A DESIGN OF SYNCHROTRON RADIATION MONITOR FOR KEK B-FACTORY

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Abstract
A synchrotron radiation(SR) monitor for KEK B-factory has been designed. The monitor consists of 1), visible SR beam extraction system having a real time surface flatness measurement system, 2),SR beam transfer system, adaptive optics system for the correction of deformation of the SR extraction mirror, 3), focusing system for the observation of the beam profile, 4), SR-interferometer for the measurement of the beam size, and 5),extra branch beamline for other measurement such as streak camera.

1 INTRODUCTION

Monitor to measure the beam profile or beam size which based on a using the synchrotron radiation will greatly improve the efficiency of the commissioning of KEKB project. In this paper, it is descried that the design of the SR monitor. Not only the ordinal SR monitor based on an imaging , we introduce newly developed techniques for this monitor. One is so called adaptive optical system(1),(2)which is an active correction system for distortion of the wavefront and other is the SR-interferometer (4),(5) for the measurement of the beam profile and the size.

2 DESIGN of OPTICAL PASS AND CLEAN ROOM FOR THE MONITOR

The design of optical pass is shown in Fig.1. A dedicated weak bending magnet is insert in the both HER and LER as a SR beam source. The parameters of the source points are listed in Table 1.

Table 1 Preliminary parameters of the weak bend

	bending radius	angular power of SR	source size
LER	183m	28.86W/mrad at 2.5A	σ_x 472μm σ_y 69μm *
HER	1172m	49.31W/mrad at 1A	σ_x 650μm σ_y 120μm *

*vertical beam size assumes an emittance coupling of 2%

The optical pass is designed to 11m pass from the source point to SR extraction mirror, and then the optical pass is divided into two passes by the use of a half mirror, one for focusing system having a adaptive optical system and other is for the SR-interferometer. Total length of the optical passes are 41m for each. At the end of the optical pass, it will be located clean room for devices of the optical monitor. The clean room is designed to class 100 dust free room and the dimension of 4.5 x 4.5 m^2.

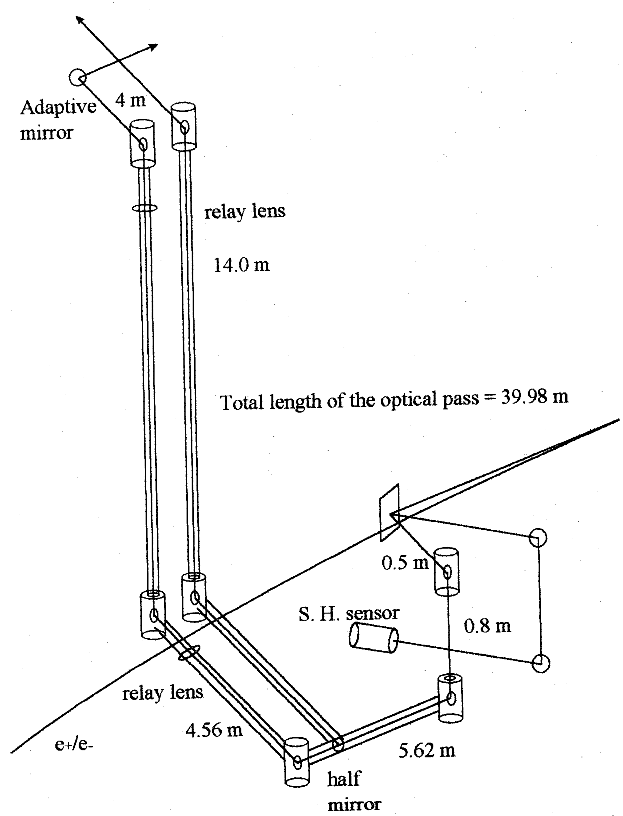


Fig.1 Outline of the SR-interferometer.

3 DESIGN OF ADAPTIVE OPTICAL SYSTEM FOR THE COMPENSATION OF WAVEFRONT ERROR FOR THE FOCUSING SYSTEM

3-1 Design of the adaptive optical system

Because of the extraction mirror for SR beam will be irradiated by a strong power of SR beam as listed in Table 1. The surface flatness will be deformed beyond Rayleigh's criterion (λ/8) of diffraction limited optics. This deformation of the extraction mirror introduce a wavefront error and finally makes a blurred image of the beam. To compensate this wavefront error, we designed an adaptive optical system by the use of deformable mirror(1). The design of the adaptive optical system is shown in Fig.2.

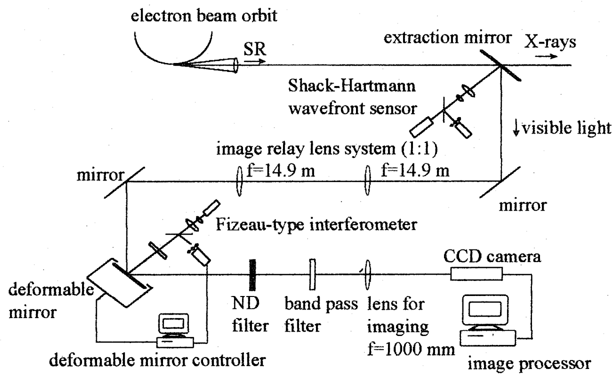


Fig.2 The design of adaptive optical system for the monitor

The wavefront error is transferred on the deformable mirror using a relay lens system (1:1) and compensated by deformable mirror. The deformation of deformable mirror is watched by the Shack-Hartmann sensor. We use a deformable mirror CILAS BIM31 which is a "bimorph" type mirror having 31 electrodes in the behind of the mirror surface. After the wavefront correction, SR beam will focused by a diffraction limited ED doublet lens. Then the image of the beam will be observed with magnifier lens and CCD.

3-2 Wavefront sensing

We designed and constructed a Shack-Hartmann wavefront sensor(2) to measure a wavefront error caused by the deformation of extraction mirror. The outline of the S-H wavefront sensor is shown in Fig.3.

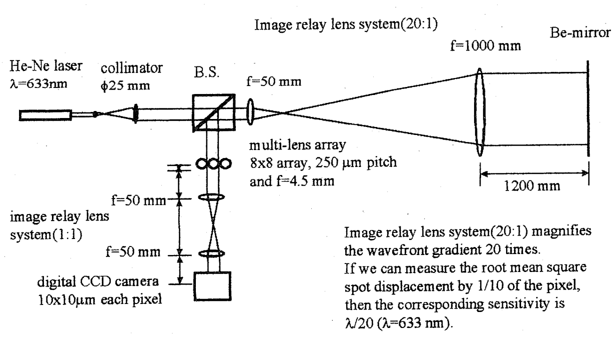


Fig.3 Outline of the Shack-Hartmann wavefront sensor.

The sensor consists a multi-lens array , two image relay lens systems and a CCD camera. The wavefront error caused by a deformation of the extraction mirror is transferred to the multi-lens array by a image relay lens system (20:1)and it is divided by each lenslet. In the focal plane of the multi-lens array, the image spot of each lenslet is shifted by a quantity proportional to the local slope of the wavefront. Then the image plane of the multi-lens array is again transferred to CCD by a image relay system (1:1), and measure the position of the image spot. We can measure the rms spot displacement by 1/10 of the pixel, then the corresponding sensitivity is λ/20 (λ =633nm). Performance of the wavefront sensor was tested at the optical laboratory 2 at Photon Factory. A result of the measurement of a wavefront error caused by SR-extraction mirror at BL-27 is shown in Fig. 4.

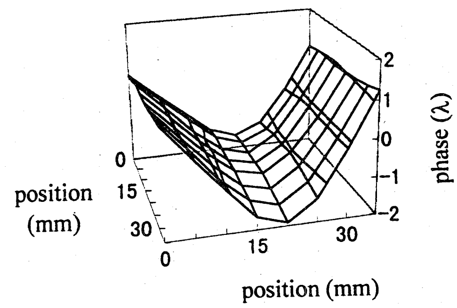
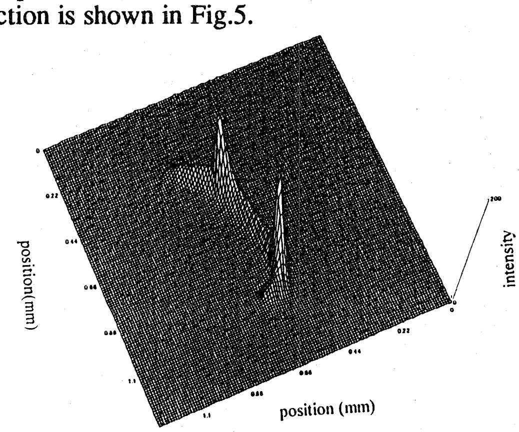


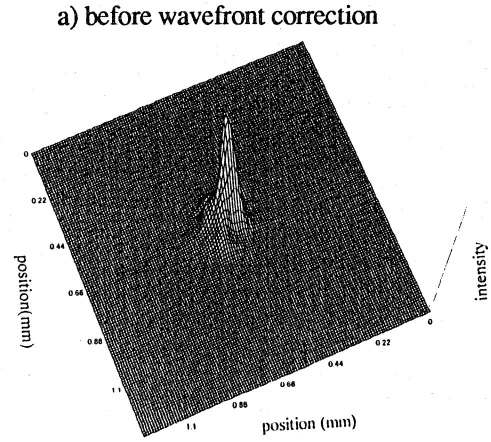
Fig.4 A result of the measurement of a wavefront error caused by SR-extraction mirror at BL-27

3-3 Performance test of the adaptive optical system at Photon Factory

Performance of the adaptive optical system was tested by the use a pinhole source by the use of Xe-discharge lamp and SR-extraction mirror of BL27 at Photon Factory. As a result, we succeeded to compensate the wavefront error less than λ/5.6 in rms. A result of point spread functions before and after the wavefront correction is shown in Fig.5.



a) before wavefront correction



b) after wavefront correction

Fig. 5 Results of point spread functions.

Figure 5-a) shows a measured point spread function before the wave front correction. It is measured by the use of pinhole source which is 200μm in diameter which is located at 8m from the focusing objective lens. Figure 5-b) shows a measured point spread function after the wavefront correction. A strong astigmatism as shown in Fig.4 caused by a cylindrical shape of the wavefront error as shown in Fig.4 is well corrected.

4 DESIGN OF SR-INTERFEROMETER FOR VERTICAL BEAM PROFILE AND SIZE MEASUREMENT

The principle of object-profile measurement by means of the spatial coherency of the light is known as the van Citterut-Zernike's theorem(3). It is well known that A. A. Michelson was measured the angular diameter of stars by his famous stellerinterferometer. Recently, this principle was applied for the measurement of vertical electron beam profile in the storage ring by one of the authors by the use of SR-interferometer(interferometer for synchrotron radiation)(4) at the Photon Factory. Since this method is based on spatial coherence of the SR beam, it is suitable to measure a small electron beam size having a good spatial coherence. Recently, very small vertical beam size (16.5μm) of AURORA at SR center of Ritsumeikan University was measured by this method(5).

4-1 Design of the SR-Interferometer

The SR-interferometer is basically a wavefront division type two beam interferometer by the use of polarized quasi-monochromatic rays(4). In this time, for the purpose with ease of data analysis, we modified the design of double slit interferometer into quadruplicate slit design of the interferometer. A schematic drawing of the new design of the SR-interferometer is shown in Fig.5.

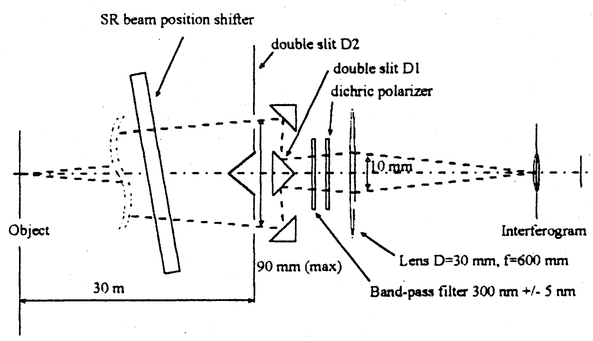


Fig.5 A design of SR-interferometer for B-factory.

For the purpose to stabilize the SR beam position in front of the interferometer, a beam position stabilizer is applied at the entrance pupil of the interferometer.

In the quadruplicate slit design of the interferometer as shown in Fig.5, the first double slit serves as a movable double slit, and second one (having no physical slits) serves a fixed double slit. By the use of this design, the interferogram is given by;

$$I(\theta) = (\sin c(\theta))^2 \left\{1 + |\gamma(D_2)| \cos(kD_1(\theta + \varphi))\right\}$$

where θ denotes observation angle of the interferogram, D_1 denotes distance of the first double slits, and D_2 denotes distance of second double slits (distance between lays). The degree of spatial coherence γ is represented by;

$$\gamma(D_2) = \sqrt{c^2(D_2) + s^2(D_2)}$$

$$c(D_2) = \int f(\Theta) \cos(kD_2\Theta) d\Theta$$

$$s(D_2) = \int f(\Theta) \sin(kD_2\Theta) d\Theta$$

$$\varphi = \tan^{-1} \frac{s(D_2)}{c(D_2)}$$

where $f(\Theta)$ denotes beam profile as a function of angular diameter Θ. In this configuration of the interferometer, the spatial frequency of interference fringe is a function of D_1 and the modulation of the γ is a function of D_2. This means spatial frequency of the interference fringe is never change according to change of D_2. Only the modulation of the γ is changing as a function of D_2. This performances of the newly designed SR-interferomater have a great advantage to measure the visibility (modulation of the γ) and phase of the interference fringe.

Usable opening angle of the visible SR beam is estimated by 3mrad for LER and 1.8mrad for HER. Under this conditions, it is estimated we can measure the beam profile having rms beam sizes 49μm for LER and 85μm (these beam sizes are corresponding to the case of 1% coupling) for HER with this SR-interferometer. To assuming a Gaussian beam profile, smaller limitation of the beam size measurement is estimated by 10μm for LER and 17μm fot HER.

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