LEBEDEV PHYSICAL INSTITUTE RADIATION COMPLEX – CURRENT STATUS AND NEW CONCEPTS

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Multipurpose radiation complex is the result of long- term permanent development of new instrumentation at the Lebedev Physical Institute. This is stand-alone large facility designed for fundamental and applied research that had been started from the high current racetrack microtron project in the mid of seventies and has been completed by commissioning of far infrared FEL nowadays. Current status of the radiation complex including research as well as linac and FEL performance improvement is discussed in paper presented followed by new ideas in further facility development and application.
PACS numbers: 29.17.+w, 41.60.Cr

1 INTRODUCTION

Free electron lasers (FEL) supplement successfully classical lasers in short as well as in long wave ranges when used for exploration of radiation with physical matter and biological objects. In addition, such property of FEL radiation as temporal structure synchronized with a beam structure makes it possible to carry out multiphoton experiments. In the simplest case the object under investigation is influenced both by FEL radiation and RF power used for linac structure excitation, and one studies the sample reaction in dependence on the phase shift, intensity, etc of two probes. Far infrared FEL excited by the electron beam from the RF linac has been commissioned successfully, and stimulated radiation has been detected. We consider this FEL as the first stage of multipurpose radiation complex to be used for solids exploration mainly with coherent electromagnetic radiation in the wave range 10 – 500 microns at the Lebedev Physical Institute. Thus, next stage has been started with the FEL commissioning, and this stage will be used for detailed FEL investigation as a device for physical research as well as for first experiment preparation. Following is the facility description as well as new problems discussion we are working at.

2 FAR INFRARED FEL FACILITY

Fig.1 represents the schematic of far infrared FEL together with the accelerator-driver and electron beamline.

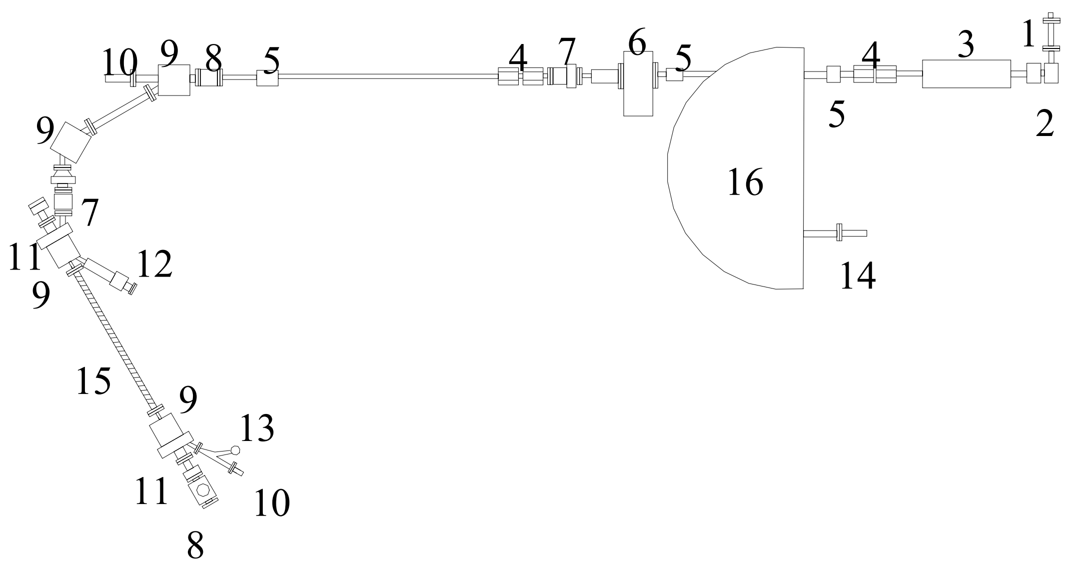

Fig. 1. Schematic of the far infrared FEL. 1- electron gun, 2 – inflector, 3 – linac, 4 – quadruple doublet, 5 – correcting coil, 6 – vacuum valve, 7 – current monitor, 8 – luminescent screen, 9 – bending magnet, 10 – Faraday cup, 11 – mirror container, 12 – observation mirror driving system, 13 – luminescent screen driving system, 14 – multiwire monitor for magnetic spectrometer, 15 – electromagnetic undulator, 16 – magnetic spectrometer.

The layout of the radiating part one can see from the photo in Fig. 2. A driving electron beam is produced in the RF linac formed by the accelerating structure on the basis of a disk-loaded waveguide and an injecting system consisting of a high gradient RF cavity and a low voltage electron gun. Such a scheme makes it possible to produce short bunches at the accelerator exit with narrow energy spread that is quite necessary for appropriate FEL performance [1]. The beam from the linac exit is delivered into the FEL interaction region by a beam line formed by focusing quadruple lenses and correction coils, a monitoring and injecting system. The latter consists of three bending magnets and provides achromatic transportation of electron bunches onto the undulator axis while the former allows keeping the injection process under control. A magnetic spectrometer at the entrance of the beam line serves to tune the accelerator to the narrowest beam energy spread. This can be achieved with the appropriate RF phase shift adjustment between the disk-loaded waveguide and RF cavity of the injection system.

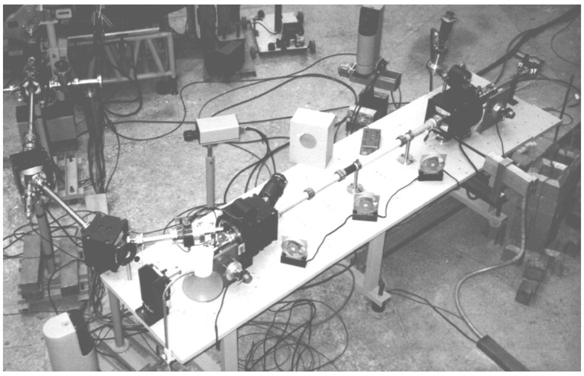

Fig. 2. Layout of the far infrared FEL facility.

A helical undulator [2] and an open resonator compose the laser itself. The driving electron beam interacts with cavity optical mode due to transverse motion in the interaction region induced by the undulator magnetic field. This interaction may result in beam self-bunching and this process results in turn in coherent radiation. To induce instability the described gain per path has to exceed the total losses inside the cavity, and this imposes serious limitation on the electron beam quality as well on the cavity and undulator parameters specification. Table 1 collects the main parameters of our FEL.

Table 1. Far infrared FEL parameters

Wavelength range (μm)	80 - 160
FEL radiation power (expected)	60 kW
Pulse duration (μs)	5 - 6
Micro pulse duration	30 ps
Electron beam energy (MeV)	6 - 8
Energy spread at FEL entrance (%)	1.5
Gain per path (at peak current 10 A)	20
Optical cavity length	165 cm
Mirror diameter	2.8 cm
Mirror curvature radius	1.8 m
Waste of laser mode	5mm
Accelerator wavelength	16.5 cm
Accelerator repetition rate (Hz)	0.1 - 5
Vertical beam emittance	3·π·mm·mrad
Horizontal beam emittance	7·π·mm·mrad
Undulator period	3.2 cm
Number of turns	35
Beam pipe aperture	2.7 cm
Maximum current through winding	45 kA
Repetition rate at maximum current	0.05 Hz
Undulator parameter	0 – 1.4

Linac and laser elements adjusting as well as thorough beam dynamics investigation had followed FEL facility assembling. A semiconductor laser diagnostic alignment system as well as a FEL adjustment and beam diagnostic system were used to align the undulator and mirrors. We refer to [3,4] for the details.

We have 0.5 A in beam pulse at accelerator exit and 350 mA at undulator exit as typical beam current values during the FEL generation experiment. Microwave radiation from FEL is gathered by the parabolic mirror with the focus at the entrance of the copper tube (waveguide) that transmits it to the sensor of the optic-to-acoustic converter that operates in a pulse mode [2]. We had fixed FEL generation at the end of 2000 after the long step-by-step resonator length adjustment. It was very unstable. Comprehensive analysis was made and FEL facility system performance improved to bring driving beam parameters to a much more stable level. We expect to obtain a much more stable generation in the new experimental run at the end of 2001.

Perhaps, the computer based monitoring and control system with adjustable user interface is after FEL facility the most remarkable result of long-term development of novel experimental technique at the Lebedev Physical Institute [5]. The system mentioned consists of hard- and software for physical data acquisition and physical equipment control in real time scale with the interface that user can adjust at the level of executability. Digit-to-analog converter and multichannel waveform digitizer are base hardware elements while the software is based on a novel visual-programming concept. Borland C++ Builder has been used for code development, and the concept of interface building is the same that software mentioned uses. The essential difference is that the form filling with the necessary components is moved to the executable level. Components used for physical data representation are: numeric indicator, plot, histogram and spectrum. These can be adjusted during the experiment and the procedure does not require compiling and linking. This is crucial for our approach since often the most dangerous errors occur after correction of the code written some time before. There are also the components that are responsible for data processing before their visualization as well as for animation of visualized data. The latter means that any time dependent component used for data representation may be played back in slower time after triggering by so called external selection pulse. The adjustment of interface is achieved in a manner similar to the Borland technology that is due to adjustment of appropriate properties in a property editor and the possibility of movement and sizing of the components on the top of the form. Network component is available too, and this clears the way for precise remote measurements – data can be digitized in the hot zone and transmitted to the main console for on-line processing and visualization. There is a possibility of importing the picture onto the form, and this we use for creation of an appropriate mnemonic scheme on the computer display.

Fig. 3 is the cut from the used interface in a design mode, used to fill in the computer display with necessary devices before real measurements. This is the code editor to fix conversion formulae and directives that may be desired before data visualization at the measurement stage.

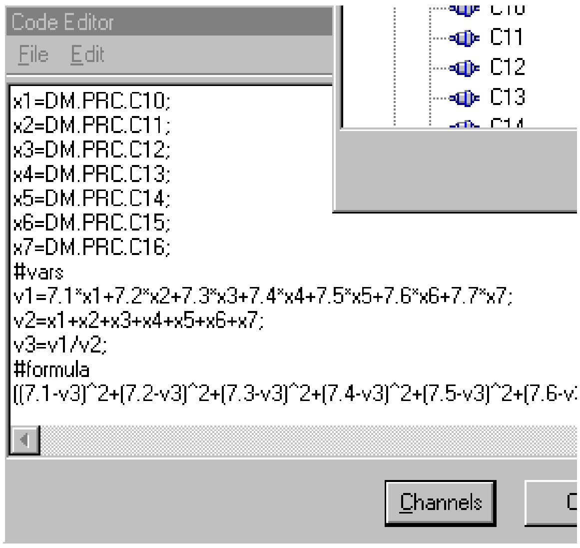

Fig. 3. Code editor – the element of processing the component of adjustable user interface.

3 NEXT STEPS – EXPERIMENT AND NOVEL TECHNIQUES

Comprehensive FEL exploration and first experiment preparation are next natural steps of our work. We are going to start from the two-photon experiment on resonance properties of high-T_c superconducting films. A film will be placed in a gap inthe inner conductor of the stripline. The design allows exposing the film to FEL microwave radiation. At the same time the stripline is the part of the microwave circuit, the rf power synchronized with the linac rf power being the second wave that interacts with the film.

Two ways of moving to shorter wavelengths of coherent radiation are foreseen. The first one is the use of driving electron beam from the next racetrack orbits – in our configuration one can reach as short wavelength as 10 microns. It seems to be very attractive to build an electron storage ring with the maximum energy up to 100 MeV with the existing racetrack used as an injector. In this case one can cover the bandwidth of 1-100 microns with the FEL installed in the strait section of such a storage ring. The advantages of the latter case are the cw mode of operation and low level of background of any kind.

Novel FEL elements and new undulator schemes, in particular, are among those things that are in the field of our interest. We suggest two electromagnetic undulators that can be made of a commercial high-temperature superconductor cable produced in Russia. The first one is a usual electromagnetic undulator with the ferromagnetic core and superconducting winding. The industrial cable allows reaching the current density up to 100 A/mm^2 thus allowing to reduce considerably the coil cross- section area.

Another attractive design using the flat cable is described in details in our paper [6]. The undulator is formed by two corrugated strips – the second one is the translation of the first strip in the direction of the x-axis (Fig. 4). This scheme is attractive from many viewpoints and may be performed in normal conducting version as well as from the superconducting cable.

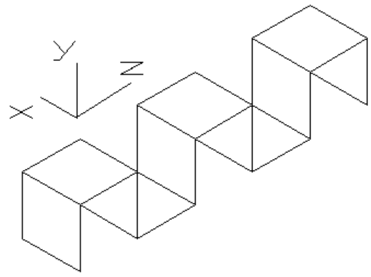

Fig. 4. Layout of planar electromagnetic undulator scheme. One half is shown.

4 CONCLUSION

Novel instrumentation for fundamental and applied research has been created at the Lebedev Physical Institute. This is the main result of the intensive work of many peoples from different laboratories of our Institute and other organizations. Not everything is mentioned in the current paper, separate publications in nearest future will be concerned to specific questions.

The work in part has been made in the frame of the Federal Program “Microwave physics”.

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