CURRENT STATUS OF LEBEDEV PHYSICAL INSTITUTE FAR INFRARED FREE ELECTRON LASER*

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INTRODUCTION

Far infrared free electron laser (FEL-100), under commissioning now, is the first stage of Lebedev Physical Institute Radiation Complex [1]. It was nice idea to cover infrared bandwidth in the range 10 - 100 microns with three or more FEL being excited by electron beams with energies 7 -25 MeV from different orbits of high current race track microtron under operation since mid of 80-th [2, 3]. The range mentioned is attractive from many viewpoints and for numerous applications as well, including for example so different fields of human activity as fundamental research and medicine practice. We are close to put FEL-100 into operation thus making the crucial step in starting light application program in the range 80 - 160 microns of coherent radiation. Following is the current status of far infrared laser project including hard ware description and adjustment as well as beam and light dynamics study.

ELECTRON BEAM SOURCE, BEAM LINE AND INJECTION

Electron beam from existing racetrack facility with average energy 7 MeV is used to drive FEL-100. Low voltage electron gun with chicane magnet, bunching cavity and disk loaded waveguide of racetrack form almost linac configuration. This configuration along with compensated beam channel in the vacuum chamber of first microtron bending magnet is used to produce high current bunches for FEL, focusing and diagnostic elements of race track being included in such a linac. There is a vacuum valve at the entrance of FEL-100 beam line, that along with some other elements of beam extraction system makes it possible to operate independently with either racetrack or FEL-100 facility. FEL-100 beam line itself formed by quadrupole doublet, correction coils, beam diagnostic system, ending by laser injection system. The latter consists of three bending magnets providing achromatic 120 grad electron rotation in horizontal plane to direct beam from linac to laser axis. As calculations have been shown such beam line configuration allows linac beam injection and matching as well. The latter means that one can provide with quadrupoles strength changing flexible transverse beam dynamics tuning, including the possibility of stationary phase space ellipse forming at undulator part of electron trajectories. Beam diagnostic system includes non intercepting current monitors and luminescent screens providing together with Faradays cups at the beam line terminals and movable luminescent screen inside helical undulator electron beam tuning.

FAR INFRARED FEL

Far infrared FEL (FEL-100) will provide coherent radiation in the wavelength range 80 - 160 microns. The are several features of this laser that differ it from other similar devises. We use pulse helical undulator with passive field correction [4] and short open resonator. The former imposes serious limitations on laser repetition rate as well as results in some specific beam and light diagnostic procedures. The latter leads to smaller diffraction losses and together with relatively high laser gain per path allows to reach FEL steady state (laser saturation) during short accelerator pulse. Resonator of nearly confocal type is formed by two spherical copper mirrors, each one being adjusted under vacuum condition with electromechanical equipment. The undulator's double-start winding has a period of 32 mm and consists of 32 turn of copper wire with diameter of 2.5 mm, the average winding diameter being equal to 35 mm. The coil is placed in slots to provide mechanical stiffness. A capacitor bank, discharged through a water cooled ignitron, provides undulator excitation. Undulator and power supply parameters allows to maintain a flatness of 0.1% during the accelerator pulse. The magnetic field of approximately 0.35 T on the undulator axis is achieved at a current of 40 kA through undulator winding. Maximum lasing repetition rate depends on guiding undulator magnetic field, cooling condition and power supply available. We expect this value to be reached around 0.1 -0.2 Hz for application experiments. The layout of the Lebedev Physical Institute Radiation Complex is presented on Fig. 1, while the main far infrared FEL parameters are collected in Table 1.

Fig.1. Layout of Lebedev Physical Institute Radiation Complex. Far Infrared FEL is at the upper left corner.

Table 1 Far infrared FEL parameters.

Wavelength range (μm)	80 - 160
FEL radiation power	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
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

ELECTRON BEAM DYNAMICS

The last two years we were adjusting various elements of FEL facility and studying beam dynamics. It had been found while commissioning racetrack microtron that beam energy spectrum at the linac exit was very sensitive to injection system tuning. This remarkable feature allows to form intense electron beam with narrows energy spectrum width down to 1 - 1.5 % with simultaneously short phase bunch length down to 18-20 degrees, thus allowing to use racetrack accelerating system as effective driver for far infrared FEL. At the same time this imposes very strong requirements on many accelerator parameters stability to provide necessary beam quality. The easiest way to maintain good beam quality at linac exit is appropriate phase adjustment of injected beam at accelerating structure entrance according beam spectrum that is achieved along with phase shifter in buncher power supply waveguide. We use the first racetrack bending magnet to control electron beam energy spectrum, the latter being measured with secondary emission beam profile monitor installed at focal plane location after 180 degrees beam rotation. Pulse signals from monitor wires are amplified and transmitted through cable to control room where these are processed by analogue-to-digit converter under computer control. Together with other facility parameters energy spectrum is displayed on computer monitor, thus allowing effective beam control. Optical resonator and undulator are the most critical FEL's parts from many viewpoints. We had developed original computer governed equipment to control beam profile and position along undulator. According program being chosen step motor positions luminescent screen at any desired point inside undulator, while TV camera transfers electron beam image to monitor at control room. Special mirror system extract luminescent light from resonator during beam dynamics studying. Beam profile and position measurement system is placed in special "home" position at light generation phase. The software allows to automate completely beam dynamics exploration, if special video card is used to enter beam co-ordinates directly to computer. Up to now we enter his values manually. Although manual input does not increase experiment time measured values are less objective because of man factor influence. The main reasons of detailed beam dynamics studying in undulator is the correction of guiding field as well as undulator input and output. Although we had made such a correction at undulator stand test, it is difficult to guaranty field quality after a lot of steps of undulator and its accessories assembling, vacuum sealing and so on. As preliminary study has shown, electron beam offset does not exceed 2-3 mm along undulator length and two quadruple doublets together with correction coils are tools that effective enough to form desired beam sizes inside undulator.

Beam monitoring system had been used to align helical undulator on FEL bench. Alignment procedure is quite necessary for our undulator because its stiffness is not sufficient and undulator sagging may result in large dynamics perturbation. The light from He-Ne laser was injected into undulator through the small aperture in its end flange and detected at the opposite undulator end, while moving luminescent screen with small aperture in its centre along undulator beam pipe. Undulator supports were adjusted and fixed when maximum intensity was detected in transmitted light.

WHERE WE GO AND WHERE WE ARE

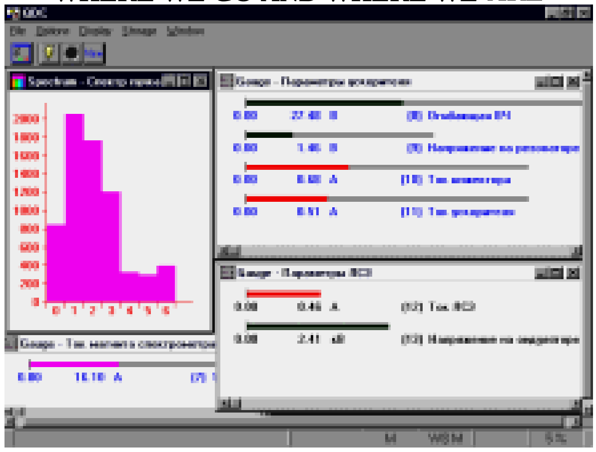

Fig.2 Typical interface for accelerator and FEL parameters measurements.

Our aim is a multi purpose radiation centre. Such a complex might activate research in many fields. We plan to start light application program from the experiment on searching energy gap in high T_c superconductors by radiating superconducting film samples by submillimeter FEL radiation with light frequency scanning. We have prepared some necessary equipment to start such a program. Our next step in FEL commissioning will be searching for stimulated radiation from our far infrared laser. We are almost ready for this step having been adjusting laser mirrors and diagnostic system and finishing mirror position monitor.

Computer with CAMAC interface is used to measure the main accelerator and FEL parameters in one accelerator pulse, that not overcomes some system inconveniences connected with low laser repetition rate only but makes it possible also on line and off line signals processing. Fig. 1 and. Fig. 2 are examples of such a measurement and control. New measurement system for any parameters monitoring in different modes is under development. The main future of this system is the possibility for operator to create any desired graphical interface before experiment run in any display mode: time dependent spectrum for multi channel measurement or oscilloscope mode for any single signal.

We expect to fix stimulated radiation from our far infrared FEL to the end of 1999.

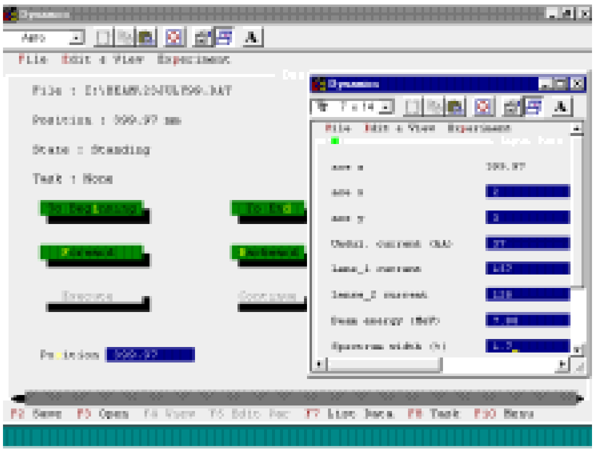

Fig.3. Computer interface for beam dynamics exploration in helical undulator.

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