FAR INFRARED FEL COMMISSIONING AT LEBEDEV PHYSICAL INSTITUTE

V.G.Kurakin, A.V.Agafonov, A.I.Bukin, A.V.Koltsov, A.N.Lebedev, Lebedev Physical Institute, Moscow, Russia

Abstract

The program of the radiation complex development on the basis of existing high current racetrack microtron had been declared in 1993. It was assumed that several free electron lasers would be excited by the beams from different microtron's orbits covering wavelength range 10 - 160 microns. Due to funding absence this program was frozen and only during last two yeas the main complex system has been completed and experiments for searching stimulated radiation from far infrared FEL have been started. The main FEL systems and parameters are described followed by the facility components tuning, results of beam dynamics studying, as well as searching for stimulated generation process. Plans for radiation application program are discussed in conclusion.

1 INTRODUCTION

At the beginning of 90-th the program of the development of new facility at Lebedev Physical Institute had been started [1]. It was nice idea to cover infrared bandwidth in the range 10 – 160 microns with several FELs being excited by electron beams with energies 7 – 25 MeV from different orbits of high current racetrack microtron. 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. Far infrared FEL in the range 80-160 μ was planed to be first stage of the facility, named as Radiation Complex for Fundamental and Applied Research. Due to financial support in the last years we were able to complete FEL assembling and tuning as well as make some important preparation for the beginning light application program. The work of stimulated radiation searching had been started and the first run at the radiation complex has been completed. Following is the current status of far infrared laser project including hard ware description and its adjustment as well as beam dynamics and generation process study.

2 FEL DRIVER

2.1 Electron beam source

Electron beam from existing racetrack facility [2] with the 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.

2.2 Beam line and FEL injection system

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.

3 FAR INFRARED FEL

3.1 Helical undulator

The undulator's double-start winding has a period of 32 mm and consists of 35 turns 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.

3.2 Optical resonator

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. Two copper mirrors with curvature radiuses of 180 cm form close to confocal open resonator. Apertures in mirrors are used for the cavity tuning and radiation extraction. Mirrors are installed in special tuning system, that allows its adjusting externally under vacuum conditions.

3.3 General

Table1 collect together the main far infrared FEL parameters

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	$3\cdot\pi\cdot$mm$\cdot$mrad
Horizontal beam emittance	$7\cdot\pi\cdot$mm$\cdot$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

4 RUNNING FEL FACILITY

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 with phase shifter in buncher power supply waveguide, the minimum energy spectrum width being the measure of proper tuning. 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 entered these values manually. Although manual input does not increase experiment time, values measured 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 quadruples doublets together with corrections 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 semiconductor 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 center along undulator beam pipe. Undulator supports were adjusted and fixed when maximum intensity was detected in transmitted light. We use stationary mounted semiconductor laser and those part of beam monitoring system, that is responsible for luminescent light extraction, for tuning and fast check of mirrors alignment.

5 WHERE WE ARE NOW

Our aim is a multi purposes radiation center. 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 Tc 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. The program of detail beam dynamics studying and linac tuning has been completed, resulting in precise beam with the pulse intensity of 0.35 A at undulator exit. Our current activity is stimulated radiation searching in the FEL under discussion.

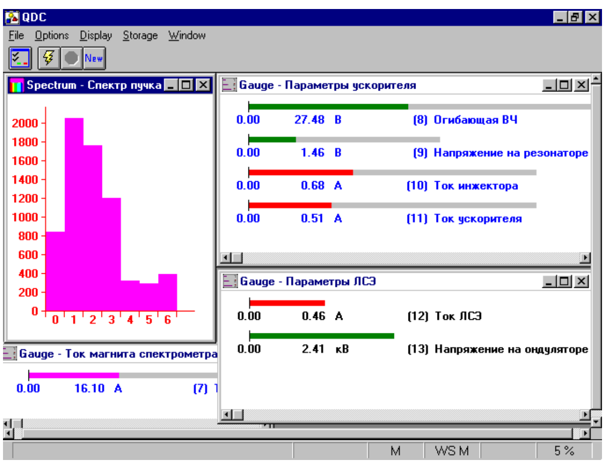

Fig.1: Typical interface for accelerator and FEL parameters measurements.

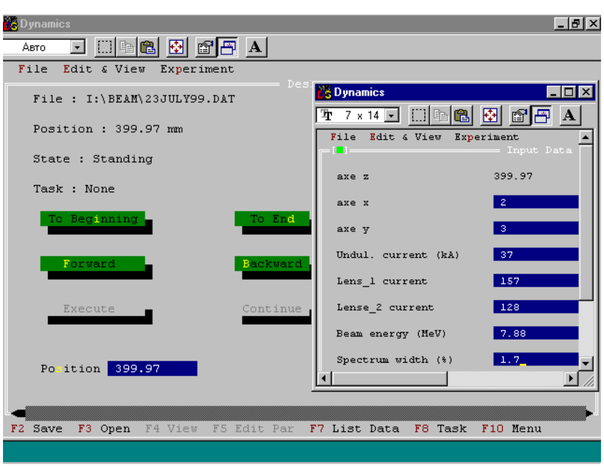

Fig.2: Computer interface for beam dynamics exploration in helical undulator.

Computer with CAMAC interface is used to measure the main accelerator and FEL parameters in one accelerator pulse, that not only overcomes some system inconveniences connected with low laser repetition rate only but makes it possible also on line and off line data processing. Fig. 1 and. Fig. 2 are examples of such a measurement and control. New measurement system for any desired parameters monitoring in different display modes has been completed and is under adjustment now [6]. The main feature 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.

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