

SYNCHROTRON RADIATION MONITOR AND MIRROR AT SSRF

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Abstract

SR monitor for the measurements of beam profile, sizes, and bunch length has been designed and constructed at the Shanghai synchrotron radiation Facility (SSRF). A water-cooled beryllium mirror is installed to extract the visible SR. This beryllium mirror was designed via thermal analysis based on ANSYS. The extracted visible SR is relayed to dark room by three mirrors. The measurement system includes, imaging system, SR interferometers (SRI), streak camera and fast-gated camera etc are set in the dark room. Both the horizontal and the vertical beam sizes are monitored by SRI, and bunch length and temporal profile of the beam are measured by streak camera. The existed system suffers with dynamic problem for beam physics studies. The commissioning of synchrotron radiation monitor system has been performed in SSRF since December, 2007. The results obtained at SSRF are presented.

GENERAL OVERVIEW

A diagnostics beamline has been installed in the BM02 bending magnet of the SSRF storage ring. The designed parameter of the SSRF is listed in Table 1.

Table 1: Designed parameter of Storage Ring

parameters	Value
Energy (GeV)	3.5
Beam current (mA)	200-300
Critical photon energy (keV)	9.96
Emittance ϵ_x (nm.rad)	3.9
Beam profile σ_x (μm) 1% coupling	53
Beam profile σ_y (μm)	22
Bunch Length (ps)	14.4

Synchrotron radiation monitor measures beam profile and beam size of the synchrotron radiation light source for performance optimization, routine operation check and various beam physics study. The monitor should be able to measure a small transverse beam dimension and motion [1]. Using this monitor, we can characterize the electron beam size, phase-space ellipse and emittance. It is described that the general design of the SRM, extraction mirror design, and measurement equipments such as SR interferometer and streak camera in this paper.

05 Beam Profile and Optical Monitors

Instruction

The source point of for SRM is bending magnet near injecting point. The synchrotron light is extracted by a water-cooled beryllium mirror. Then three mirrors guide the light to the dark room. The synchrotron light interferometers [2] [3] is set in the dark room and they measure horizontal and vertical beam sizes. Also a focusing system is applied to obtain the image of beam profile. The result beam profile is passed on the display in the control. Bunch length measurements is performed with a streak camera (HAMAMATSU C5680) that uses a scan streaking of 125MHz (1/4 RF) and also dual time streaking is available. (Fig.1). The general arrangement of the SRM system is shown in Fig.1.

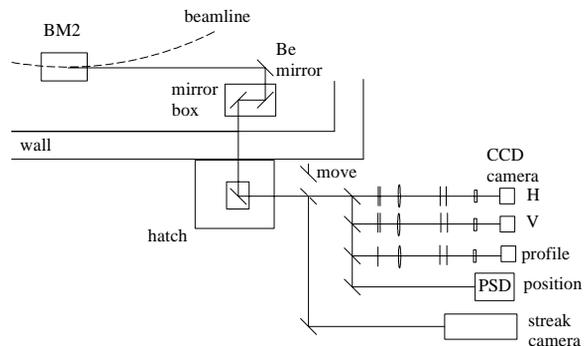


Figure 1: General arrangement of synchrotron radiation monitor.

EXTRACTION MIRROR

The vertical opening angle of visible SR is roughly 3mrad. 4mrad opening will be available in the horizontal direction. The visible part of the synchrotron radiation is reflected by water-cooled Beryllium mirror.

Water-cooled Beryllium Mirror

The first mirror is set 9m apart from the source point, which reflects the visible light by 90° downward. Thermal distortion of the Be mirror for a given absorbed heat load by X-rays is simulated using the technique of finite-element analysis. The deformation of the mirror has been studied in detail in comparison with other materials. The result shows Be is best material for the extraction mirror.

Thermal Distortion Analyse

A thermal-mechanical analysis experiments with electron beams show: the quality factor for different metals dynamic formation is indicated. The thermal distortion values for metals between 0°C to 400°C, these

effects were especially good in Beryllium mirrors than Invar and Copper mirrors [4].

We designed the mirror shape having a parabolic shape in the backside as shown in Fig.2. Most of the X-ray will pass through the central thin part of the mirror. The incident and the transmit power densities are shown in the right side graph in Fig.2.

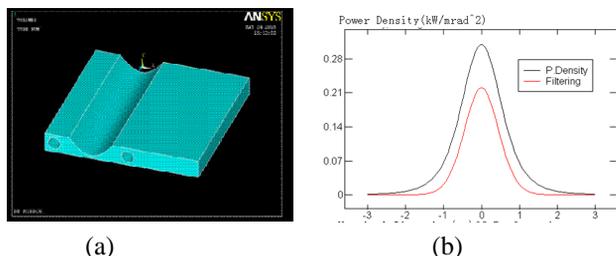


Figure 2: (a): The design of mirror which has two water-cooling tubes. (b): Power Density distributions.

The deformation of Be mirror is simulated by ANSYS and XOP [5] for varying the shape, size, and diameter of cooling tube. We fixed outer-dimension of beryllium mirror is 80mm(wide), 60mm(high), 12mm(thickness). With the diameter of water-cooling tube will 8mm, the centric deformation of mirror surface results 3.9 μ m with inlet water temperature 26 $^{\circ}$ C. The highest temperature of mirror will be 56 $^{\circ}$ C.

The results of Be mirror deformation and temperature distribution for number of water cooling tube 7 and 2 are shown in Fig. 3

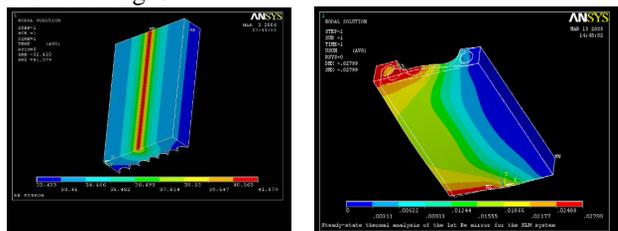


Figure 3: Analyse the deformation of two types of mirror those have seven cooling tubes (right) and two cooling tubes (left).

The convection coefficient will depend on cooling water velocity. The dependence of convection coefficient against cooling water temperature is shown in Fig 4 with various tube diameters. From this figure, the effect of the tube diameter is smaller than the velocity of cooling water. Because the diameter of the tube 6mm-7mm is easy to handle, we used the 6mm tube. Increase of Water temperature by 3-4 $^{\circ}$ C while beam current rise from 10mA to 100mA was observed in real operation of the mirror.

Actually, the key point in the design of the mirror is to make deformation smooth and symmetry about the centre of mirror. So we chose two tubes those arranged in symmetry. In the case to use the SR interferometer, we need only two pencils of light.

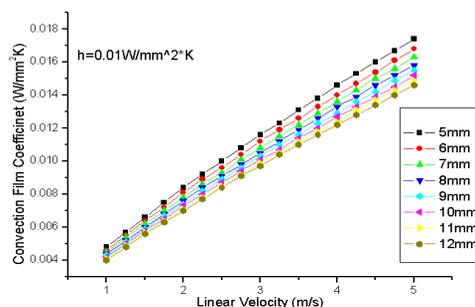


Figure 4: Convection coefficient as a function of cooling water velocity with various diameters of water cooling tubes.

It isn't important for interferometer that 1 to 2 μ m deformation of the mirror. We can calibrate the interferometer with ray trace technique. So, the beryllium mirror with two cooling tube which has a parabolic shape in backside is applied in the SSRF.

IMAGING SYSTEM AND SR INTERFEROMETER

The synchrotron radiation monitor consists of an imaging system to obtain a profile of electron beam and SR interferometers to measure the beam sizes. This imaging system is also used for observing a beam image position. A result of beam image and image position are shown in Fig. 5

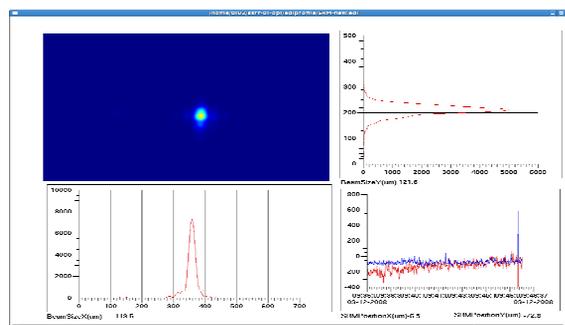


Figure 5: Result of beam profile measurement, and beam image positions.

Two Harshierian-type reflective SR interferometers are installed to measure the both of vertical and horizontal beam sizes. The double slit is set at 18 meter apart from source point. A focusing mirror, $f=2000$ mm, is used as an objective mirror. A small off-axis diagonal mirror is set for the convenience of the observation. A band-pass filter, which has 80nm bandwidth at 550nm, is used to limit the wavelength of input light. The σ -polarization of SR is selected by dichroic polarization filter. The arrangement of SR interferometers are shown in Fig. 6. A ray tracing method using a Hartman square mask is used to calibration of SR interferometer due to the first mirror deformation.

The measured interferogram are fitted by the intensity distribution of the form. The image analysis system works

extracting the orthogonal profile, center position, and least square fit to evaluate the beam sizes.

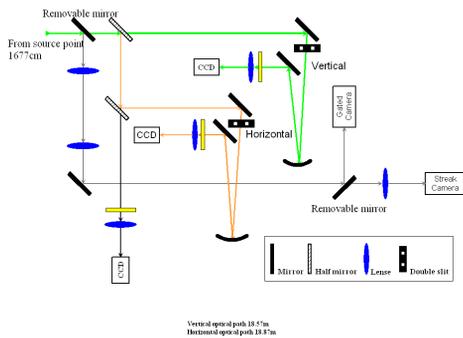


Figure 6: Arrangement of SR interferometers.

An example of observed vertical interferogram is indicated in Fig. 7.

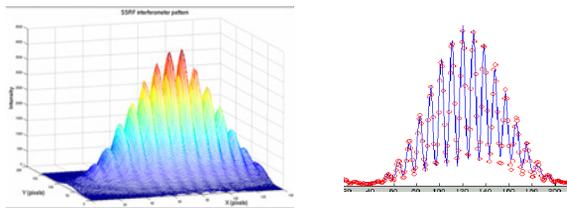


Figure 7: An example of observed vertical interferogram.

Application software is located at workstation /Unix and PC/Linux control console, supporting commercial software Matlab and LabVIEW. The high level physical application environment has been set up and done the online test of device control using MatLab and middle layer with the SSRF centre database.]

Preliminary commissioning of the SRM is performed recently. The glass window has been used to overcome the effect of air flow. The linearity between electron beam intensity and radiation image intensity in such system is good. Accompany with neutral density filter. The dynamic range can be extended to 10^3 and with excellent linearity.

Beam size of electron in storage ring has been achieved by synchrotron radiation interferometer successfully . The results of vertical beam size measurement for beam regulation are shown in Fig.8. When beam current is 200mA, using a wave length $\lambda = 550\text{nm}$, with acquired data 600 times, the results of vertical RMS beam size is $34.3 \pm 0.4\mu\text{m}$, and horizontal RMS beam size is $52.3 \pm 0.4\mu\text{m}$.

The beam size measurement also used to adjust the transverse feedback system for SSRF storage ring. It is shown as in Fig.9, when beam current is getting higher than 40mA, the vertical beam size is getting large. If beam current change from 40mA to 100mA; the vertical beam size becomes larger from 35 um to more than 100 um. When the multi-bunch transverse feedback is work; the vertical beam size becomes smaller and stable. The observed beam size with transverse feedback is 35 μm

just same as in the low current. The variation is observed for xy coupling parameters from this measurement

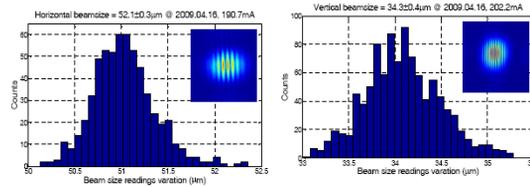


Figure 8: The results of beam size (RMS) measurement.

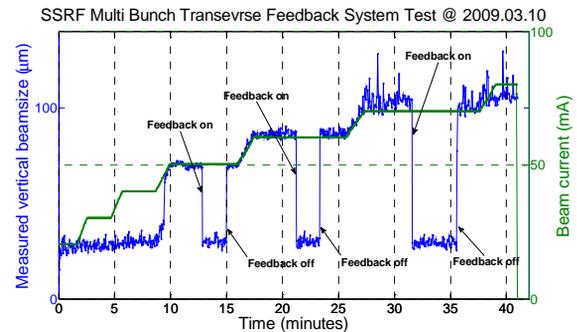


Figure 9: Beam size measurement for transverse feedback.

CONCLUSIONS

The SR monitor to measure the beam size, and bunch length etc. is constructed at the SSRF. The transverse RMS beam sizes in both horizontal and vertical direction are measured in the range of a few mA to 200mA. The observed horizontal beam size is $52.3 \pm 0.4\mu\text{m}$ and it is good agreed with designed value. The observed vertical beam size is $34.3 \pm 0.4\mu\text{m}$, and it is stable with transverse feedback system. From this observed vertical beam size, emittance coupling is 1.2%.

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