THE BEAM CONTROL SYSTEM OF THE ELECTRON STORAGE RING VEP-1

E. T. Zinin, L. S. Korobeynikov, G. N. Kulipanov, B. L. Lazarenko, Ju. G. Matveev, S. G. Popov, A. N. Skrinsky, T. P. Starodubtseva and G. M. Tumaikin.

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

The possibility of carring out physical experiments in colliding beams machine depends considerably upon precision of beam control and measurement of main parameters of stored beams. The description of such systems used at various stages of adjustment and investigation on machine VEP-1 is given below (1).

1. For study of capture and storage processes it is necessary to know intensity of injected beam, its phase volume, energy and energy spread as well as beam position and inclination to orbit at the exit of electron-optical channel.

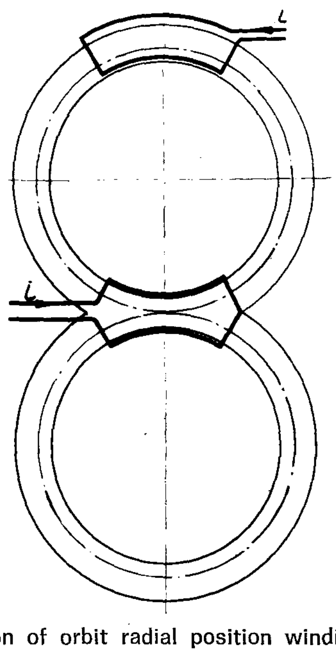

Fig. 1 - Position of orbit radial position windings.

Number of injected particles was determined within 30% accuracy by measurement of charge hitting a lead probe. By means of such a probe one can check phase locking of ejection- injection system and measure bunch length if the number of injected particles is of the order of 10^{10}. These probe are mounted in aperture of electron channel inside thin walled vacuum proof metallic pipes. These pipes may by used also for films exposure to determine precisely beam shape and density distribution. For a fast check and trimming the remotely-controlling multisection lead probes are

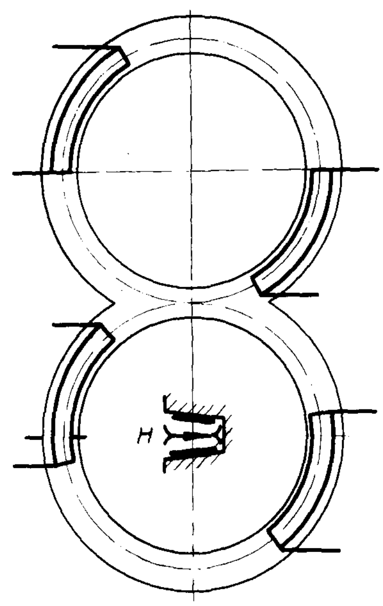

Fig. 2 - Position of orbit axial position plates.

used providing a simultaneous charge detection on each section in a single pulse. These probe are mounted at the input of storage ring and at the distance of one half of betatron oscillation wavelength for control of energy-field matching.

The observation of first revolutions of captured particles is carried out by synchrotron radiation detection by means of a photomultiplier with time resolution better then 9 ns (time of one revolution). The use of diaphragms provides the measurement of residual amplitude of betatron oscillations.

Synchrotron radiation detection is used for measurement of captured and stored intensity. The calibration was made by single electron radiation at the energy 100 MeV. The necessary overlap of intensity regions up to 10^{10} - 10^{11} was obtained by use of optical attenuator, change of photomultiplier intensity, etc. Current measurement accuracy is 10%.

For beam intensity measurement electrostatic pick-up electrodes are used also. Their main feature is independence of signal on particle energy.

2. It is necessary to control equilibrium orbits position and bunch phasing with accuracy much better than beam natural size for precise tunning of beam intersection point (1).

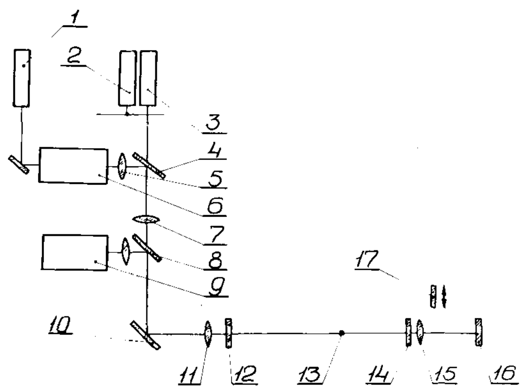

Fig. 3 - Scheme of optical system - 1,9) TV-camera; 2) Disk with a slit; 3) Photomultiplier; 4,8) Semitransparent mirror; 5, 7, 11, 15) Lenses; 10,16) Mirrors; 12, 14 Window; 13) Point intersection; 17) Moving mirror; 6) Image convertor.

The radial orbit position is controlled:

a) by changing of equilibrium orbit one may vary relative position of bunches in the intersection region by ± 4 mm. The change of driving frequency in this region is performed without detuning of r.f. power amplifier.

b) by producing azimuthal distortions with help of auxiliary windings. One of windings affects both beams changing relative position by ± 4 mm, the other shifts the orbit on the upper ring. By varying currents in both windings one can establish the orbits contact point in the middle of slit for scattered electrons. Excitation of magnet and correcting by the same way permite to keep the beam relative position within 0,3 mm.

For orbit axial position control copper plates in which current flows are used. They are mounted on magnet poles (Fig. 2) and provide equilibrium orbit shift in each ring by ± 2 mm and crossing angle up to 10^{-2} rat (at 100 MeV).

The orbit corrections was made on azimuths where small angle counters are mounted.

Betatron oscillation frequency may be shifted within ± 0,12 without changing orbit axial position by producing different currents in copper plates if currents sum is constant. Accuracy of frequency shifting is $5 \cdot 10^{-4}$.

The frequency measurement with an accuracy of 10^{-4} may be done by resonant excitation of betatron oscillations.

The variable increase of beam size (on TV-screen) was produced by electric field 10^{-2} V/cm. R.f. excitation voltage (0,2 V) is supplied to axial plates.

There are two bunches in each ring. By switching off r.f. voltage on several μ sec. one may provide on equal number of particles in each bunch, practically without particles losses. The control of bunches' equality is provided by pick-up electrode amplifier tuned on the first harmonic of rotation frequency.

Beam phasing is controlled by phase shifting lines at the input of power amplifier. The feedback system conserves phase shift with accuracy 1°-2°. The preliminary tuning was done by optical system and image convertor with a circular sweep supplied from r.f. resonator power supply.

3. For luminosity measurement and its comparison with calculations it is necessary to know beam size. The possibility of beam size control is very essential for lifetime increase and beam-beam phenomena study.

We can change beam radial dimension by suppling inflector plate with pulses with variable peak voltage (u = 1-10 kV) and repetition rate (f = 50 3000 c/s). Beam size is change as $< a^2 >^{1/2} \sim u \sqrt{f\tau}$, were τ – radiation damping time.

Vertical beam size is controlled by the same way. The excited oscillation seem not to be coherent. It is proved in particular by life time increase in agreement with AdA-effect (2).

Roughly the transverse beam size may determined on TV-screen pattern. Precise measurement were done by photomultiplier and rotating disk with 0,2 mm slit. On this disk enlarged beam image was projected.

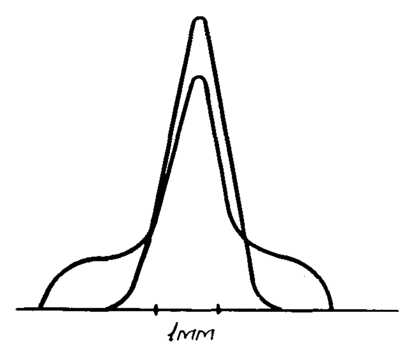

Fig. 4 - Transversal density distribution measurement by means of photomultiplier and rotating disk.

The shape of photomultiplier pulse corresponds to density distribution in beam cross-section in a chosen direction (Fig. 4). Resolution is better than 0.1 mm. A good idea about beam shape and size

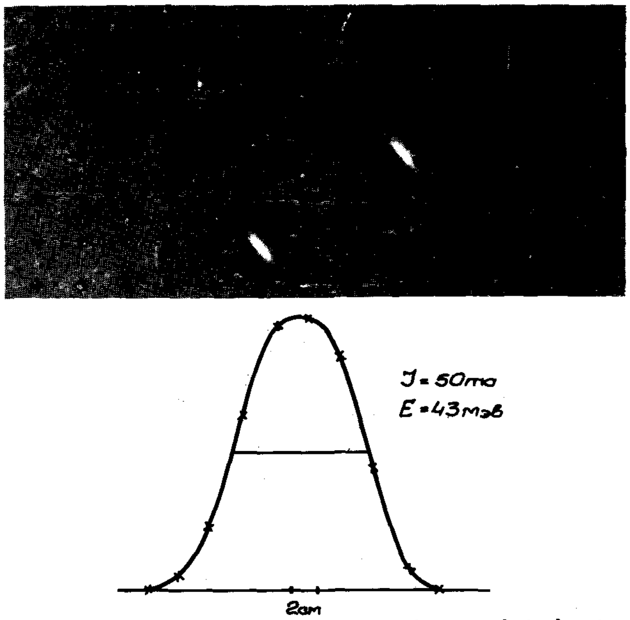

Fig. 5 - Image convertor picture and azimuthal density distribution (after scanning given picture).

one may get by taking beam pictures and film scanning by photometry method.

Beam length may be measured by means of image convertor. By scanning the pictures from image convertor screen one can obtain particles azimuthal distribution. Time resolution is $3 \cdot 10^{-11}$ sec, corresponding to linear resolution 1 cm.

Beam length control is provided by modulation of r.f. voltage with a frequency equal to double of radial-phase oscillations. Incoherent increase of phase size is provided by pulse modulation of r.f. voltage.

Electrostatic pick-up electrodes are used for detection and measurement of coherent effects (transverse and radial-phase). Detection and measurement of coherent chase oscillation were carried out by means of "integral" pick-up electrodes and frequency detector. Detection of coherent betatron oscillations was carried out by means of "differential" pick-up electrodes tuning on betatron frequency or difference frequency. No coherent oscillations were detected within accuracy of 0,1 mm at currents up to 100 mA.

Lifetime is an essential parameter of stored beam. It depends on many other ring parameters, beam intensity and beam-beam phenomena. Continuous monitoring of life-time is provided by a special logarithmic derivative circuit.

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CAVITY RESONATOR SYSTEMS FOR SUPPORTING NONSINUSOIDAL PERIODIC WAVEFORMS*

Q. A. Kerns

Lawrence Radiation Laboratory, University of California, Berkeley, California (USA)

INTRODUCTION

Electromagnetic fields varying periodically in time have widespread technological application. Low-power electronic systems like telemetry, oscilloscopes, and digital computers exhibit a great variety of waveforms including narrow spikes, flat-topped pulses, sawtooth forms, and many others. In contrast, high-power r.f. systems in accelerators, radar, and communications tend to rely on waveforms that may be modulated in various ways, but are almost sinusoidal in time.

The reason low-power electronic systems freely utilize waveforms of practically arbitrary shape, whereas high-power systems tend toward sine waves, is largely that cost scales up rapidly with

(*) Work done under auspices of the U. S. Atomic Energy Commission.