

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

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(Presented by S. G. Popov)

The possibility of carrying 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,

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 be 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 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 wave-length 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 than 9 nsec (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 ra-

diation 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

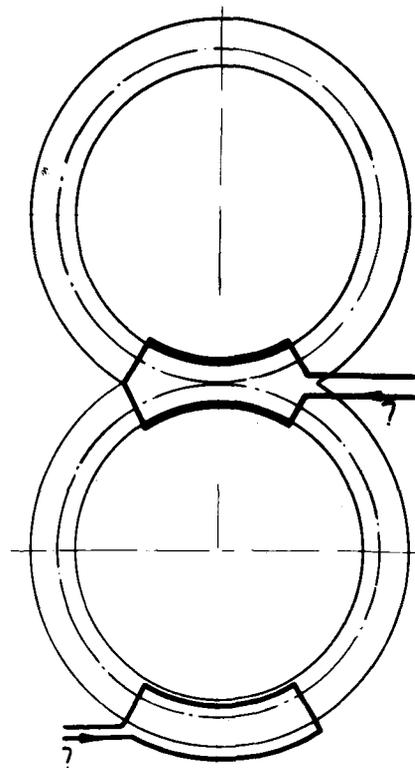


Fig. 1 - Position of orbit radial position windings.

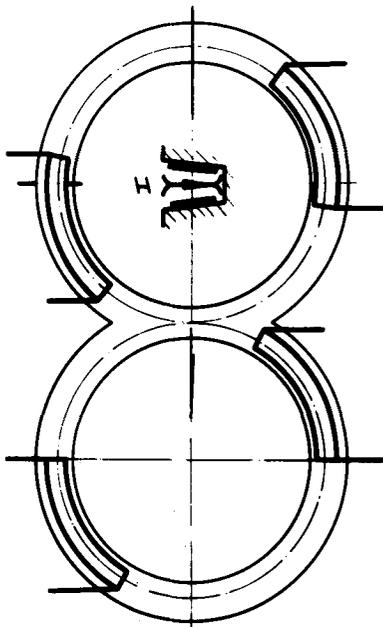


Fig. 2 - Position of orbit axial position plates.

better than beam natural size for precise tuning of beam intersection point(1).

The radial orbit position is controlled:

a) by changing 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 permits 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} rad (at 100 MeV).

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

Betatron oscillation frequency may be shifted within $\pm 0,12$ 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 $1^{\circ}-2^{\circ}$. The preliminary tuning was done by optical system and image converter 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 increases and beam beam phenomena study.

We can change beam radial dimension by supplying inflector plate with pulses with variable peak voltage ($u = 1 - 10$ kV) and repetition rate

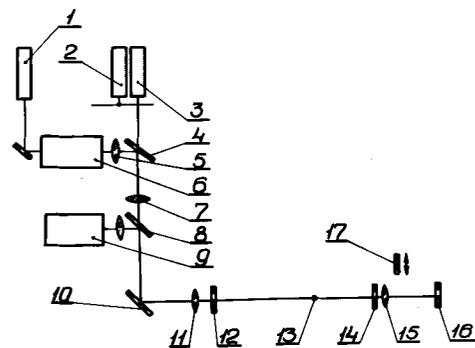


Fig. 3 - Scheme of optical system: 1,9) TV - camera; 2) disk with a slit; 3) photomultiplier; 4,8) semitransparent mirror; 5, 7, 11, 15) lenses; 6) image convertor; 10, 16) mirrors; 12, 14) window; 13) point intersection; 17) moving mirror.

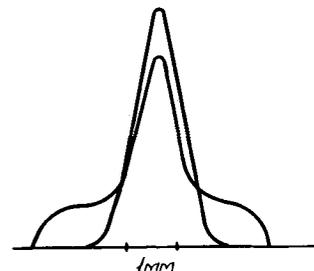


Fig. 4 - Transversal density distribution measurement by means of photomultiplier and rotating disk.

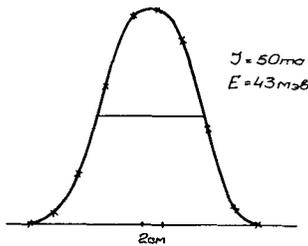


Fig. 5 - Image converter picture and azimuthal density distribution (after scanning given picture).

($f = 50 - 3000$ c/s). Beam size is change as $\langle a^2 \rangle^{1/2} \sim u \sqrt{\tau f}$, where τ - radiation damping time.

Vortical 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.

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

Beam length may be measured by means of image converter. By scanning the pictures from image converter 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 phase 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.

REFERENCES

- (1) G. I. Budker et al.: Status report on electron storage ring VEP-1. Paper presented to this Conference, see Session VIII.
- (2) C. Bernardini, et al.: Phys. Rev. Letters, 10, 407 (1963)

DISCUSSION

BARBER: How is the longitudinal (length) dimension of the beam measured and does the measured length agree with theory?

POPOV: The measurement of the phase dimensions of the bunch in the storage ring was done in our case using an electronic-optical transformer whose circular sweep is driven by a high frequency generator, that accelerates electrons. Measurement results are given in a review report on VEP-1. These dimensions increase appreciably. This increase is roughly in agreement with the AdA effect.

AMMAN: Do you have an explanation for the increase of

incoherent radial betatron oscillations, obtained by pulsing the inflector?

POPOV: Possible mechanisms for the decoherence of the betatron oscillations may be, e. g., the presence of non linearities of the magnetic field, the finite transverse dimensions of the bunch, the dependence of the value of the kick on the longitudinal position of particles in the bunch (due to the bad fronts of the kicking pulse) and the mixing due to the quantum fluctuations in the particles phase motion. The non coherence of the increases dimensions is confirmed by the right dependence of the electrons life time (due to the AdA-effect) on the bunch dimension, which can be seen.