COMPACT INFRARED FEL FOR SCIENTIFIC APPLICATIONS

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Abstract

This paper describes design of a compact infrared FEL for scientific applications. The driving rf accelerator consists of two accelerating sections providing the electron beam with the energy up to 20 MeV. Each accelerating section is powered by compact S-band klystron (frequency 2450 MHz, peak power 10 MW, pulse duration 10 microseconds, average power 10 kW). Average power in the electron beam is up to 2 kW. The injector of the driving accelerator consists of a conventional thermionic gun and subharmonic bunchers providing the value of the peak current up to 30 A with programmable pulse format. The undulator is a hybrid planar one with $Nd_2Fe_{14}B$ permanent magnets. Operating wavelength range of the FEL is 3-100 microns, and average output radiation power is about of a few watts.

1 INTRODUCTION

Presently free electron lasers of an infrared wavelength range are considered as unique sources of coherent radiation for variety of scientific applications. A number of specialized centers on the base of infrared FELs are in operation all over the world [1]-[8]. However, more wide application of this sources is partially limited by a complicated infrastructure, mainly due to driving accelerator requiring qualified technical service. Recently Kawasaki Heavy Industry announced on commercial production of FEL laboratories [9]. Similar activity has been also undertaken several years ago at the Automatic Systems Corporation (Samara, Russia) aiming in construction of inexpensive infrared FEL facility. The driving beam is produced by a compact rf accelerator designed by Efremov Institute (S. Petersburg) for industrial and medical applications. At present most fraction of the equipment has been transferred to Dubna, and in this report we briefly describe main features of the FEL facility.

2 FACILITY DESCRIPTION

General scheme of the FEL facility is shown in Fig. 1. The FEL is driven by an rf accelerator consisting of two accelerating sections manufactured by Efremov Institute (S. Petersburg). Accelerating structures are of conventional travelling wave type. Each accelerating section is powered by S-band klystron KIU-11 produced by Tory Company (Moscow). This klystron has been developed for application in industrial systems. Peculiar feature of the klystron is that it has low anode voltage (60 kV), small dimensions and weight (60 kg) due to application of permanent magnet focussing. Parameters of the klysron KIU-111 are: frequency 2450 MHz, peak power 10 MW, pulse duration 10 μs, average power 10 kW. Average power in the electron beam at the exit of the accelerator is expected to be up to 2 kW.

An industrial accelerator in its present design is equipped with conventional thermionic gun, and peak value of the current is too low for driving the free electron laser. To solve this problem, we designed special injector consisting of 100 keV thermionic grid-controlled gun, 490 MHz subharmonic buncher, and a buncher operating at 2450 MHz frequency. The gun operates in pulsed mode and can produce within rf pulse duration of 10 μs the trains of short electron bunches (pulse duration 1 ns, peak current 0.9 A) separated by 4, 8, 16, and 32 ns (resonator round-trip is equal to 32 ns). Then pulses are compressed in the bunchers to the duration of 10-20 ps. Designed value of the normalized emittance at the exit of the injector is 30π mm-mrad.

An undulator is a hybrid permanent magnet – steel one. $Nd_2Fe_{14}B$ permanent magnets of $3.2 \times 2.9 \times 1$ cm dimensions are used in the design. Period of the undulator is equal to 3 cm and magnetic field changes from 0.13 to 0.24 T by means of changing the pole gap from 26 to 16 mm. Total weight of the undulator is about 80 kg. Measured values of the field are well within specifications required for lasing.

Optical cavity is formed by two gold-coated mirrors placed on the distance of 367.35 cm. Both mirrors have curvature radius of 205 cm. Outcoupling of the radiation is performed via a hole in one of the mirrors. Power losses of the radiation per one round-trip in the cavity is about 4% (including outcoupling losses).

Project parameters of the FEL are presented in Table 1. At the final stage the FEL will be equipped with two beam lines and two undulators which will allow to cover continuously the wavelength range from 7 to 100 μm.

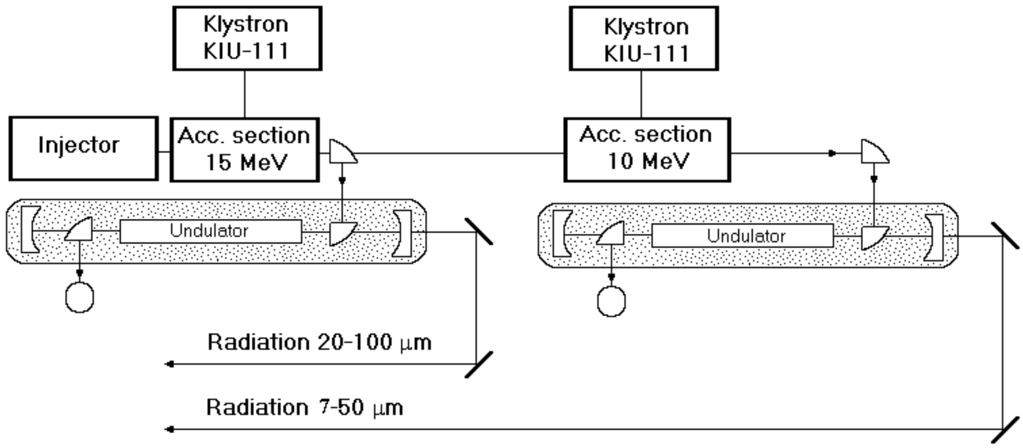

Figure 1: General layout of free electron laser

Table 1: Parameters of the free electron laser

Accelerator	
Type	Linear rf
rf frequency	2450 MHz
Energy of electrons	6 – 25 MeV
Type of accelerating section	TW
Number of sections	2
Length of accelerating section	2 m
Klystron	KIU-111
Pulse duration	10 μs
Repetition rate	50 Hz
Micropulse duration	10-20 ps
Peak current	30 A
Bunch separation	4-32 ns
Average beam power	up to 2 kW
rms normalized emittance	30π mm mrad
rms energy spread	0.7 %
Undulator	
Type	planar
Period	3 cm
Magnetic field	0.13-0.24 T
Number of periods	40
Optical cavity	
Base	367.35 cm
Mirror curvature radius	205 cm
Power losses per round-trip	1 %
Mirror transmission coefficient	2-4 %
Radiation	
Wavelength	7-100 μm
Average power	0.1-1 W
Peak power	1-5 MW

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