BEAM MEASUREMENT SYSTEM OF VEPP-2000 INJECTION CHANNELS*

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Abstract

The paper presents single-flight beam diagnostic system for VEPP-2000 acceleration complex injection channels. The system includes two types of beam position monitors: six secondary emission monitors and eight wall current monitors joined into the facility automation system. Beam monitors suited for beam energy up to 900 MeV and number of electrons or positrons 10^8 – 10^{11} particles per bunch.

The paper describes beam position monitors and their peculiarities, hardware and software, as well as automation possibilities which the system provides to lossless beam transportation tuning.

OVERVIEW

Tuning of transportation channels and beam injection system was an important stage of commissioning of the new accelerator complex VEPP-2000 [1, 2]. Injection channels have complicated 3-dimensional geometry (figure 1) [3, 4]. They have 15 m length and 12×6 mm^2 physical aperture. Beams, stored in the booster, are injected to the collider by the one-turn method in horizontal plane to the straight section with zero dispersion function. Both DC and pulsed (quads and dipoles) magnets (figure 2) are used in channel's optics.

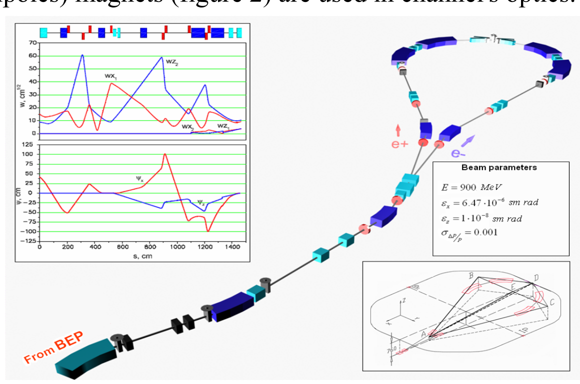

Figure 1: Injection channels of the VEPP-2000 accelerator facility. On the left insets amplitude Floquet functions (top) and dispersion functions (bottom) are shown. On the right insets beam parameters and the wire frame model of the channel's geometry are shown.

The work on lossless beam transport through the channels was closely related to commissioning of the single-turn beam position monitors in the channels. The system of beam diagnostics, presented on figure 2, consists of secondary emission monitors and wall current monitors.

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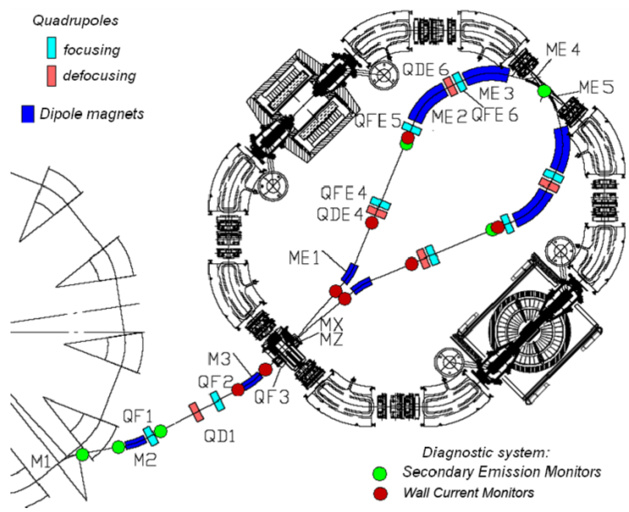

Figure 2: Magnetic system and beam diagnostic system of VEPP-2000 injection channels.

SECONDARY EMISSION MONITOR

Secondary emission monitor (SEM) is a set of thin tungsten wires positioned like net with 45° rotation in transverse to the beam plane. Wire diameter is 28 mkm, step between wires – 1 mm. The beam, passing through the monitor, emits out secondary electrons from the wires making it positively charged. Wires are connected to the inputs of the integrating amplifiers. The amplified signal digitized by the multi-channel 14-bit ADC [5].

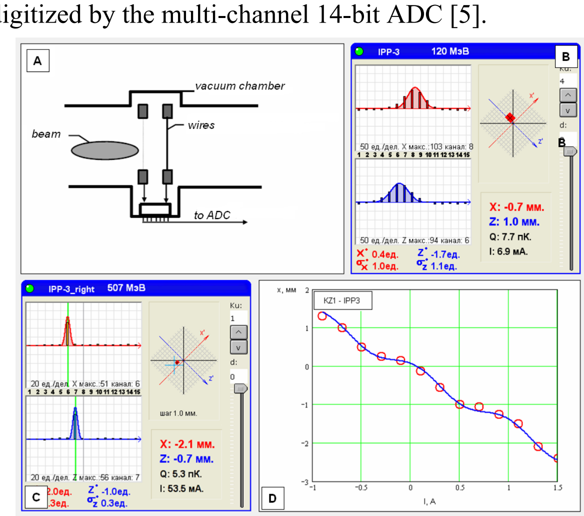

Figure 3: Secondary emission monitors. A) Scheme of monitor; B) Beam profile at the energy of 120 MeV; C) The beam profile, energy 507 MeV; D) The dependence between some steering dipole field and beam position. Picture demonstrates typical systematic error of the SEM – "staircase" effect.

The time of discharge of the wire is about 10 ms because of the connecting cable capacity (200 pF/m). It allows having SEM start time shift about several milliseconds to avoid the influence of pulsed systems on the signal from wires.

Secondary emission sensors have a good protection to the pulse influence and low noise level but the precision of the measurements decreases dramatically if the beam size is comparable to the step of sensor wires [6]. Moreover this type of sensors is not beam transparent. Typical transparency of the SEM used at VEPP-2000 is about 2-4% dependent on the beam size.

WALL CURRENT MONITOR

Wall current monitors (WCM) measure pulses of current which induced by the beam in the wall current lines placed in the insulator gap of conducting vacuum chamber. The lines are connected through 1:20 increasing transformers by 50 Ohm cables to the inputs of special peak detectors. Beam position determines by proportion between amplitudes of pulses on different image current lines. Sum of these amplitudes gives total current of the beam. The algorithm of normalization on doubled own sums leads to purely radial distortions of coordinate grid of the monitor, which could be calculated analytically.

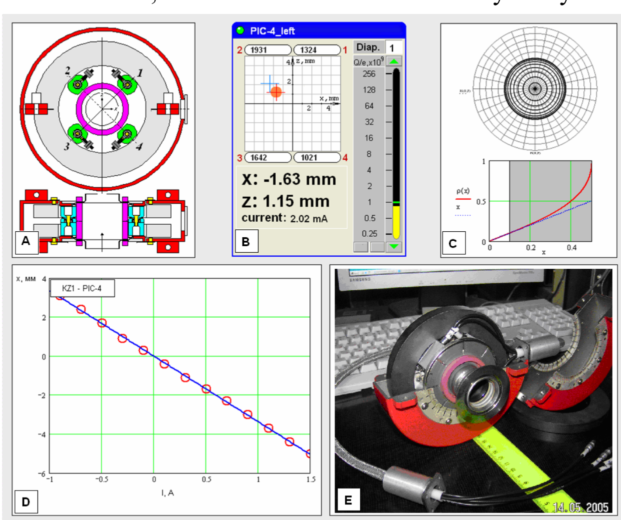

Figure 4: Wall current monitors. A) Monitor schematic (vertical and horizontal cross-sections); B) Signal from WCM. Amplitudes from four image current lines and a level of a signal in a logarithmic scale are shown; C) Typical distortions of a coordinate grid and the physical aperture of the channel in comparison with the linear diapason; D)The dependence between current of correcting dipole magnet and measured beam position; E) WCM picture.

Analogous part of each detector includes the shaper made from section of long line, which splits input signal onto two opposite polarity ones digitized separately. Use of such shaper allows solving some part of problems with the noise effects [7]. All eight signals (positive and negative for each of four current transformers) are digitized by the multi-channel 14-bit ADC with the same characteristics as for the SEM.

Main advantages of the WCM to SEM are its beam transparency and absence of the “staircase” effect.

HARDWARE AND SOFTWARE

Every secondary emission sensor is served by Beam Position Monitor (BPM) station [5]. Image current monitors are connected to Pickup (PU) stations [7]. BPM and PS have unified interface and could be connected serial way to the BPM-standard line, providing power supply for stations and data transfer from them by the same line. To connect BPM-line to PC on VEPP-2000 facility CAN-BPM interface modules are used (CAN Bridge at figure 5) [8]. The module connects BPM-lines to a control PC through a CAN-Bus interface [9].

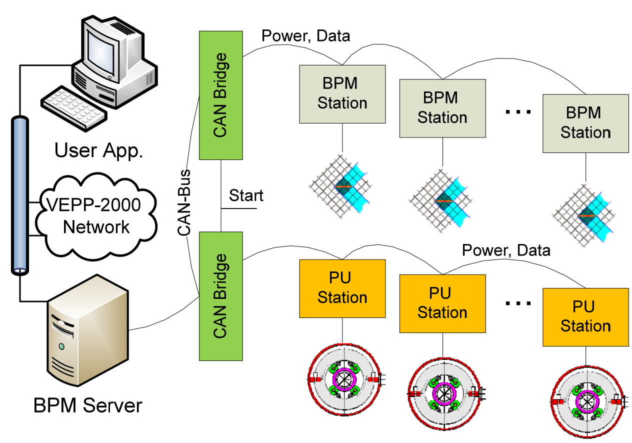

Figure 5: Hardware of the beam measurement system schematic.

Software of the beam diagnostic system is based on client-server architecture over TCP/IP protocol and integrated into the automation system of the facility. The software provides to operator all functionality for the beam measurement: collecting and subtracting backgrounds, automatic switching to electrons or positrons mode of operation, remembering best beam passages, writing history and averaging selected beam “shots” etc. Figure 6 shows screenshot of up-to-date graphical user interface of beam channel diagnostic system.

CONCLUSION

The experimental investigation of the properties of both sensors types during the facility commissioning was carried out. Noise levels of measurement of coordinate and current were determined. Systematic errors of secondary emission sensors, which are defined by the discrete properties of the set of sensitive elements (wires), were carefully studied also.

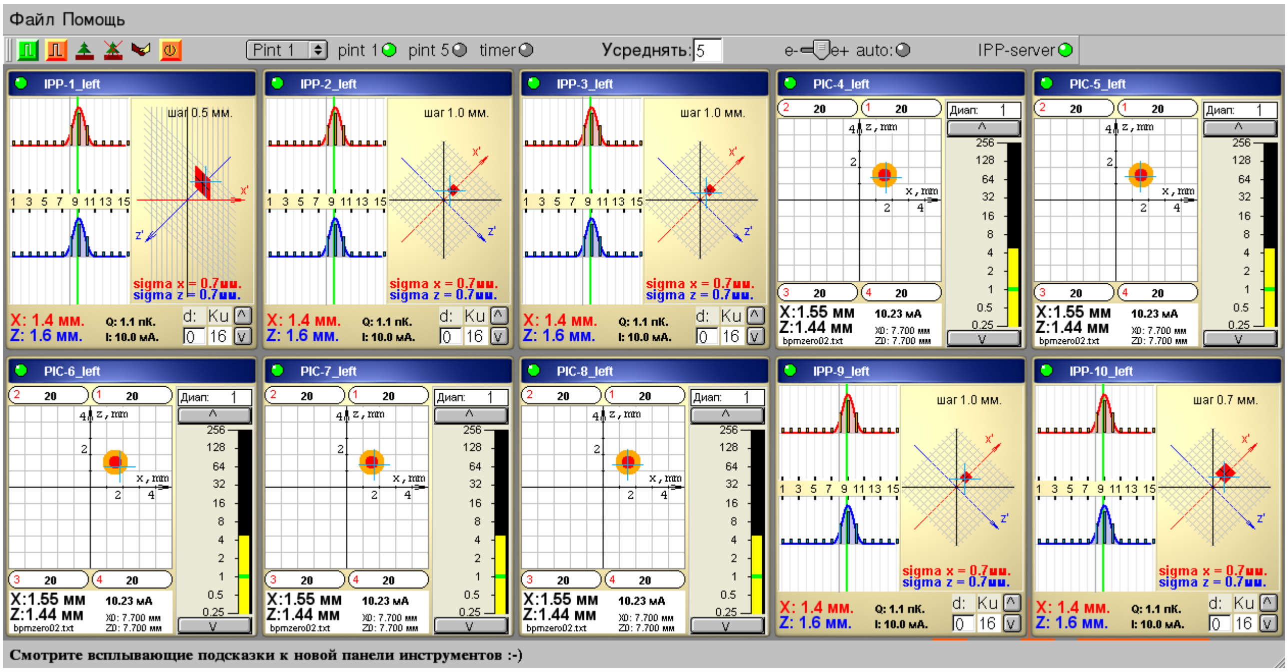

Figure 6: Graphical user interface of client program for beam diagnostic system.

Wall current monitors have demonstrated coordinate measurement noise level about 50 mkm, and nearly zero relative error due to nonlinearity in the aperture of the monitor (see figure 4D). Image current monitors of this type were used on VEPP-2000 for the first time, and they had demonstrated good performance during facility commissioning especially with the beams with low number of particles.

As for the SEM, one interests not of the absolute beam position but dependence between tuning parameter and beam position in process of tuning the channels magnetic system. This dependence could be measured very precisely by fine scanning beam position with the tuning parameter (magnetic field of one of correctors in the injection channel steering) and with averaging and using fitting procedure to avoid “staircase” effect (figure 3D). In this case determined noise level of coordinate measurement for secondary emission sensors is about 60 –70 mkm even for beams which transverse size comparable with wires step.

Worked out beam measurement system of VEPP-2000 injection channels provides flexible instrumentation for beam tuning and almost lossless beam transportation was achieved during facility commissioning.

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