NON-DESTRUCTIVE SINGLEPASS BUNCH LENGTH MONITOR: EXPERIMENTS AT VEPP-5 PREINJECTOR ELECTRON LINAC

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Abstract

In this paper we present the experimental results of calibration of non-destructive diagnostic tool for a monitoring of longitudinal charge distribution in an intensive relativistic electron bunch. One of these devices is installed in VEPP-5 preinjector electron linac. The probe beam is injected across the path of primary relativistic bunch. As a result of interaction of probe beam electrons with main bunch electromagnetic field, the testing beam traces the closed curve on the screen.[1]

Also we discuss the new application of this tool as a non-destructive single path submicron resolution BPM.

1 EXPERIMENTAL SETUP

This device was held at VEPP-5 preinjector electron linac at the bunch energy 300 MeV . We placed the device between accelerating structure and spectrometer. Bunch energy in the whereabouts is 100 MeV. The schematic diagram of the layout is shown in Fig. 1. The probe electron gun had a flat diode geometry with two anode diaphragms (See Fig 2.). First 1.5 mm diaphragm acts as defocusing lens. Next 0.2 mm diaphragm decreased beam emittance. This construction of electron gun provides 0.5 mm beam spot on the screen within voltage range 30-100 kV. We used 4 mm dispenser cathode with emission ability 3 A/cm^2. The maximum pulse current of the probe

Fig. 1: The scheme of installation

electron beam was 1 mA at the energy of 60 keV.

Axial magnetic focusing lens formed a minimal probe beam spot on the screen. Transverse correction coils were installed to adjust the position of the probe beam on the screen. We used to direct the probe beam to the thing strip placed just before the Micro Channel Plate (MCP). It allowed to avoid the MCP saturation by 5 μs, 1mA probe beam and to measure its pulse current. We also measured probe beam energy. These parameters gave us a possibility to restore the charge distribution in relativistic bunch. [1]

The maximum repetition rate for our system was limited by video data transfer time (7 s). So all presented calibration measurements were made at the repetition rate of 0.14 Hz.
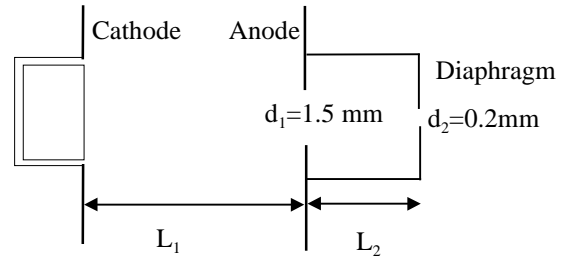

Fig. 2: The scheme of electron gun

2 CALIBRATION SYSTEM

Apparatus function brightness to charge density can not be calculated and it can be determinated by the calibration procedure. The calibration system main task is to produce known surface charge density on the MCP surface which is close to the normal operation value. The direct exposition of MCP by the probe beam with normal parameters is not helpful due to the huge value of the charge density on the MCP surface. So one needs to decrease the pulsed beam current by decreasing the cathode temperature. The minimum value of pulse beam current we can measure is in the range of few microamps. But it is still not enough to reach the charge density which we meet in experiment. Then we use the linear scanning to reduce additionally the charge density on the MCP surface in controlled manner. The synchronous start of deflecting system with modulators provides a good time and amplitudes stability (a maximum time jitter was less than 0.3 ns). The pulse to pulse voltage stability at the period of relativistic bunch passing is better than 3% for
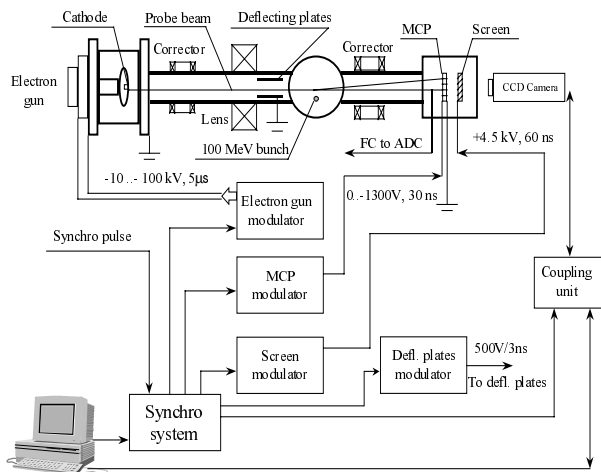
each modulator. The surface nonuniformity of the detection system is less than 3%. All presented measurements has made with 60 keV, 0.3 mA probe electron beam. The probe beam size is 0.5 mm on the screen.

The calibration procedure consists of the following steps. The first is reducing the beam current to the minimum value we can measure. Then the beam spot is directed to the MCP surround ring which acts as a Faraday cup. The fast linear scanning pulse and MCP gate pulse come together (See Fig.3) and the beam spot with known current moves along the screen with known velocity, so one can calculate the surface charge density on the MCP.
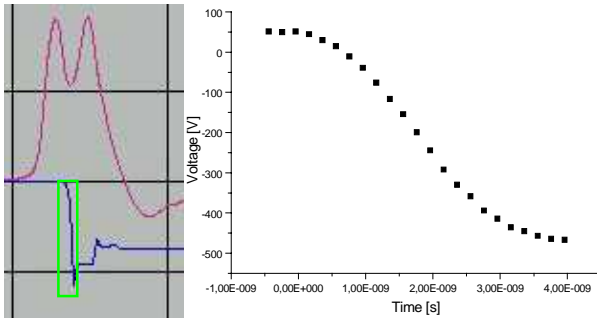

Fig. 3: Modulators pulses: MCP+PhSc – two peaks curve and deflection plates modulator, enlargement front of pulse of deflection plates modulator.
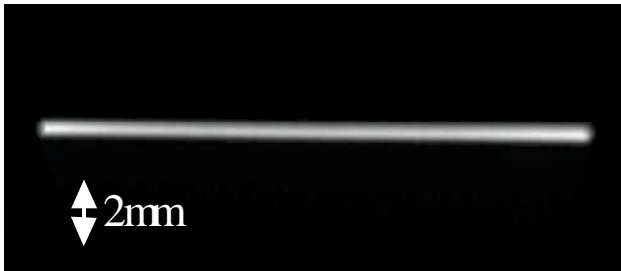

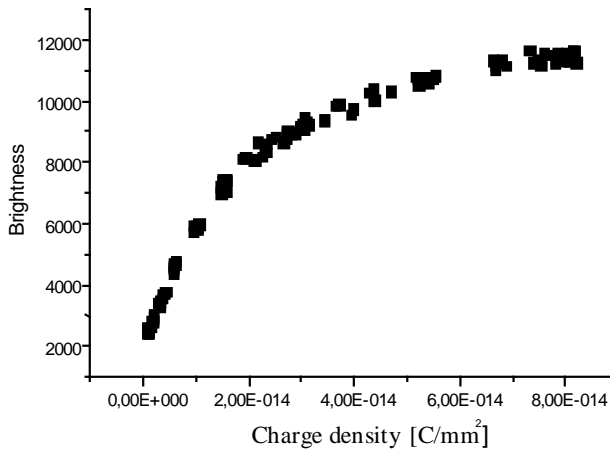Fig. 4: Typical linear scanning picture.

Fig. 5: Apparatus function of MCP-PhSc-CCD Video.

3 BASIC IDEA OF BPM

Let us assume the vertical size of probe beam is larger than one of the main bunch. When the relativistic bunch passes through the probe beam, relativistic bunch cut the probe beam into two parts. The value of main bunch displacement relative to the center of probe beam can be calculated by the ratio of charges located in different regions A_1 and A_2 (See Fig 6)
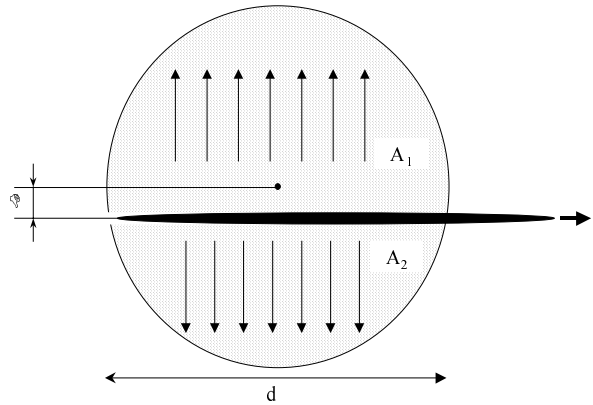

Fig. 6: Probe beam cross section at the interaction point.

Let region A_1 contains charge Q_1 and A_2 contains charge Q_2 then we can calculate Δ in case $\Delta<<d$:

$$\Delta = \frac{Q_1 - Q_2}{Q_1 + Q_2} \frac{\pi d}{8} , \quad \text{(Eq1)}$$

The basic idea of this diagnostic looks simple, but one should be very careful evaluating the time resolution of this method. Time resolution is limited by probe beam vertical position instabilities. Typical value of these instabilities is $5*10^{-3}$. (See Error bar on the Fig 7.) Beam size d is 2 millimetres. Then spatial resolution value is 0.004 mm.
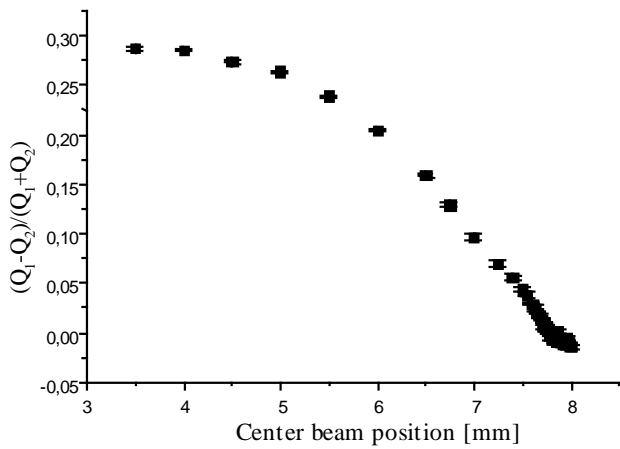
Fig. 7: Dependence $\dfrac{Q_1 - Q_2}{Q_1 + Q_2}$ on beam position.

4 CONCLUSION

The design of the monitor essentially depends on the relativistic beam parameters. Here we just note the general useful qualities of the method:

1. The ability to measure not only longitudinal distribution of beam density, but also the transverse position of its center of mass with good resolution.
2. The testing beam has practically no influence on the relativistic bunch, so its parameters don't get worse.
3. The small slots for testing beam transit in main vacuum chamber don't change its impedance.

REFERENCES

[1] P.V. Logatchov et al. Nondestructive diagnostic tool for a monitoring of longitudinal charge distribution in a single ultrarelativistic electron bunch. PAC-99.