THE SRI BEAM SIZE MONITOR DEVELOPED AT NSRRC

T.C. Tseng*, D.J. Wang, S.Y. Perng, C.J. Lin, H.C. Ho, C.K. Kuan, Jeremy Wang, J.R. Chen,
NSRRC, Hsinchu, Taiwan

Abstract

A beam size monitor based on the synchrotron radiation interferometer (SRI) was installed in the NSRRC TLS. This monitor consists of a simple diagnostic beamline with a water-cooled beryllium mirror inside and a detecting optical system for both vertical and horizontal beam size measurement. The beam sizes measured are 47 micron and 160 micron respectively and are more close to the theoretical values than the synchrotron image monitor. Comparing with other monitors, at least 1 micron beam size variation is detectable. To minimize the thermal effect, the mirror is located far away from the source point and closed to the detecting optical system. The thermal distortion of the mirror is quite small measured by a portable long trace profiler (LTP) and agrees with the simulating analysis. The detailed monitor system design and testing results are presented in this paper.

INTRODUCTION

Beam size monitor, beam position monitor and I_0 monitor are the three major monitors in the synchrotron facilities. There was already an SR image beam size monitor system installed at the TLS (Taiwan Light Source) of NSRRC (National Synchrotron Radiation Research Center). Due to the limitation of diffraction phenomena and the aberrations of optical components, the resolution of the SR image beam size monitor is far beyond micron and sometimes is not sensitive to the variation of the electron beam in the study of the storage ring instability. A more precise monitor system was thus demanded.

With the study and comparison of some precision monitor systems developed such as wire scanning, laser interferometer or laser wire, residual gas ionization, optical transition radiation (OTR), X-ray image and synchrotron radiation interferometer (SRI), the SRI monitor was adopted because it is a non contact method and easer to construct.

The SRI beam size monitor was firstly introduced by Dr. Mituhashi in KEK[1]. The basic principle of this monitor is to measure the profile or size of small beam through the spatial coherency of the light and is known as the Van Cittert-Zernike theorem. Dr. Mituhashi and other researchers had demonstrated the feasibility, precision and high resolution of this monitor[2,3,4]. The detailed theoretically approaches can be found in these references. In the paper, the monitor system set up, tests and results are presented majorly.

MONITOR SYSTEM SETUP

The SRI beam size monitor system set up in the TLS of NSRRC consists of a diagnostic beamline, an optical detecting system and a software system. The general optical layout is illustrated as in the Fig.1. It consists a main reflecting beryllium mirror and two rows of optical system for both horizontal and vertical beam size measurement.

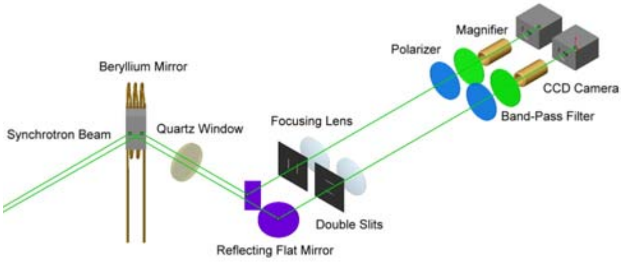

Figure 1: General optical layout of the SRI beam size monitor at the TLS of NSRRC.

Beamline Construction

The diagnostic beamline was constructed at the 10th beamline port of the TLS. Since the major component of this beamline is the reflect mirror to extracted the synchrotron beam out in 90 degree and absorb most heat laod, the beamline is quite simple. In order to minimize the thermal effect, the mirror is located far away from the source point and closed to the detecting optical system as shown in the Fig. 2.

Connecting to the frontend, a shutter chamber consists of 2 photon shutters and 1 absorber to separate the photon beam into 2 ports since the photon beam is quite wide (27 mrad) outside the frontend aperture. The other beam port is reserved for another diagnostic purposed.

The middle vacuum pipe was adopted from existed parts. So the reflect mirror was located at 13.6m away from the source point.

The mirror chamber was designed with 2 mirrors capacity for future expansion. The reflect mirror is a beryllium mirror purchased form Pascal Co.,Ltd. Japan and was measured by the LTP (Long Trace Profiler) to an acceptable quality. With the finite element simulation, the temperature rising of the mirror during operation is less than 1 degree and the maximum surface distortion less than 0.2 μm. The extraction quartz windows were purchased form the Kiyohara Optics Inc. Japan and sealed with Helicoflex gaskets. The surface distortion of the widows was controlled within $\lambda/10$ during screwed with the measuring of a Zygo surface interferometer.

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* tctseng@nsrrc.org.tw

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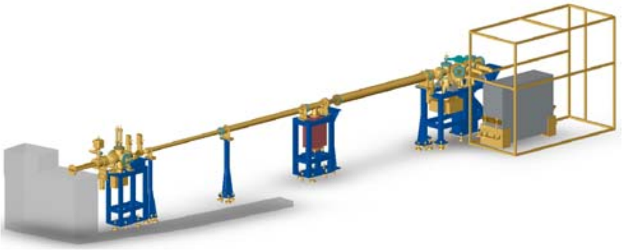

Figure 2: The diagnostic beamline layout for the SRI beam size monitor.

Optical Detecting System

The optical detecting system for both horizontal and vertical directions is located on a granite foundation to minimize the vibration effect as shown in Fig.3. The mirror and lenses were purchased from Melles Griot. The focusing length of focusing lens is 1m. The band pass filter is of 10nm range with the centre at 500 nm. The CCD cameras adopted are the Pulnix TM-1020-15CL with camera link interface to speed data acquisition and also with high resolution (1000 pixels) to minimize measurement error. The cameras were both checked to be of good uniformity and linearity in the laboratory before installed.

Figure 3: The optical monitoring system for both horizontal and vertical bean size monitor.

Software Program

The measurement program was implemented using the Labview graphical development software form the National Instruments to be compatible with the frame grabber card (NI PCI-1428). The software control panel is shown as Fig. 4.

With the aid of the nonlinear fitting sub VI of Labview, the visibility (γ(ν))can be calculated from the general interferogram equation (1).

$$I(y_1) = I_0[\sin c(\frac{2\pi a}{\lambda R_1} y_1)]^2 \cdot [1 + |\gamma(\nu)| \cos(\frac{2\pi D}{\lambda R_1} y_1 + \varphi)] \quad (1)$$

where a denotes the half of slit height of the double slit, R_1 denotes distance between the interferogram and the back principle point of objective lens of the interferometer, D denotes the slit separation, and φ denotes the phase of the interference fringe.

Thus the beam size can be calculated from the equation (2). Where R_0 denotes the distances from the source point to the double slits.

$$\sigma_{beam} = \frac{\lambda \cdot R_0}{\pi \cdot D} \cdot \sqrt{\frac{1}{2} \cdot \ln\left(\frac{1}{\gamma}\right)} \quad (2)$$

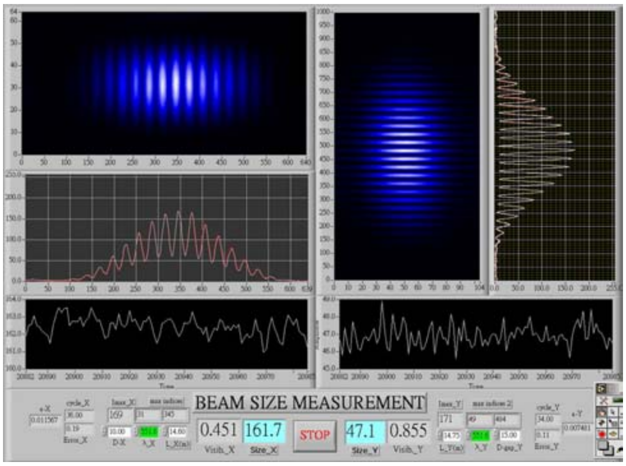

Figure 4: The software control panel of the bean size monitor.

TESTS AND RESULTS

A series of tests and adjustments were carried out to insure the correctness and sensitivity of the monitor system.

Since the beam size calculated form equation (2) is based on the Gaussian beam assumption. If the photon beam is not Gaussian then the measuring results should be not the same with different gap double slits plate. While the measured beam sizes were almost the same and the Gaussian fitting of the visibility versus different slits gap as shown in Fig. 5 and Fig. 6 are quite well. These tests results indicate that the photon beam of TLS is quite Gaussian. The fitting in Fig.6 with small slits gap shows a little bit far apart should be due to the error magnified as approaching unity[5]. So the gaps of the double slits are 10mm for horizontal and 15mm for vertical respectively.

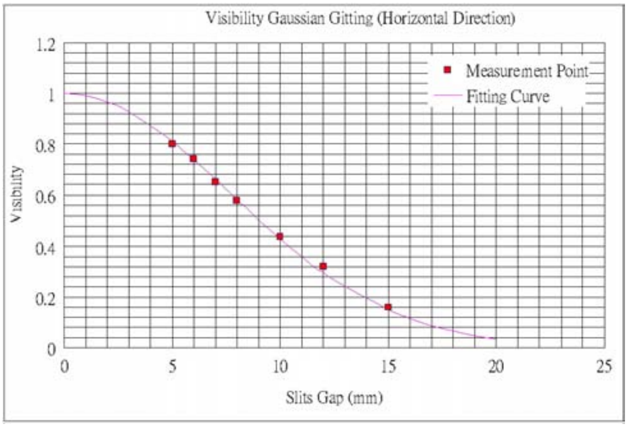

Figure 5: Gaussian fitting of the visibility versus different slits gap in horizontal direction.

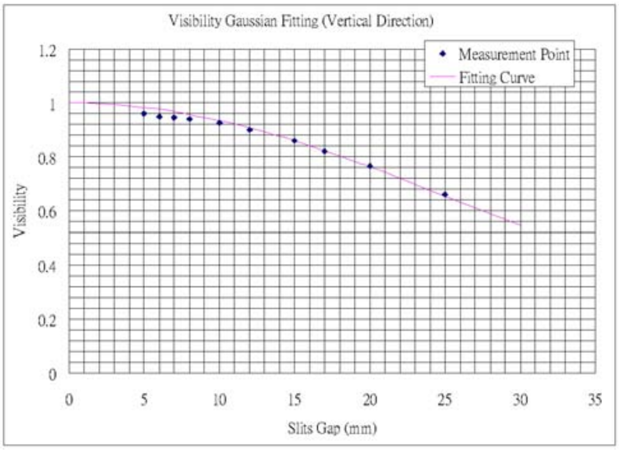

Figure 6: Gaussian fitting of the visibility versus different slits gap in vertical direction.

Another tests were to check the beam size with different gain and electrical shutter speed to examine the variation due to different photon intensity. After adjusting the parameters of the CCDS, the results were also almost the same. Also, different wave length filters were tested and adjusted.

Using a potable LTP system, the surface distortions of the beryllium mirror were measured at different energy levels. The maximum variation is less than 0.2 micron and is consistent with the finite element simulation.

After these tests and adjustments, The SRI beam size monitor at TLS was placed into normal operation. The beam sizes measured are more close to the theoretical values (design spec with 1% coupling) than the synchrotron image monitor as shown in the Table 1.

Comparing with other monitors in the archive system, it shows good sensitivity to the photon beam variation and at least 1 μm beam size variation is detectable as shown in Fig. 7 and Fig. 8.

Table 1: Photon beam size comparison of theoretical, SRI monitor and Image monitor.

Beam Size	**Theoretical**	**SRI**	**Image**
σ_y	48μm	47μm	120μm
σ_x	135μm	162μm	260μm

Figure 7: The SRI beam size monitor shows good correlation with the variation of I_0 monitor.

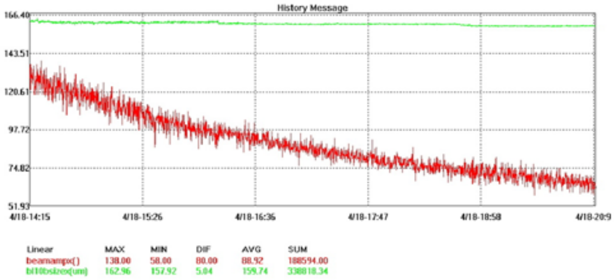

Figure 8: Comparing with other monitors in the archive system, at least 1 micron beam size variation is detectable.

CONCLUSIONS

The SRI beam size monitor installed in the NSRRC TLS is now under normal operation. It shows good sensitivity and correctness and also provides precise information for the improvement of the storage ring stability.

However, though the aberrations of the optical components are not quite significant, a further calibration still demanded according the experience of KEK and will be carried out soon.

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