STATUS OF THE LINAC-800 CONSTRUCTION AT JINR

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Abstract

800 MeV electron linac (LINAC-800) is under construction at JINR. It will be used as a driver for Volume FEL and as a test bench for commissioning of elements of the ILC. Presently the electron injector is commissioned and the electron beam of 50 keV of the energy at current of about 15 mA was obtained. The results of the injector operation at nominal parameters (400 keV, 300 mA) and commissioning of the first accelerating section at 20 MeV are discussed.

THE LINAK-800 PROJEKT

The LINAC-800 project is being under development at the JINR, Dubna, Russia. It is based on an accelerator facility presented to JINR by the NIKHEF, Amsterdam.

Project will be accomplished with the construction of a complex of free electron lasers covering continuously the spectrum from far infrared down to ultraviolet (of about 150 nm) [1]. The far-infrared coherent source will cover continuously the submillimeter wavelength range.

Realization of this project will not require a significant modification of the JINR infrastructure. In Table 1 we present a summary of the radiation properties from coherent radiation sources being planned to build in project. Notations G1-G4 refer to the FEL oscillators, and FIR stands for the far-infrared coherent source.

ACCELERATOR LINAC-800

The electron beam with necessary parameters for the Free Electron Laser will be generated with the electron linac, which is a modified version of the Medium Energy Accelerator (MEA) transferred to JINR from NIKHEF[2]. The energy of electrons at the linac exit is 800 MeV and peak current of 30-60 A, with subharmonic buncher of the frequency of 476 MHz, a buncher at the frequency of 2856 MHz and 24 acceleration sections, which are combined in 14 acceleration stations (A00 – A13). To operate FEL, one needs an injector with a special subharmonic prebuncher. Such an injector has to be developed at JINR.

MEA Injector

To start the linac operation and test its condition, we plan to use the MEA injector consisting of an electron gun, chopper, prebuncher and buncher [2].

The electron gun (Table 2) has a dispenser thermocathode with the diameter of 8 mm. Its heater current is 15 A at the heater filament voltage of 12 V. The cathode lifetime is of the order of 20 thousand hours. The gun optics elements contain Pirce electrode at the cathode potential, control electrode and acceleration tube, which has 15 diaphragms forming homogeneous acceleration field. Linear potential distribution along the tube is provided with the divider, the voltage between two neighbour diaphragms is of the order of 30 kV. One can “close” the gun by applying the voltage of –150 V between the cathode and control electrode. The gun is operated in a pulsed mode by applying voltage pulses of +6 kV amplitude between the cathode and control electrode.

Table 1: Summary of Radiation Properties from Coherent Radiation Sources in Project

	FIR	G1	G2	G3	G4
Radiation wavelength [μm]	150-1000	20-150	50-30	1-6	0.15-1.2
Peak output power, [MW]	10-100	1-5	1-5	3-15	10-20
Micropulse energy, [μJ]	500	50-200	25-100	25-100	50-100
Micropulse duration (FWHM),[ps]	5-10	10-30	10	10	3-5
Spectrum bandwidth (FWHM),[%]		0.2-0.4	0.6	0.6	0.6
Micropulse repetition rate, [MHz]			19.8/ 39.7/ 59.5		
Macropulse duration, [μs]			5-10		
Repetition rate, [Hz]			1-100		
Average output power (max.), [W]	10-50		0.2-1		

Table 2: The Electron Gun Parameters

Scheme	Triode
Type of cathode: Diameter, [mm] Heater: voltage, [V] current, [A]	Dispenser 8 0-12 0-15
Electron energy, [keV]	400
Peak current, [A]	0.45
Cathode current stability	$1.5{\cdot}10^{-3}$
Beam diameter, [mm]	1.5
Normalized emittance (1σ), [π·mm·mrad]	8

Buncher

The MEA buncher system (Table 3) contains three elements, and the first of them is the chopper.

Table 3: The Buncher System

Chopper	Scheme	RF-cavity (TM_{110})
	Frequency, [MHz]	2856
	Amplitude of transverse deflection, [mm]	16
	Drift space Length, [cm]	50
	Quality factor (unloaded)	4000
	Transmission efficiency, %	20
	Peak RF power input,[kW]	3.0
Prebuncher	Scheme	RF-cavity (TM_{010})
	Frequency, [MHz]	2856
	Mode	2π/3
	Peak electric field at the gap center, [kV/cm]	10.3
	Bunch phase length at the prebuncher exit: at 10 mA current at 20 mA current	 6° 10°
	Distance between chopper collimator and the buncher entrance, [cm]	98.7
	Distance between prebuncher exit and the buncher entrance, [cm]	132.7
Buncher	Frequency, [MHz]	2856
	Mode	2π/3
	Number of cavities	38
	Shunt impedance, [MΩ/m]	51.2 – 55.1
	Length at 24° C, cm]	127.77
	Bunch phase length at the buncher exit: at 10 mA current at 20 mA current	 ≤ 1° ≤ 2°
	Electron energy, [MeV]	6

It is a deflector cavity of S-band type with collimator. The peak RF power consumed by the chopper is of 3 kW.

The prebuncher cavity is installed just after the chopper cavity. It is fed with RF of 2 kW power from klystron of the first acceleration section through attenuator and phase shifter.

The buncher is actually the short acceleration section of the accelerator structure. The bunch phase length at the buncher exit is of 6°. Its structure is supplied with RF power of 2 MW from the first klystron. The RF power is transmitted from the buncher exit through phase shifter to the first acceleration section.

Acceleration Sections

The MEA linac contains acceleration waveguide sections of six types. They are similar in mechanical features, but differ in RF-parameters (Table 4). Each section contains eleven uniform 2π/3-mode segments. The numbering of the sections is done with the alphanumeric identifiers, in which first letter symbol (A or B) means the way of RF-feeder connection to the section: symbol A indicates that the feeder is connected to the top of the section, the symbol B – to the bottom. The last symbols (one or two) mean the type of the section. Besides, double letter symbol AA or BB indicates the short section, single letter A, B, C, D – a long section. The short sections have the length of 3.6 m, they are immersed in constant solenoidal magnetic field of the order of 500 Gauss. The long sections of the length of 7.35 m have no magnetic field. All the acceleration sections are combined in acceleration stations that comprise an RF-power source (klystrons with modulators), waveguide, acceleration section and drift section. The drift section is used as a place of disposition of beam diagnostic devices (monitoring of the electron energy, beam current, size, position and emittance).

Table 4: The Parameters of Acceleration Sections

Type of section	Short	Long
Number of sections	3	18
Number of cells per sections	105	210
Section length, [m]	3.673	7.346
Frequency, [MHz]	2856	
Traveling-wave mode	2π/3	
Acceleration gradient, [MeV/m]	5	
Filling time, [μs]	1.3	
Beam load, [MeV/mA]	2.6	
Shunt impedance, [MΩm]	56.5 - 48	
Aperture: diameter, [mm] thickness, [mm]	32 5.84	

FEL INJECTOR

Generation of an electron beam with the parameters suitable for feeding of FEL requires significant upgrade of the linac injector. The requirements to the FEL electron beam listed in Table 5 can be satisfied using a subharmonic bunch compressor (SBH) described in Ref. [4]. It contains in our case (Figure 1) an electron gun, a cavity operating at subharmonic frequency, a drift section and the first acceleration section of the linac.

The electron gun has a modulation grid, which provides generation of short electron bunches with the duration of 0.5 ns. The electrons emitted from the dispenser thermocathode are accelerated in the electric field of the gun electrodes up to energy of the order of 400 keV and are formed in the injector elements – prebuncher, drift section and acceleration section[5].

Table 5: Parameters of Electron Beam after Injection and Acceleration in the First Linac Section

Energy, [MeV]	7
Peak current, [A]	50-70
Micropulse duration, [ps]	20
Normalized emittance, [πmm·mrad]	≤ 30
Electron energy spread, [%]	< 3
Micropulse frequency, [MHz]	19,8/39,7/59/5
Macropulse duration, [μs]	5-10
Repetition frequency, [Hz]	1-100

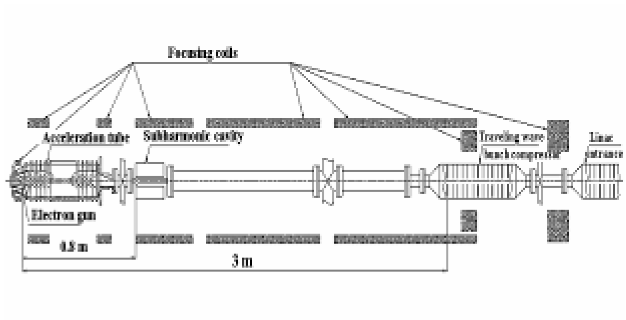

Figure 1: Injector layout.

Three first linac sections have focusing solenoids with magnetic field of 500 G. In the FEL injector the most critical position for beam space charge influence is the exit part of the drift section and the entrance part of the first linac section. There $I_{peak} \approx 36\ A$. The value of the solenoid magnetic field has to exceed the level of so-called Brillouin field.

$$B_{Brillouin} \approx 500 \text{ G.}$$

Keeping in mind future development of the injector, we have chosen maximum value of drift section magnetic field equal to 1 kG.

RESULTS OF THE WORK

During realization of LINAC-800 project the injector of electrons with buncher, short accelerating section and four long accelerating section have been assembled (Figure 2). The injector and accelerating sections power supply units were installed.

The control system of the injector was upgraded. As a result of the fulfilled works the vacuum pressure in the injector of 10^{-8} Torr has been achieved. The injector commissioning was done. In the first experiments on the injector commissioning the voltage on the accelerating tube was 50 kV. The current at of the accelerating tube output up to 12 mA in the pulse duration up to 10 μs was achieved (Figure 3). The works aiming to increase the voltage up to 400 kV and current up to design value are in progress.

After launching the electron injector at 50 keV these works are continued. The reconstruction of the HV transformer and its control systems was performed, the pressure of nitrogen in the transformer tanks achieved at 6 bar, now we provide works aiming to achieve voltage of 400 kV at injector. Besides that on the first accelerating station the klystron was mounted, forming lines were tested and prepared, commissioning works have been started.

Figure 2: The injector of electrons with buncher, short accelerating section and four long accelerating section.

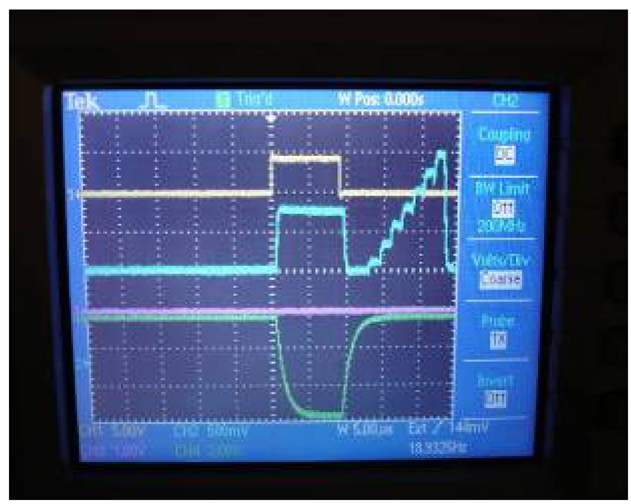

Figure 3: Beam current signal from injector.

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