STARTING UP THE SYNCHROTRON B-3M-INJECTOR FOR POSITRON-ELECTRON STORAGE RING

G. I. Budker, A. V. Kiselev, N. G. Konkov, A. A. Naumov, V. I. Niffontov, G. N. Ostreiko, V. S. Panasyuk, V. V. Petrov, L. I. Yudin and G. I. Yasnov

Institute of Nuclear Physics, Siberian Division of the USSR Academy of Sciences, Novosibirsk (USSR).

(Presented by U.S. Panasyuk)

It was reported in (1), (2), (3) that the pulsed synchrotron B-3M was employed as an injector into the electron-positron ring VEPP-2

The weak focusing ($n = 0{,}6$) ring C-magnet ($R = 1$ m) with four straight sections 40 cm long each works in a pulse regime. The cross-section of the magnet is shown in Fig. 1. The magnetic field in the working region is produced both by pole's slope and by a special shape of two copper bars in which current flows in opposite direction.

Curves of equal values of the field drop index without correction are shown in Fig. 2.

A characteristic feature of the design is the fact that the electromagnet and the vacuum chamber are a single unit. Bars are the side walls of the vacuum chamber and lids are made of organic glass. The chamber's working vacuum is $2 - 3 \cdot 10^{-6}$ torr.

The working width of the chamber is 90 mm, and the height is 85 mm.

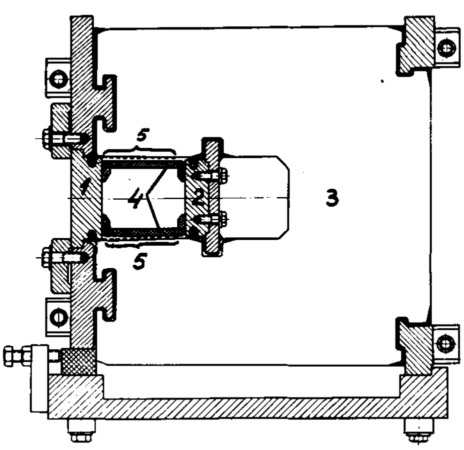

Fig. 1 - Electromagnet cross-section - 1. Outer bar; 2. Inner bar; 3. Yoke; 4. Plexiglass lids; 5. Correction coils.

Excitation of the magnet is produced by a power supply system providing one-pole current pulses of sinusoidal form of $1{,}5 \cdot 10^{-3}$ sec duration and by the auxiliary generator providing quasi-constant field at injection.

A smooth increase of the rate of the magnetic field rise in transition from injection to acceleration is provided by the saturable reactor connected in series with magnet bars.

The magnetic field during one cycle of acceleration is shown in Fig. 3.

A high current linear accelerator ILU (4) is used as injector for B-3M. Injector provides electron energy of 1-1,5 MeV with the pulse duration being $\tau \simeq 7$ nsec and the energy spread $\pm 0{,}5\%$ was used at the first stage.

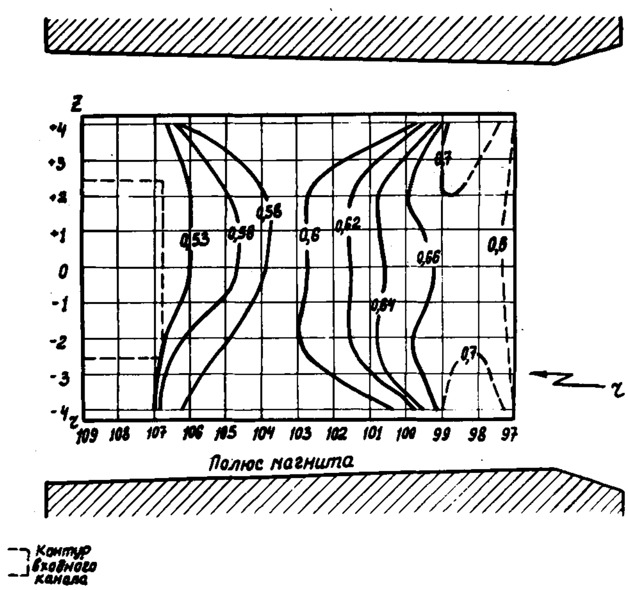

Fig. 2 - Field index values in chamber region.

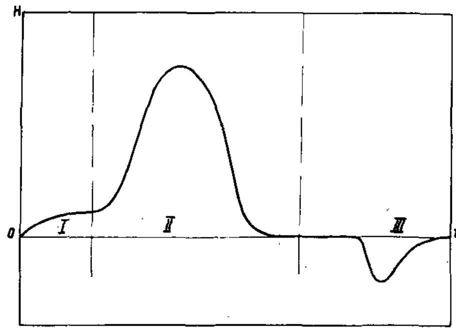

Fig. 3 - Magnetic field in B-3M - 1. Injection field $\tau = 750$ μsec; 2. The main field $\tau = 1{,}5$ msec; 3. Demagnitizing pulse. The fields are drawn out of scale.

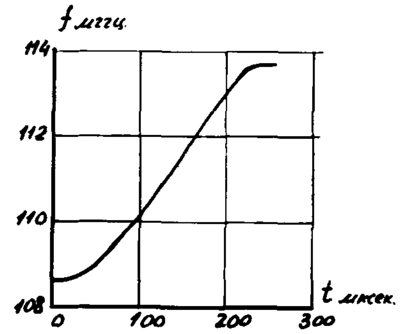

Fig. 5 - Frequency variation at the beginning of acceleration.

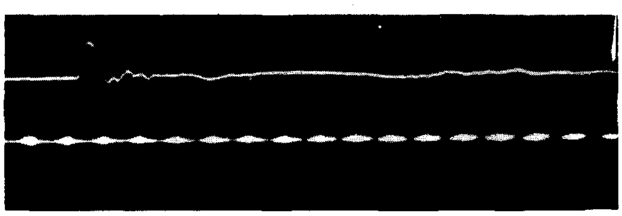

Fig. 4 - Voltage pulse on inflector Time is scaled in 50 nanosec.

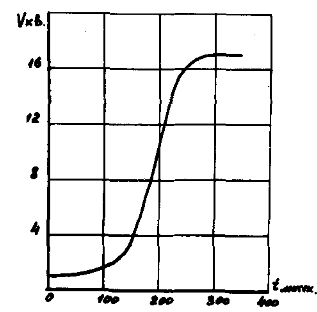

Fig. 6 - R.f. voltage variations at the beginning of acceleration.

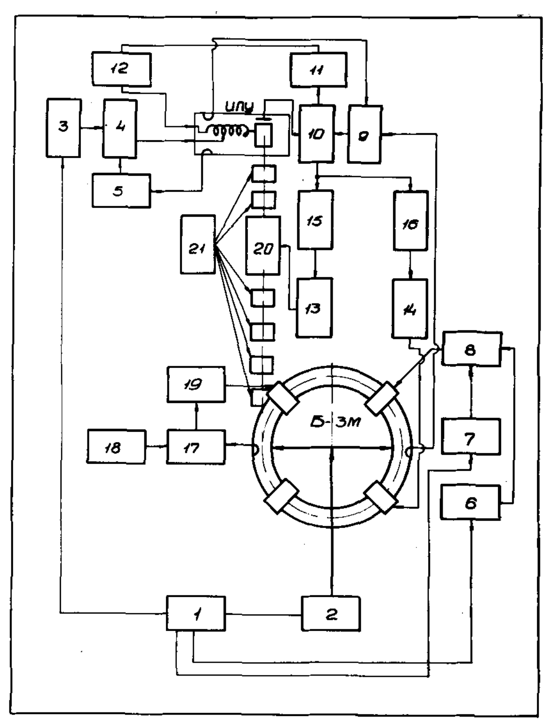

Fig. 7 - Block-diagram of electronics - 1. Master pulse unit; 2. Excitation system; 3. R.f. modulator; 4. ILU R.f. generator; 5. Phase shifter; 6. Frequency modulation unit; 7. Amplitude modulation unit; 8. R.f. amplifier; 9. Program; 10. Phase fixing unit; 11. Delay line; 12. Electronic gun pulse generator; 13. Gate pulse generator; 14. Inflector voltage generator; 15-16. Delay line; 17. Comparator; 18. Reference voltage; 19. Deflector voltage generator; 20. Gate; 21. Power supply unit.

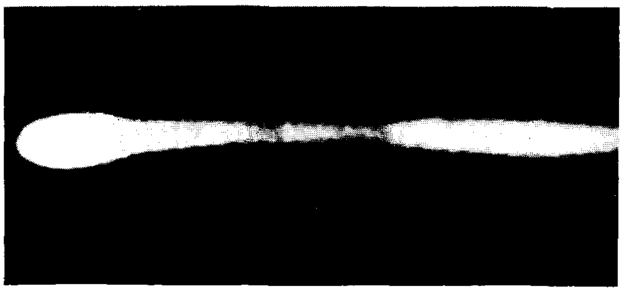

Fig. 8 - Radiation of electrons before ejection. Visible corresponds to electron rotation on stable orbit before ejection.

Synchrotron operates with a single-turn injection. Electrons are injected at the moment when the equilibrium orbit is in the middle of the working region of the chamber. Beam enters the chamber via a special channel in the outer bar. A single-turn capture is realized with the aid of electrostatic inflector located in the straight-section at a distance of a ¼ of radial betatron wavelength from the point of injection (5). The duration of the voltage pulse point on the inflector is 25 nsec. Towards the end of the first revolution the inflector voltage is switched off within about 3 nsec (Fig. 4).

In testing the system of the single-turn injection it was obtained the capture efficiency close to 100% for the beam, with the energy spread at the input of the accelerator being and the phase volume being 10^{-2} rad $\times$ cm. It was done with low injection current when one can neglect the space charge effects. Accelerator operates of third harmonics of particle revolution frequency. The frequency at the beginning of the cycle is varied from 108,4 to 113,7 Mc with the increase of energy (Fig. 5). At the end of the process of acceleration the beam is shifted toward the outer wall by varying the frequency up to 109,5 Mc when modulating the frequency and the ejection then takes place. In order to provide the necessary shape of the accelerating voltage the resonator has a low Q-value (Q = 12). In order to increase the capture the coefficient of synchrotron and to eliminate lossed in the process of acceleration, a modulation of H.f. voltage amplitude is introduced at the beginning of the accelerating cycle (Fig. 6).

Two versions of capture to synchrotron regime were tested:

1. r.f. switch-on, prior to electron injection (inlet). With such a regime one or two bunches are accelerated in the chamber because the injected beam due to its small duration in time cannot fill three separatrices.

2. r.f. switch-on 10-20 nsec after the injection of electrons. In this case electrons are previously debunched and then form three bunches. With both acceleration regimes one gets nearly the same averaged currents of accelerated electrons. However, the second regime destinguishes in a higher stability of the ejected beam, being of importance in storage ring tuning.

A single-turn ejection of electrons is realized by deflector which is a shortened long line supplied from a high voltage nanosecond pulse generator.

The small duration of acceleration cycle and the injector system used put on very rigid requirements to the pulse and r.f. electronics.

Inflector voltage is excited, in particular, by means of a high voltage (up to 50 kV) nanosecond pulse generators synchronized with the master pulse up to one nsec.

The difficulties connected with the stabilization of pulse elements of magnet's power supply and the accelerating voltage of ILU made it necessary to use at the moment of injection a special compu-

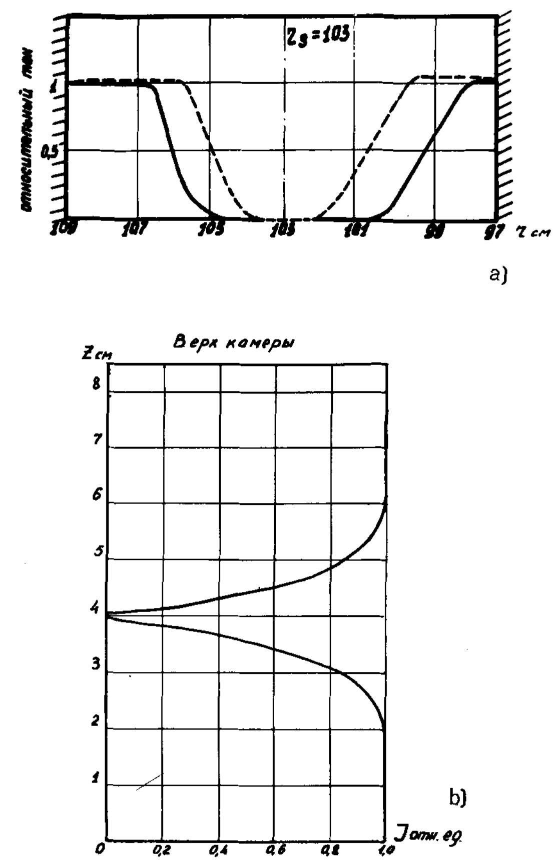

Fig. 9 - Current distribution in quasibetatron regime:

a) radial: { broken line is a filament results. solid line is a plate-probe results,

b) vertical: solid and broken lines coincide.

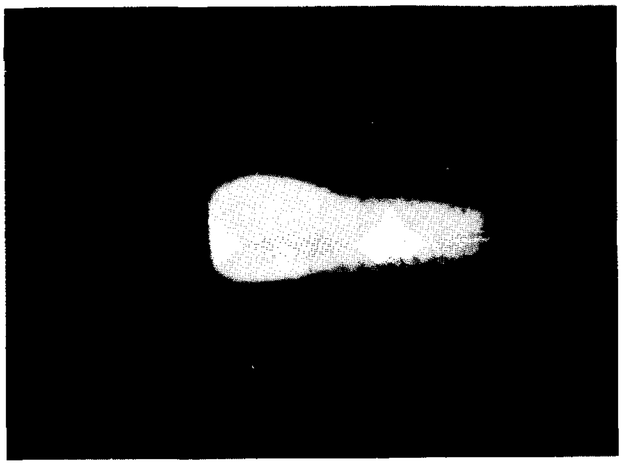

Fig. 10 - Ejected beam.

ting machine. This machine opens the electronic gun of ILU at the moment when the magnetic field strength on the beam orbit and the accelerating voltage of ILU attain such a value that the equilibrium orbit of the injected particles is in the middle of the synchrotron's chamber.

The block diagram electronics of the synchrotron is listed in Fig. 7.

To determine the position and the structure of beam injected into the chamber as well as the distribution of the captured beam in the chamber, probes in the form of copper or lead plates of various size and form and also probes in the form of thin filaments were used. Probes were used as current indicators, movable diaphragms and targets while the registration of bremsstrahlung was carried on.

The bremsstrahlung registered by scintillation counter, with the resolution time being 10^{-7} sec. The beam structure in a quasibetatron regime was studied by observing the shapes of the current and γ-pulses while spilling the electrons by means of orbit expansion and constriction. In the synchrotron regime the radial beam dimensions and the orbit position were determined by varying the resonator frequency after a special rule. The size of electron beam at the end of acceleration cycle with over 50 MeV energy was also determined by the visible beam light (Fig. 8).

As it was shown by estimation the reflected pulses (Fig. 4), damping time of which is about 20 turns, may bring to increase and subsequent decrease of the amplitude of the radial betatron oscillations. The combined use of plate-probes and filament ones makes it possible to investigate the dynamics of the transverse structure formation of the beam. As it is shown in Fig. 9 the amplitude of radial betatron oscillations decreases during the transitional period.

For current value measurements we used Rogovsky coils having 0,7 mV/mA sensitivity. The calibration of the coils was performed by means of the calibrated current in a special coil. The calibration accuracy was $\pm$ 5%.

Peak-up electrode was applied to observe the fast current variations in the process of acceleration. One could observe signals proportional to the first and the third harmonics of the circulating current.

At present time (currently), Synchrotron B-3M provides the tuning of the storage ring VEPP-2 in the regime $E = 100\text{-}130$ MeV, $I \simeq 100$ mA ($1{,}6 \cdot 10^{10}$ electrons per pulse) the repetition rate was one pulse per second (determined by the damping time in the storage ring); the transverse size of the ejected beam was $\Delta z = 3$ mm, $\Delta r = 7$ mm, and the angular divergency $\Delta\alpha = \pm 1{,}5 \cdot 10^{-3}$. The efficiency of ejection is about 90%.

In the last time a temporary injector was replaced by the basic one (4) with injection energy being 2,5-3 MeV and injection pulse duration of 15 nsec.

This allowed to start the program on increasing accelerated particle currents.

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