THE UPGRADED OPTICAL DIAGNOSTIC OF THE VEPP-4M COLLIDER

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Abstract

The upgraded optical diagnostic of the VEPP-4M collider is described. The system abilities are improved sufficiently in comparing with [1]. Now the diagnostic supplies the data about electron/positron beam transversal and longitudinal size, shape and position. It is applied to study the electron beam "tails" and turn-to-turn beam profile dynamics. The system is used to tune of the beam pass-by from the VEPP-3 booster to the VEPP-4M collider and to measure of the synchrotron and betatron frequencies.

INTRODUCTION

VEPP-4M [2] is an electron-positron collider at the energy up to 6 GeV. This collider consists of 2 semi-rings with the average radius R of 45.5 m, which are connected by two linear segments. Computed dimensions of the beam at the point of the optical diagnostic location are: $\sigma_z \approx 0.1$ mm, $\sigma_r = 0.5$ mm, $\sigma_\varphi = 2.5$ cm (E = 1550 MeV, $U_r = 0.5$ MeV). The current physical program of the facility is directed at the energy area of J/ψ meson and τ lepton (up to 2×2 GeV).

LAYOUT OF THE OPTICAL DIAGNOSTIC

Optical diagnostic provides the following data:

- transversal and longitudinal beams sizes;
- XY Beams coordinates at the points of SR outlet;
- Electron beam tails distribution;
- Electron beam profile with one-turn temporal distribution during 2^{17} turns;
- Electron beam synchrotron and betatron frequencies.

Two channels of SR output are located in the bending magnets of the semi-rings and separated by a linear segment. Each channel outputs a radiation of electron or positron beam only. Each channel is equipped with practically identical diagnostic systems (Fig. 1).

The optical component of SR is reflected from cooled metallic mirror and outlets from the vacuum chamber through a quarts window. Mirror 1 reflects a part of light to the optical coronagraph, which is applied for beam tails study. Mirror 2 matches the light with an optical axis of the system. The beam image is set up on lens 3 on all the optical detectors simultaneously. A remote controlled

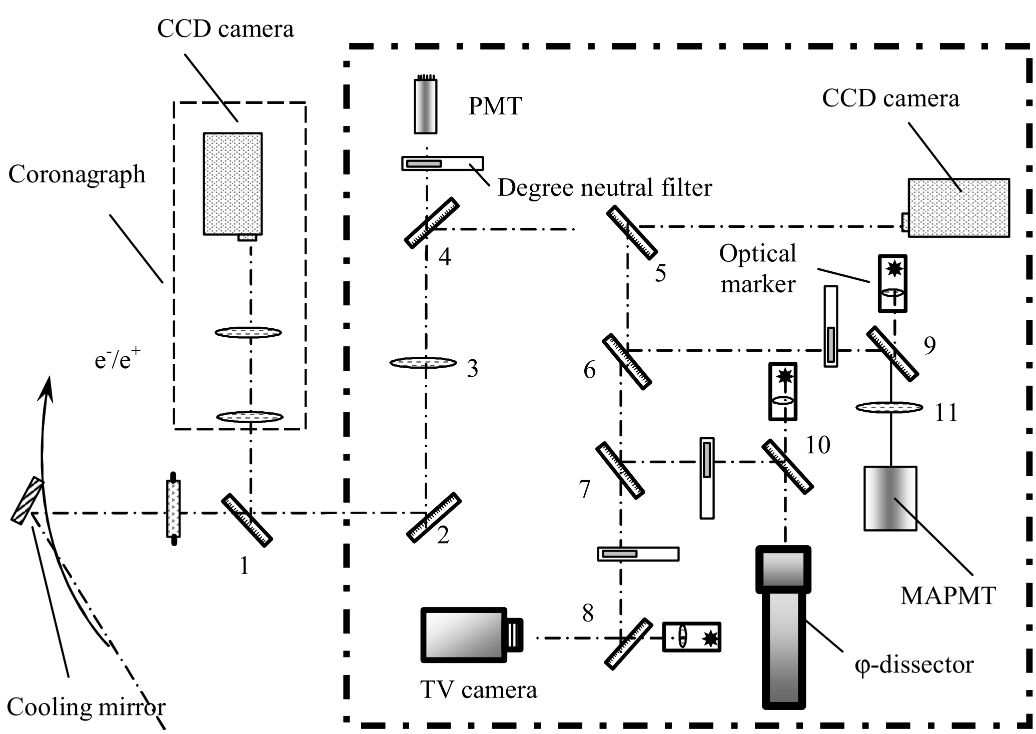

Figure 1: Layout of the optical diagnostic. 3,11 – lenses, 4÷10 – mirrors

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switchable neutral filters expand the dynamic range of the system.

A part of light reflected from the semi-transparent mirror 7 is used for measurement of a longitudinal size of the beam. The φ-dissector with electrostatic focusing and deflection is employed for this purpose [3]. It has FWHM of instrumental function at 40 ps.

CCD-CAMERA WITH 100 MBIT ETHERNET INTERFACE

CCD-cameras [4] are employed for measurements of transversal beam dimensions and position. Value of σ_Y of the electron and positron beams is permanently displayed on the monitor, what is convenient, in part, for tuning of luminosity of the collider (Fig. 2). Camera has an external trigger with jitter of 100 mcsec. This is enough for quality control of the process of beam transport from the booster VEPP-3 to the collider VEPP-4M. Camera is applied also for image acquisition of the tails of the electron beam at distances over $5\sigma_Y$.

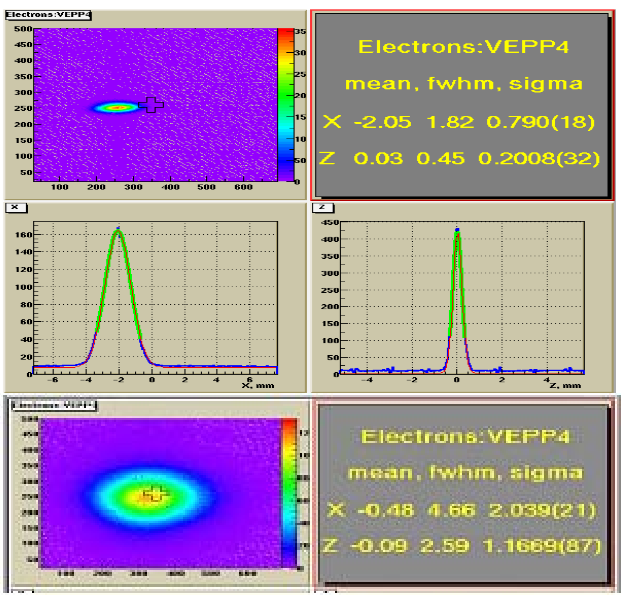

Figure 2: CCD camera results. Upper image is the current view of the electron beam. Down image is the first 100 turns of electrons after pass-by from VEPP-3 to VEP-4M. Data refreshing frequency is nearly 0.3 Hz.

OPTICAL CORONAGRAPH

The ability of on-line measurements of the tails is sufficient for the accelerator tuning. Two methods are widely applied for that nowadays: scraping collimator [5] and a wire scanner [6]. Both methods interact with beam, change its properties and destroy it. Moreover, scraper application takes long term and poor combine with another experiments carried on the machine. The advantage of both diagnostics is a wide dynamic range, up to 10^6.

The development of non-disturbing method that enables on-line fast study of the beam distribution function within the limit of 5σ seems relevant. We have applied the optical coronagraph for this purpose [7]. The coronagraph is intended for study of beam-beam effects and polarization experiments. We tested the device on VEPP-3 preliminary. The coronagraph was applied for study of the beam scattering on the atoms of residual gas. This process can be theoretically simulated [8] and comparison with experimental data is possible (Fig. 3) [9].

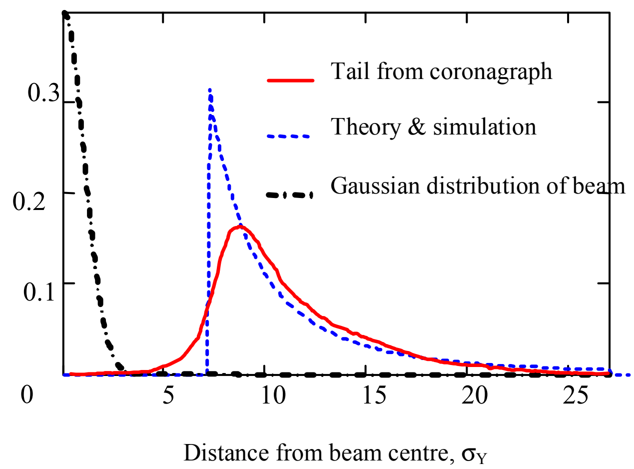

Figure 3: Measured and simulated beam tails distribution. Gauss distribution is given for comparison.

FAST MULTI-TURN BEAM PROFILE MEASUREMENT

The interest to study of beam distribution within devel-opment of fast instabilities the same, as beam-beam ef-fects always existed in the physics of accelerators. The corresponding diagnostics should provide a one-turn dis-tribution during tens thousand turns of beam. For this purpose we have designed the device based on the multi-anode photomultiplier R5900U-00-L16 HAMAMATSU, Fig. 4 [10]. This device is capable to record a transversal profile of a beam at 16 points at one turn during 2^{17} turns of a beam. Some features of the diagnostic are listed in the Tab. 1.

Table 1: The technical data of the beam profile monitor

Size	250 × 100 × 100 mm
Interface	100Mb ethernet
Internal memory	~4 M (2^{17} beam profile at 16 points)
Discontinuity of record	$1 \div 2^8$ turns
Analyzable frequency range	10 Hz $\div$ 1 MHz
Single anode size	0.8 × 16 mm

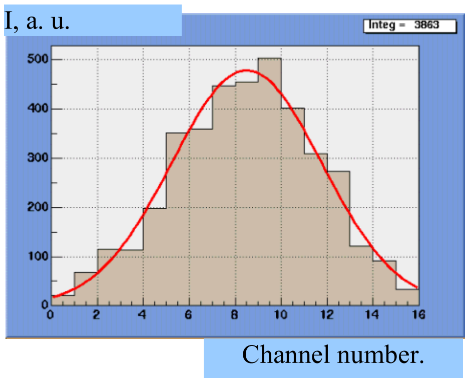

Figure 4: Typical beam profile, recorded of the device. Gauss approximation is realized for each turn.

Fig. 4 represents a typical beam profile. Fig. 5 shows a process of electron and positron beams convergence in the interaction point. The total duration of the process is about 2 sec., or nearly $2 \cdot 10^6$ of the beam turns.

CONCLUSION

The upgraded optical diagnostic of VEPP-4M has been described. Spatial and temporal resolution of the diagnostic corresponds to the demands of the current VEPP-4M experiments. The diagnostic provides a simultaneously data of the beams size, position and frequency oscillations. This information is effectively used for machine tuning and running.

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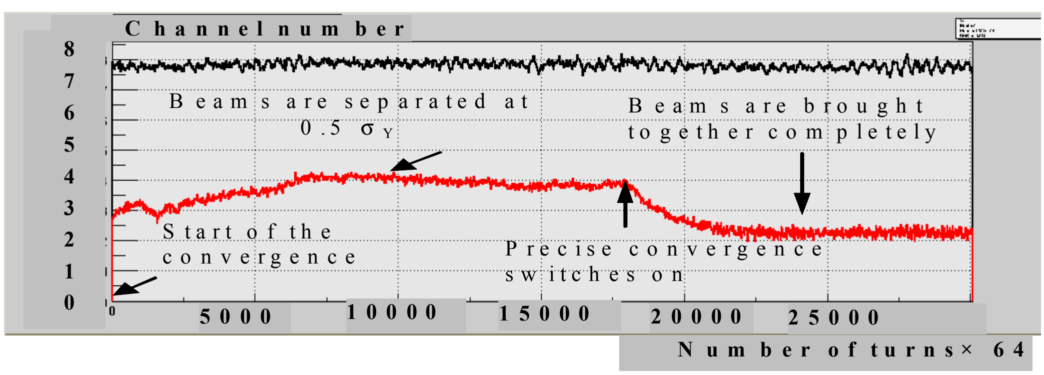

Figure 5: The position of center-of-weight of electron beam (upper line) and size σ_Y behavior (down line) during the beams convergence in the interaction point. The total process duration is nearly $2 \cdot 10^6$ turns of the beams. Time of the single turn is 1220 ns. Channel constant is 0. 12 mm.