# NEW STATION FOR OPTICAL OBSERVATION OF ELECTRON BEAM **PARAMETERS AT ELECTRON STORAGE RING SIBERIA-2**

E. Fomin, G Kovachev, V. Korchuganov, V. Moryakov, D. Odintsov, A. Stirin, Yu. Tarasov, A. Zabelin, NRC Kurchatov Institute, Moscow 123182, Russia

A. Khilchenko, O. Meshkov, L. Schegolev, E. Zinin, A. Zhuravlev, Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia

#### Abstract

The given paper focuses on the project of the electron beam optical observation station which is being carried out at the synchrotron radiation storage ring SIBERIA-2 at Kurchatov Institute.

The station serves for the automatic measurement of electron bunches transverse and longitudinal sizes with the use of synchrotron radiation (SR) visible spectrum in one-bunch and multi-bunch modes; the study of individual electron bunches behaviour in time with changing accelerator parameters; the precise measurement of betatron and synchrotron oscillations frequency. The station with its optical measurement system will be located outside the shielding wall of the storage ring.

The paper contains an outline scheme of optical SR beam line and a block-scheme of optical measurement part, describes the principle of operation and technical characteristics of main system elements (dissector tube, CCD-matrix, etc.), and gives an estimation of accuracy of electron bunches parameters measurements.

### **INTRODUCTION**

Kurchatov SR facility is the 2<sup>nd</sup> generation SR light source. It consists of LINAC (pre-injector) with electron energy of 80 MeV, electron booster SIBERIA-1 (SR light source in the VUV spectrum) with electron energy of 450 MeV and main storage ring SIBERIA-2 (SR light source in the X-ray spectrum) with electron energy of 2.5 GeV.

The electron beam optical observation station which is currently operating at SIBERIA-2 uses SR from bending magnet and is located inside the shielding wall of the storage ring. This station transmits to the operator in the control room the visual data about shape, transverse and longitudinal sizes, location and phase oscillations of the electron beam.

Parameters of 2.5 GeV electron beam of SIBERIA-2 storage ring at the azimuth of optical observation station disposition are given in Table 1 below.

The existing optical observation station does not meet modern requirements of beam parameters precise measurement, automatic monitoring and control of electron bunches parameters, computer processing of measurement results.

A new station for optical observation of electron beam parameters is being designed at SIBERIA-2 storage ring in collaboration with Budker Institute of Nuclear Physics, Novosibirsk, Russia. For the purpose of easy operation, control and alignment, the new station will be located outside the shielding wall of the storage ring.

Table 1: Electron Beam Parameters at SIBERIA-2

Bunch repetition rate, MHz	2.415 - 181.14
Revolution frequency, MHz	2.4152
Bunch duration (FWHM), ns	0.16
Bunch sizes, mm: $\sigma_y$ , $\sigma_x$ , $\sigma_s$	0.059, 0.34, 20.0

# **NEW OPTICAL OBSERVATION STATION**

#### Measurement Part

In Fig. 1 a block-scheme of the optical measurement at SIBERIA-2 storage ring is presented. SR originating from bending magnet of SIBERIA-2 storage ring propagates further along the vacuum tube and falls on a metal cooled mirror M1. The visible spectrum of SR reflected from mirror M1 and mirror M2 parallel to it goes through the quartz output window OW out of the vacuum chamber. The light reflected from semitransparent mirror M5 follows to the first diagnostic system based on the doubleslit interferometer.

With the help of mirrors M3 and M5 the light beam is aligned with the optical axis of the main lens L1 which projects a beam image simultaneously on radiation receivers of all systems that make up the diagnosis. Having penetrated through mirror M5, the light beam is distributed by mirrors M4, M6 - M11 between the five remaining diagnostic systems with different functions. All diagnostic systems are located on the optical table outside the storage ring shielding wall. Below is the description of the systems.

Transverse beam sizes precise measurement system based on the double-slit interferometer serves to measure transverse sizes with resolution bunch 1 μm. Interferometry is presently a well developed diagnostic method ([1, 2]).

SR intensity measurement system with turn-by-turn temporal resolution in all separatrices contains an avalanche photodiode functioning as photodetector. For the increase of diagnostic dynamic range a discrete optical attenuator DOA1 is used which consists of a set of neutral light filters with attenuation rate ranging from 10 to  $10^6$  with a step of 10, including one non-coloured glass for optical path alignment. The change of light filters and the control of the lens L1 are performed remotely from main control room.



Figure 1: Block-scheme of the optical observation station measurement part at SIBERIA-2 storage ring.

The measurement system of transverse bunch sizes and bunch relative displacement in radiation point contains CCD-matrix which can operate in continuous and pulse modes (see Table 2).

Table 2: Two-dimension	CCD-matrix parameters
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Number of pixels	659 × 494
Pixel dimensions, µm <sup>2</sup>	7.4 × 7.4
Image accumulation time, s	$10^{-4} - 10$
Frame scan time, ms	80

The result of computer processing of signal from CCDmatrix is a visual two-dimension image of electron beam cross-section, x- and y- curves of electron density distribution within beam, FWHM, position of electron beam centre.

**Beam dynamics TV monitoring system** based on a TV camera is used for transferring the electron beam cross-section image to the video monitor. The mark projector MP2 comprised into this system is an optical device consisting of light source, grid plate and lens, and is used for estimating the beam image scale and matching this image with beam reference orbit.

**Bunch longitudinal sizes measurement system** includes dissector tube with electrical focussing and deflection [3], DOA4 and mark projector MP1. Dissector tube is a photoelectronic device operating in stroboscope mode. Optical electron beam image is projected on the front semitransparent photocathode of the dissector tube. Electrons emitted by photocathode produce an electronic image of the beam which is transferred and focused on

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the plane of scanning slit diaphragm with the help of electric field. After the slit diaphragm electrons follow to the secondary electron multiplier and further to the collector. The signal from the collector is proportional to the density of transverse distribution in x- or -y directions. The scanning of longitudinal distribution of electrons within the beam is performed by low-frequency sweep voltage applied to dissector tube deflecting plates simultaneously with high-frequency sweep voltage.

Dissector tube is also used for the diagnostic of longitudinal multibunch instability caused by electron bunches interaction with high modes of cavity electromagnetic field. Dissector tube time resolution is 40 ps.

The mark projector MP1 serves for the control and calibration of measurement system time scale.

Turn-by-turn beam transverse cross-section measurement system serves the purpose of measuring xand y- distribution of electron density within a chosen bunch, betatron and synchrotron oscillation frequency (defined by way of Fourier analysis of bunch dipole oscillations triggered by kick) as well as investigating xor y- dynamics of beam shape in a chosen separatrix. The system comprises a measuring linear photo-receiver based on 16 avalanche photodiodes (type AD-LA-16-9-DIL18, active area / element -  $648 \times 208 \ \mu\text{m}^2$ , gap - 112  $\mu\text{m}$ ), DOA2 and lens L2. In each of the 16 channels the signal from photodiode is integrated and transmitted to the 12bit ADC with sampling frequency of 50 MHz. 4 MB internal buffer stores the results of ADC measurement and allows recording up to  $2^{17}$  (131072) beam profiles for further processing.



Figure 2: Model of SR beam line under development with measurement part of the station for optical observation of electron beam parameters at SIBERIA-2 storage ring.

**Special software** for optical observation station will allow for automated monitoring and control of electron beam parameters. Graphical user interface will enable the operator to control system operation modes, to change the detectors parameters, to scan, to process and to archive the data.

### SR Beam Line

SR emitting point is located in the vacuum chamber of the storage ring bending magnet. The existing 3 m long initial part of vacuum SR beam line is located inside the shielding wall of the storage ring. It comprises SR absorber, pumping and diagnostic block (PDB) with ion pump (IP) and vacuum shutter.

Fig. 2 represents the model of SR beam line with the optical observation station measurement part. The length of the beam line new part under development is 7 m. This new part will be connected to the existing beam line and will go outside through the shielding wall. SR falls on the cooled metallic mirror M1 (see Fig. 1) installed inside the vacuum unit at the distance of 6 m from SR emitting point. Metallic mirror M2 is installed parallel to mirror M1 in the same unit. The visible spectrum of SR reflected from mirrors M1 and M2 goes through the quartz output window OW and further along the non-vacuum beam line which is 120 mm above the vacuum beam line to the optical observation station measurement part. In place of passage of beam line through the shielding wall a lead beam stopper is installed to absorb scattered X-rays.

The new beam line under development has two collimators to form SR beam of required sizes (width of SR beam on mirror M1 is 30 mm) and divergence angles providing passage of light through SR beam line without its being reflected from its walls. First collimator (cooled) is installed at SR beam line entrance at the distance of 3.5 m from SR emitting point. The second collimator (non cooled) is installed after the quartz output window at the distance of 6.4 m from SR emitting point.

At the entrance of vacuum SR beam line a shutter is installed followed by two PDB with IP for vacuum pumping as well as SR gate and phosphor-like detector of SR beam position (is not indicated in Fig. 2).

# CONCLUSION

We hope the new optical observation station will meet the requirements of accelerator physics experiments and experiments with the use of SR related to the knowledge of exact parameters of separate electron bunches.

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