ASPECTS OF CONTINUOUS ELECTRON BEAM INJECTION INTO A STANDING WAVE ACCELERATING STRUCTURE

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The paper deals with processes during injection of continuous electron beam into a standing wave accelerating structure. Not all the electrons of the beam are captured into the process of acceleration. Some of them are scattered on the accelerating structure walls or return to the cathode. At short beam current pulses, it is possible to place a cathode on the system axis. In a case of high average beam power, it is necessary to inject a beam angularly to exclude hitting the cathode by returned electrons.

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1. INTRODUCTION

Synchrotron radiation sources at RRC Kurchatov Institute and TNK (Lukin State Research Institute for Problems in Physics, Zelenograd) have been developed in BINP SB RAS [1,2]. They include the main ring for the energy of 2.5 GeV and booster ring for the energy of 450 MeV. 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 resonator. 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 8 μs, 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 A.

2. LU INJECTION CHANNEL

Fig.1 presents the LU injection channel scheme. The beam is injected into LU from the diode gun 1 in maximum of the accelerating structure field. The beam injection moment should take place at the minima 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. The 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].

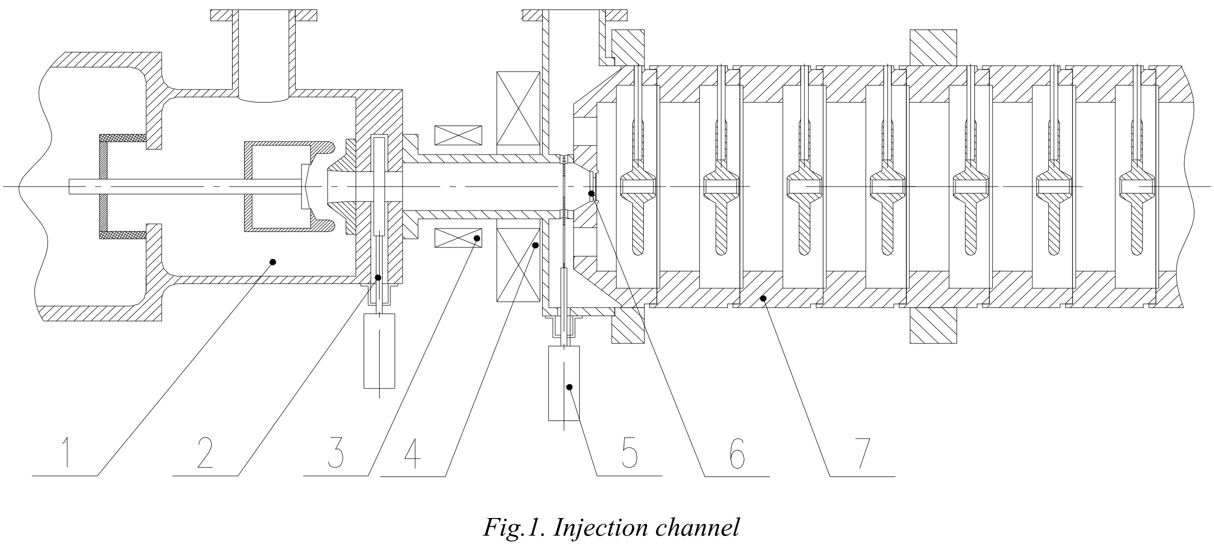

Fig.1. Injection channel

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3. FORMING THE "BUNCH" LONGITUDINAL SIZE IN THE ACCELERATING FIELD OF A STANDING WAVE LU

The beam accelerating regime in LU of SIBERIA facility in RRC Kurchatov Institute is realized at the field strength on the axis of about 280…300 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.

Curves on Figs.2–5 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.1). Fig.4 presents the energy spread 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.

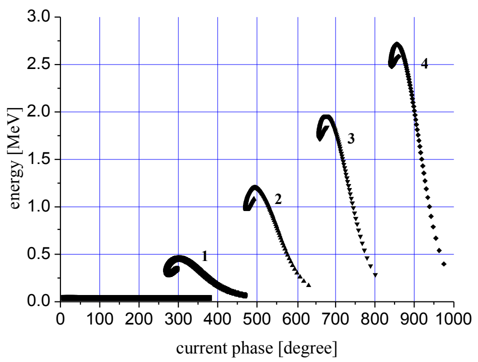

Fig.2. Bunch dynamics in initial LU section after 1, 2, 3, and 4th accelerating gaps

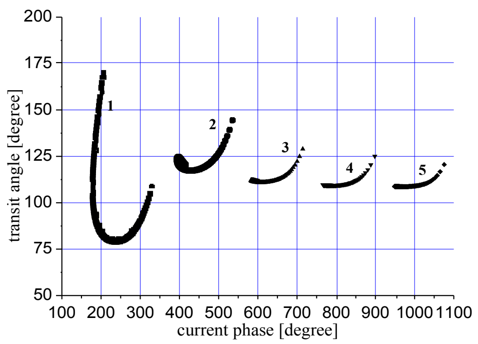

Fig.3. Particle transit angles for accelerating gaps

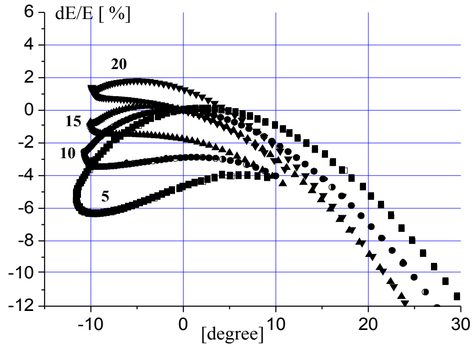

Fig.4. Energy spread of the bunch head after 5, 10, 15, and 20 accelerating gap

Fig.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 at 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.

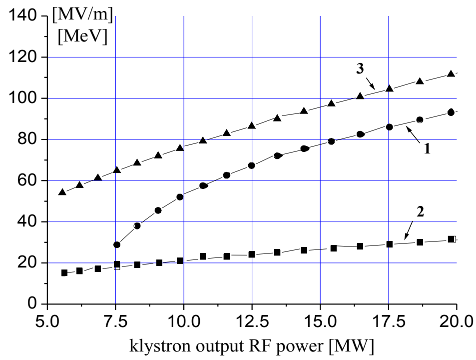

Fig.5. 1 — accelerated electron energy; 2 – accelerating field on the axis; 3 – maximal surface field versus the klystron power

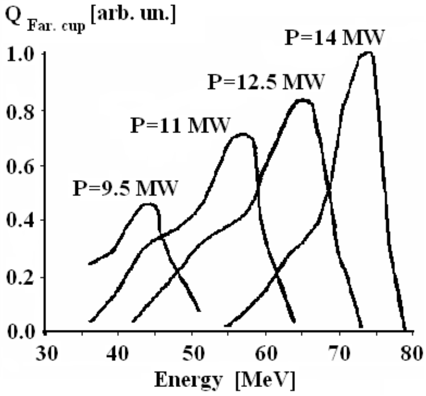

Fig.6. Beam energy spectrum

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

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ОСОБЕННОСТИ ИНЖЕКЦИИ НЕСГРУППИРОВАННОГО ПУЧКА ЭЛЕКТРОНОВ В УСКОРЯЮЩУЮ СТРУКТУРУ НА СТОЯЧЕЙ ВОЛНЕ

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Рассмотрены процессы, возникающие при инжекции низковольтного несгруппированного пучка электронов в ускоряющую структуру на стоячей волне. Не все электроны пучка захватываются в режим ускорения, часть электронов рассеивается на стенках ускоряющей структуры, а часть возвращается на катод. При малой длительности импульса тока пучка возможна постановка катода на оси структуры. В случае большой средней мощности пучка необходимо инжектировать его под углом, исключающим попадание возвращенных электронов на катод.

ОСОБЛИВОСТІ ІНЖЕКЦІЇ НЕЗГРУПОВАНОГО ПУЧКА ЕЛЕКТРОНІВ У ПРИСКОРЮВАЛЬНУ СТРУКТУРУ НА СТОЯЧІЙ ХВИЛІ

К.Н. Чернов, В.М. Корчуганов, Г.І. Кузнєцов, І.Г. Макаров, Г.М. Острейко, С.І. Рувинський, Г.В. Сердобинцев, В.В. Тарнецький, М.А. Тиунов

Розглянуто процеси, що виникають при інжекції низьковольтного незгрупованого пучка електронів у прискорювальну структуру на стоячій хвилі. Не всі електрони пучка захоплюються в режим прискорення, частина електронів розсіюється на стінках прискорювальної структури, а частина повертається на катод. При малій тривалості імпульсу струму пучка можлива постановка катода на осі структури. У випадку великої середньої потужності пучка необхідно інжектувати його під кутом, що виключає влучення повернутих електронів на катод.