MEASUREMENT OF BEAM SIZE WITH A SR INTERFEROMETER IN TPS

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Abstract

Taiwan Photon Source (TPS) has operated since 2015. An optical diagnostic beamline is constructed in section 40 of TPS for the diagnosis of the properties of the electron beam. One instrument at this beamline is a synchrotron radiation interferometer (SRI), which is operated to monitor the beam size. In this paper, we present the beamline structure and recent results of measurement with the SR interferometer.

INTRODUCTION

Taiwan Photon Source (TPS) was commissioned in 2015. The electron beam stored in the storage ring of circumference 518 m has current 500 mA and energy 3 GeV. The beam is at present operated at 150 mA for user applications. To monitor the beam status, two facilities are adopted for the transverse beam size – an X-ray pinhole camera and a synchrotron radiation interferometer (SRI) [1].

That interferometer, presented by Dr. T. Mitsuhasi in KEK, is widely applied to monitor synchrotron light sources; it is based on visible optics and can resolve a beam size 3-4 μm [2,3,4]. The monitor gives both a static and a dynamic observation of the beam size. The basic principle of a SR interferometer (SRI) is to measure the profile of a small beam through the spatial coherency of light, and is known as the Van Citter-Zernike theorem. The distribution of intensity of the object is given by the Fourier transform of the complex degree of first-order spatial coherence. The beam size is given by

$$\sigma_{beam} = \frac{\lambda R}{\pi D}\sqrt{\frac{1}{2}\ln\left(\frac{1}{\gamma}\right)} \quad (1)$$

$$\gamma = \left(\frac{2\sqrt{I_1 . I_2}}{I_1+I_2}\right)\left(\frac{I_{max}-I_{min}}{I_{max}+I_{min}}\right) \quad (2)$$

According to the above equation, the beam size is observed by the visibility of the interferogram.

SRI MONITORING SYSTEM

Beamline Construction

The SRI beam-size monitor is constructed at TPS section 40. The radiation produced at the dipole magnet propagates 19.2 m to pass through the shielding wall. The distance from the source point to the double slit is 22 m. As the minimum gap in the bending chamber of the TPS case is 3.8 mrad, the maximum separation gap of the SRI double slit is constrained by the vacuum chamber. The maximum gap is 70 mm.

The main error of the visible SR interferometer arises from the distortion of the mirror by the radiation power [5]. A cooled beryllium mirror (Pascal Co., Ltd. Japan) was adopted to prevent distortion, with profile quality under 1/4 λ. The extraction window was purchased, with quality within $\frac{\lambda}{10}$. After passing the extraction window, one aluminium reflection mirror is adopted for transport through the shielding wall, shown in Fig. 1. In the outside of the shielding wall, two folding mirrors are used to connect the synchrotron light source to the SRI beam-size monitoring system, shown in Fig. 2.

Before operating the SRI system, a reference laser is used (see Fig. 3) to position and to align the three folding mirrors. These three mirrors are held with mirror mounts with two linear motors for two-directional adjustment.

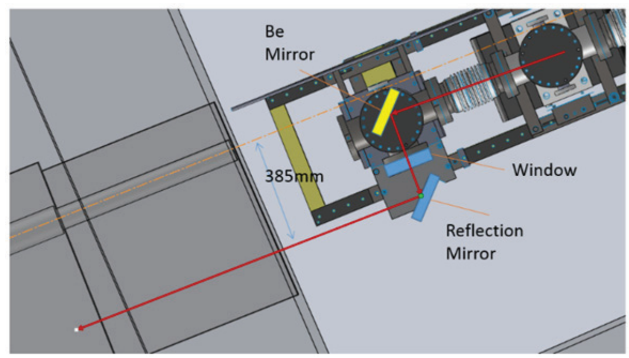

Figure 1: Architecture of beam transport inside the shielding wall.

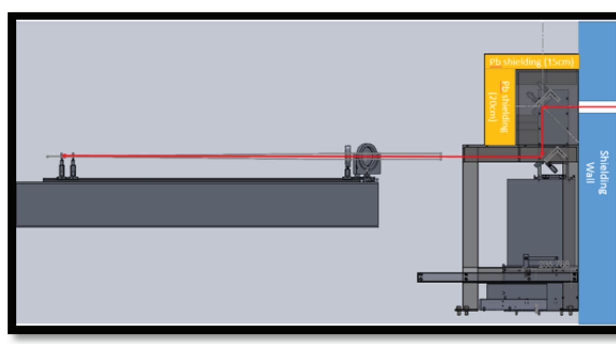

Figure 2: Architecture of beam transport from the beam position (1350 mm) to the optical table.

Optical System

The beam-size monitoring system for both horizontal and vertical directions is located on an optical table shown in Fig. 4. The distance from the source point to the double slit is 22 m. The light arriving at the SRI is shown in Fig. 5. The presence of a coloured band at the upper and lower sides means that light is not homogeneous along the transport line.

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Figure 3: A reference laser is used to align the folding mirrors that are held on a motorised mirror mount.

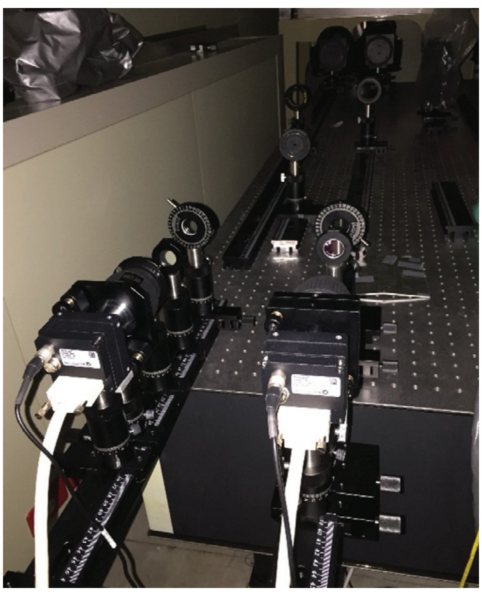

Figure 4: Synchrotron radiation interferometers to monitor the horizontal and vertical beam sizes.

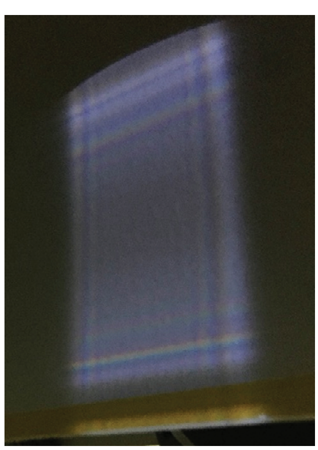

Figure 5: Light arriving at the optical system after three folding mirrors.

The SRI is a polarized and monochromatic wavefront deviation type interferometer. A diffraction-limited high-quality lens is used for focusing; the focusing length of this lens is 2 m; the wavefront error is less than $\frac{1}{10}\lambda$. A polarizer and a band-pass filter are used to obtain quasi-monochromatic light. The centre wavelength of the bandpass filter is 500 nm with 10 nm bandwidth. An eyepiece is applied to magnify the interferogram; Two CCD are applied to observe the horizontal and vertical interferograms respectively.

TESTS AND RESULTS

In TPS hutch 40, a series of tests and adjustments was undertaken. The measurement program was implemented using Labview with non-linear fitting of the visibility, calculated from the general interferogram equation (3).

$$\mathrm{I(y1)} = I_0\left[sinc\left(\frac{2\pi a}{\lambda R}y_1\right)\right]^2\left[1+|\gamma(\nu)|\cos\frac{2\pi D}{\lambda R}y_1+\varphi\right] \quad (3)$$

For a horizontal beam size, the slit separation (*D*) is 20 mm and the half opening (*a*) is 0.5 mm. The beam size is 55 μm with standard deviation 2.6 μm.

For the vertical beam size, the interferogram of the vertical direction is sensitive to the position of the double slit and to stray light; somewhere it becomes disordered, and the program fits with huge errors. The vertical slit separation (*D*) and half opening (*a*) were tested with varied size. The half opening (*a*) was eventually chosen as 1.5 mm to intensify the light passing through the slit to prevent interference from stray light. Several vertical slit separations (*D*) were tested for the beam size. When the slit separation was enlarged to 70 mm, the interferogram became feeble (see Fig. 6). The maximum suitable separation is 65 mm. The average vertical beam size was 32.5 μm; the standard deviation of the vertical beam size was 3.5μm. The larger slit separations (60, 65 mm) had larger variations, corresponding to the wavefront error of the light edge. The error of the vertical beam size is larger than of the horizontal beam size.

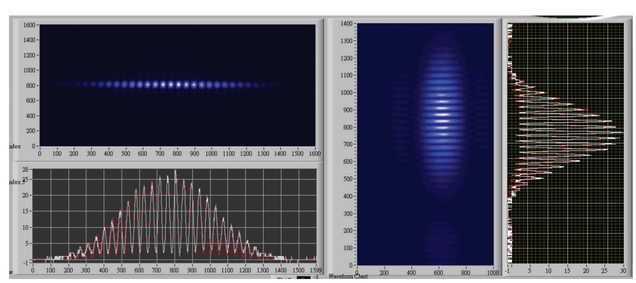

Figure 6: Horizontal and vertical interferograms detected with a CCD.

The horizontal and vertical beam sizes of a pinhole camera are 53 and 32 μm. The results of measurements of the two instruments have under 3.7 % difference. See the results on Fig. 7 and 8.

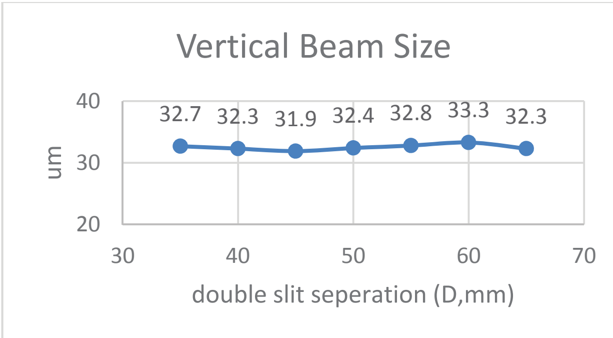

Figure 7: Vertical beam size with varied slit separation.

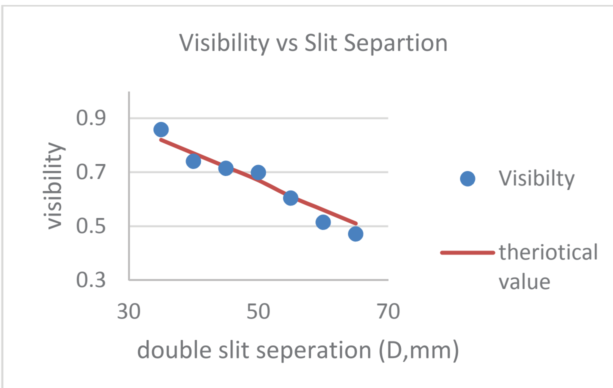

Figure 8: Visibility versus slit separation in the vertical direction.

SUMMARY

A SRI beam size monitor was installed in NSRRC TPS. The horizontal and vertical beam sizes are 55 μm and 32.5 μm at beam current 149mA. The result of measuring the beam size is near that with a pinhole camera. The measurement information will be verified on comparison with other instruments. To minimize the measurement error of the beam size, the stray light should be eliminated and the optics should be optimized continually.

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