The new electron-positron collider VEPP-2000 ring is a part of VEPP-2000 complex [1] at BINP has been successfully commissioned and is being delivered luminosity at energy close to 200 GeV since June 2007. VEPP-2000 is a new machine with luminosity up to 10^35 cm^-2s^-1. The synchrotron oscillation frequency from hadron production threshold up to 2 ev. 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 and ask us to monitor the beam status quickly and accurately.

The measurement and control of the closed orbit is one of the basic functions of any accelerator beam instrumentation and control systems. A beam position monitor (BPM) system is operated for two kinds of orbit measurements, a relative measurement and an absolute measurement. The former is to measure the orbit displacement from the initial or standard orbit when some optics perturbation is applied. The latter case is to measure orbit position relative to the geometrical center monitor. This function will be especially important in a ring in which the optics depends strongly on the orbit, particularly at nonlinear optics settings.

The VEPP-2000 electrostatic BPMs system is not only used to measure the beam orbit and correct the closed orbit distortion (COD). It has also been used in the interaction point (IP) beam steering along the detectors, control and adjustment of the beam oscillation amplitude during the injection, measure the dispersion functions and the betatron frequency.

2. SYSTEM HARDWARE

The VEPP-2000 collider ring is equipped with a system of position monitors situated in a technical straight section located near BPMs and readout electronics in CAMAC standard. A set of low loss coaxial cables brings up the BPM signals of each detector to the local control room, where the signal readout and processing electronics is located. The lengths of cables vary from 5 to 200 cm corresponding to the locations of the detectors in the storage ring. Each BPM is placed in the center of the technical straight section surrounded with two quadrupole magnets. Between them, electrical very close pickup electrode for each BPM is calibrated by a calibration bench with a wire method.

2.1 BPM Block

The beam position monitor for VEPP-2000 ring consist of four 15 mm diameter button style pickups are mounted on the diagonals of its housing and are centered symmetrically. The button type pick-up electrodes are capacitive coupled to the beam, are most popular with electron-positron rings because they occupy very little longitudinal space and the coupling impedance is small. Buttons orientation is ± 90 degrees to avoid the fan of synchrotron radiation. All parts precisely machined from solid stainless steel, button electrode and feedthroughs with ceramic material. The electrode surface is smoothed with that of the vacuum chamber, so the impedance induced by the electrode may be reduced greatly.

2.2 Electronics

The signals from four BPM electrodes are simultaneously processed in a dedicated BPM electronics unit. Each channel consist of LPF with cut-off frequency of 100 MHz, programmable gain amplifier and 12-bit ADC. Time interval between electron and positron bunches is about 25 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 BPM signal. It is achieved by means of programmable delay of reference pulses with revolution frequency. Delay range covers all revolution period with step equal 0.25 ns. Amplifier range of 45 dB allow us operate with 1 - 100 mA beam current.

3. DATA ACQUISITION SYSTEM

The data acquisition system is based on client-server model over TCP/IP protocol. PowerPC embedded CAMAC controller, which running Linux operating system [2], is used to initialize electronics and perform the data acquisition operation. Such choice is caused by heavy traffic limitation and high rate response requirements. Two server-level 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). The controller communicates with electronic via CAMAC bus by using compiled command system for programmable instruments. All software uses the CX libraries set. The network interface is developed under X-Windows/Qt/TeTk environment.

The acquired signals from button electrodes are filled into the memory of the ADC with a revolution clock of the ring (f = 12.5 MHz). The memory depth of the digitizer is up to 12 Kwords (i.e. beam position is measured at each turn with maximum record length is about 7.5 ms). So one can measure betatron frequencies using FFT technique, or obtain slow data with averaging of results for any chosen number of turns (say 50 turns, 8 point average @ 10 Hz). System is based on 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 oscillation.

The raw data, the calculated beam position, the betatron tune and the phase space plot are presented on the screen in interactive basis. The experimental data can also be stored on mass storage devices for off-line analysis.

4. ACCURACY OF THE SYSTEM

During storage ring commissioning precision and stability of the BPM system has been measured. [4]. There are several numbers of sources of errors during beam position measurements: temprature instability, time jitter of the ADC trigger pulses, quantization noise of ADC, interferences in BPMs and cables connecting BPMs with processing electronics and so on. Temperature instability of the processing channels gains and the delays formed with Delay lines leads to temperature instability of the beam position measurements. Experimental examination gave the temperature instability value ± 5 µm/°C. Then temperature instability of the time delays leads to temperature instability of the beam position measurements mainly due to the differences in BPM cables lengths and gain-frequency characteristics of the processing channels. So electrical length of each cable was measured and made equal ones for each BPM. An和其他 experimental investigations have shown that major contribution to coordinate error is brought by interferences in the cables connecting BPMs with processing electronics. Some measures and efforts have been made to reduce these interference. One of them is using of double-shielded coaxial cables.

<table>
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<tr>
<th>Table 1: BPM system parameters.</th>
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<tr>
<td>Resolution</td>
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<td>0.5 – 10 m</td>
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<td>10 – 50 m</td>
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The main reason of beam position from beam current dependence is nonlinearity of programmable attenuators, amplifiers and multipliers. Some results and parameters are present in Table 1.

5. APPLICATIONS

5.1 Beam position and Tune monitor

The flexibility of the system allows to perform a series of turn-by-turn measurements. The FFT can be moved over the data by a user defined step to generate a "spectrum movie" and see dynamic processes in the beams during injection or other operations. The signal-to-noise ratio and proper signal characteristics have been made on the client side. Examples of user-end application presented on Fig. 3(a). Beam injection is one of the significant tasks for the client side. Examples of user-end application presented on Fig. 3(b). Beam injection is one of the significant tasks for the client side.

Figure 1: The beam position monitor for VEPP-2000 ring. The BPM is integral part of the quadruple vacuum chamber of the technical straight section, which in turn is referenced to the magnet axis by means of supporting arms, and assembled on the top of the vacuum chamber by welding, assuring no gas leak. To reduce the interference of magnetic field from the same vacuum chamber dimensions, BPM housing has the same cross section form and dimensions, and coincides with the vacuum chamber within ± 5 mm. Fig. 1 shows a beam insensitive area and common view of the BPM before assembling.

Figure 2: Structure of VEPP-2000 electronics.

Figure 3: Beam oscillation after external kick during 256 turns and their betatron spectra.

Figure 4: Beam oscillation after injection.

Figure 5: Dispersion function. Point near picks maximums is the BPM measurements. The BPM system is very sensitive for dispersion function measurements, because our BPMs located in the places with maximum dispersion function. Fig. 5 shows the dispersion measured before and after applying of calculated corrections for quadrupoles gradients and solenoids fields.

5.2 Intensity and Lifetime measurements

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 during operations with higher intensity level circulating beams. This information one can obtain from the BPM system, because total signal from all BPMs' signals is proportional to the beam current. So one can calculate beam lifetime.

References


Abstract

This paper reviews the present state of electromagnetic beam position monitors (BPMs) at VEPP-2000 collider. It includes description of BPM position monitors, typical interfaces for these monitors, and their system characteristics (resolution, stability, bandwidth and problems or limitations) are discussed. The paper also reviews several types of diagnostic measurements using BPM position monitors which are useful in improving accelerator operations.