Physics

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1964

SovietRxiv

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Abstract

Full Text

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A HIGH-VOLTAGE INJECTION SYSTEM FOR BETATRONS AND SYNCHROTRONS

Increasing the number of particles captured in the acceleration process is the most important task in improving operating accelerators. One means of solving this problem is high-voltage injection. As the injection energy is increased, the limiting charge that can be confined by magnetic forces at first grows linearly; then the dependence becomes quadratic, and later changes to cubic (^{1}). Experiments carried out on a number of accelerators ($^{2-4}$) have shown good agreement between the experimental data and the calculated values. Thus, in going from an injection energy of 30 keV to an injection energy of 300 keV, the number of accelerated electrons and, consequently, the intensity of the γ-radiation increase by an order of magnitude. An even greater increase in intensity should be expected when going to an injection energy of 1-2 MeV.

As an injector-accelerator for a betatron and a synchrotron with an energy of 30-300 MeV, the following may be used: a Van de Graaff generator, a pulse transformer (^{5}), a linear accelerator (^{6,7}), or a microtron (^{8}).

The most acceptable characteristics among the accelerators mentioned are possessed by the Van de Graaff generator, from which pulse currents up to 1 A can be obtained. In this case the beam diameter does not exceed 1 cm, and the angular divergence of the beam is 1 mrad. The monoenergetic nature of the beam fully satisfies the requirements imposed on high-voltage injection into an accelerator. The disadvantages of the Van de Graaff generator as an injector are its bulkiness and high cost.

Fig. 1. High-voltage injection system. 1 —accelerator chamber; 2 —inflector; 3 —magnetic channel; 4 —resonator; 5 —waveguide; 6 —electron gun

When a high-voltage injector ($^{2-8}$) is used, it must be placed at a considerable distance from the accelerator. This is due to the fact that the magnetic field of

Fig. 2. Elliptical resonator with truncated cones

Figure 2: Fig. 2. Elliptical resonator with truncated cones

the accelerator can disturb the operation of the injector. In this connection, it becomes necessary to use a beam-transport and beam-alignment system.

It should be noted that, unless special tasks are involved, raising the injection energy above 2.0 MeV for operating accelerators with energies of 30–300 MeV is inadvisable. At an injection energy of 2.0 MeV, the existing "injectors" cannot provide a charge greater than the limiting one. In addition, a further increase in the injection energy would require a voltage of more than 100 kV on the inflector, or a transition to other types of input devices, which have not yet been developed.

As an injector for synchrotrons and betatrons it is quite expedient to use an ultrahigh-frequency resonator.

A resonator operating in the centimeter range has sufficiently small dimensions to allow it to be placed close to the accelerator chamber or in the chamber itself, thereby making it possible to dispense with complicated devices for guiding and collimating the beam. The distance from the injector to the point of exit from the inflector will not exceed 300 mm. In the resonator the electrons can be accelerated to energies above 1.5 MeV (9). The half-width of the electron energy distribution can be reduced to several hundredths of a percent if preliminary bunching is used. The diameter of the electron beam will be several millimeters with a small angular divergence. If sufficient high-frequency power is available, the pulsed currents from the resonator can reach 1 A and higher. Despite the high energy of the electrons, the use of the resonator as an injector will not create difficulties associated with insulation at high voltages, since the voltage on the inflector and the electron gun will not exceed several tens of kilovolts. A system of such resonant high-voltage injection is shown in Fig. 1.

Fig. 2. Elliptical resonator with truncated cones

In our work resonators of two types were used: an elliptical one with truncated cones and a rectangular one. The resonators were made of copper by electroforming. The wall thickness of the resonators was 0.3 mm. The quality factor of the unloaded resonators was $\sim$ 7000. Figure 2 shows a photograph of an elliptical-type resonator. The resonator was placed in a chamber made of stainless steel. A stainless-steel resonator with copper walls, which does not require a vacuum chamber, was also tested. Heating of the resonator and chamber, caused by eddy currents, is insignificant when the accelerator magnet is supplied with current at a frequency up to 80 Hz. A magnetic channel was placed between the resonator and the inflector. The channel was made of transformer steel. In such a channel the magnetic field is weakened by a factor of 20 and therefore does not exert a noticeable influence on the electron beam. The channel does not affect the capture process and saturates in fields greater than 200 Oe. The inflector was made of stainless steel and was tested at pulsed voltages up to 100 kV. The angular size of the inflector plates is 25°.

Experiments on capture into the acceleration regime from an external injector were carried out at injection energies of 35 keV (resonator switched off) and 500 keV (resonator switched on). Stable capture was obtained in both cases. An increase in the intensity of γ-radiation by approximately an order of magnitude was observed in going from an injection energy of 35 keV to an energy of 500 keV.

Further work on improving the electron gun will make it possible to introduce into the accelerator chamber up to 10^{12} electrons per pulse with an energy of 500–1000 keV and with an energy spread acceptable from the standpoint of injection into a cyclic electron accelerator.

Physico-Technical Institute named after A. F. Ioffe
Academy of Sciences of the USSR

Received
2 VII 1964

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