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MODIFICATION OF THE SYNCHROTRON RADIATION INTERFEROMETER AT THE TPS

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Abstract

During TPS operation, the stability of beam size measurement with the synchrotron radiation interferometer (SRI) does not compare well with the older SRI at the TLS. Ground vibrations appear to transmit to the SRI optics. This paper describes how to reduce the effect of vibration and improve the system stability to improve the stability of the SRI beam size measurement dramatically. To enhance the SRI sensitivity, an intensity imbalance method is incorporated and its results are discussed.

INTRODUCTION

The Taiwan Photon Source (TPS) was commissioned in 2015 and operates now routinely at 300 mA and 3 GeV energy. To measure the transverse beam size, two monitors are installed in the 40th beam port of the TPS. One is a synchrotron radiation interferometer (SRI) and the other a X-ray pinhole camera [1,2].

The SRI monitors horizontal and vertical beam sizes and its measurement results agree well with the pinhole camera, but the stability of the beam size measurements are not acceptable. In this paper, we present the recent work to stabilize the SRI beam size response.

PRINCIPAL FEATURES OF THE SYNCHROTRON RADIATION INTERFEROMETER

The synchrotron radiation interferometer, presented by Dr. T. Mitsuhasi in KEK, is now widely used to monitor beam sizes in synchrotron light sources [2,3,4,5]. The basic principle of a SR interferometer is to measure the profile of a small beam through the spatial coherence of light, and is based on 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 intensity of the interferogram pattern is defined in Eq.1 as a function of position y1, where λ is the wavelength, R the distance from the light source to a double slit, D the double slit separation and a the half-height of the slits.

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

The visibility ν is related to the complex degree of coherence by a factor involving the intensity of each beam.

The quantity ρ is the power imbalance ratio of the double slit defined by the ratio of the power intensities I1 and I2 from the double slits

$$\rho = \frac{I_1}{I_2} \quad (2)$$

The beam size is observed by the visibility of the interferogram and the beam size is given by

$$\sigma_{beam} = \frac{\lambda \mathrm{R}}{\pi \mathrm{D}}\sqrt{\frac{1}{2}\ln\left(\frac{1}{\gamma}\right)} \quad (3)$$

where

$$\gamma = \nu\frac{1+\rho}{2\sqrt{\rho}} \quad (4)$$

Using the power imbalance method, the visibility γ can be reduced by lowering the imbalance ratio ρ while bringing the interferogram fringes above the noise level and increase the dynamic range of the SRI [6].

MONITOR SYSTEM SETUP

An SRI beam-size monitor is installed at the 40th beam port of the TPS and the beam line structure is shown in Fig. 1. The radiation produced from a dipole magnet propagates 19.2 m to pass through the shielding wall.

After a beryllium mirror in the vacuum chamber, the light passes through the extraction window and an aluminium reflection mirror, and then through the shielding wall. Outside of the shielding wall, two folding aluminium mirrors are used to deflect the synchrotron light to the optical table in the hutch.

The light is collected in the SRI beam size monitoring system by a diffraction-limited high-quality lens with 2 m focal length followed by a polarizer and a band-pass filter 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 on the CCD; Two CCDs are used to separately observe the horizontal and vertical interferograms.

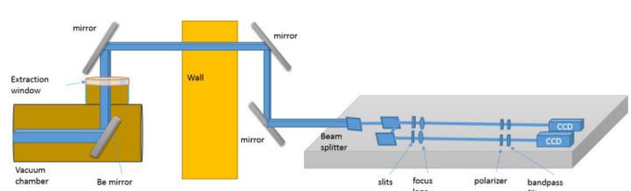

Figure 1: Optical set-up of the TPS SRI system at the 40th beam port.

VIBRATION MEASURMET

Since the stability of the TPS SRI does not match the stability achieved at the SRI in the TLS, laboratory ground vibrations are suspected and checked by an accelerometer (PCB393B31) and velocity sensor (MST-1031). As shown in Figs. 2 and 3, vibrations were observed not only on the ground but also on the optical table.

Observing the intensity variations of the interferograms on the CCD, we noted that the intensity variations are

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caused by the slits, because the mechanical stability of the optical setup is not firm enough. To improve the systems rigidity, we performed some experiments as described in the following.

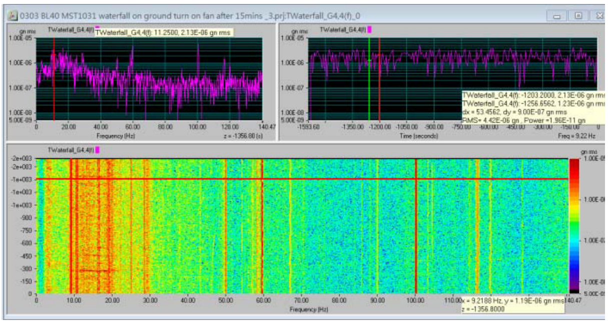

Figure 2: A time-frequency vibration graph of the hutch floor. The horizontal axis is frequency and the vertical axis is time. Many vibrations appear at low frequencies.

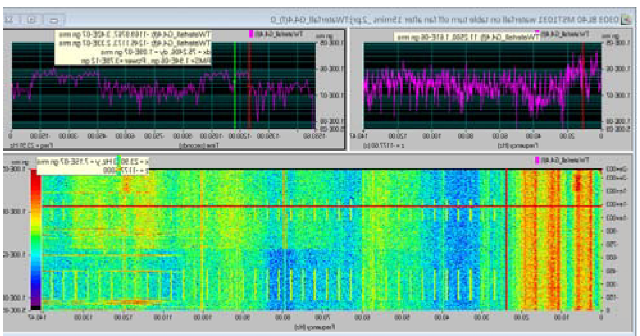

Figure 3: Time-frequency vibration graph of the experimental optics table. The horizontal axis is frequency and the vertical axis is time. There are many low frequency vibrations and periodically higher mode frequencies appearing on the optical table.

STABILITY IMPROVEMENT EXPERIMENT

Vibration Suppression

In an attempt to improve the problem of intensity variation, the distribution of synchrotron light from the front end is checked by a power meter, as shown in Fig. 4. While the centre area of the synchrotron light is more uniform, the slit position is adjusted in the lower intensity gradient area. Furthermore, the slit separation (D) is reduced to less than the centre area.

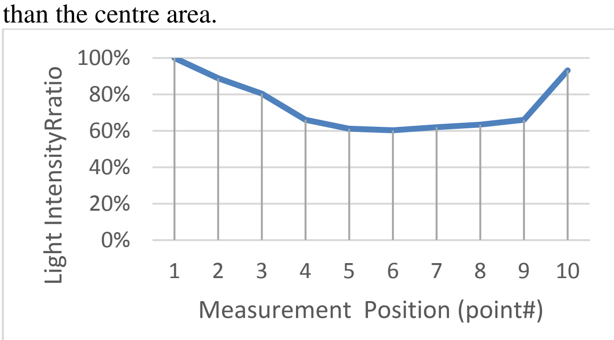

Figure 4: Intensity distribution of synchrotron light.

To absorb the vibration of the SRI opto-mechanism, vibration damping materials (Nitto D-300N) are added to the mechanisms. The damping films are attached to the slit and mirror holders.

This not only absorbs vibration, but also strengthens the mechanical stability. From observations, we know that the slit holder is the most sensitive part in the system. The holding design influences obviously the stability as shown in the following Table1.

Table 1: Horizontal Beam Size Measurement Results of Two Holding Methods. Clearly, the beam size stability is related to the strength of the holding jig.

	1	2	3
CCD exposure time	2ms	2ms	2ms
Wavelenth bandwidth	10nm	10nm	10nm
Slit Seperation (D)	30mm	30mm	30mm
SlitOpening (A)	a5	a5	a3
Holding Method	Method A	Method B	Method A
Beam size	54.20	58.49	53.30
rms	0.56	1.14	0.60

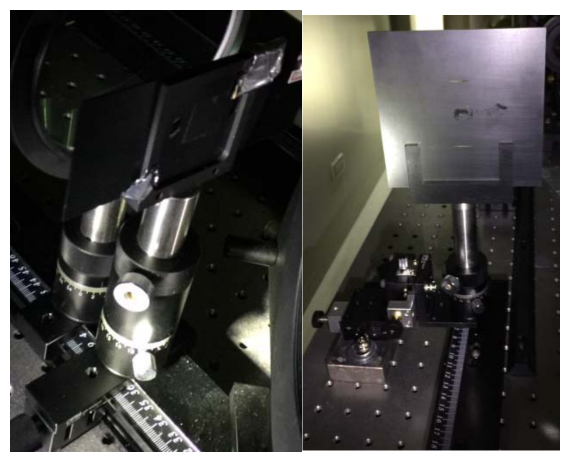

Figure 5: The double slit is supported by two types of mechanisms. (A) Method A: The slit holder is fastened on a single rod with a damping pad. (B) Method B: The slit holder is installed on a stage with two axis adjustments.

CCD Exposure Time Minimization

The CCDs are used to catch and integrate the interferogram. To prevent the signal vibration to integrate on the CCD, the exposure time is minimized to decrease vibration signal accumulation.

To minimize the CCD exposure time, the slit opening (a) is enlarged from 1mm to 5 mm and the exposure time is reduced to 2 ms. As Fig. 6 shows, the stability of the meas-ured beam size is proportional to the exposure time and the beam size can now be measured to better than 1 um.

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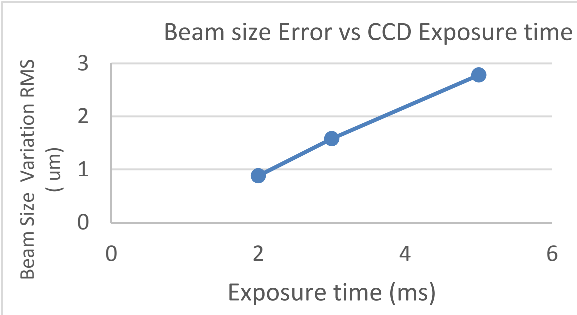

Figure 6: Relation between stability of the measured beam size and the CCD exposure time.

Air Disturbance Elimination

We also examined the air flow to prevent air turbulence and related vibrations. The synchrotron light exits the vacuum chamber through a window and passes through three aluminium reflection mirrors followed by a long path from the storage ring to the experimental area.

The air pressure in the storage ring and experimental area is different because the air flows continuously from the tunnel to the experimental laboratory area along the optical path through the shielding wall. Therefore, a flat optical window has been installed on the shielding wall to cut off this air flow (Figure 7).

Figure 7: Flat optical window installed on the shielding wall to block the air flow.

Table 2: Beam Size Measurements After Applying all Countermeasures as Described

	Beam SizeX	Beam SizeY
exposure time	2ms	2ms
bandwidth	10nm	10nm
average	10	10
Double slit	D30	D45
	a5	a5
average	54.20	35.21
rms	0.56	0.35

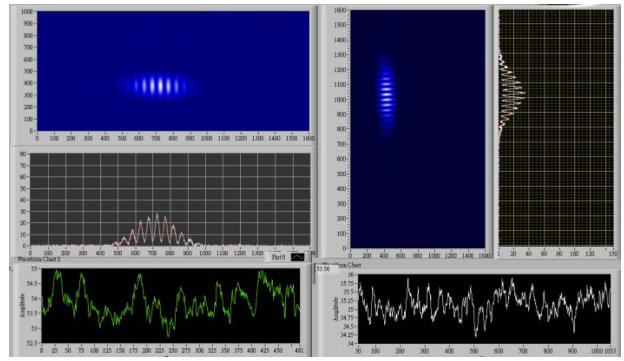

Figure 8: Interferograms of the horizontal and vertical channels.

After vibration suppression, minimization of the CCD exposure time and elimination of air turbulence, the RMS beam size variation is reduced to 0.3 um and the stability is equal to that of the TLS SRI.

POWER IMBALANCE METHOD

A method of power imbalance has been introduced to verify the visibility of the interferogram. Power meters measure the light intensity passing through the double slits and different transmission ND filters are used in the vertical BSM system to produce different power imbalance ratios. While reducing the power imbalance ratio, the visibility parameter γ is also reduced and the interferogram fringes exceed the noise level.

The experimental results are shown in Fig. 9 where the beam size variation is related to the imbalance ratio. A lower imbalance ratio improves the beam size variation as shown in Fig. 10. When the power imbalance factor is introduced in the vertical BSM system, the vertical beam sizes are corrected from 35.8um to 35.2um.

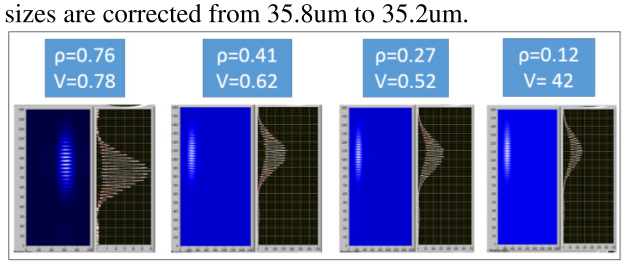

Figure 9: The power imbalance ratio is reduced by ND filters which also reduces the visibility parameter γ and the interferogram fringes become more prominent.

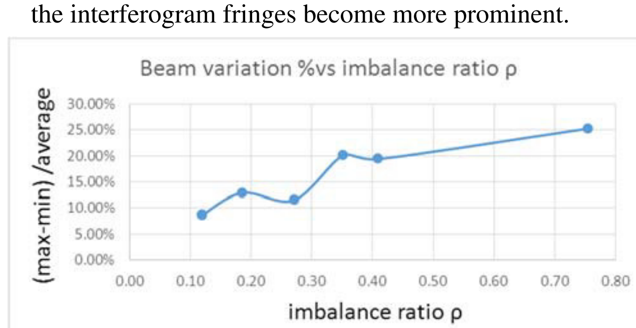

Figure 10: Beam size variation improves as the imbalance ratio ρ is lowered.

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CONCLUSION

A SRI beam size monitor was installed in the NSRRC TPS. Ground vibrations translate to the SRI causing beam size variations. In order to improve the system stability, vibrations were suppressed, the CCD exposure time was reduced and air turbulence in the optical path were eliminated. This improved the beam size stability to 0.3 um which is equal to that achieved in the TLS SRI. Introducing also an intensity imbalance method to the vertical BSM system, the beam size variation could be improved and the beam size measurements are optimized by adjusting power imbalance ratios.

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