TOUR OF THE INSTITUTE
OF NUCLEAR PHYSICS

A SERIES
OF ARTICLES

We are ready to meet the journalists. We are excited: not every day and not everyone gets a chance to talk about their work, and we could tell about our Free Electron Laser (FEL), a large facility whose design was taken up by the best minds of the Institute of Nuclear Physics twenty years ago.

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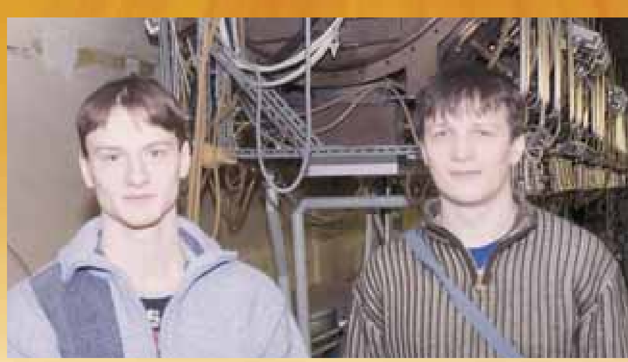


The main advantage of our laser is that it allows the radiation wavelength to be adjusted in a wide range, from 0.1 to 0.2 mm. What is more, within this range its beam is most powerful.

FEL consists of two parts, an accelerator-recuperator and an undulator. To describe the processes in FEL shortly, an electron beam is first accelerated in the accelerator-recuperator. Then, interacting with an electromagnetic wave in the undulator, the beam slows down, giving its energy back to the accelerating unit of the machine. Then the beam comes to the absorber where it "dies heroically" having done its job by enhancing the electromagnetic wave in the undulator. After being reflected from the mirrors of the optical resonator, the wave interacts with a new electron beam. The power of the electromagnetic wave increases sharply and very soon, in several milliseconds, reaches the saturation mode. Part of this power, laser radiation, is what the users receive for their work.

We can talk about our laser for hours, but it is better to see it with your own eyes. That is why we go to the "sanctum sanctorum" of the FEL, the accelerator room.

Concrete walls of the accelerator room are three meters thick. This is necessary for ensuring radiation safety, for when the accelerator is running the radiation level in the room increases.

By the way, everything is perfectly in order with safety at our laser setup. First of all, before the accelerator is switched on, the buttons are pressed to inform the personnel about this. A gloomy voice kindly asks you to leave the room. After that you take the keys of all the doors of the accelerator room and go to the keys assembling place. There you put them in the dashboard and turn. Only then it is possible to start the accelerator. The whole procedure resembles a lot movies about the launching of nuclear missiles.

There are certain safety measures for the machine, too. Well, you have to care for it to obtain a flash of the precious "light". All units of the FEL accelerator are equipped with heat sensors. If a unit of the machine gets severely overheated, the computer responsible for the processing sensor signals lets out a very unpleasant, piercing sound. So, at that very moment the operator will run to check why the machine parts are overheated. Moreover, the facility also has beam current sensors. If the current is lost in one section, the machine is immediately shut down to prevent the formation of "holes" in the vacuum chamber.

Currently FEL can operate at the radiation wavelength from 120 to 235 micrometers. There are few lasers emitting in this submillimeter range, even though it is this range that intrigues scientists all over the world today.

The power in the cavity is about 10 kW, and the users are provided with radiation power of up to 400 W. Now the first single-track line of the laser operates in the accelerator room. We are planning to launch a second four-track line,

The entrance to the accelerator room is barred by an enormous one-meter thick lead door, an electric motor with a dashboard next to it. First, it is difficult to believe that something can move this metal "crag". Then you insert the key, and there it is: the slowly moving door lifts the veil of the "accelerating mystery".

Laser is a source of electromagnetic radiation (infrared, visible, and ultraviolet), based on stimulated emission of atoms and molecules. Compared with other sources of light, laser radiation is monochromatic (it is in a narrow wavelength range) and highly directional. Lasers differ in energy pumping and in the lasing medium. The medium for FEL is electrons accelerated to relativistic speeds in the accelerator of elementary particles.

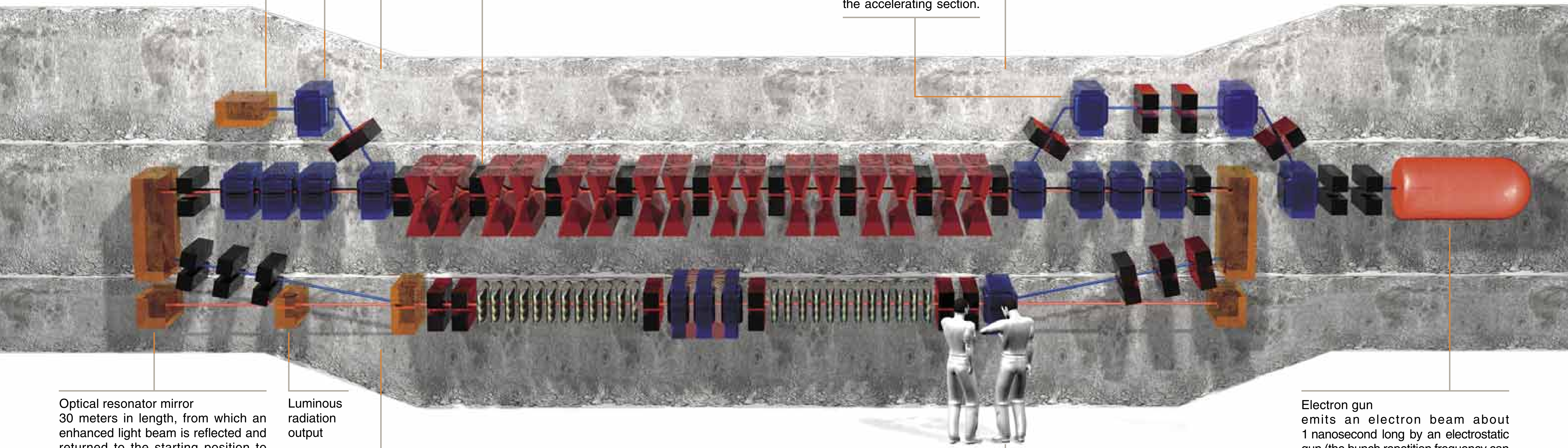
Magnet
changes the trajectory of passing beams. The slowing beam is directed to the absorber, and the accelerating beam to the undulator. Similarly, when coming to the line of resonators, the beams with different energy are merged into one right line.

Absorber
of electron beam that gave up a greater part of energy at the slowing phase of the line.

ACCELERATING SECTION
is a line of resonators, which first accelerate a beam up to 13 MeV and then, after the interaction of the beam with the electromagnetic wave, damp it to an energy of 2 MeV. Thus, beams of different energies, that is, accelerating and slowing energy, fly through each resonator.

Quadrupole lens
is a doublet of lenses that focuses the beam simultaneously in two directions.

Bending magnet
directs the electron beam grouped and accelerated to 2 MeV to the accelerating section.



Optical resonator mirror
30 meters in length, from which an enhanced light beam is reflected and returned to the starting position to interact with a new electron beam.

Luminous radiation output

UNDULATOR
forms a multisectional oscillating magnetic field, in which the electron beam flies along a sinusoidal trajectory. Simultaneously with the electron beam, an electromagnetic wave comes to the undulator. As the result of the interaction, the electrons change their energy and begin to group – the quicker electrons catch up with the slower ones.

The grouped electron beam begins to emit light, enhancing the wave inside the optic resonator.

Electron gun
emits an electron beam about 1 nanosecond long by an electrostatic gun (the bunch repetition frequency can be regulated and increased to 22 MHz).

Laser radiation is delivered through a transport canal to the user stations, where experiments in physics, chemistry, biology, mineralogy, aerodynamics, aero-optics, and other fields are planned and carried out.

An FEL consists of an accelerator-recuperator and an undulator.

By analogy with the terminology used in spaceflights, this room can be called “laser tracking headquarters”. Here you can see and sometimes touch all that makes the FEL work in a given mode.
Fine tuning of the machine is not a piece of cake. Those who succeed in this are fondly called “shamans”. It is really an art in itself, communication with something unknown, like the shamans’ ancient sacred rites with songs and tambourines.
Our shaman’s name is Aleksandr Matveyenko. Sometimes we try to repeat what he is doing, step by step, but there is no beam! And then we believe that every piece of iron has its own soul.

where the energy of the electron beam will reach 50 MeV. It will allow the wavelength to be varied from 5 to 200 micrometers, and the radiation power received by the users will reach several kilowatts.

As for the users, they are scientists — physicists, biologists, chemists — who provide us with a positive feedback. Ultimately, nothing should exist for its own sake. That is why it is the users who call the tune, and physicists must do their best to make good pipers.

The best point to finish the excursion over our laser facility is the user stations. Here, at each separate outlet of submillimetre radiation the scientists can assemble their setups and run experiments. The wavelength range of our laser is of interest for various specialists. And it is far from being fully studied — both we and our laser have a long way to go.

A.N. MATVEYENKO, researcher:

Every year a big conference dedicated to FEL is held. A former researcher of the Institute of Nuclear Physics, V. Litvinenko (now living and working in the USA), quoted the Bible when he was awarded the Annual Prize of FEL Physical Community: ““In the beginning God created the heavens and the earth. Now the earth was formless and empty, darkness was over the surface of the deep, and the Spirit of God was hovering over the waters. And God said, ‘Let there be light,’ and there was light. God saw that the light was good.’ You have no idea how great it is — to feel that you have ‘created light’!”
It was a good joke of a man who did what nobody else had done. Of course, unlike God, the abilities of scientists are limited by their resources and the level of technology. But the purpose of their work is very similar: to lit up the “light of knowledge” for humankind. On the day FEL was launched I saw the faces of people who have “created light”. And then I understood what they were worked for.