ISBN: 978-3-95450-240-0 ISSN: 2673-5539 doi:10.18429/JACoW-RuPAC2021-WEA03

200 MeV LINAC DEVELOPMENT FOR THE SKIF LIGHT SOURCE INJECTOR

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Abstract

A new synchrotron light source SKIF of the 4th generation is construction at Budker institute of nuclear physics (Novosibirsk, Russia). It consists of the main ring, the booster ring and the linear accelerator. This paper presents design of the linear accelerator which is expected to provide electron beams with the energy of 200 MeV. Construction of the linear accelerator is discussed. Description of the linear accelerator main systems is presented.

INTRODUCTION

The SKIF light source is designed for the top-up injection to the main ring from the booster ring at the electron energy of 3 GeV. The linear accelerator is designed based on the injector technical requirements and BINP experience at the linac development. Electron linac with the energy of 200 MeV is similar to that of the Injection complex VEPP-5 [1]. The booster synchrotron with the maximum energy of 3 GeV is a modification of the synchrotron designed by BINP for NSLS II [2].

In the main operation mode the SKIF storage ring will be supplied by approximately 500 bunches with the total current of 400 mA. There is also a possibility to work in other modes depending on the requirements of the light source users. Table 1 presents required parameters of the electron beam to be obtained at the linear accelerator.

Table 1: Requirements for the Electron Beam Parameters

Parameter	Value
Operating energy	200 MeV
Energy spread (RMS)	1%
Injection rate	1 Hz
Bunch period	5.6 ns
Number of bunches	55
Single bunch charge	0.3 nC
Horizontal emittance at 200 MeV	150 nm

Figure 1 presents layout of the linear accelerator. The injection rate is 1 Hz and the operating frequency of the RF gun is 178.5 MHz while the booster and storage rings operate at 357 MHz. Thus, it is supposed that a single linac beam consisting of 55 electron bunches fills every second separatrix and after the phase shift next bunch train fills other separatrices. After the gun the beam passes through the bunching channel which consists of the third harmonic cavity, the solenoids and the preaccelerator. Three klystrons Canon E3730A with the peak power of 50 MW are used as RF power sources for the preaccelerator and five regular accelerating structures. Linac ends by the diagnostic channel with the magnet spectrometer and the Faraday cup.

ELECTRON GUN

RF gun which is an electron source for the linac has an operating frequency 178.5 MHz and is planned to be built on the cathode-grid assembly. Using this scheme allows one to perform modulation of the cathode current, providing variation of the bunch charge.

Parameters of the RF gun cavity are shown in Table 2. At the electric field amplitude on the axis of 13 MV/m it is possible to extract electron bunches with the charge up to 1.1 nC (Fig. 2, left) while the average particle energy is about 0.6-0.7 MeV.

Table 2: RF Gun Parameters

Parameter	Value
Operating frequency	178.5 MHz
Electric field amplitude	13 MV/m
Injection rate	1 Hz
Pulse power	500 kW
Quality factor	10300

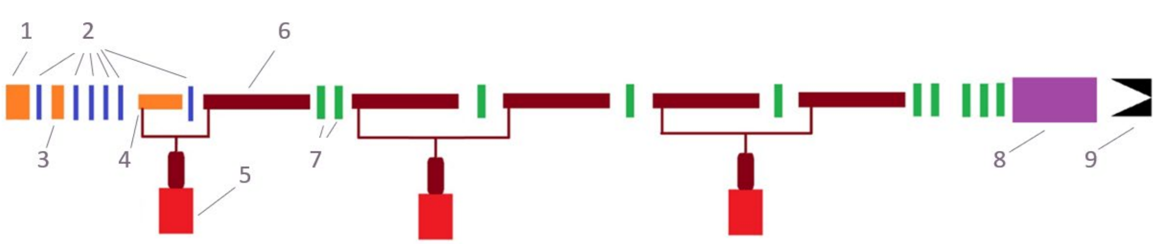

Figure 1: Layout of the linac. 1 – electron gun, 2 – solenoids, 3 – 535 MHz buncher, 4 – preaccelerator, 5 – klystrons, 6 – regular accelerating structures, 7 – quadruple lenses, 8 – spectrometer, 9 – Faraday cup.

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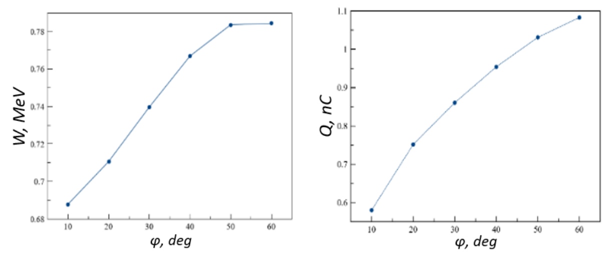

Figure 2: Left – dependence of the electron average energy on the injection phase, right – bunch charge dependence on the injection phase.

SYSTEM OF BUNCHING AND PREACCELERATION

The beam is emitted from the RF gun at the bunching phase, for the linearization of the bunching forces the third harmonic cavity is to be used. The bunching cavity operates at the frequency of 535 MHz with the electric field amplitude of about 2.5 MV/m.

After the third harmonic cavity the beam is injected to the preaccelerator which is a part of the linac regular accelerating structure. It consists of two wave type transformers and accelerating cells. Due to the beam injection energy of 0.6 MeV there is no need in the optimization of first accelerating cells. The preaccelerator input power is 10 MW, providing the electron energy of about 3 MeV.

System of beam bunching includes also solenoids, their parameters are given in Table 3.

Table 3: Parameters of the Bunching Channel Solenoids

Magnet	Qty	L, mm	B_{max}, kGs
Solenoids of the bunching channel	5	100	0.65
Preaccelerator solenoids	2	250	1.0
Matching solenoid	1	100	1.5

MAGNET SYSTEM

Besides solenoids in the beginning of the linac, its magnet system includes also two-dimensional dipole correctors of the beam trajectory. There are 8 small correctors in the bunching channel and 6 correctors with the yoke in linac regular part. Parameters of the dipole correctors are shown in Table 4.

Table 4: Parameters of the Dipole Correctors

Magnet	Qty	L, mm	B_{max}, kGs
Small correctors	8	140	0.021
Correctors with a yoke	6	140	0.5

For the regular linac part seven quadruple lenses are provided, there is also a triplet of quadruple lenses in the diagnostics channel (Fig. 1). Quadruple lens parameters are given in Table 5.

Table 5: Parameters of the Quadruple Lenses

Magnet	Qty	L, mm	G_{max}, kGs/cm
Quadruple lenses in the regular linac	7	100	1.2
Quadruple lenses in the diagnostics channel	3	150	1.2

ACCELERATING STRUCTURES

Linear accelerator includes five disk loaded regular accelerating structures (Fig. 3) operating at the $2\pi/3$ mode with the frequency of 2856 MHz. Accelerating structure parameters are shown in Table 6.

Table 6: Parameters of the Accelerating Structures

Parameter	Value
Operating frequency	2856 MHz
Quality factor	13000
Period	34.99 mm
Cell diameter	83.75 mm
Diaphragm thickness	6 mm
Length	2.93 m
Shunt impedance	51 Ohm/m
Phase velocity	*c*
Group velocity	0.021 *c*
Filling time	0.456 mcs

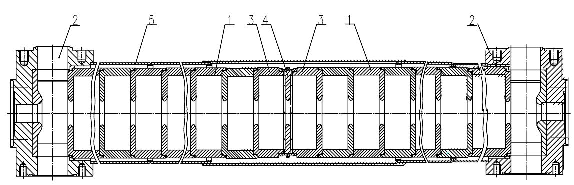

Figure 3: Disk loaded waveguide accelerating structure: 1 – accelerating cell, 2 – wave type transformer, 3–junction cell, 4 – junction diaphragm, 5 – cooling shielding.

With the input power of 40 MW in the first accelerating structure, the beam increases its energy by about 50 MeV. In other accelerating structures with the input power of 25 MW the beam energy gain is about 40 MeV. Corresponding electric field distributions in the structures are given in Fig. 4.

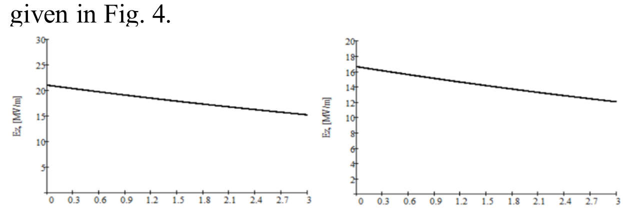

Figure 4: Electric field distribution along the accelerating structure. Left – input power of 40 MW, right – input power of 25 MW.

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DIAGNOSTICS

Measurement of the beam current will be performed by 3 fast current transformers (FCT). Beam position control and transverse profile registration are to be carried out by 9 fluorescent screens. Beam longitudinal profile along the bunching channel is to be measured with the help of 3 Cherenkov sensors. Seven beam position monitors are provided, the linac ends by the magnet spectrometer with the Faraday cup in the radiation shielding.

WAVEGUIDE SYSTEM

Figure 5 presents the waveguide scheme for the distribution of the klystron RF power in the linac beginning. The klystron power is divided with the help of 7 dB coupler in the ratio 1:4 between the preaccelerator and the regular accelerating structure, the couplers for the power measurements are provided. There are also phase shifters for both accelerating structure while the preaccelerator input power is to be adjusted with the help of the attenuator. Waveguide schemes for other accelerating structures consist of the same elements besides the 7 dB coupler and the attenuator.

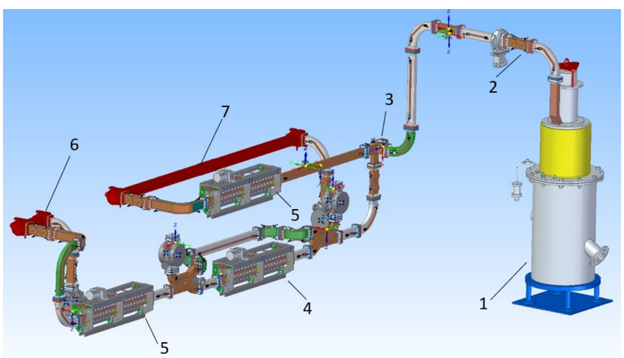

Figure 5: Waveguide system for the linac beginning. 1 – klystron, 2 – power measurement couplers, 3 – 7 dB coupler, 4 – attenuator, 5 – phase shifters, 6 – preaccelerator, 7 – accelerating structure.

BEAM DYNAMICS SIMULATIONS

Beam dynamics simulation in linear accelerator with the described systems were performed using ASTRA [3]. There are no particles loss during the acceleration, the beam transverse size in the linac is shown in Fig. 6. Beam parameters and its distribution in the longitudinal phase space are shown in Fig. 7 and Table 7, correspondingly.

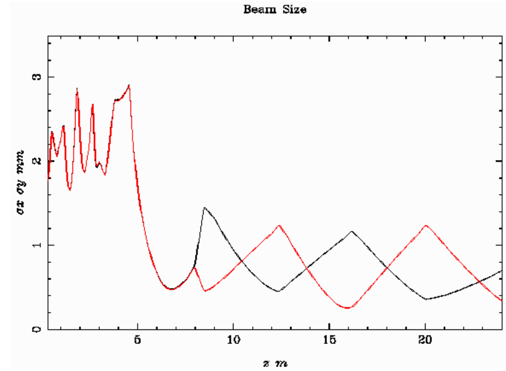

Figure 6: Beam transverse size evolution in the linac.

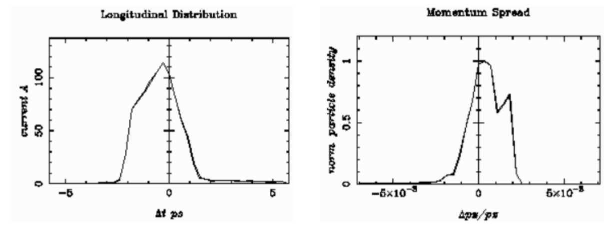

Figure 7: Longitudinal phase space of the beam at the linac output.

Table 7: Parameters of the Accelerated Beam

Parameter	Value
Energy	200 MeV
Energy spread (RMS)	0.3 %
Horizontal emittance	50 nm
Single bunch charge	0.3 nC

CONCLUSION

The linear accelerator of electrons with the energy of 200 MeV was designed as a part of the injector for the SKIF light source. Simulations of the beam dynamics show parameters of the accelerated beam to meet the requirements.

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