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SIBERIAN CENTER FOR PHOTOCHEMICAL RESEARCHES: STATUS AND PROSPECTS

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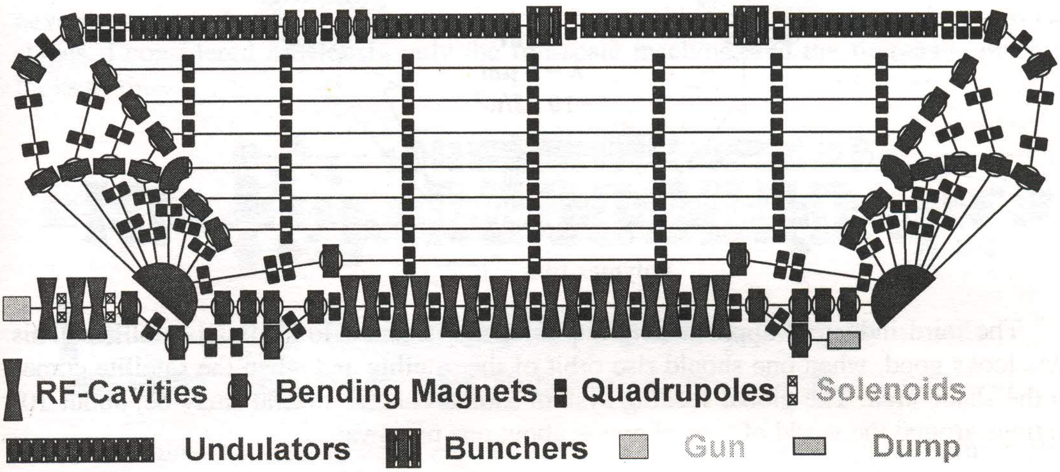
First of all, a few words on the history of the Center. It was organized several years ago as a collaboration project between two institutes: the Budker Institute of Nuclear Physics and the Institute of Chemical Kinetics and Combustion. It is based on a high-power high-scale and expensive machine, so-called free-electron laser. It is widely tunable and contains a set of user stations to permit effective application of the light, emitted by the free-electron laser.

What is free-electron laser, or FEL, in abbreviation? Conventional lasers are used solid, liquid or gas medium to amplify light. Instead of that, FEL uses electron beam, traveling through a permanent periodic magnet, called undulator, for the same purpose. The wavelength of emitted radiation depends on the properties of the undulator and electron energy. Both parameters, the magnetic field and the electron energy, can be controlled well. So, one can tune FEL in wide band continuously and easily. The available average power of electron beam now exceeds 100 megawatts, so one can expect to design and maybe develop in future FEL of output power of several megawatts. Unfortunately, each FEL is expensive enough and complicated, as it contains an electron accelerator inside a shielded room and it power consumption from plug is sufficient, any time. So one can conclude, that free electron laser is attractive and efficient, in comparison to conventional lasers, only in the case when it is a really high-power machine.

Our machine is a step in this direction. Its expected parameters are as follows:

◆ Wavelength of emitted radiation, μm		3...10
◆ Pulse duration, ps		10...100
◆ Pulse energy, J	up to	$5\cdot10^{-3}$
◆ Repetition rate, MHz		2.25...22.5
◆ Average power, kW	up to	100
◆ Relative bandwidth of emission spectrum		$3\cdot10^{-5}...10^{-3}$

Its power is planned to be about 100 kilowatt. It looks like this.



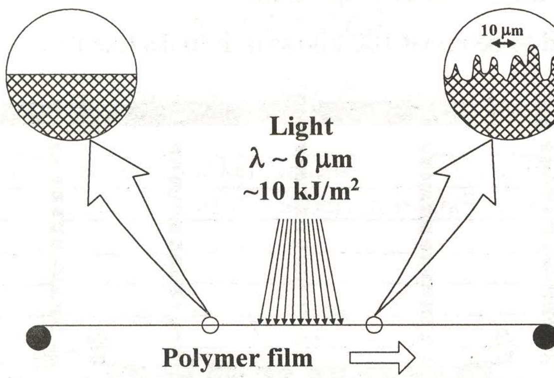
This is an electron injector and a RF accelerating structure, a set of beamlines and the free electron laser structure itself. Electrons from the injector come to a RF accelerator structure, pass it eight times, and gain energy 100 MeV. Then the radiate some part of their energy inside the FEL structure. The rest energy is recovered in the same RF accelerating structure. The recuperation is extremely desirable to avoid radiation hazard from the absorbed electron beam.

Of course, the most important applications of this large, expensive and high-power machine lay in technological region and also industrial applications.

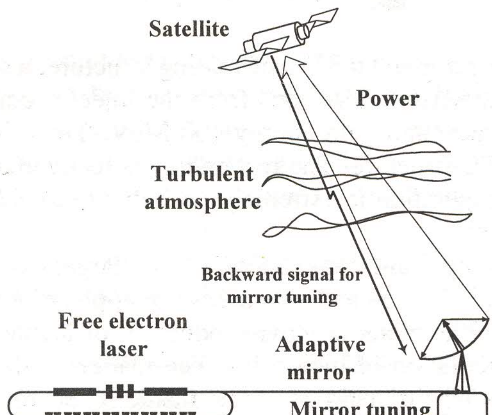
The first group of applications is mass production of stable isotopes. The process used is multi-photon dissociation of molecules. The matter is that the frequency of molecular vibration depends on the mass of atoms inside it. So for molecules, containing different isotopes, the frequencies of molecular vibrations are different. Tuning the FEL, one can choose only one isotope and involve only it into the reaction. So one can separate this selected isotope from the mixture. For example, ^{28}Si possesses heat conductivity greater than the natural mixture of silicon. So it leads to great advantages in production of microchips and high-power semiconductor devices.

- ^{28}Si – heat conductivity is ~ 50% greater than for natural mixture of isotopes. Great advantage in micro-chips and power semiconductors.
- ^{13}C and ^{15}N – spin label in NMR-tomography for biomedical and biochemical research and fertilizer monitoring.

The next group of technological applications is modification of surfaces of polymers. The surface can be modified chemically or mechanically, depending on the type of polymer, the exposure and the wavelength, of course. New properties, that can be achieved, are anti-bacterial, great absorption, great surface area and many other ones, for example, a new color.



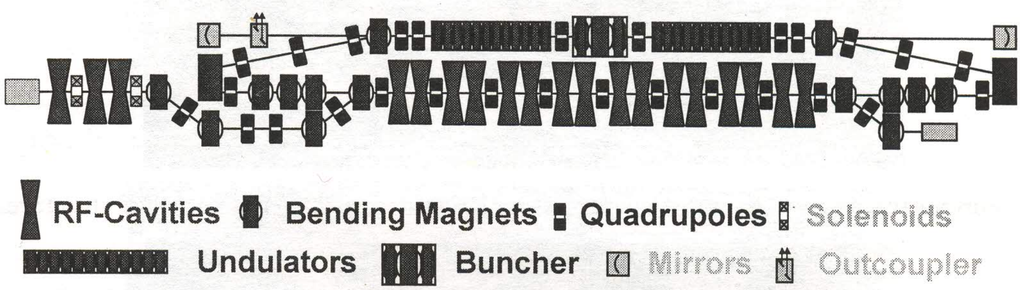
The third industrial application group is energy transfer to artificial satellites. This idea looks good, when one should rise orbit of the satellite and when the satellite comes to the shade area. The global feeding system should contain several (may be, about 10) stations around the world of typical power about one megawatt.



Of course there are a lot of pure research applications. Some of them are listed on the slide.

• semiconductors – admixture levels, excitation, dynamics of recombination;
• superconductivity – conductivity zones, admixtures;
• optical reflecting surfaces and monomolecular layers;
• physics of surface;
• rotational and vibrational transitions in molecules;
• diagnostics of combustion zone;
• lidar;
• calibration of IR-sensors;
• selective reactions and isotope separation;
• dynamics of molecular excitation;
• laser catalysis.

Our problems. Right now, our funds are very limited. Of course, we get some funds from the Siberian Branch of RAS, from other sources, and invest our own money. But nevertheless our funds are still limited. So it was decided to divide the project into two stages. I considered previously only the full-scale machine, and the first-stage machine looks as this.



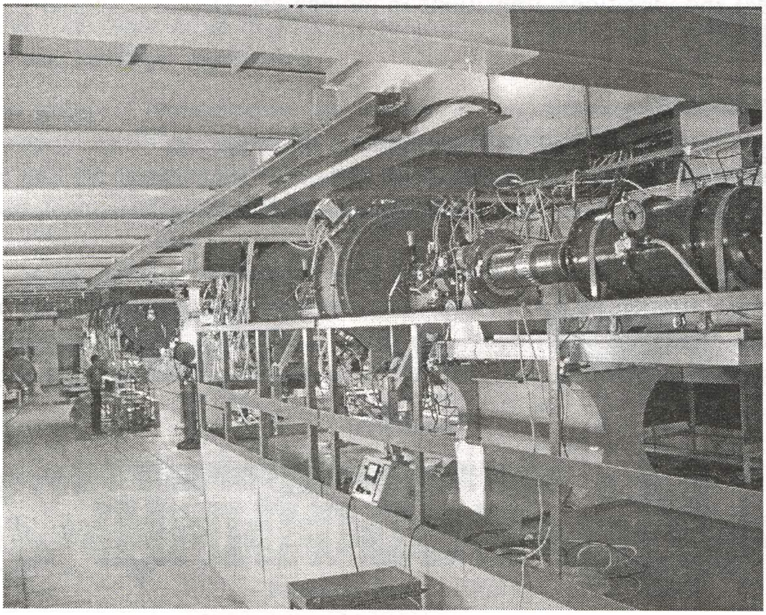
It contains the same injector and the same RF structure and only one turn of electrons. The main advantage in this case is that we expect to assemble totally this first-stage machine by the end of this year. At the beginning of the next year we expect to get lasing, install user stations, and start first experiments in our Center. Of course, in this case the electron energy is lower, and the wavelength of emitted radiation is longer.

◆ Wavelength of emitted radiation, μm		100...200
◆ Pulse duration, ps		20...100
◆ Pulse energy, J	up to	$3\cdot10^{-4}$
◆ Repetition rate, MHz		7.5...22.5
◆ Average power, kW		0.6...7
◆ Relative bandwidth of emission spectrum		$3\cdot10^{-3}...\ 3\cdot10^{-2}$

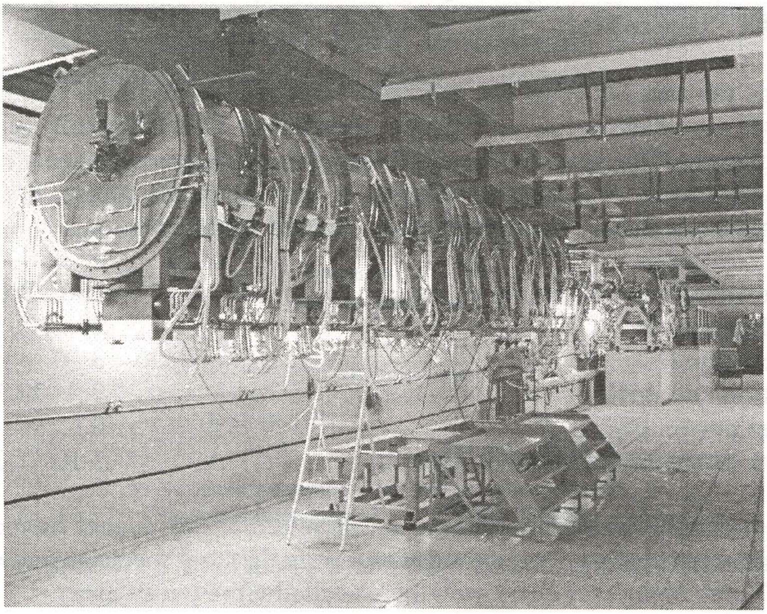
But except of this fundamental harmonic, there are several higher harmonics in the spectrum of emission, and they can be separated from the total spectrum and used for the experiments. These harmonics cover well the so-called vibration IR area.

One should note that both machines will exist simultaneously, as they are arranged in different planes. One can switch from one machine to another only by switch button, not more.

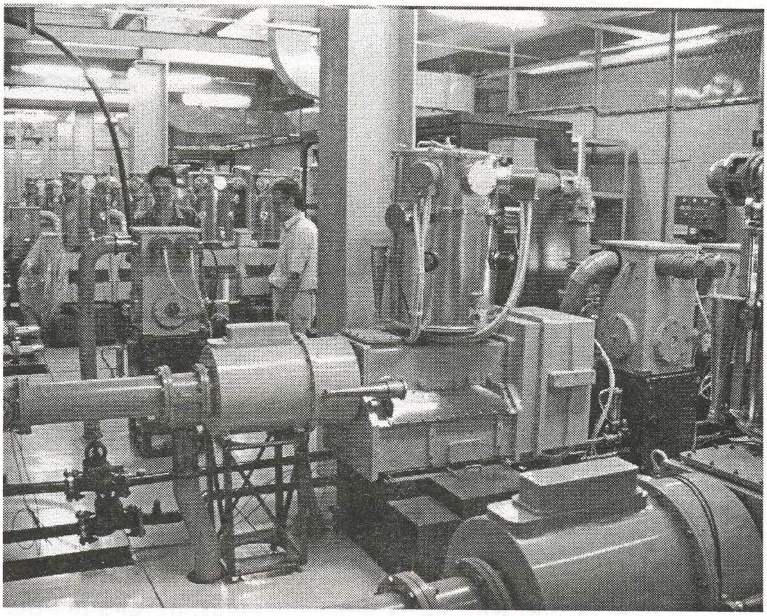
Current situation. This is the accelerator room of our Center, one can see the injector inside it. It is commissioned several years ago, and now is operating successfully.



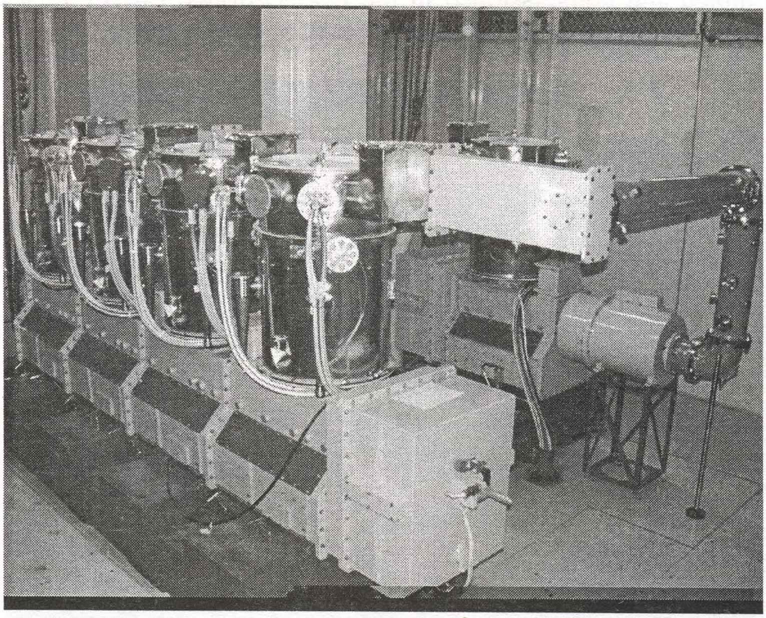
Further there is the assembled accelerating RF structure. The full-scale RF structure.



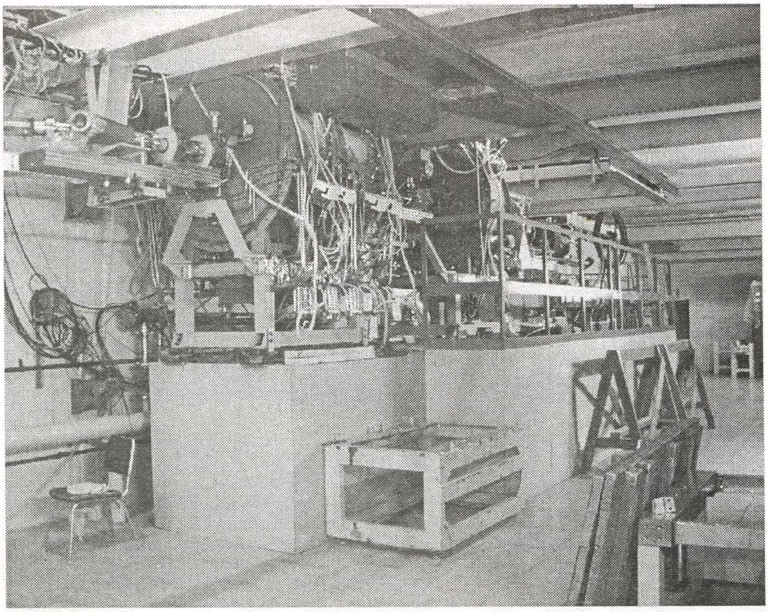
This is the RF-generator room, and a full set of RF-generators for the whole machine inside it.



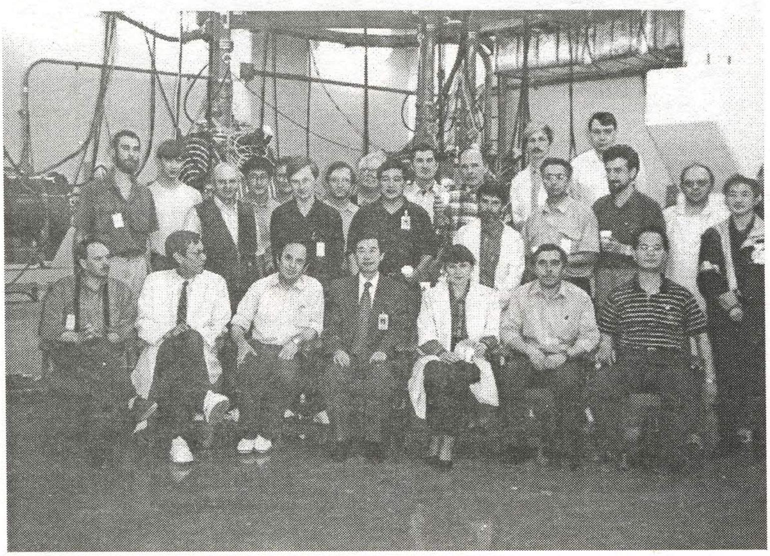
This is one of RF generators.



One more photo of the injector from another point of view.



We have a good relationship with many other institutes, developing free-electron lasers. For example on the photo below one can see the injector, quite analogous to our one, that was assembled and commissioned in the Korea Atomic Energy Research Institute several years ago, according to the agreement between our institutes.



We also have collaboration projects with the Japan Atomic Energy Research Institute, the University of Tokyo and many other institutes around the world and in Asia.

We would like to invite all the potential users of our Center to consider the future experiments in general and in details and then visit our Center, of course, after commissioning the machine. And we would like to invite potential investors to join our Center. Increased funds will permit to fasten the commissioning of the full-scale machine, a really unique one. And if anybody wants to visit the Center right now, please contact me as soon, as possible. I'll be here. We shall find appropriate time and I'll guide you to the Center, it is not far from here.