WAVEFRONT DISTORTION MEASUREMENT AT SSRF *

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Abstract

The Synchrotron Radiation Monitor (SRM) system has been designed and constructed, at the Shanghai synchrotron radiation Facility (SSRF), for several years and runs good [1]. However, the monitor extraction mirror deformation is quite common at different facilities and other reflecting mirrors in the optic path also have surface error and angle error. As we decide to upgrade the SR monitor system at SSRF, this issue is also one of the most import thing what we should overcome. In order to verify the feasibility and evaluate the accuracy, simulations based on SRW code have been done. In this simulation, a dedicated algorithm was developed to reconstruct wavefront. The result and the algorithm is very useful for our experiment and upgrade program. In this paper, the algorithm and the experiments based on Shark-Hartmann wavefront sensor will be presented detailed.

INTRODUCTION

There are two diagnostic beam lines in the storage ring of SSRF, one of them adopt interferometer to measure the transverse electron beam size of storage ring. One beryllium mirror with water-cooling was used to transmit X-ray and reflect visible light to satisfy the measurement request. Several reflecting mirrors were used to transmit the visible part of synchrotron radiation to the laboratory [1]. Layout of optical path of SR interferometer is as shown in Figure 1.

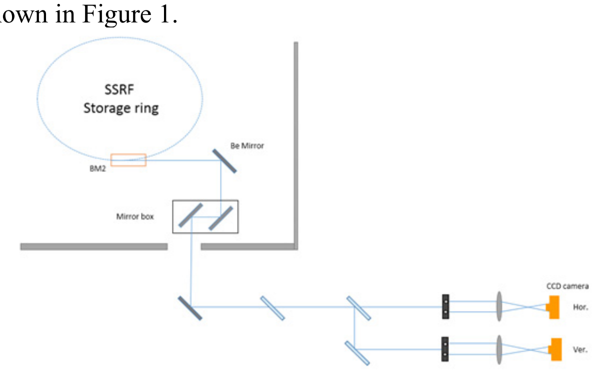

Figure 1: Layout of synchrotron radiation interferometer at SSRF.

The surface of Be mirror was deformed because of X-ray heat. A set of Hartmann Screen test was used to measure the Be mirror deformation at SSRF [2]. However, other reflecting mirrors also have surface error and angle error due to equipment. The impact of all mirrors in the optic path to the wavefront transport before interferometer need to be measured and corrected. However, at SSRF or other facilities, Hartmann masks have been used to measure the deformation of the Be mirror, but the impact from all mirrors to wavefront has never been measured yet. In our experiment a Shark-Hartmann wavefront sensor was used, before interferometer, to measure wavefront deformation through the whole optic path. The result of wavefront distortion measurement can be used to correct the measurement of beam size by interferometer.

The Beryllium Mirror Designed at SSRF

The Be mirror was special designed to reflect visible light from vacuum and let x-ray pass through. Part of the energy of x-ray was absorbed by the Be mirror and the heat cause deformation of the mirror [2]. The Be mirror shape used at SSRF is shown as Figure 2. The power of our Synchrotron Radiation light is about 531.4W. The thinnest part of our Be mirror is about 0.254mm. Even though Beryllium is the best metal to conduct x-ray, the power absorbed by our Be mirror is about 200W. The impact of the deformation on Be mirror cannot be ignored.

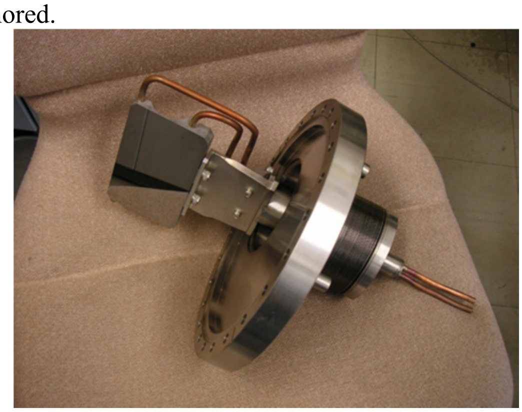

Figure 2: Be mirror with water-cooling used at SRM of SSRF.

SRW

"Synchrotron Radiation Workshop" (SRW) is a physical optics computer code for calculation of detailed characteristics of Synchrotron Radiation (SR) generated by relativistic electrons in magnetic fields of arbitrary configuration and for simulation of the radiation wavefront propagation through optical systems of beam lines. Frequency-domain near-field methods are used for the SR calculation, and the Fourier-optics based approach is generally used for the wavefront propagation simulation [3].

Hartmann Method

Hartmann method wavefront sensor is a very common method to measure the wavefront distortion. The Hartman

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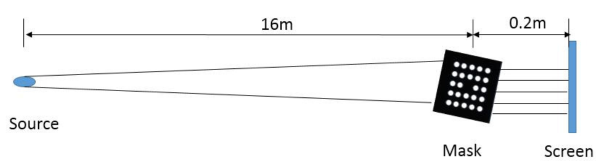
test, invented by Hartmann (1900, 1904a, b and c) to test the Great Refractor at Postdam, has its antecedent in the measurements of eye refractive defects using a screen with two holes in front of the eye as described by Tscherning (1894). It uses a screen with an array of holes placed close to the entrance or exit pupil of the system under test [4].

SIMULATION

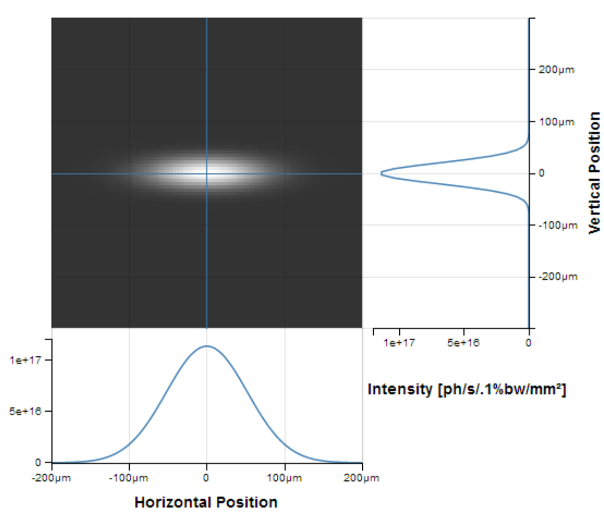
To verify the feasibility of the method and design a good wavefront reconstruct algorithm, we used Synchrotron Radiation Workshop (SRW) code for the source description and wavefront transport, while algorithm based on python is used to analyse its outputs. This algorithm can be used for similar Hartmann based wavefront metrology such as Shark-Hartmann to calculate the wavefront aberration.

Source Description and Wavefront Transport

We use SRW code to generate a Gaussian beam. Beam size is same as the regular model of SSRF: σHor. = 52 μm; σVer. = 20 μm. The optic path and the visible part of the SR light is shown as Figure 3.



(a)



(b)

Figure 3: (a) Optical path designed in the simulation; (b) Visible part of the SR light.

Algorithm Description

Due to the misalignment during fabrication of the device, the image we get from the detector is tilted. In order to overcome this issue, a new approach is introduced in our algorithm. We use FFT method to find the phase information, then we unwrapped phase to get position of each spot, at last we use centroid method to figure out each centroid of spot array. The Algorithm flow is shown as Figure 4.

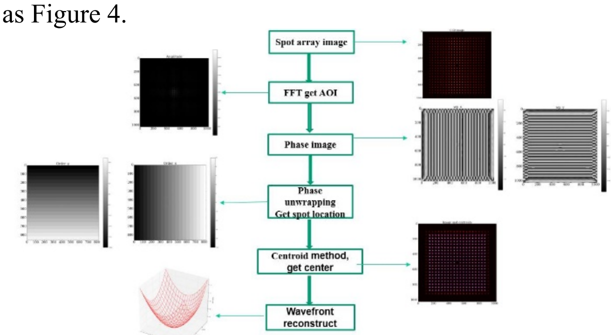
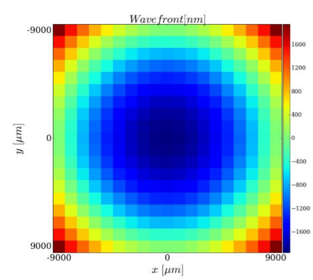


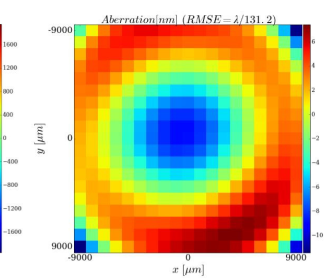
Figure 4: Algorithm flow of wavefront reconstruction.

Simulation Result

The result of our simulation is shown as Figure5. Figure 5(a) shows the wavefront map constructed by our algorithm. Figure 5(b) shows the aberration of the wavefront w based on the perfect sphere wavefront, RMSE is λ/131.2(λ= 550 nm).



(a)



(b)

Figure 5: The result of our simulation. (a) The wavefront map; (b) The aberration of the wavefront we measured.

EXPERIMENT

Measurement Setup

Figure 6 shows the fundamental parts and their arrangement in our experiment. The wavefront is tested with OMI Shark-Hartmann wavefront sensor. The lenslet array specs are as follows: diameter 200 microns and focal length 22 mm for each lens in the lenslet array. The CCD camera used in measurements has 1280 * 1024 pixels with 6.5 * 6.5 μm pixel size.

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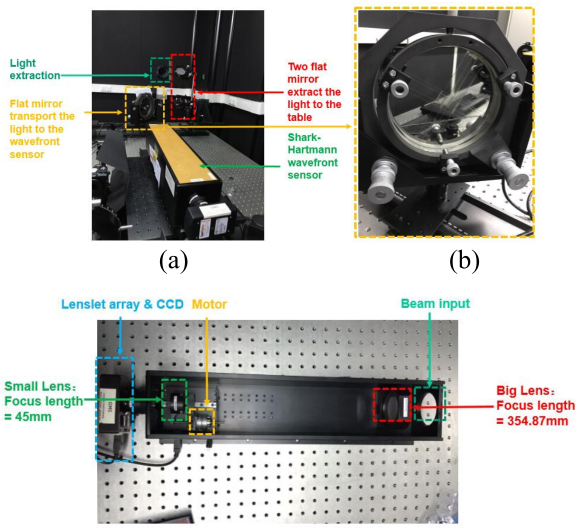

(c)

Figure 6: Shark-Hartmann experiment setup. (a)Experiment setup; (b) The detailed drawing of the last flat mirror; (c) Shark-Hartmann wavefront sensor.

Verification Experiment

A verification experiment has been done to verify our wavefront sensor and algorithm. The last mirror in our optical path is an adjustable mirror, the detailed drawing of this mirror is shown as Figure 6 (b).

We tilt the last flat mirror in vertical direction and observe the change of the wavefront. The angle variation each time is 3.3 μrad. The result is shown as Figure 7.

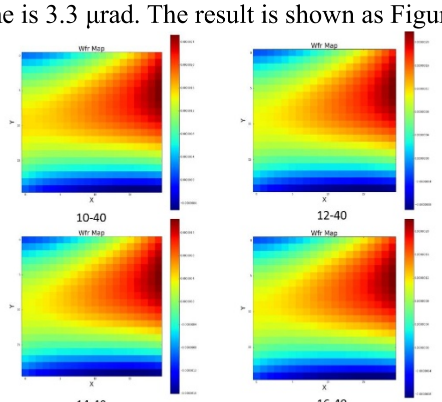

Figure 7: (a) The wavefront map of different angle of the last flat mirror.

From the 3D wavefront we can clearly see the angle change in Y direction and average angle change of wavefront is 3.893 μrad. The result of the verification experiment shows the performance of the sensor, we can believe the result of our wavefront sensor.

Wavefront Measurement at SSRF

We used the algorithm designed in the simulation to reconstruct the wavefront we got from synchrotron radiation light of the ring current 260 mA. The result is shown as Figure 8 From the result we can see the wavefront in

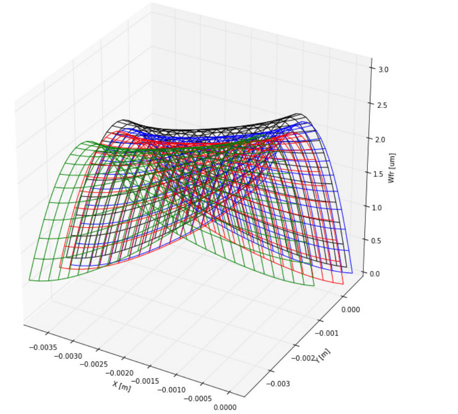

Figure 7: (b) Comparison of the 3D wavefront of different angle of the last flat mirror.

horizontal direction is symmetrical, and the distortion in vertical direction

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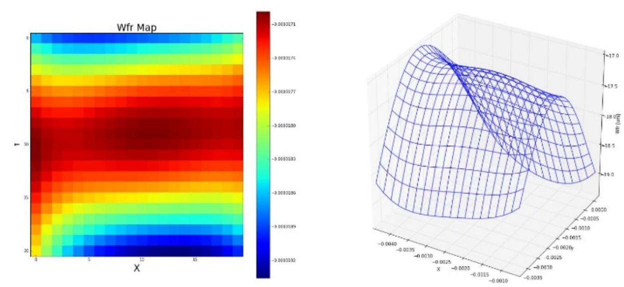

Figure 8: Wavefront reconstruct result.

CONCLUSION

We described the simulation and the experiment of the wavefront distorition measurement at SSRF. In the simulation we verify the accuracy of the Hartmann mask designed in simulation and the algorithm, the resolution can reach to λ/131.2 (λ= 550nm). From the experiment we get the wavefront in the position of the double tilt mask of our SRI. And a verification experiment has been done to verify our wavefront sensor and algorithm. The performance of our wavefront sensor is enough to measure the wavefront error of SR beam. In the future, another experiment will be done to study the wavefront change at various ring current; we will figure out the wavefront distortion and calibrate the synchrotron radiation interferometer at SSRF.

REFERENCES

[1] Ye K R, Leng Y B, Chen J, *et al.,* in *Proc. DIPAC'01,* pp. 26–30.

[2] Chen J, Ye K R, Leng Y B. , in *Proc. IBIC'12,* pp. 191-193.

[3] GitHub, `https://github.com/ochubar/SRW/`

[4] D.Malacara and I.Ghozeil, Optical Shop Testing. A John Wiley & Sons, Inc., Publication.