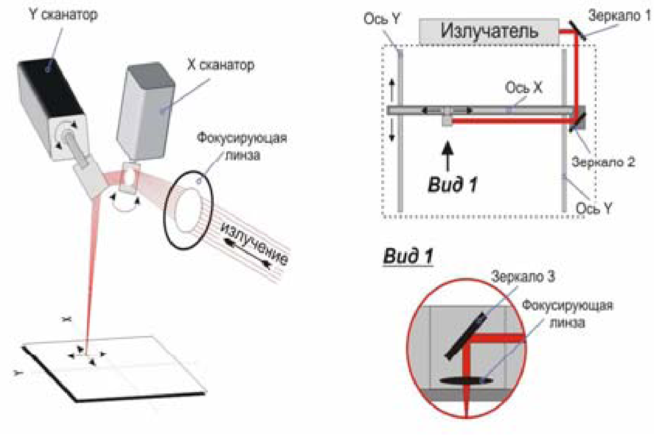


Fig. 1.Scanning and plotter systems for laser beam control moving

High speed of laser beam and high concentration ratio of energy allow marking and engraving any materials: metals, alloys, hard materials, nonmetal materials and etc. It determine, wide range marking application for cording, identification, stock-taking, goods movement and etc. in all industry branch from nuclear till jewelry. Modern laser marking and engraving systems are very compact, effective, reliable, and can be easy integrated to any technological process. One of the best samples of this kind equipment is the precision laser marking and engraving system MiniMarker® , see fig 2.

Fig. 2. Laser precision marking and engraving system MiniMarker®

MiniMarker® is based on fiber laser producing IRE-Polus (included in IPG Photonics group), doesn't require any consumable materials (only electricity), has unique reliability, has a very stable parameters of laser radiation and speed of movements of laser beam up to 8.7 m/s with accurate + 2.5 µm in the 100mmx 100mm working field. Today experience of industrial operating of MiniMarker® is over 25000 hours without any maintenance. Modern laser marking systems meet the heist requirements and can be successfully operated in any kinds of industry.

Modern research and developments in new lasers gives a new technological possibility for other application of laser marking and engraving [3,4]. It seems the future of laser marking and engraving is in the precision heat injection of materials by laser beam. The laser beam quality stability of new fiber lasers is open the real way to the future of laser marking and engraving process. Some samples of today and future application of laser marking and engraving process are showed in the fig 3.

Fig. 3. Samples of laser marking application

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S1-5 State & perspective for laser welding

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Fundamental Examination for Laser Welding of steel and alloys up to 12-30 mm thick of CO_2 – Lasers Power up to 12-30 kWt.

To day are Welding of IPG Ytterbium Fiber Lasers Power - 2, 5, 10, 15, 30 kWt.

Laser Welds of low-alloy, medium-alloy and high-alloy steels have High Mechanical Properties. Laser Welding needs size precision of welds blanks and better applications for precision pipe workpieces (AvtoIndustry). Arc-Laser-Welding have applications for lengths workpieces (ShipBulding).

Laser Welding and Arc-Laser-Welding have effective and wide applications, good future in industry.

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RMC Lasers and apparatus TM is one of the founders and the basic scientific and manufacturing centre of the group of companies ESTO.

ESTO is an association of leading Russian companies, whose specialization is research, development, manufacturing, modernization, sales and service of electronical special technological equipment.

More than 20 years of experience, high efficiency of the centre's specialists, up-to-date research laboratories, design-engineering department, manufacturing departments, service centre – all these allow to provide full cycle of the laser material processing projects. It starts with research and technological experiments, than goes to production, serial production, putting into operation and service. According to the number of R&D projects in process, wide range of the lines of research and manufacturable equipment, quality and volumes of production, RMC Lasers and apparatus is an acknowledged leader among Russian manufacturers of laser equipment.

Hundreds of technological systems of ML1, ML2, ML3, ML4, LTA4, LTK4, ML5 series for laser microprocessing, marking and engraving, cutting, welding, trimming and also the recently developed systems MLP (with cutting-edge components, such as fiber and Nd:YAG lasers and kinematic systems with patented linear motors) for micro- and nanoprocesing successfully work at the companies and plants of electronic, atomic, aerospace, instrument engineering branches of industry, at the small and medium enterprises of high-tech, purpose-made and innovative technologies.

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