APPLICATION OF THE BEAM PROFILE MONITOR FOR VEPP-4M TUNING

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Abstract

A transverse beam profile monitor based on the Hamamatsu multi-anode photomultiplier with 16 anode strips is used at VEPP-4M collider. The monitor is used to study turn-to-turn dynamics of the transverse beam profile during 2^{17} turns. In addition, it provides a permanent measurement of synchrotron and betatron frequencies. The operation of the device for tuning the collider and studying of collective effects is described.

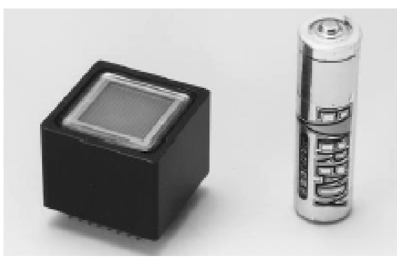

Figure 1. MAPMT R5900U-00-L16 HAMAMATSU

INTRODUCTION

The interest in the study of beam distribution within fast instabilities like beam-beam effects has always existed in accelerator physics. The corresponding diagnostics should provide a one-turn distribution for a few ten thousand turns of the beam. For this purpose we have designed a device based on the Multi-Anode Photomultiplier Tube (MAPMT, Fig. 1). The Fast Profile Meter (FPM) is a part of the VEPP-4M optical diagnostic system [1,2]. It is applied also for determination of synchro-betatron resonances, phase oscillation monitoring and studying of collective effects.

DESIGN OF THE FPM.

The device includes a MAPMT, a 12-byte ADC, a controller module, an internal memory of 4Mb and 100 Mb ethernet interface. It can record 2^{17} profiles of a beam at 16 points. Discontinuity of the records can vary within $1 \div 2^8$ turns of a beam. Revolution time of a beam in the VEPP-4M collider is 1220 ns and the recording time can last between 0.16 s to 20 s. As a result, the device can analyze the frequency oscillation of a beam in range of 10 Hz — 1MHz. The main parameters of the device are listed in Tab. 1

Table 1. The technical data of the Fast Profile Meter.

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

The optical arrangement (Fig. 2) allows to change the beam image magnification on the cathode of MAPMT from 6× to 20×, which is determined by the experimental demands.

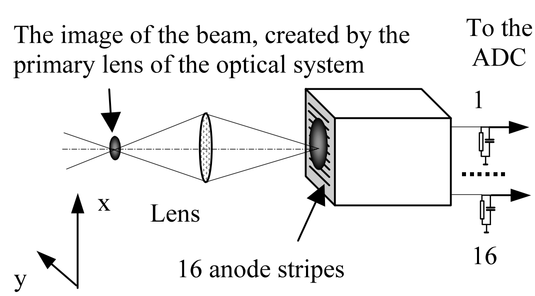

Figure 2. Optical layout of the diagnostics. The lens sets up a beam image on the photocathode of the MAPMT. The radial profile measurement is shown.

The operating cycle of the device is as follows. MAPMT signals are recorded to the ADC after start pulse. The starting moment is either chosen by user or coincides with the beams convergence in the interaction point, “kick”, beam pass by, etc. The ADC triggering is synchronized with the beam revolution frequency. The recorded signals are stored in the internal memory and read out to the PC.

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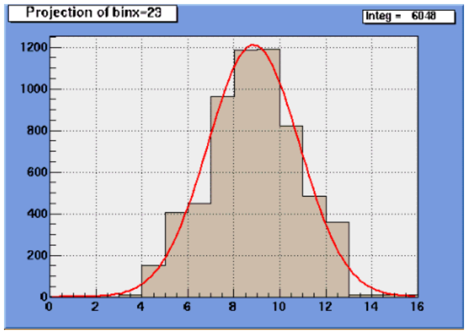

Figure. 3. Example of the single beam profile fitted by the Gauss function.

At present, the signals processing consists in fitting a Gauss function to every single profile and perform a Fourier transformation. The relative sensitivity of the MAPMT channels is taken into account. Typical single profile is shown in the Fig. 3.

EXPERIMENTAL RESULTS

Beam profile behavior during convergence in the interaction point

The standard procedure of the beams convergence is described at [1]. Fig. 4 presents the beam size and position behavior in the case of beam-beam instability. The currents of the beams were restricted by beam-beam effects (Ie^+=3.4 mA, Ie^- =3.0 mA.), and the positron beam is the "strong" one. During evolution of instability taking place, both, dipole oscillations and beam size, increase. Every "flash" of oscillations is accompanied by beam losses.

Frequently beam convergence is accompanied by instability, this looks like beam "twinkling" on the TV screen. The image looks like a small periodical kick applied to the beam. As a matter of fact, this "twinkling" is caused by the oscillation of vertical beam size as Fig. 5 demonstrates.

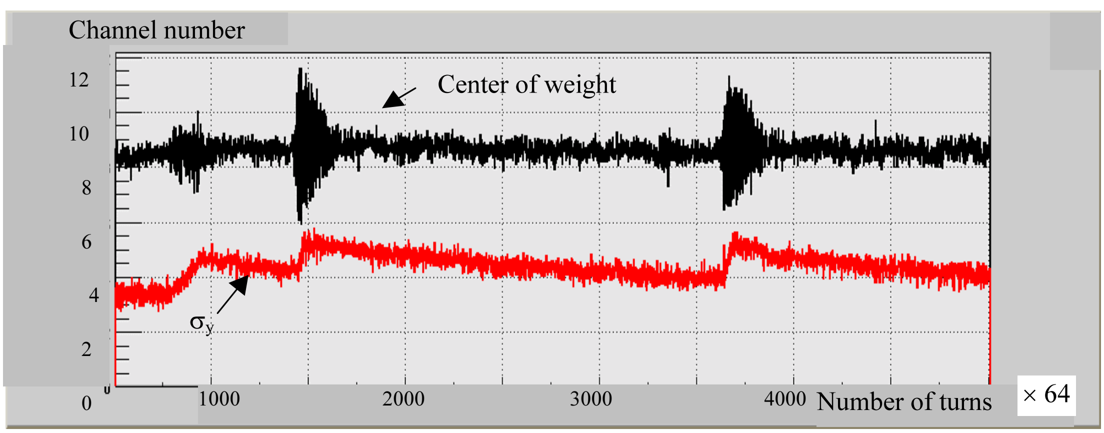

Figure 4. Beam dipole oscillations (black plot) and σ_Y behavior (red plot) during the beams convergence in the interaction point. Duration of the single turn is 1220 ns. Channel constant is 0.12 mm. Ie^+= 3.4 mA, Ie^- = 3.0 mA.

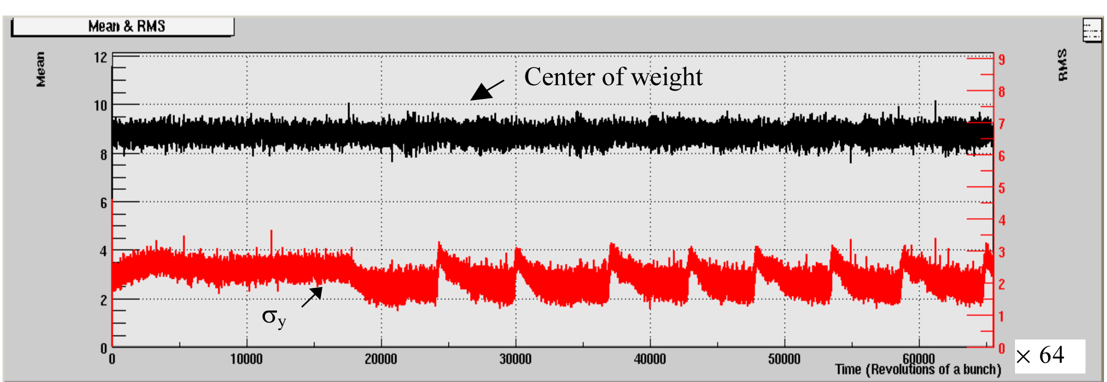

Figure 5. Convergence of the beams with currents of Ie^+=2.4 mA, Ie^- =2.9 mA, accompanied by quadrupole instability.

Measurement of synchrotron frequency and monitoring of phase oscillations.

The experimental program of the VEPP-4M collider and the KEDR detector consists of precise J/ψ -, $\psi^{/}$-, $\psi^{//}$-mesons and c-τ lepton mass determination, for which the method of resonance depolarization is applied [3]. This technique requires a storage of a polarized beam as long as possible. The level of polarization can be destroyed by synchro-betatron resonances. The knowledge of synchrotron frequency and its dependence on the accelerating voltage is necessary for the choice of the working point of the collider. The experimental dependence of the synchrotron frequency with respect to the accelerating voltage have been determined by using MAPMT (Fig. 6). Phase oscillations of the electron beam were excited by slightly detuning the accelerating resonator.

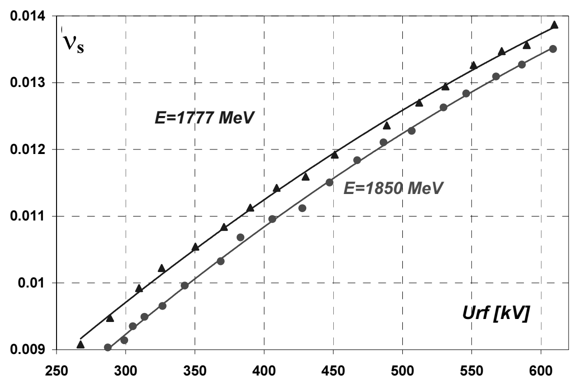

Figure 6. The dependence of the synchrotron frequency ν_s with respect to the accelerating voltage U_{rf}

Parasitic phase oscillations appearing during collecting the data can distort the beam energy and the energy spread. MAPMT is used as a phase oscillations monitor during the collider operation. Monitoring consists in a permanent measurement of the radial position of the beam and Fourier analysis. The maximal value of the Fourier harmonics within an area corresponding to synchrotron oscillations (0.01-0.014 for VEPP-4M) is determined. The KEDR team uses this information (Fig. 7) for selection of the events.

12. 05. 05. The VEPP-4M night run.

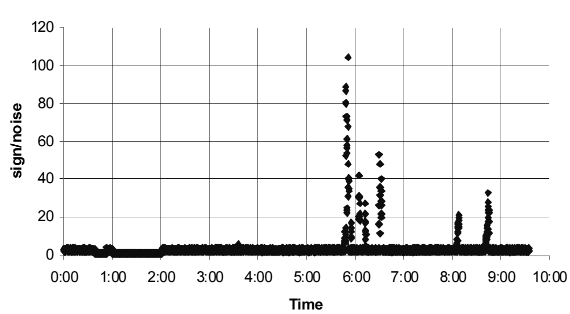

Figure 7. Monitoring of parasitic phase oscillations. MAPMT data are shown.

Tune plane scanning.

The knowledge of betatron resonances is necessary for the determination of the accelerator working point. It is easy to calculate a tune plane, but experimental proof of the resonances manifestation is of immediate interest. Fig. 8 represents the result of betatron tunes scanning around the working point of VEPP-4M. Frequency measurement was made with the help of MAPMT. The beam was kicked with an amplitude of 0.2 $\sigma_{x,y}$ and the ν_x, ν_y frequencies were determined by Fourier transformation. The vertical beam size σ_y was measured permanently with optical system [1] and the resonances appear as an increase of the vertical beam size.

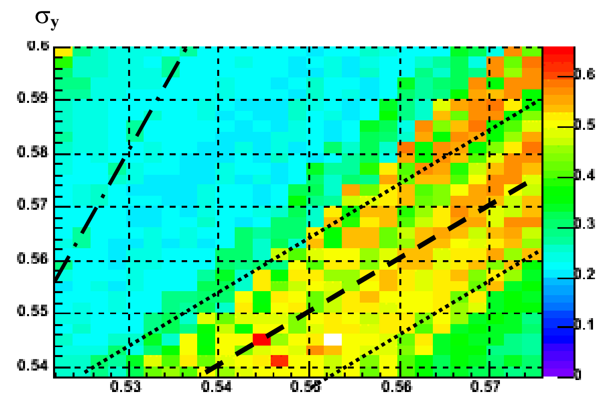

Figure 8. Vertical beam size σ_y with respect to betatron frequencies. The main resonance ν_x-ν_s = 0, two synchro-betatron resonances ν_x-ν_s ±ν_s =0 and 3ν_x-ν_s=1 are shown.

CONCLUSION

The Fast Profile Meter based on MAPMT was designed and applied at the VEPP-4M collider. The device enables the study of the beam profile behavior under diverse experimental conditions and the measurement of beam frequencies within a wide range. The FPM can be used for accelerator physics research and routine machine service.

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