Beam Measurements With Visible Synchrotron Light on VEPP-2000 Collider
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1. INTRODUCTION
The new electron-positron collider VEPP-2000 ring is a part of VEPP-2000 complex [1, 2] at BINP has been successfully commissioned and has been delivering luminosity at energy close to 18 GeV since June 2007. VEPP-2000 is a new machine with luminosity up to \(10^{32} \text{ cm}^{-2} \text{s}^{-1}\) and the beam energy from hadron production threshold up to \(2.1 \text{ GeV}\). 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 VEPP-2000 optical BPM system equipped with \(6 \times 6\) cameras registering beam synchrotron radiation have high precision of \(1 \mu\text{m}\), and used to monitor the beam orbit and correct the closed orbit distortion (COD), but hasn’t absolute calibration.

2. 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(a)-2.

2.1 SR acquisition system
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2.2 CCD camera
Processing of optical part of the SR in circular accelerators allows one to obtain various beam parameters – longitudinal 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 nonlinear (gamma correction) and low spatial resolution put some limitations on "TV camera + video grabber" 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 576 elements (i.e. about 300,000 active diode target (cell) and uses so-called line-to-line transfer, when down columns alternate with light-proof vertical storage registers. For high sensitive to obtain a matrix of light-collecting microstructure is placed on the CCD surface. Saturation current density of the cell is about \(60\, \text{mA}\), a noise charge is about 30–40 carriers. The camera structure is developed under Ethernet 100 Mbit/s 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 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).

2.3 Software
The subsystem software is based on client-server model over TCP/IP protocol. All cameras have own unique MAC addresses and are connected to the special private subnet, because of traffic limitation. It may be more than 10 Mbytes/sec, so CCDs subnet is placed on the CCD output. For generation of light on the charge of the cell is about \(60\, \text{mA}\), a noise charge is about 30–40 carriers. Therefore the server provides for requests optimal execution and primary development of CCD frames. Elliptical beam profile model is fitted to each frame and position, axes main sizes and axes tilt are calculating. For the optimized algorithm it takes about 10 milisec to approximate a frame (20000 pixels \(\times\) 500 bits) on Athlon 4000 machine. Also, the server provides clients for more detailed information, such as beam profiles, along X-Y axes, such as beam profile with level lines marked by pseudocolours. According its purposes, clients may request any type of data. The user interface is developed under X-Windows/Motif Qt environment.

2.4 Applications
The system widely used for routine operations: common control, measurement and correction of closed orbit (CO) distortions, specific beam measurements. More precise experiments of solenoid position determination with respect to CO was done in regular "round beam" optics also with use of ORM measurements [3]. There is regime for the system with external synchronization to perform some specific measurements. Synchronization of the system with beam injection gives the possibility of the beam position measurements for the first turn after injection or external signal. Transverse Profile Monitor application, providing to the operator online picture of the beam, presented at Fig. 3. The program can store pictures in different formats and allows online hardware configuration.

3. LIFETIME MONITOR
Online Luminosity calculations based on beam sizes measurement along the ring. The system widely used for routine operations: common control, measurement and correction of closed orbit (CO) distortions, specific beam measurements. More precise experiments of solenoid position determination with respect to CO was done in regular "round beam" optics also with use of ORM measurements [3]. There is regime for the system with external synchronization to perform some specific measurements. Synchronization of the system with beam injection gives the possibility of the beam position measurements for the first turn after injection or external signal. Transverse Profile Monitor application, providing to the operator online picture of the beam, presented at Fig. 3. The program can store pictures in different formats and allows online hardware configuration.

3.1 Low Intensity (\(\sim 10^{10}\)) circulating beam
A DC Beam Transformer (DCBT) is used to measure the bunched or unchurned circulating beam current. 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.

3.2 Higher intensity (\(\sim 10^{13}\)) circulating beams
If there are two beams with different charge rotating together the additional information about relative beam intensities which can be obtained from the BPM system, because DCBT can measure only total charge amount and sum. signal from all BPMs tablets is proportional to the beam current.

4. OTHER SYSTEMS
There are a number analog TV cameras distributed around the ring for both 
(a) 1-beam orbit, (2a, 2b)-radiation point of e+e-, (3)-copper mirror, (4)-output window, (x,y) = (1-1)°.
(b) Vacuum chamber and mirror after assembling. Additional mirror is placed in the center for comparison. Figure 1: SR output in bending magnet.

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

Figure 3: Beam profile at different moments.

Figure 4: Online Luminosity calculations based on beam sizes measurement along the ring. The system widely used for routine operations: common control, measurement and correction of closed orbit (CO) distortions, specific beam measurements. More precise experiments of solenoid position determination with respect to CO was done in regular "round beam" optics also with use of ORM measurements [3]. There is regime for the system with external synchronization to perform some specific measurements. Synchronization of the system with beam injection gives the possibility of the beam position measurements for the first turn after injection or external signal. Transverse Profile Monitor application, providing to the operator online picture of the beam, presented at Fig. 3. The program can store pictures in different formats and allows online hardware configuration.

Figure 5: Beam sizes along the ring vs. lattice model.

Figure 6: Beam currents and life time monitor.

Figure 7: Both colliding beams: electron - left, positron - right. There are couple scintillation screens in the VEPP-2000 injection channels, 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