LOW ENERGY ELECTRON BEAM AS A NONDESTRUCTIVE DIAGNOSTIC TOOL FOR HIGH POWER BEAMS

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Abstract

This paper is devoted to possible applications of low energy electron beam in diagnostics of intense beams. The method is based on the scanning of the thin electron beam within the energy range 20-200 kV in the electromagnetic field of an intensive bunch. Experimental results of electron beam probe applications in BINP are presented. Possible applications of this approach for particular ILC and SNS beam diagnostic systems are discussed.

INTRODUCTION

Probe beam is injected across the path of relativistic bunch. This type of an electron beam probe is suitable for both circular and linear accelerators. The prototype results obtained on the VEPP-3 storage ring and on the electron linac of VEPP-5 injector complex at BINP have found out some new features of this non-destructive single bunch diagnostic tool. It is able to investigate not only the longitudinal charge distribution in the bunch [1], but also the transverse one. It is also sensitive to the transverse density variations inside the bunch and, it can even feel wake-fields after the bunch [2]. On the base of these results new diagnostic techniques were suggested for intense lepton and hadron beams [5].

ELECTRON BEAM PROBE FOR RF LINACS

Nondestructive beam diagnostic, which is sensitive to internal bunch structure, can be very useful for fine accelerator tuning and for online control of beam stability [4]. The particular method of electron beam probe application depends on the geometrical sizes of the bunch under investigation. Two cases can be considered. The first corresponds to small transverse size of probe beam in comparison with the transverse size of investigated bunch. For this particular case it is possible to monitor transverse charge distribution in the bunch. If, additionally, longitudinal bunch size is significantly larger than transverse one, it is also possible to measure the longitudinal charge distribution in the bunch. The second case reflects the opposite situation when transverse bunch size is significantly smaller then the transverse size of probe beam. In this case the device can measure the transverse displacement of bunches in the train (as very fast BPM) and single bunch tilt angle with respect to the direction of bunch motion. Linear scanning of the probe beam is used to separate images from different bunches. This scanning is performed in the direction of bunch motion and helps to observe wake fields propagating in the vacuum chamber of accelerator [3].

ELECTRON BEAM PROBE FOR STORAGE RINGS

As a rule the transverse beam size in storage ring is significantly smaller than the probe beam transverse size. So in order to control bunch-to-bunch position and bunch tilt the probe beam and main beam trajectories should be in the same plane. The device operates in the regime of collision with the main beam. The asymmetry of obtained image brightness can give bunch position and tilt.

If the main bunch length is significantly larger then the probe beam transverse size, one can use electron beam probe as a longitudinal charge distribution monitor. But for this measurement the stability of the bunch center of mass position is required. This kind of measurements was realized at VEPP-4 collider (see Fig. 1,2). Probe beam was set to the position of exact collision with stored bunch (zero offset parameter). The bunch population was controlled by circulating beam current measurement. If transverse bunch size is significantly smaller than the probe beam transverse size in the interaction region and longitudinal bunch size is mach bigger than the probe beam transverse size in the interaction region, it is possible to restore the longitudinal bunch sigma by means of the image height measurement on the screen of the device (see Fig. 1).

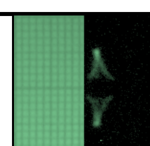
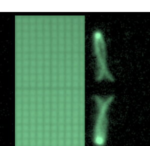
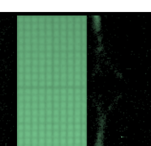
Image on the screen			
Number of e- in the bunch	7,6·109	14,2·109	22,8·109
Vertical size of the loop	0.5 см	0.8 см	1.0 см
Bunch current duration	87.5 ps	110 ps	130 ps
Bunch length	2.6 см	3.3 см	3.9 см

Figure 1: Images and bunch parameters obtained from electron beam probe of VEPP-4 collider.

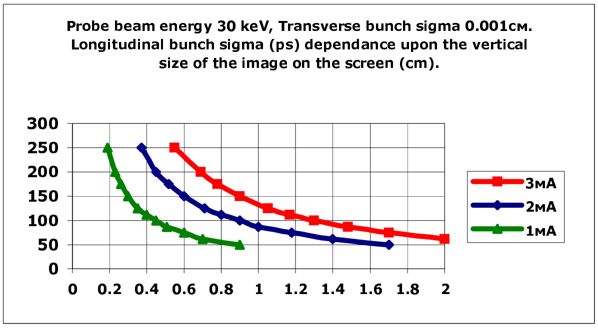


Figure 2: VEPP-4 bunch length dependence (ps) upon the half vertical size of the image on the screen (cm) for three different circulating current values in the ring. Another possibility, which utilizes a linear scanning of the probe beam and multy-pulse operation of electron beam probe, is connected with the observation of bunch properties at different turns in storage ring.

ELECTRON BEAM PROBE FOR ILC

The most important possibility which is offered by electron beam probe for Linear Collider application is the bunch tilt measurement . (The bunch tilt is the amplitude of transverse bunch tail displacement with respect to the transverse position of the bunch head.) These measurements are necessary for control of transvrse wake fields exitation in ILC main linac and as a result for better control of ILC beam emittance.

In order to measure the bunch tilting in Y-direction (head –up and tail-down), the image on the screen was divided in four parts: 1-(x>0,y>0), 2-(x<0,y>0), 3-(x<0,y<0), 4-(x>0,y<0). Fig 3,4. represents the picture with 8 microns of tilting amplitude. N1 is the number of electrons in the part 1 of the screen, N2 – in part 2 and so on. As a result tilting angle amplitude at the level of 0.03 rad can be clearly detected.

ELECTRON BEAM PROBE AS A PROFILE MONITOR FOR INTENSE PROTON BEAM OF SNS

Low energy electron beam can be used as a very fast, nonperturbing “wire scanner” for intense ion beams. The parallel motion of probe electron beam across the ion beam is provided by initial electrostatic deflection and its further amplification in two quadrupole lenses (see Fig. 5). Scanning plane is tilted at 45º with respect to the vertical direction (see Fig. 6) in order to extract from the image the current offset paraneter during the scanning process.

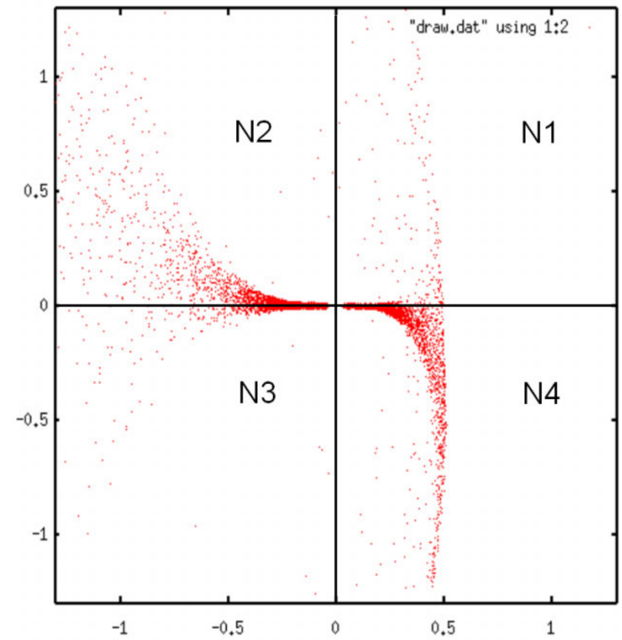


Figure 3. Probe electrons distribution on the screen of the device (result of simulation) for the following bunch parameters: σ_z = 0.1 mm, σ_x = σ_y = 10 μm, N =$0.7*10^{10}$. Probe electron beam energy – 200 keV. Vertical and horizontal sizes of the image are givven in cm.

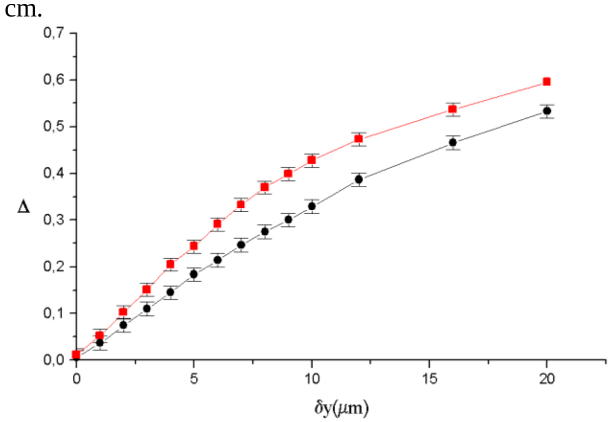


Figure 4. The image asymmetry dependence on the bunch tilting amplitude The error bars show the statistical error 1/sqrt(Nparticles), Nparticles=5000 (Δ= (N4-N1)/(N4+N1) - lower curve, Δ = (N2-N3)/(N2+N3) – upper curve).

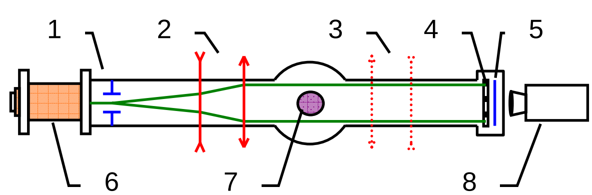
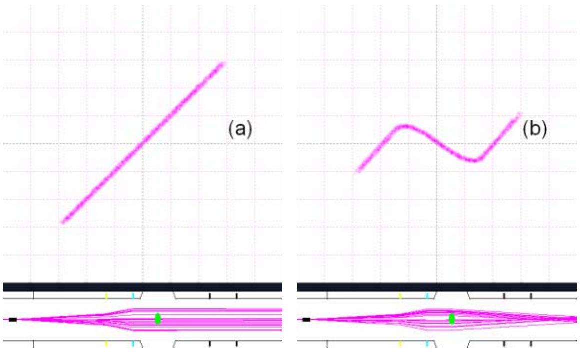


Figure 5: Scheme of electron beam probe for SNS acumulator ring (1 – scanning device, 2,3 – quadrupole lens, 4 – micro channel plate, 5 – phosphor screen, 6 – electron gun, 7 – proton beam, 8 – ccd camera).



Firgure 6: Images from SNS electron beam probe screen: a) – proton beam is abcent, b) - with proton beam (results of simulation).

For the high intensity proton beam of the SNS ring, the bunch is much longer than the typical linac beams (160 meters versus 1 cm), but the fast response of the electron probe allows to get proton beam profile dependence on the longitudinal coordinate with a good time resolution. Besides, if the integral deflection of the electron beam is measured as a function of azimuthal angle around the vacuum chamber axis, it is possible to restore asymmetric transverse profile of SNS proton beam.

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