VEPP-4M OPTICAL BEAM PROFILE MONITOR WITH ONE-TURN TEMPORAL RESOLUTION

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Abstract

The transverse beam profile monitor based on Hamamatsu multi-anode photomultiplier with 16 anode strips is used at VEPP-4M collider. The monitor is applied to study turn-to-turn dynamics of the transverse beam profile during 2^{17} turns. The device enables to provide a permanent measurement of synchrotron and betatron frequencies as well.

INTRODUCTION

The interest to study of beam distribution during development of fast instabilities the same, as beam-beam effects always existed in the physics of accelerators. The corresponding diagnostics should to provide a one-turn distribution during tens thousand turns of a beam. For that we have designed the device based on the multi-anode photomultiplier (Fig. 1). The fast profile meter (FPM) is a part of the VEPP-4M optical diagnostic.

DESIGN OF THE FPM.

The device includes MAPMT, 12-byte ADC, controller module, internal memory of 4M and 100 Mb ethernet interface. It enables to 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 record time can continue from 0.16 s to 20 s. As a result the range of frequency oscillation of a beam, that the device can analyze, is as big as 10 Hz — 1MHz.

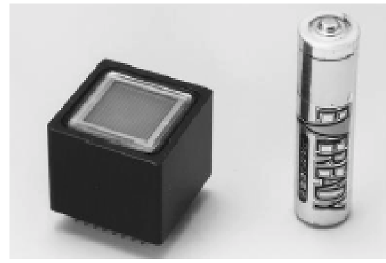

Figure 1: MAPMT R5900U-00-L16 HAMAMATSU

Main parameters of the device are listed in Tab. 1

Optical scheme enables to change the beam image magnification on the cathode of MAPMT from $6^{\times}$ to $20^{\times}$. The choice of this value depends on the experimental demands.

Fig. 2 presents electrical network of the device. MAPMT is figured as a source of current, that generate pulses following with a beam revolution frequency. Rise-up portion of the pulse $\tau \approx 2$ ns determines of temporal resolution of MAPMT. Falling edge of the pulse depends on time constant of RC-chain, $\tau_{RC} \approx 200$ ns. Operating point for ADC measurements was selected experimentally. It was determined of the maximal signal-to noise ratio.

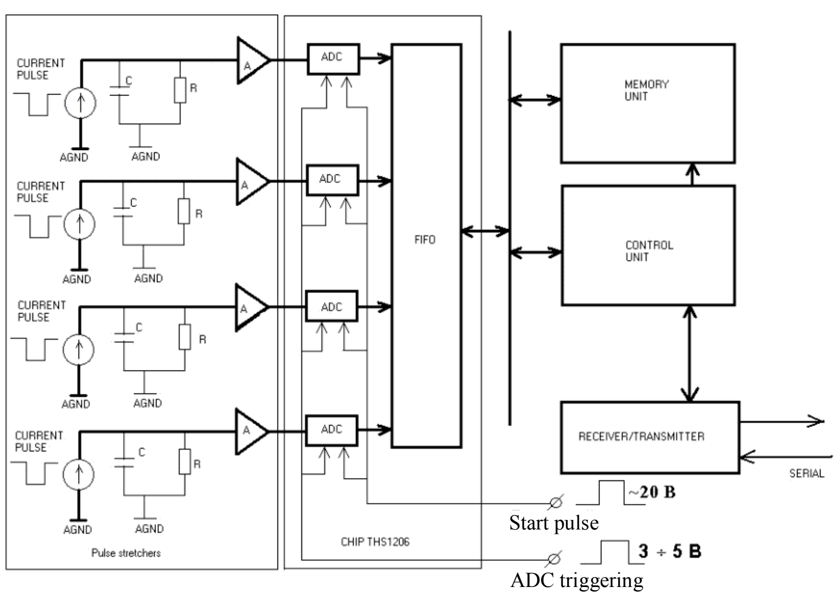

Figure 2: The electrical layout of the fast profile meter.

Table 1. The technical data of the fast profile meter

Size	250 x 100 x 100 mm
Interfacec	100M 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 $\times$ 16 mm

The operating cycle of the device is the following. MAPMT signals were recorded of ADC after pulse of a start. The start moment was choice by user or connected with beam convergence in interaction point, “kick”, beam pass by, et.. ADC triggering was synchronized with a beam revolution frequency. The recorded signals was stored in the device internal memory and read out to the PC. The preliminary data presentation is shown on the Fig. 3.

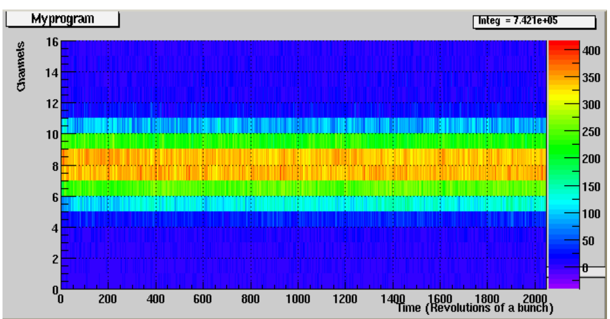

Figure 3: Preliminary data presentation. Amplitude of the signal is scaled in artificial colors.

At present time the signals processing consists in fitting of a single profile by the Gauss function. Relative sensitivity of the MAPMT channels takes into account. Typical single profile is showed on the Fig. 4.

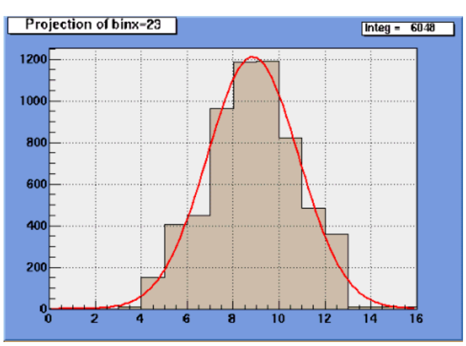

Figure 4: Example of the single beam profile fitted of the Gauss function.

EXPERIMENTAL RESULTS

Kick

Example of the device operation is presented on Fig. 5. The vertical beam position and size (σ_Y) after kick was recorded. The kick started at a time $t \approx 400$ of the beam turns. Upper curve on each figure shows the dynamic of a centre of the beam and down curve is the beam size. One can see that beam oscillations damps after 1000 turns and beam size relaxes to the equilibrium value during radiation dumping time. The time of decoherence could be obtained from these data as well.

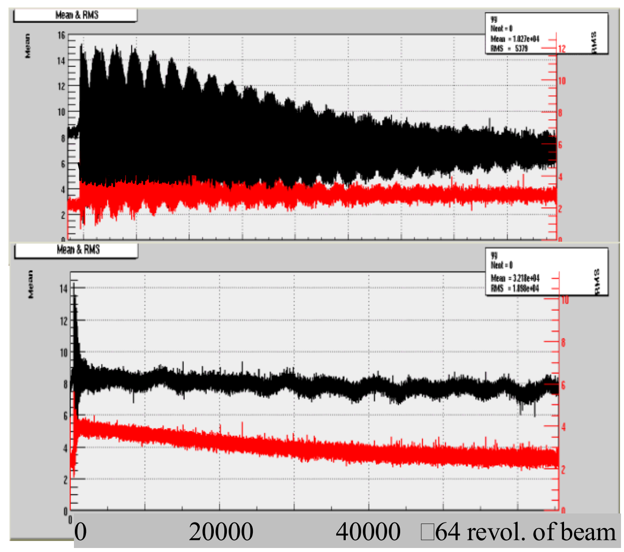

Figure 5: Beam profile dynamic after kick. Upper curve of every plot is a centre-of-weight of the beam. Down curve represents behavior of the beam size σ_Y.

FPM sensitivity sufficiently exceeds a sensitivity of the pickup electrodes, besides it the devise provides information about beam size. FPM enables to study a quadruple mode of a beam oscillations, which pickups aren’t sensitive. It demonstrates very clearly during record of beams convergence in the interaction point.

Beam profile behavior during convergence in the interaction point

The process of beam convergence is presented on the Fig. 6. The currents of the beams weren’t restricted of beam-beam effects, and no particle losses took place. The procedure of the convergence involves two stages. At the beginning of it the beams converged at the distance of $0.5\,\sigma_Y$. It corresponds to the zero moment on the Fig. 6. One can see the slow growing of the beam size. That value rises to some equilibrium level. After 1.4 s the precision enrollment switches on and a size decreases during radiation dumping time. It is significant that dipole oscillations are practically absent, thus couldn’t be recorded of pickup electrodes.

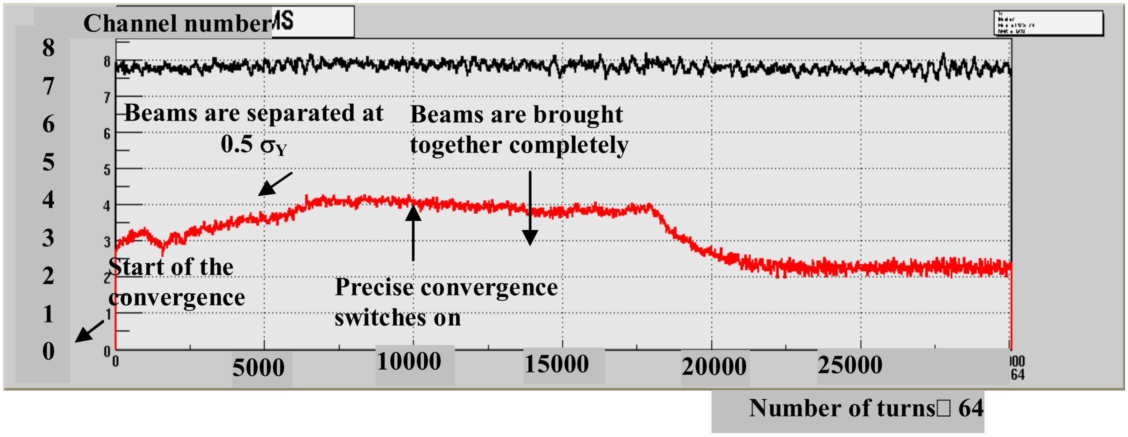

Figure 6: The position of center-of-weight of electron beam (upper line) and σ_Y behavior (down line) during the beams convergence in the interaction point. The total process duration is nearly 10^6 turns of the beams. Time of the single turn is 1220 ns. Channel constant is 0.2 mm.

Beam frequencies measurement

Fourier analyze of the beam center position enables to measure synchrotron ν_s and betatron ν_X, ν_Y frequencies. Besides it, the oscillations of Hz range can be determined (Fig. 8). The last one is important for polarization experiments, that are carried on the VEPP-4M because 50 Hz noise can distort data during the precise energy calibration.

CONCLUSION

The fast profile meter was designed and applied at the VEPP-4M collider. The device enables to study a beam profile behavior under diverse experimental conditions and to measure beam frequencies within a wide range. The FPM can be used for accelerator physics researches and routine machine service.

REFERENCES

[1] O. I. Meshkov et al. The upgraded optical diagnostic of the VEPP-4M collider. This conference.