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# BEAM SIZE MONITOR BASED ON MULTI-SILT INTERFEROMETER AT SSRF*

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*Abstract*

Double-silt synchrotron radiation interferometer is a common and useful tool to measure transverse beam size around the world. In order to satisfy the requirement of high speed measurement and improve the accuracy of BSM (beam size monitor), multi-silt interferometers have been designed and tested at SSRF. Multi-silt mask pattern has characteristics of high flux throughput and high SNR of the interferogram, which is very useful at high-speed beam size measurement. This technique has a relative complex algorithm to deconvolve the result image and figure out the beam size. Principle of the multi-silt SR interferometer, mask design and experiment will be present detailed in this paper.

## INTRODUCTION

The emittance of an electron beam,which is inversely proportional to the brilliance of the synchrotron radiation, is one of the most important characteristics of a storage ring operated as a synchrotron light source. To monitor degradation of the emittance, which could be caused by beam instabilities or ion-trapping phenomena, it is necessary to observe the transverse profile of the electron beam in real time. Third-generation synchrotron light sources such as the SSRF storage ring are designed to achieve low emittance and a small emittance-coupling ratio. To measure the small beam size in few tens micro meters level is very necessary. Visible light interferometer, developed by T. Mitsuhashi [1] has high resolution in beam size measurement, which has been used in different facilities around the world. However, each method has advantages but also limitations, Double-silt synchrotron radiation interferometer is limited at high speed measurement. A novel approach was proposed to satisfy the requirement of high speed measurement. Multi-silt mask pattern has characteristics of high flux throughput and high SNR of the interferogram, which is very useful at high-speed beam size measurement. A prototype 3-silt mask has been designed and test at SSRF.

## DOUBLE-SILT INTERFEROMETER AT SSRF

The arrangement of double-silt interferometer at SSRF is shown in Fig. 1. The measuring interferogram is fitted by the intensity distribution of the form. The image analysis system works extracting the orthogonal profile, centre position, and least square fit to evaluate the beam sizes. The 800Mb/s interface enables full frame rate and even more cameras on the same bus. The IEEE-1394b cable with jack screws allows a more secure connection to the camera. 12-bit A/D converter, Via external trigger, software trigger (on same bus), This equipment has been tested and found to comply with the limits for a Class A digital device, have good linearity It provide reasonable protection against harmful interference when the equipment is operated in experimental environment.

After all environments and system calibration, Interferometer is good enough for the measurement of a few micro meters small beam size [2]. But the data refresh rate is 2Hz, which is not able to meet the demand of high speed measurement.

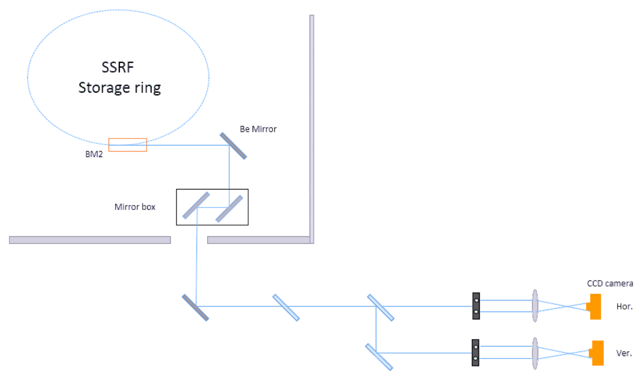


Figure 1: Layout of double-silt interferometer at SSRF.

## MULTI-SILT INTERFEROMETER

The N-slit interferometer was first applied in the generation and measurement of complex interference patterns [3]. A demo beam size monitor(BSM) based on multi-silt interferometer has been proposed and developed for high speed measurements at SSRF. Multi-silt mask has characteristics of high flux throughput. A 3 silts mask for use at SSRF has been installed for demo tests, intercepting the synchrotron radiation fan at the location of an existing double-silt interferometer. In order to verify the performance of Multi-silt interferometer, images have been observerd through both double-silt and 3-silt mask using same CCD camera for a variety of beam size at same exposure times. For simplicity of demo experiments, 3-silt masks have been produced for beam size measurements.The beam size can be controlled via adjustment of the emittance coupling ratio. Figure 2 shows the prototype 3-silt mask installed at SSRF.

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Arrangement of SR 3-silt interferometer at SSRF is shown in Fig. 3.

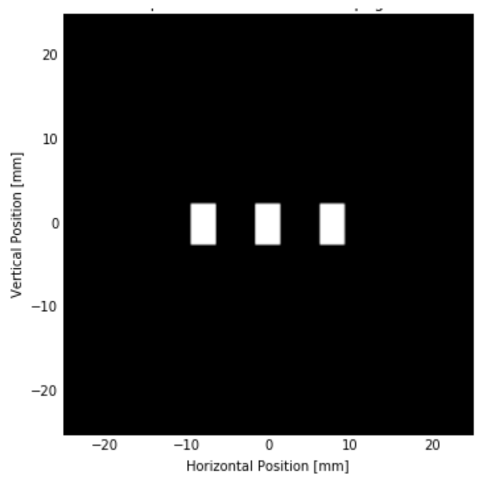


Figure 2: The mask design. Silt width: 3 mm, Pitch: 5 mm.

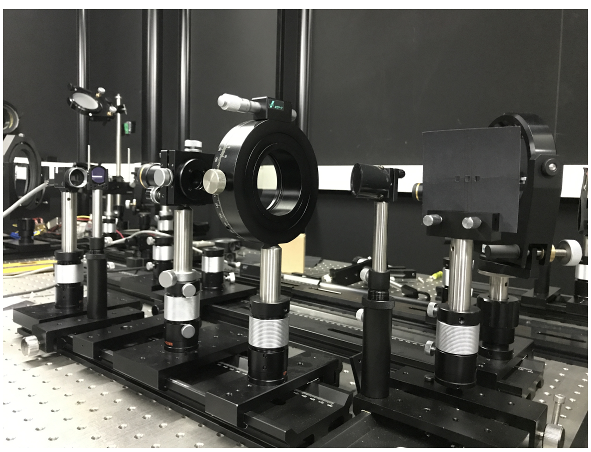

Figure 3: Arrangement of SR 3-silt interferometer at SSRF.

## COMPARISONS OF 3-SILT AND DOUBLE-SILT INTERFEROMETER

Double-silt interferometers are currently relied upon to give an accurate beam size measurement at SSRF. Images obserderd through both double-silt and 3-silt mask using same CCD camera at same exposure times can be compared. Figure 4 shows image and profile observed through double-silt mask. Figure 5 shows image and profile observed through 3-silt mask.

The results shows the peak intensity of the three-slit interference is twice that of double-slit interference, and the light intensity concentrated in the two main peaks.

For double-slit interferometer, the formula to calculate beam size is shown as Eq. (1). $\lambda$ is the wave length,D is preparation of double slits,$\gamma$ is spatial coherence. The coherence is measured by Levenberg–Marquardt fitting of intensity distribution of interference fringe and the other parameters can be measured by simple way. The disadvantage is we need to measure the valley of the interference fringe, which can not satisfy the high speed measurement. In order to overcome this limit, we prefer to find a new way to calculate the beam size. We found the beam size can be measured from first and second peaks intensity of 3-silt interference fringe(shows on Fig. 5).

$$\sigma = \frac{\lambda R}{\pi D}\sqrt{-\frac{ln\gamma}{2}} \tag{1}$$

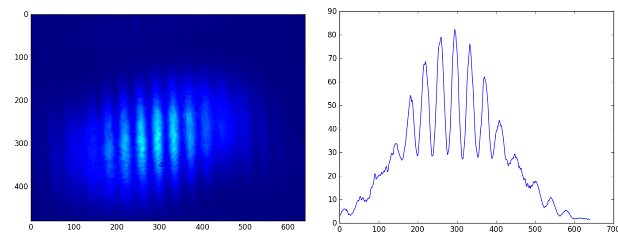

Figure 4: Double-silt interference fringe at SSRF.

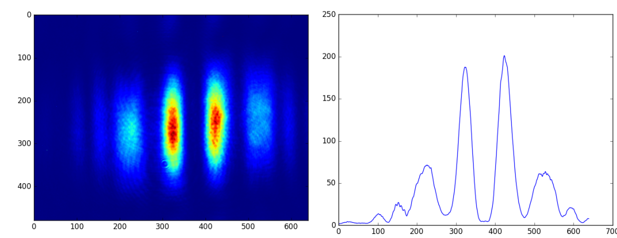

Figure 5: 3-silt interference fringe at SSRF.

## COMMISSIONING AND FIRST BEAM SIZE MEASUREMENT OF 3-SILT INTERFERENCE

In order to verify the usability and reliability of 3-silt interference, beam-based calibration method had been developed in the SSRF storage ring. By varying the beam size, at the source point and observing images of the synchrotron radiation through the 3-silt using a CCD camera. The experiment was carried out in a horizontal plane with 500 electron beam bunches, while the current was around 200 mA. The beam size of the source point was changed by modifying the power supply current,$I_{Q5}$, of the 5th set of the quadrupoles. As we know, the beam size could be described as Eq. (2).

$$S_i^2 = \beta_i \epsilon_i + \left(\eta_i \sigma_{epsilon}\right)^2 \tag{2}$$

where $S_i$ is the beam size in the horizontal or vertical plane, respectively, (i=x,y), $\beta_i$ and $\epsilon_i$ are the betatron and dispersion functions at the source point and in the corresponding plane; and $\eta_i$ and $\sigma_\epsilon$ are the emittance and the relative energy spread of the electron beam.

The detected flux seen at each detector pixel for different beam size shown as Fig. 6.

The image at the CCD camera shows the characteristic interference pattern difference of the different beam size.

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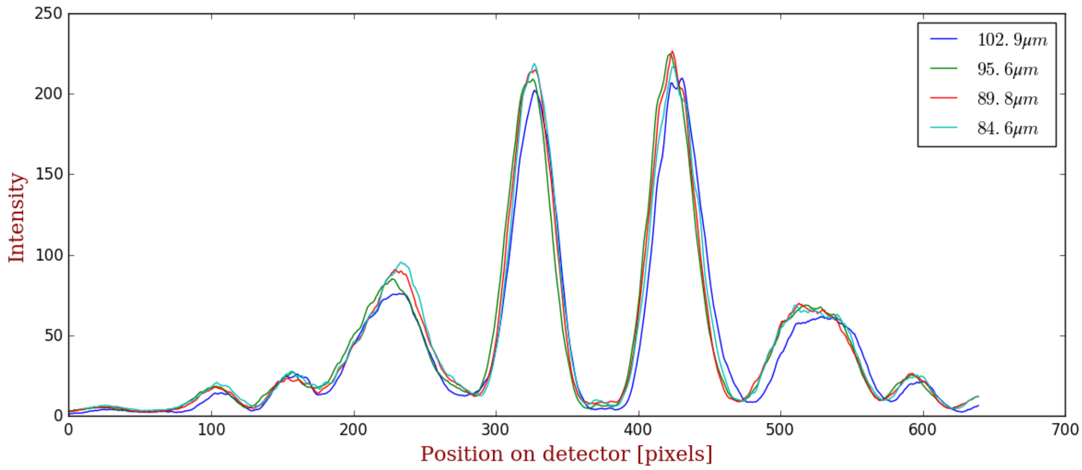


Figure 6: The detected profile of 3-silt interference for different beam sizes.

The maximum intensity of the pattern is defined as $I_1$ , while the second maximum intensity of the pattern is defined as $I_2$. $I_1$,$I_2$ and the ratio of the ($I_1$ - $I_2$) and $I_1$ depends on the Horizontal source size(Horizontal width of the electron beam, $\sigma_x$), as shown in Figs. 7, 8 and 9. The result shows

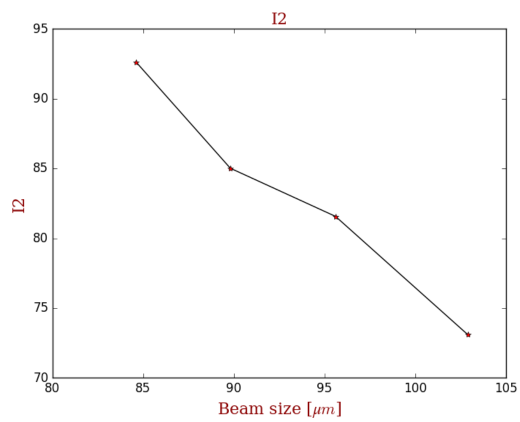


Figure 7: $I_1$ as a function of beam size.

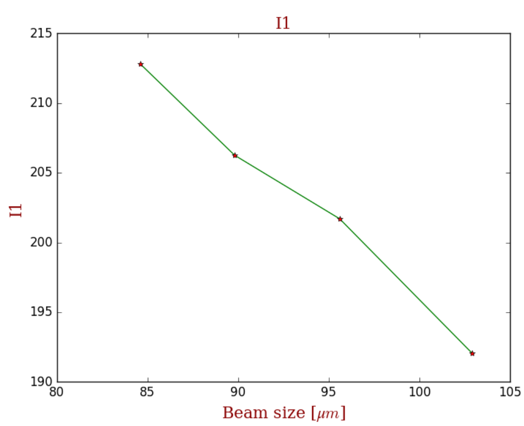


Figure 8: $I_2$ as a function of beam size.

$I_1$,$I_2$ is related to beam size. In order to eliminate the effect of beam current on the intensity of the pattern, the ratio of the ($I_1$ - $I_2$) and $I_1$ was choosed to measured the beam size.

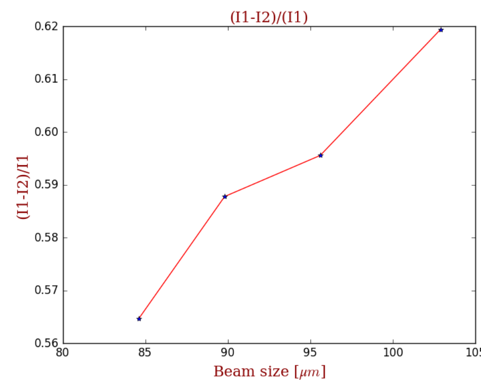


Figure 9: The ratio of ($I_1$ - $I_2$) and I1 as a function of beam size.

## CONCLUSION

The 3-silt interferometer measurements of beam size shows the ratio of ($I_1$ - $I_2$) and $I_1$ is as a function of source size. Compared with double-silt $I_2$ is similar with the maximum intensity of the double-silt pattern, and the $I_1$ is twice of it. In 3-silt interference beam size monitor, we only need to observe 4 detector points, all of this 4 points has high intensity, and can be used for high speed measurement.

In the future, we prefer to use machine learning method and theoretical formula derivation to optimize the beam size extracting algorithm.

## REFERENCES

[1] T. Mitsuhashi *et al.*, "Spatial coherency of the synchrotron radiation at the visible light region and its application for the electron beam profile measurement", in *Proc. PAC'97*, 1997, vol. 1, pp. 766-768.

[2] J. Chen *et al.*, "The Synchrotron Radiation Diagnostic Line at SSRF", in *Proc IBIC'12*, Tsukuba, Japan, Oct, 2012, paper MOPB70, pp. 232-236.

[3] F. J. Duarte *et al.*, "Quantum mechanical description of N-slit interference phenomena", in *International Conference on Lasers'88*, McLean, USA, Dec, 1988, paper MOPB70, pp. 42-47.