ELECTRON BEAM PROBE AS A NONDESTRUCTIVE SINGLE BUNCH DIAGNOSTIC TOOL FOR CIRCULAR COLLIDERS.

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Abstract

In this article we present the experience of using electron beam probe (EBP) on VEPP-4.

EBP is destined to determine such parameters of ultrarelativistic bunches of charged particles as centre of mass transverse position, longitudinal charge distribution, spatial orientation. The method is based on a deflection of a thin probe beam on an electromagnetic field of investigated ultrarelativistic bunch. Measured deflection value allows to calculate the spatial charge density. Detailed description of methods for reconstruction of bunch's parameters is presented in [1], [2], [3].

THEORY

A). Longitudinal charge distribution can be reconstructed according to a following scheme.

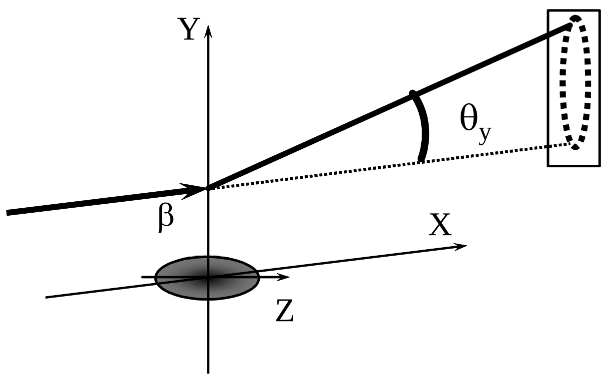

Fig.1

Thin, small-current, low-energy (several dozens keV) electron beam moves along *X* axis, that is orthogonal to the direction of the relativistic bunch motion (*Z* axis), with the offset parameter ρ (see Fig.1). Electrons of a probe beam, deflected by electromagnetic fields of investigated bunch, draw some curve on a screen. Vertical deflection angle θ_y is determined by transverse component of bunch's electric field. Horizontal deflection angle θ_z is formed by a difference of integral effect of magnetic field in [*-d/2,0*] and [*0,+d/2*] ranges, where *d* is a size of interaction area, which is virtually equal to the size of vacuum chamber. The value of vertical deflection in a case of far pass is described by a following expression:

$$\theta_y(x) = \frac{2\rho r_e}{\beta}\int_{-\infty}^{+\infty}\frac{n(z)dz}{\rho^2 + (x+\beta z)^2}$$

This equation can be solved:

$$n(z) = \frac{\beta^2}{4\pi^2 r_e}\int_{-\infty}^{+\infty}\theta_y(k)e^{(ikz\beta+|k|\cdot\rho)}dk \text{ , where}$$

$$\theta_y(k) = \int_{-\infty}^{+\infty}\theta_y(x)e^{-ikx}dx \ .$$

Conditions of applicability for these expressions: diameter of a probe beam in interaction area is much less than ρ, ρ is much less than a longitudinal size of investigated bunch, $\theta_y << 1$.

Dependency $\theta_y(x) = \frac{2\rho r_e}{\beta}\int_{-\infty}^{+\infty}\frac{n(z)dz}{\rho^2 + (x+\beta z)^2}$ can be measured in experiment [1].

B) For bunch's center of mass transverse position to be determinable, its transverse size must be much less than diameter of a probe beam. In this case the bunch, crossing the probe beam, will "cut" it into two parts (see Fig.2).

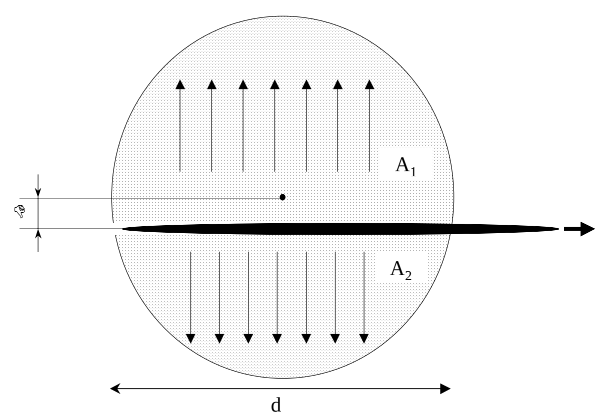

Fig.2

In case of *Δ<<d* displacement of bunch's center of mass can be expressed as $\Delta = \frac{Q_1 - Q_2}{Q_1 + Q_2}\frac{\pi d}{8}$, where Q_1 – charge in A_1 area, Q_2 – charge in A_2 area. Spatial resolution of this method is limited by instability of probe beam's energy and instability of magnetic fields of a probe beam's focusing and position correction system. Precision of this method is 10 μm.

EXPERIMENTAL IMPLEMENTATION OF A METHOD ON VEPP-4

Scheme of EBP is presented on Fig.3. Electron beam from a thermoelectronic gun passes through interaction area.

Focusing and magnetic correction system allows to select the size and position of a probe beam in the interaction area. Scattered electrons are registered by a system consisting of MCP, phosphor screen and CCD camera, as shown on Fig.3. Detailed description of EBP is available in [2].

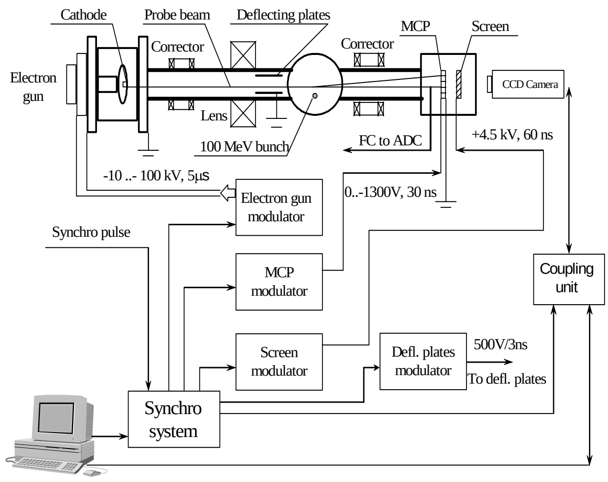

Fig.3

We had a need to investigate bunch instability with a pulse time of 100μs (about 60 turns) on VEPP-4. A synchronization system was designed, which generates a series of starting impulses – up to 5 impulses, with interval from 5μs to 100μs – repeating with 1Hz. This mode of operation allows, due to slow horizontal sweep, to have on a single screen images of a same bunch on different turns (uniformly parted in time; one turn takes 1.6μs).

A square screen 40×60mm accommodates up to 5 such images. Shapes of high-voltage impulses on a gun, MCP and phosphor screen should be as uniform as possible in the corresponding moments of relativistic bunch's passes through EBP.

Plus, amplifying characteristics of MCP's and phosphor screen's surfaces should be as constant as possible.

Conducted experiments had exposed following problems:

1. Despite the vacuum about 10^{-8}Pa in VEPP-4, EBP gun's impregnated cathode had a life time of only 10 days. The problem was solved by using LaB6 cathode. This, additionally, enabled to raise the probe beam current.
2. Gun's voltage lowers from one impulse to next one in one sequence. This significantly complicates interpretation of acquired images, since size of a loop depends on probe beam energy.
3. Decrease of MCP's voltage on each next impulse in a series leads to decrease of images' brightness, which also hardens processing.

CONCLUSION

Currently CDM can operate in multi-pulse mode. In future VEPP-4's beam instability, as well as beam behavior during injection will be investigated with CDM.

A long-living cathode was chosen and tested, which allows raised probe beam current.

For the future we have a task to measure impulse current of a probe beam for system calibration. This will enable to perform quality measurements of VEPP-4 bunches' parameters.

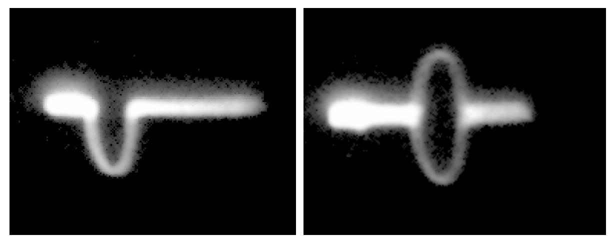

Fig.4

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