BEAM MEASUREMENT SYSTEM FOR VEPP-2000

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Abstract

This paper describes several beam instruments for VEPP-2000 [1] ring at Budker Institute of Nuclear Physics. These beam instruments include: a DCCT measurement system to measure the beam DC current and beam lifetime; a closed orbit measurement system and a transverse beam profile measurement system including several button-type electrostatic beam position monitors (BPM), optics, acquisition tools and high resolution CCD cameras distributed around the storage ring to measure the beam profile and its position; a tunes measurement system to measure the beam tune. Some applications of these measurement systems and their measurement results are presented.

INTRODUCTION

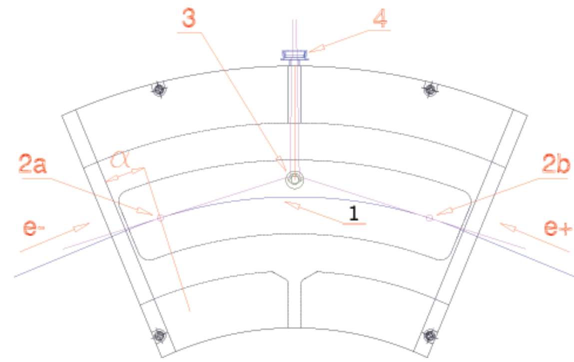
The new electron-positron collider VEPP-2000 ring is a part of VEPP-2000 complex [2] at BINP has been successfully commissioned and has been delivering luminosity at energy close to 508 MeV since June 2007. VEPP-2000 is a new machine with luminosity up to 10^{32} $cm^{-2}s^{-1}$ and the beam energy from hadron production threshold up to 2×1 GeV. Small ring size and sophisticated optics lay on limitation on beam quality and operations. Therefore such modern machines requires various beam diagnostics for perfect tuning.

BEAM ORBIT AND TRANSVERSE PROFILE MONITOR

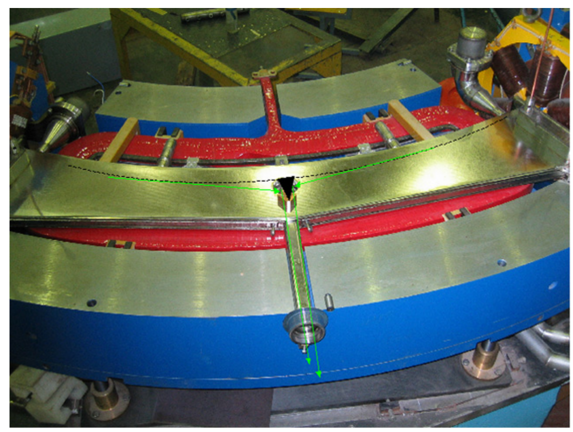
SR Acquisition System

Beam parameters in the VEPP-2000 collider measured by the Synchrotron Radiation (SR) at 8 points along the ring for both (e^+e^-) directions. Polished copper plates installed in the vacuum chamber, are used for output the SR from the bending magnets. The SR after passing through vacuum glass window comes to the optical diagnostics station and then is distributed by the half-transmitting mirrors Fig. 1-2.

Each station equipped with two CCD cameras (for positron and electron beams) for measurements the beam size and position. Because the SR outputs are located in orbital positions with very small dispersion function, four additional places are foreseen for dispersion and its symmetry control, and the beam position is measured in these points with pick-ups. In some stations the SR are used for beam current measurement (by the PMT) and will be used for the longitudinal beam sizes control in future (by the dissectors).



(a) 1-beam orbit, (2a, 2b)-radiation point of e^+e^- beams, 3-copper mirror, 4-output window, $\alpha = 4°47'$.



(b) Vacuum chamber and mirror after assembling. Additional mirror is placed in the center for comparison.

Figure 1: SR output in bending magnet.

CCD camera

Processing of optical part of the SR in circular accelerators allows one to obtain various beam parameters – vertical and radial sizes, axes tilt, position in a vacuum chamber. There is non-perturbative diagnostics that can work with super small beam currents.

The essential nonlinearity (gamma correction) and low spatial resolution put some limitations on "TV camera + videograbber" system. In the case of a cheap digital TV camera the limitations appear due to space between camera and a computer. Typical values for this distance are about 100 m. Therefore the decision of development special camera based on b/w CCD of the type *ILX084AL* was taken from the very beginning. This CCD in 1/3-inch format has in working area 494 rows of 659 elements (i.e. about $330{,}000$ active diode target cells) and uses so-called line-to-line transfer, when diode columns alternate with light-proof vertical storage registers. For high sensitive to obtain a matrix of light-collecting microlenses is placed on the

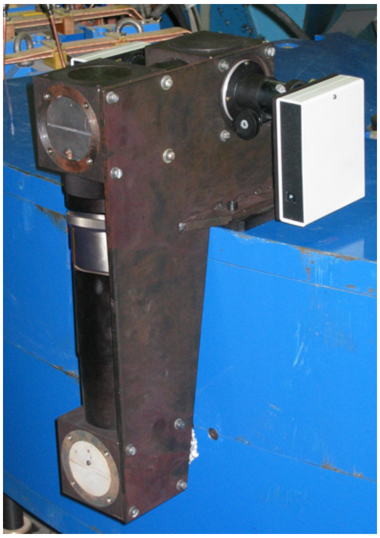


Figure 2: Optical bench with system of movable mirrors and SR diagnostic station with two CCD cameras.

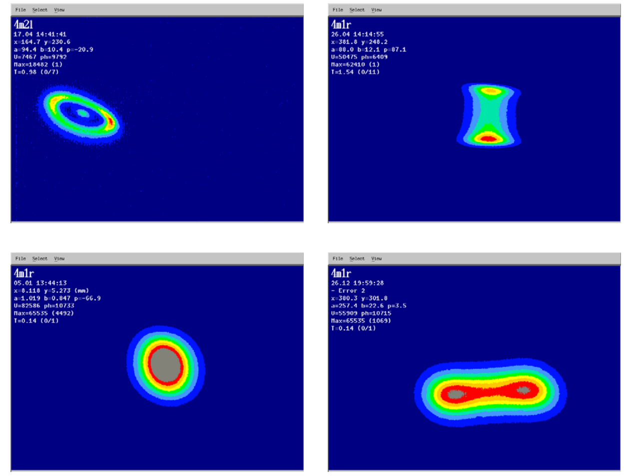


Figure 3: Beam profile at different moments.

CCD surface. Saturation charge of the cell is about 40000 carriers, a noise charge is about $30 - 40$ carriers.

The camera structure is developed under Ethernet 100 MHz standard. Usage of this standard allows one not to have in the camera internal memory unit and to real-time transfer the information from the camera to a computer. Reading rate is about 1/12 sec per frame. It is possible to install in the camera 3-channel ADC AD922. This 14-bit ADC has a double correlated sampling regime as well as independent correction of sensitivity and offset for each channel. In a standard configuration only one ADC channel is connected to the main CCD, but it is possible to use two channels as is needed in case of VEPP-2000 collider (electron and positron monitors is placed together).

Software

This subsystem software is based on client-server model over TCP/IP protocol. All cameras have own unique MAC address and are connected to the same private subnet (because server interact with CCD over RAW TCP protocol) in the VEPP-2000 private net. Server execute incoming configuration or measure requests and return to the client both picture of beam and calculated data. Elliptical beam profile model are fitted to the real data, so special algorithms are implemented in server for data fitting and calculation position, axes main sizes and axes tilt, parasitic background. Transverse Profile Monitor application, providing to the operator online picture of the beam, presented in Fig. 3. The program can store pictures in different formats and allows online hardware configuration.

BEAM POSITION AND TUNE MONITOR

The VEPP-2000 collider ring is equipped with a system of beam position diagnostics based on four electrostatic Beam Position Monitors (BPM), frontend electronics located near BPMs and readout electronics in CAMAC standard. BPM consists of four button-type electrodes at the angle of 45° to horizontal plane, mounted into vacuum chamber ($\varnothing 34$ mm).

The signals from four BPM electrodes are simultaneously processed with four channels of processing electronics. Each channel consist of LPF with cut-off frequency of 110 MHz, programmable gain amplifier and 12-bit ADC. Time interval between electron and positron bunches is about 20 ns for each BPM. Analog electronics bandwidth of 100 MHz allows us to decrease the crosstalk of electron and positron bunches signals at level of $0{,}5$ dB. Timing circuit provides ADC samples at the top of beam signal. Delay range covers all revolution period with step equal $0{,}25$ ns. Amplifier range of 22 dB allow us operate with $1 - 100$ mA beam current.

Beam position is measured at each turn (up to 32k). So one can measure betatron frequencies using FFT technique, or obtain slow data with averaging of results for any chosen number of turns. Synchronization of the system with beam injection gives the possibility of the beam position measurements for the first turn and measurements of the betatron frequencies after injection. Although the system allows measurements of the betatron frequencies after external excitation.

Each BPM was calibrated on the special test bench before vacuum chamber installation. During storage ring commissioning precision of the BPM system has been measured [3]. For example coordinate temperature stability value 2 μm/$^\circ$C, another parameters are in Table 1.

Software

This subsystem software is based on client-server model over TCP/IP protocol. CAMAC controller based on PowerPC with OS Linux [4] is used, because heavy traffic limitation and high rate response requirements. Two level

Table 1: BPM System Parameters

Beam Current	**Resolution Turn by turn**	**Resolution 256 turns average**
0,1 – 1 mA	150 – 500 μm	10 – 30 μm
1 – 10 mA	50 – 150 μm	3 – 10 μm
> 10 mA	< 50 μm	< 3 μm

server scheme is used: there main server works on PC and its main goal is to receive incoming requests and initiate measurements; slave server works on CAMAC controller and its main goal is hardware serving and returning measured data to the master server as fast as possible (actually speed is limited only by hardware carrying capacity). Tune calculation with specific filtering, approximation and signal-to-coordinate conversion are made on the client side. Examples of an end-user application is presented in Fig. 4.

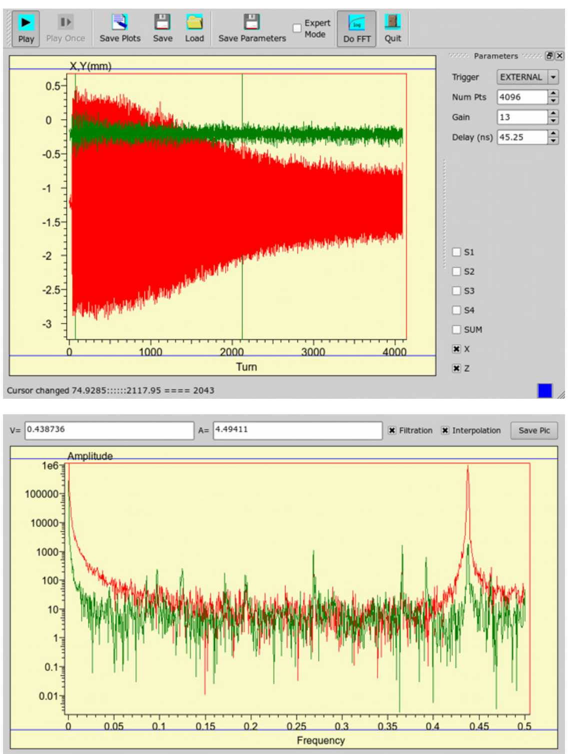


Figure 4: Beam oscillation after injection during 4000 turns and their betatron spectra.

BEAM CURRENT AND LIFETIME MONITOR

Higher Intensity ($\sim 10^{10}$) *Circulating Beams*

A DC Beam Transformer (DCBT) is used to measure the bunched or unbunched circulating beam current. Because DCBT can measure only total charge amount and there are two beams with different charge rotating together, so we need some additional information about relative beam intensities. This information one can obtain from the BPM system, because total signal from all BPM's tablets is proportional to the beam current.

Low Intensity ($\sim 10^{8}$) *Circulating Beam*

As mentioned above the SR intensity measurement is used for beam current measurements in case of low beam intensity. Signal from PMT measured by the integrating 8-bit ADC is proportional to the real beam current. So the DCBT values with sufficient electron beam are used to cross-calibrate the low intensity PMT-based measurement system. This system was used in early stage of VEPP-2000 commissioning, and now days used in some specific cases for tuning, because adequate optical intensity attenuation system is under construction.

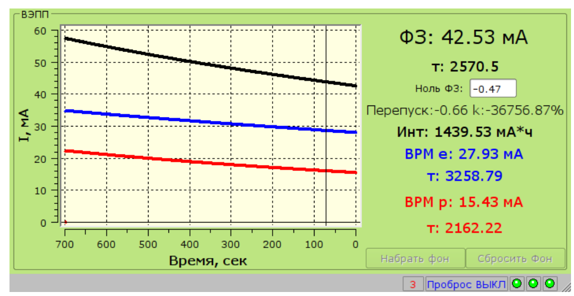


Figure 5: Beam currents and life time monitor.

OTHER SYSTEMS

The VEPP-2000 and the beam transfer lines have other measurement systems installed for routine usage. There are a number of secondary emission monitors and image current monitors to measure beam position and tuning beam transport, installed into injection channels [5]. There are couple scintillation screens used for beam observation with TV cameras. For specific tune measurements the swept Beam Transfer Function (BTF) measurements is used. All systems are integrated in common VEPP-2000 Collider Control System.

REFERENCES

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