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

A. Stirin*, G. Kovachev, V. Korchuganov, D. Odintsov, Yu. Tarasov, A. Zabelin,
NRC Kurchatov Institute, Moscow 123182, Russia
V. Dorohov, A. Khilchenko, A. Scheglov, L. Schegolev, E. Zinin, A. Zhuravlev,
Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia
O. Meshkov, BINP SB RAS, Novosibirsk 630090, Russia; NSU, Novosibirsk 630090, Russia

Abstract

The station for optical observation of electron beam parameters (hereinafter referred to as "station") at electron storage ring Siberia-2 serves for automatic measurement of electron beam transverse and longitudinal sizes with the use of synchrotron radiation (SR) visible spectrum in one-bunch and multi-bunch modes, for the study of individual electron bunches behaviour in time in the conditions of changing accelerator parameters, and precise measurement of betatron and synchrotron oscillations frequency.

The article briefly describes the main elements of the measurement part, gives an estimation of accuracy of electron beam parameters measurements and also outlines the current condition of the station. In the article we attempt to compare and analyze the results of experiments with two different diagnostic systems aiming to measure beam transversal sizes.

INTRODUCTION

The station which is currently operating at Siberia-2 located inside the shielding wall of the storage ring. The station transmits to the control room the visual data about transverse and longitudinal sizes, shape and location of the electron beam. By now the station has already become technically obsolete.

The project of a new station which was launched in 2012 is now under way at the synchrotron radiation storage ring Siberia-2 at Kurchatov Institute. The station with its measurement part uses SR from bending magnet and for the purpose of easy operation, control and alignment, is located outside the shielding wall of the storage ring.

The new station will meet modern requirements of beam parameters precise measurement, automatic monitoring and control of electron beam parameters.
Parameters of 2.5 GeV electron beam of Siberia-2 storage ring at the azimuth of station disposition are given in Table 1.

OPTICAL OBSERVATION STATION

Measurement Part

In Fig. 1 the layout of the optical measurement at Siberia-2 storage ring is presented. SR emitted from source point in bending magnet of the storage ring propagates further along the vacuum beam line and falls on cooled metallic mirror. The optical component of SR reflected from the cooled mirrors goes through the quartz vacuum window out of the vacuum chamber and further along the non-vacuum beam line which is 120 mm above the vacuum beam line to the optical measurement part.

Table 1: Electron Beam Parameters at Siberia-2

Revolution frequency, MHz	2.4152
Bunch repetition rate, MHz	2.415 – 181.14
Bunch sizes σ_y, σ_x, σ_s, mm	0.059, 0.45, 20
Bunch duration (FWHM), ns	0.16

This measurement part consists of six diagnostic systems with different functions located on the optical table outside the storage ring shielding wall. With the help of mirrors and semitransparent mirrors the light beam is distributed between the remaining diagnostic systems. The main lens and magnifying lenses form a beam image simultaneously on all the optical detectors of the systems. Remotely controlled neutral filters expand the dynamic range of the system. Below is a short description of the systems. The detailed description of the systems is provided in [1].

Transverse beam sizes precise measurement system (1) based on the two-beam interferometer serves to measure beam transverse sizes with resolution 1 µm. Interferometry is currently a well developed diagnostic method ([2, 3]).

Beam longitudinal size measurement system (2) based on the dissector tube with electrical focussing and deflection is also used for the diagnostics of longitudinal multi-bunch instability caused by electron bunches interaction with high modes of cavity electromagnetic field. The optical marker can project an image of calibrated light source on the dissector photo-cathode. The marker is used for determining and controlling the linear scale of the diagnostics. Dissector tube time resolution is 40 ps [4].

Beam dynamics TV monitoring system (3) based on a TV camera is used for transferring the electron beam cross-section image to the video monitor.

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*Stirin_AI@nrcki.ru

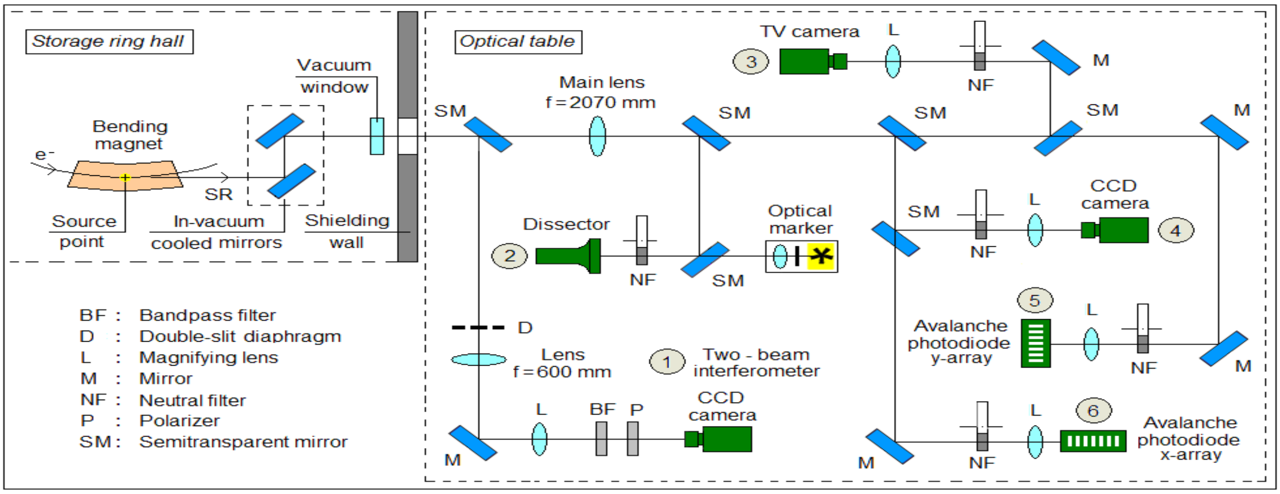

Figure 1: Layout of the optical observation station measurement part at Siberia-2 storage ring.

The measurement system of beam transverse sizes and beam relative displacement in source point (4) is based on high resolution 1280×960 pixels CCD camera with 100 Mbit Ethernet interface. The result of computer processing of signal from CCD-matrix 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 [5].

Turn-by-turn beam transverse cross-section measurement systems (5, 6) serves the purpose of measuring y - and x - 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 y - or x - dynamics of beam shape in a chosen separatrix. The diagnostics should provide a one-turn distribution during tens of thousands turns of beam. The systems comprise a measuring linear photodetector based on 16 element avalanche photodiode array.

Software

Special software for the station allows for automated monitoring and control of electron beam parameters. Graphical user interface enables the operator to control system operation modes, to change the detectors parameters, to scan, to process and to archive the data.

SR Beam Line

Fig. 2 represents the model of SR beam line outlet part with the station measurement part. Cooled mirrors are installed inside the vacuum unit at the distance of 6 m from source point. In the place of beam line passing through the shielding wall a lead beam stopper is installed to absorb scattered X-rays.

The beam line has two collimators to form SR beam of required sizes providing propagation of light through the beam line without it being reflected from its walls. First collimator (cooled) is installed at SR beam line entrance. The second collimator (non-cooled) is installed after the quartz vacuum window. The inlet part of vacuum SR beam line (is not shown in Fig. 2) comprises SR absorber and ion pump. The full length of the beam line from source point is about 10 m.

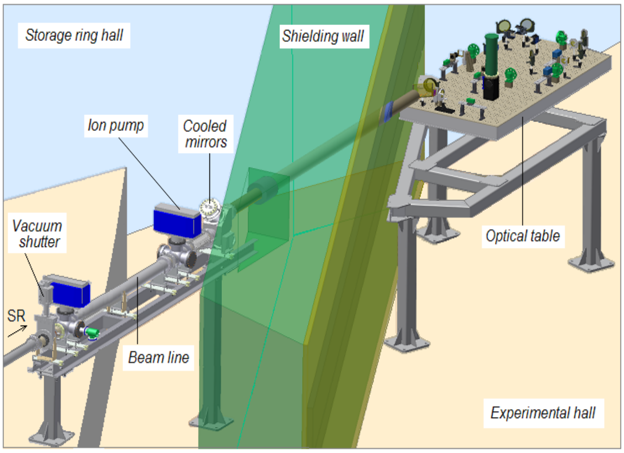

Figure 2: Model of SR beam line with the station measurement part placed on the optical table.

Current Condition of the Station

In 2013 SR beam line and optical table were built and installation of diagnostic systems was begun on the optical table. At present three systems are used for test measurements of electron beam parameters. The first data were provided by the beam dynamics TV monitoring system (3), double slit interferometer (1) and the measurement system of beam transverse sizes (4).

EXPERIMENTAL RESULTS

The first experiments were done simultaneously with the double slit interferometer (1) and beam transverse sizes measurement system (4). The interferometer was applied for measurement of the vertical beam size. We changed the slit separation (D) within 15 – 30 mm with step of 5 mm. The visibility of interference patterns clearly correlates with theoretical calculations. The slit separation of 15 mm and 20 mm best corresponds to the expected vertical beam size (Fig. 3).

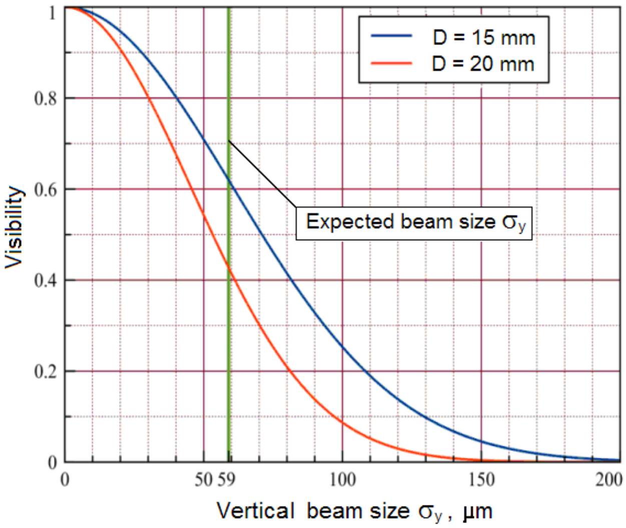

Figure 3: Calculated visibility with different slit separations vs vertical beam size.

Typical interference patterns for two different vertical beam sizes and their cross-sections are presented in Fig. 4a, b.

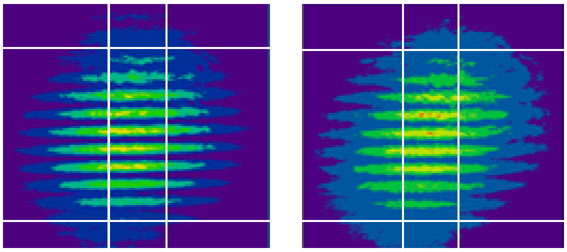

Figure 4a: Interference patterns for vertical beam sizes of 60 µm (left) and 90 µm (right), D = 15 mm.

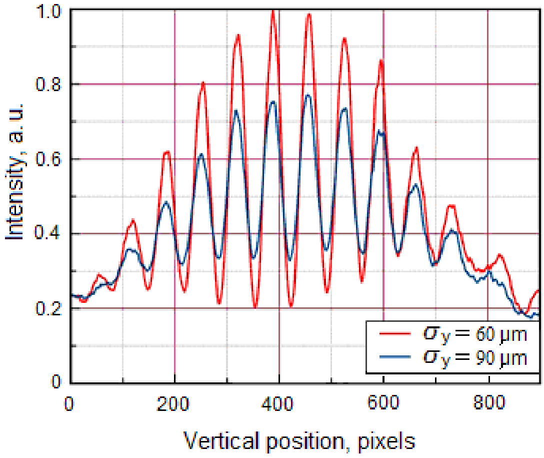

Figure 4b: Cross-sections of the interference patterns presented in Fig. 4a. The light intensity was integrated at the region between the vertical lines.

Measuring beam profiles with the help of beam transverse measurement system revealed particular problems connected with the quality of the projective optics. The beam image and fit of its profiles by Gaussian curves are presented in Fig. 5.

Comparison of the results obtained from both methods enables to determine the value of instrumental function for beam transverse measurement system as $\sigma_{inst} \approx 80$ µm. This value can be explained by the poor quality of the first cooled mirror.

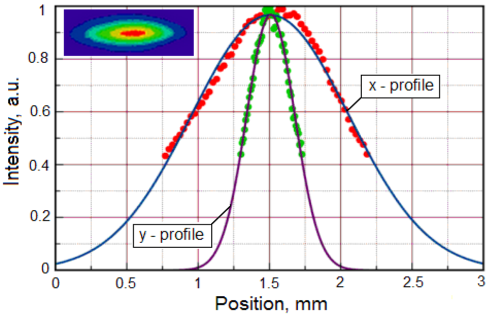

Figure 5: Beam image and its x, y - profiles fitted by Gaussian curves.

Resolution of the double slit interferometer is estimated as $\sigma_{int} \approx 5$ µm. This value was obtained by means of comparison of the beam size measurements with slit separation of 15 mm and 20 mm (Fig. 6).

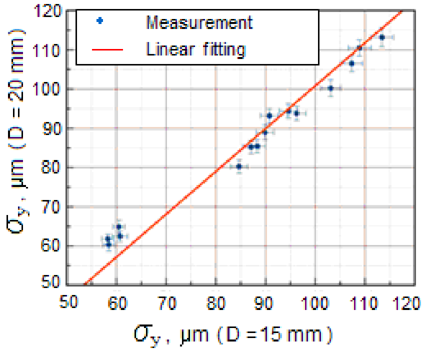

Figure 6: Comparison of σ_y data obtained with 15 mm and 20 mm slit separation.

CONCLUSION

The first measurements of beam sizes were done with the new optical diagnostics of Siberia-2 SR source.

We hope that in the future 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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