ELECTRON INJECTOR FOR LINEAR ACCELERATOR OF TNK FACILITY

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Abstract

The paper presents the electron injector for the linear accelerator of TNK facility (Zelenograd). The injector has rather simple design because of realized injection scheme with no prebunching. The beam is divided into bunches directly by the accelerating RF field of the linear accelerator.

The injector block diagram is presented, the process of electron beam bunching and acceleration is described.

INTRODUCTION

Industrial storage facility TNK (Lukin State Research Institute for Problems in Physics, Zelenograd) have been developed in BINP SB RAS [1, 2]. It includes the main ring for the energy of 2.0 GeV and booster ring for the energy of 450 MeV. The 100 MeV linear accelerator is used as an electron source. Disk-and-washer (DAW) accelerating structure has 30000 Q-factor at the coupling constant higher than 40% that provides RF storage energy operating regime in 112 regular cells which form a single resonant cavity. A low-voltage electron injection from a pulsed diode gun with no beam pre-bunching is used. The beam is divided into bunches directly in the accelerating structure under the action of the RF field. At the LU output, the beam consists of 40 bunches which were formed by the linear accelerator 2.8 GHz RF field. The beam dynamics and output energy are determined by the RF power level from the klystron station. At power of 16 MW and RF pulse duration of 8μs, the beam is accelerated up to 80 MeV. The injection time is defined by the arriving time of the negative 40 kV voltage pulse of 15–20 ns duration at the gun cathode. The electron current source is a 17 mm diameter LaB_6 hot cathode. The gun microperveance is about 0.5 $\mu A/V^{3/2}$, it provides the cathode pulse current of 3.8 .

LU INJECTOR SCHEME

Figure 2 presents the LU injector scheme. The beam is injected into LU from the diode gun 1 in the maximum of the accelerating structure field. The beam injection moment should take place at the minimal magnetic field produced by the heater helix. The valve 2 is installed to separate the gun volume from the accelerating structure during cathode unit replacement. x/z corrector 3 serves to correct the beam axis position at the accelerating structure input. The focusing lens 4 provides the needed electron angular convergence at the entrance of the accelerating structure first cavity. A Faraday cup 5 made as lamellar probe is used for beam charge measuring at the LU input. By shifting the Faraday cup, the aperture hole may be set to 4 mm or 14 mm that is required to tune the current passing and indicate the beam in the operating regime. The molybdenum grid 6 is installed at the accelerator input to decrease the transverse RF field in the first accelerating gap. The input accelerating gap is formed by DAW structure regular half-cell. Then there is a regular structure 7 with 112 accelerating cells [3, 4].

FORMING THE “BUNCH” LONGITUDINAL SIZE IN THE ACCELERATING FIELD OF A STANDING WAVE

The beam accelerating regime in LU at TNK is realized at the field strength on the axis of about 250 kV/cm. During acceleration, RF energy is extracted from every cavity that leads to accelerating voltage decreasing in the gap, so the beam dynamics slightly varies for every next bunch. In accelerating gaps of a linear accelerator, the prevalent force is the accelerating Lorenz force rather than Coulomb forces of the bunch space charge. The microbunches are formed in the initial part of the linear accelerator first section.

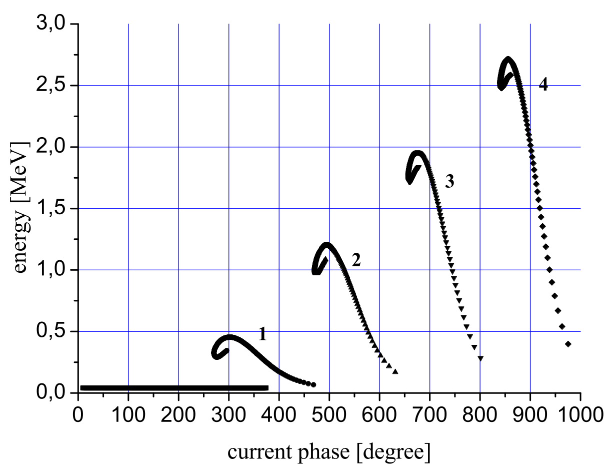

Figure 1: Electron microbunch dynamics in the LU beginning after 1-st, 2-nd, 3-rd, and 4-th accelerating gaps.

Curves on Figs. 1–4 present the main simulation results for the longitudinal beam dynamics of the first bunch macroparticles. It is clear that some particles are reflected. During RF period, about half beam electrons pass the first gap. The charge of the returned electrons is indicated on the probe 5 (Fig.2). Figure 4 presents the energy spread

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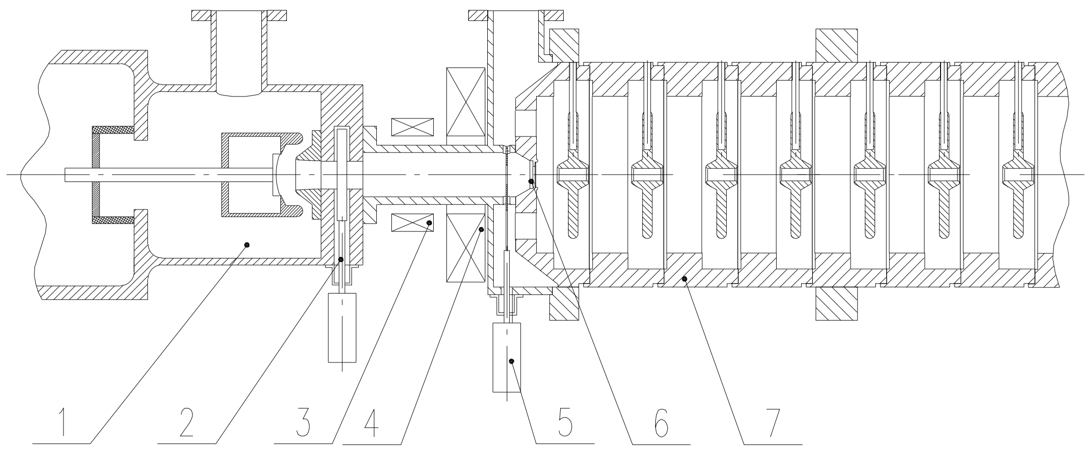

Figure 2: LU injector.

in the head of bunches after 5, 10, 15, and 20 accelerating gaps in the first part of LU. During acceleration, the energy spread decreases. The bunches become less extensive due to the accelerating structure body current, it leads to the background radiation increase.

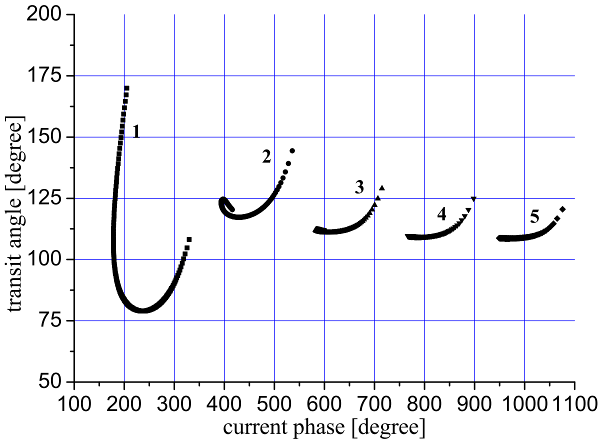

Figure 3: Particle transit angles in the accelerating gaps.

Figure 5 presents the field strength in the accelerating structure surface and axis versus KIU-53 power. It is clear that at power losses in the structure higher than 10 MW the electron energy grows almost linearly with the field strength increase. It is also proved by graphs in Fig. 6 which presents the accelerated electron energy spectrum obtained for the similar linear accelerator of SIBERIA facility in RRC Kurchatov Institute (the facility was commissioned in 1992). With the power increase, LU output energy grows, energy spread decreases, and accelerated current increases. A simple injection scheme with no considerable bunching along LU may be realized only at high accelerating field strength in pulsed linear accelerators. In our case, the use of a diode gun is justified because of the beam duration of 18 ns is rather low at the repetition rate of 1 Hz. In that regime, the cathode unit has been working for about 10 thousand hours. It the case of high beam average power, installation of a diode gun on the axis is inadmissible. So, a triode RF gun is installed in ILU-6 accelerator [5] with applying the negative voltage to the grid to eliminate emission of the electrons which return to the cathode. Otherwise, the cathode is destroyed. There is a pulsed accelerator [6] for high average beam power (higher than 100 kW) with angularly injection from a diode gun to prevent the cathode hitting by returned electrons.

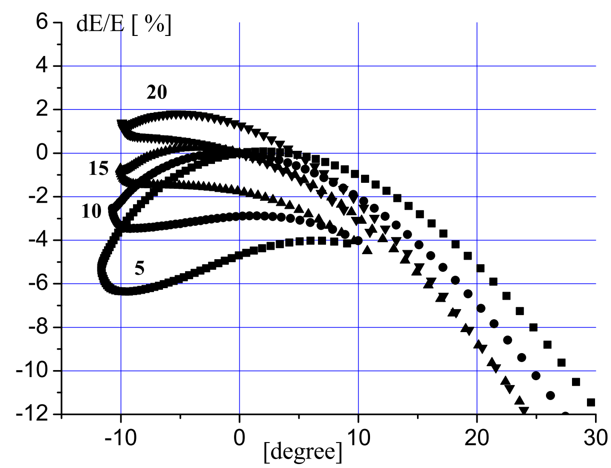

Figure 4: Energy spread of the microbunch head after 5-th, 10-th, 15-th, and 20-th accelerating gaps.

CONCLUSION

A simple injection scheme for a low-voltage continuous electron beam injection into a standing-wave accelerating structure has been realized. Beam dynamics has been simulated, the following injection features have been revealed: presence of reflected electrons, increased background radiation, large energy spread, necessity of high accelerating rate. Injection applicability on the axis has been proved for

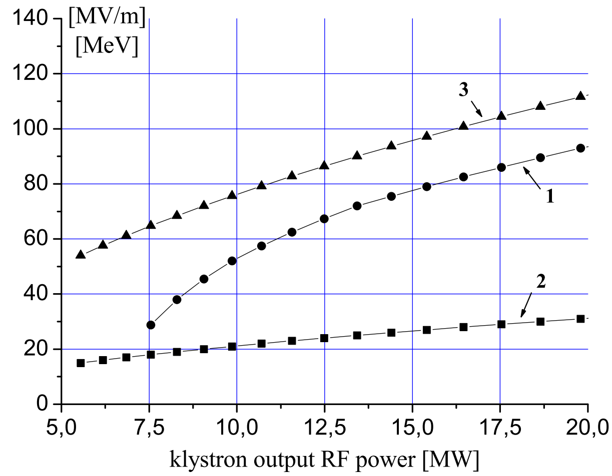

Figure 5: 1 — accelerated electron energy, 2 — accelerating field on the axis, 3 — maximal surface electric field strength versus the klystron power.

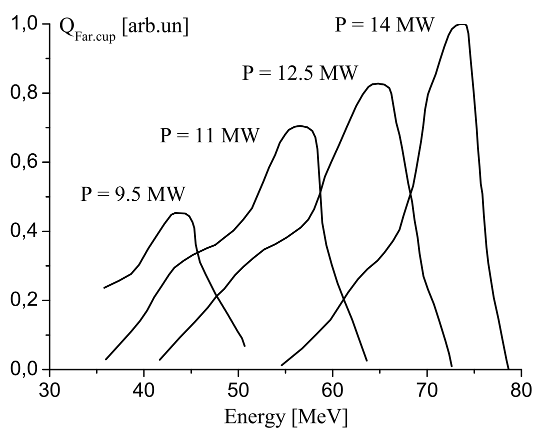

Figure 6: Electron energy spectrum.

low-duration beams, when backward electrons do not destroy the cathode and cavity body current does not produce over-background radiation.

REFERENCES

[1] O.A. Nezhevenko et al., Proc. of PAC'91, San Francisco, 1991, vol.5, . 3186.

[2] V.N. Korchuganov et al., Proc of PAC'93, Washington, 1993, vol.1, p. 564–566.

[3] V.N. Korchuganov et al., Proc. of EPAC'94, London, 1994, vol. 1 , pp. 739–741.

[4] V.N. Korchuganov et al., Commission of the Linear Accelerator-Injector of the TNK Facility. Report of XVIII Conf. on Charged Part., ACC., Alushta, 2003.

[5] V.L. Auslender. ILU-type Electron Accelerators for Industrial Technologies. Nuclear Instruments and Methods in Physical Research, B89 (1994), pp. 46–48.

[6] G. Loda, private communication.