30 MEV INJECTOR FOR A SYNCHROTRON

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An electron source for a synchrotron is described. The source consists of RF gun, bunch forming system, and linear accelerator operating at 2856 MHz. Packets of electron bunches are formed within the RF gun with time intervals, which correspond to the accelerating RF voltage period of the synchrotron, that decreases the radiation background during injection.
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1 INTRODUCTION

In industrial synchrotron radiation sources, the collecting of electrons is carried out at the full energy of the storage ring, which lies within the range of 2-3 GeV to provide the needed level of luminosity [1]. Acceleration of electrons up to that energy level is carried out by synchrotrons. A linear accelerator is used as a rule as an injector [2]. The paper describes the design of an electron injector with the following parameters: an average accelerated beam energy of 30 MeV, current pulse duration of 50 ns, beam current of 25 mA. Problems of bunch formation in the RF gun and buncher-accelerator are also described in the paper. The RF gun generates the microbunches with the repetition rate, which corresponds to the synchrotron operating frequency that is multiple of the operating frequency of the buncher-accelerator and TW linear accelerator, that allows us to noticeable decrease the radiation background at the linear accelerator and at the synchrotron input.

2 ELECTRON INJECTOR SCHEME

The electron injector scheme is shown in Fig. 1. It consists of the following main parts: electron source, buncher-accelerator, RF chopper with collimator, and 30 MeV linear accelerator. Focusing solenoids and beam center location correctors are used to produce the magnetic accompanying. The pulse beam current monitor and the Faraday cup integrated with the TV camera are used to measure the beam current in the pulse and bunch location relative to the channel axis at the linear accelerator input, correspondingly. The channel of the linear accelerator and buncher-accelerator may be separated by a gasket.

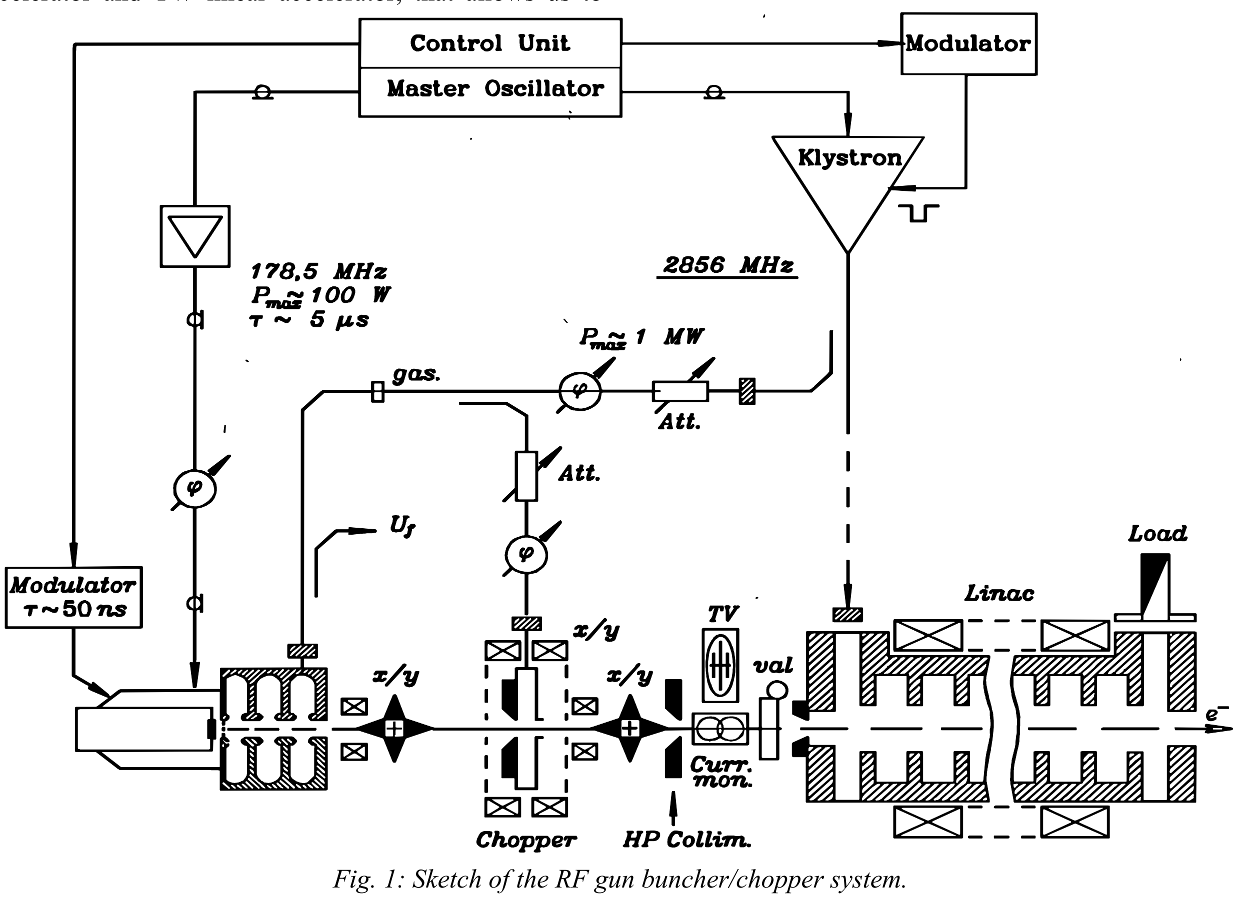

Fig. 1: Sketch of the RF gun buncher/chopper system.

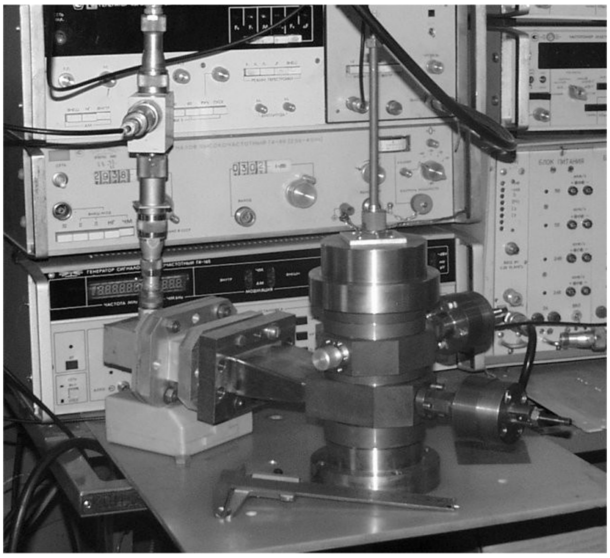

Fig. 2. Buncher-accelerator at the workbench.

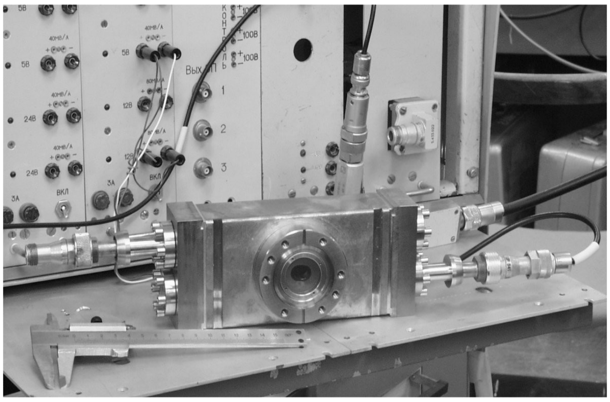

Fig. 3. RF Chopper.

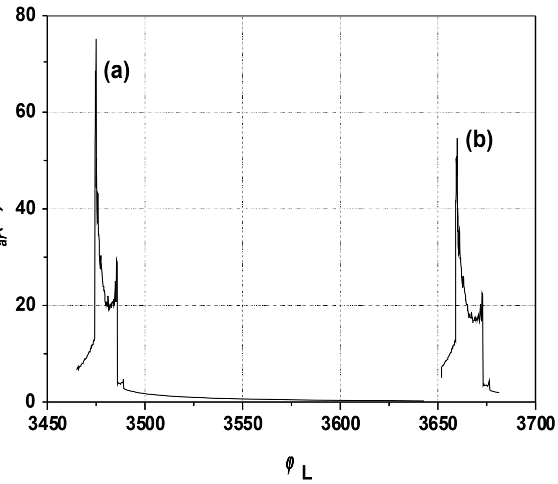

Fig. 4. Microbunch pulse current after the chopper before the collimator (a) and after the collimator at the linac input (b).

A thermocathode with two-grid control (tetrode) is used as an electron source. It is located directly at the input of the first accelerating cavity of the buncher-accelerator. The first-time electron bunch forming takes place in the tetrode. The bunch length depends on the voltage at the first tetrode control grid and RF field amplitude in the cathode-first grid gap. The RF field frequency of 178.5 MHz is the operating frequency of the synchrotron. The number of bunches is determined by the enabling voltage pulse duration at the second grid of the tetrode [3].

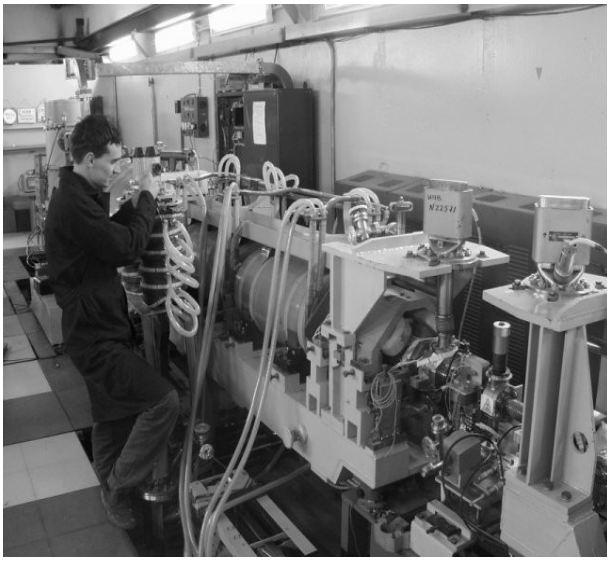

Fig. 5. Accelerating structure of the linac.

The accelerating section of the buncher (see Fig. 2) is a biperiodic structure operating on π/2 oscillation with three accelerating gaps and two coupling cavities. Operating mode is E_{010} at 2856 MHz. Field strength in the accelerating gaps is 150–250 kV/cm depending on the operating regime. A klystron is used as an RF source. Bunches previously formed in the tetrode comes directly into the first gap of the accelerating section. In this gap, the bunches are divided into the separate microbunches which follow with repetition rate corresponding to the frequency of the linear accelerator (2856 MHz). In the second and third gaps bunches are additionally accelerated up to the energy of about 1 MeV and gain the energy spread that is needed for the future bunching in the drifting tube. The total pulse RF power consuming of the buncher-accelerator is about 600 kW that is needed to provide the energy of electrons of about 1 MeV. In this case decreasing of the accelerating voltage in the buncher-accelerator should be about 2.2% per pulse at an average current of 25 mA. The required amplitude and phase ratios in the buncher-accelerator and linac element circuits are tuned by phaseshifters and attenuators built in their RF section.

The low-power RF chopper (Fig. 3) together with the collimator are used for additional separation of each microbunch down to the background current level. The chopper consuming RF pulse power is about 20 kW. The calculated current pulses of a separate microbunch directly after the chopper and at the linac entrance are shown in Fig.4. In this case micrbunches will be almost completely captured into the linac accelerating mode, and RF power will be maximally effective used for the microbunch acceleration with low radiation background of the linac.

The accelerating structure is a disk-loaded cylindrical waveguide with a constant impedance which is connected to the RF power source and RF load by the input and output wave type transformers. The accelerating structure design is the same as for the VEPP-5 facility preinjector [4]. The main accelerating structure parameters are listed in Table 1.

Table 1. Accelerating structure parameters

Operating frequency	2856 MHz
Operating mode	2π/3
Q-factor	$1.32x10^4$
Group velocity	0.021c
Shunt impedance	51 MOhm/m
Accelerating section length	2.93 m
Accelerating structure filling time	0.471 μs

A TV 2019W klystron amplifier with 10 MW pulse power and pulse duration not less than 5 μs may be used as RF power source for the linac. In this case the relative RF power losses in the main parts are: bunch forming system – 6%; accelerating structure – 43%; RF load – 47%; electron beam – 1%; waveguide section – 3%. The tests carried out at a high-power level have shown the possibility to increase the electron beam energy by the use of a more powerful klystron.

3 CONCLUSION

In the RF electron injector for a synchrotron, the cathode beam is divided into the electron bunch packets following with the RF accelerating voltage period of the synchrotron. Each packet is additionally divided into microbunches at 2856 MHz frequency in the buncher-accelerator. The microbunch repetition rate corresponds to the linac operating frequency. In this case the bunching of each microbunch takes place, and there is an effective capturing of the microbunches into the regime of the later accelerating by the linac and synchrotron without beam current losses. The low-power RF chopper may be turned on for the additional separation of the number of particles within each microbunch by the phase length and clearing from charges down to the background current level. Hence, only the local bio-defense in the collimator area is required for an energy up to 1.5 MeV at the linac input, that is much cheaper than bio-defense for the total energy of 30 MeV at the synchrotron input. The use of the RF gun built in the buncher-accelerator as an electron source allows us to obtain the particle energy of 0.7–1.5 MeV at a short distance of about 17 cm, as well as to noticeable decrease the space charge forces influence and shorten the vacuum drift tube length, where the short bunch is formed. Moreover, the thermogun does not require high-voltage power sources or high-voltage pulse modulators, as well as there is no need for RF gun isolation.

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