# A CONSTRUCTION AND COMISSIONING 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 and constructed. The monitor consists of following systems;1) visible SR beam extraction system having a real time surface flatness measurement system; 2) SR beam relay system; 3) focusing system for the observation of the beam profile,; 4) SR-interferometer for the measurement of the beam size; 5) extra branch beamline for other measurement such as streak camera. The two sets of SR monitor systems are constructed for the HER and the LER. The results on commissioning of SR monitor are also reported.

## 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. A synchrotron radiation (SR) monitor for KEK B-factory was designed and constructed. The visible SR beam for the monitor is produced by a dedicated week bending magnet and is extracted by a mirror system which has a real- time surface flatness measurement system. The extracted SR beam is transferred to the SR monitor hat on the ground by about 40m long optical path system. An image of the electron (positron) bean is observed by the use of a focusing system based on the adaptive optics[1]. Since the diffraction limit of the focusing system, we cannot measure the small beam size precisely. We use the SR interferometer [2] for the precise measurement of the small beam size. The extra few branch beam lines are prepared for the other measurements such as streak camera. In the commissioning of the B-factory, immediately after the beam storage in the ring, we succeeded in observing the beam image. After getting a few10mA beam current, the SR interferometer is applied to measure both of the horizontal and the vertical beam size. Now the beam images for the HER and the LER are continuously displayed in control room and automatic analysis system for the interferogram via SR interferometer is running on the control computer[3].

## 2. OPTICAL PATH AND CLEAN ROOM FOR THE MONITOR

To reduce a strong power of SR beam due to hard X-rays component, we insert dedicated 5mrad weak bending magnets into the both HER and LER as a SR beam source. The optical paths from the source point to the optical hat for the HER and the LER have almost same design [4]. The SR beam is extracted by water-cooled Beryllium extraction mirror. The outline of extraction mirror system is shown in Fig.1. Surrounding structure of the mirror is designed by electrically smooth to reduce the corrective effects for the stored beam.

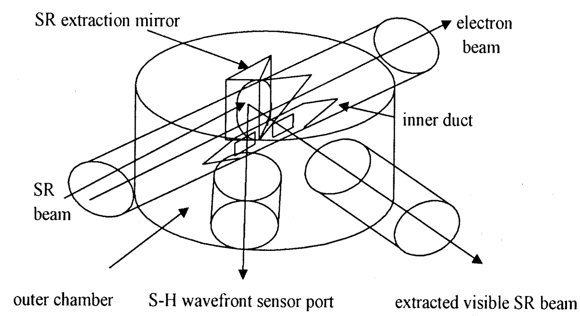



Fig.1 Outline of SR extraction mirror system.

After extraction, the SR beam is divided into two beams by a half mirror, one is for focusing system by means of adaptive optics and other is for the SR-interferometer and extra branch beamlines. Total length of the optical path is about 40m. At the end of the optical path, the clean rooms (monitor hat) are set on the ground floor. The outline of optical path is shown in Fig.2. The clean room (SR monitor hat) is designed to class 100 dust- free room.

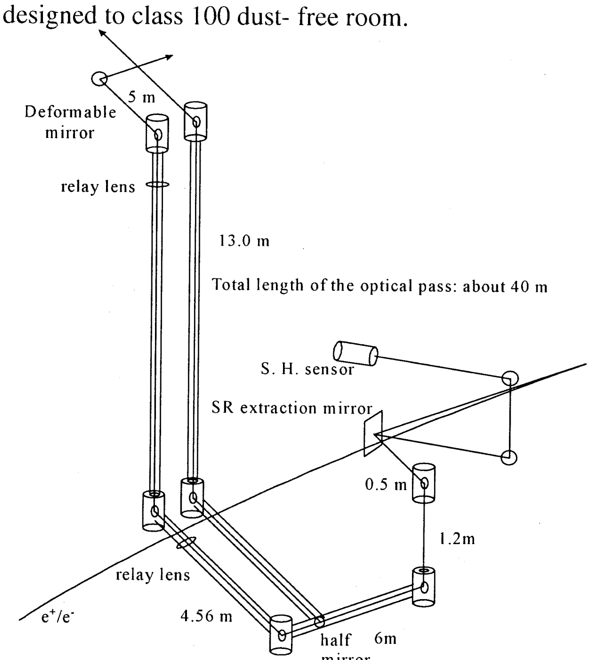



Fig. 2 Outline of optical path.

## 3. IMAGING SYSTEM FOR PROFILE MEASUREMENT

Because of the extraction mirror for SR beam will be irradiated by a strong power of SR beam. The surface flatness will be deformed beyond Rayleigh's criterion ($\lambda/8$) of diffraction. 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 imaging system by means of adaptive optical system[1]. The outline of the design of imaging system is shown in Fig. 3.

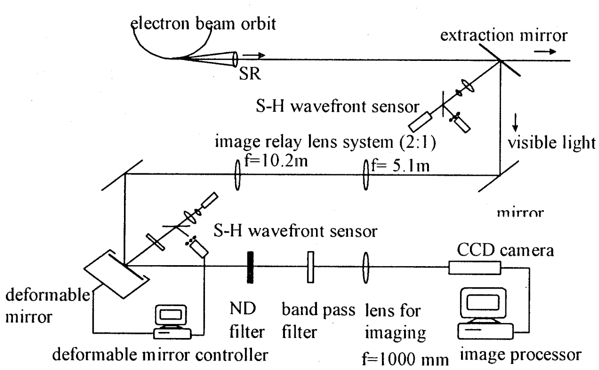



Fig.3. Outline of the imaging system

The wavefront error is transferred on the deformable mirror using a relay lens system (2:1) [4] and compensated by deformable mirror.

To measure a wavefront error caused by the deformation of extraction mirror, we designed and constructed a Shack-Hartmann wavefront sensor[4]. The outline of the S-H wavefront sensor is shown in Fig.4.

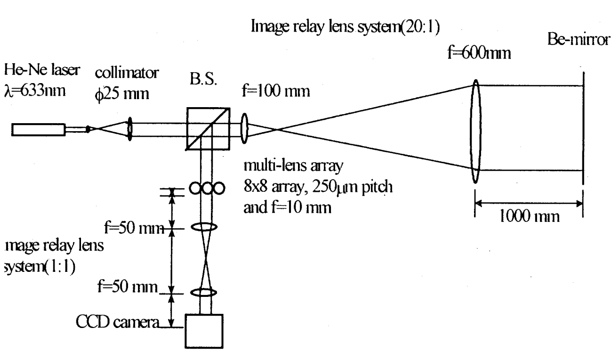
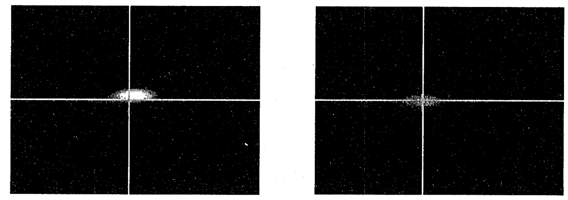



Fig.4 Outline of the Shack-Hartmann wavefront sensor.

The sensor consists a multi-lens array , two image relay lens systems and a CCD camera. 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.

After the wavefront correction, SR beam will focused by a diffraction limited doublet lens. Then the image of the beam will be observed with magnifier lens and CCD.

The deformable mirror system will be installed in the LER in coming autumn. Right now the beam profile images of the HER and the LER are observed without the deformable mirror. Figure 5 shows typical examples of the beam profile of the HER and the LER.



(a) HER (b) LER

Fig. 5 Observed beam profiles at the HER and the LER.

## 4 SR-INTERFEROMETER FOR BEAM SIZE MEASUREMENT

To measure the vertical and horizontal beam sizes, the SR interferometers were installed in both of the HER and LER [2]. The set up of SR interferometer is shown in Fig.6.

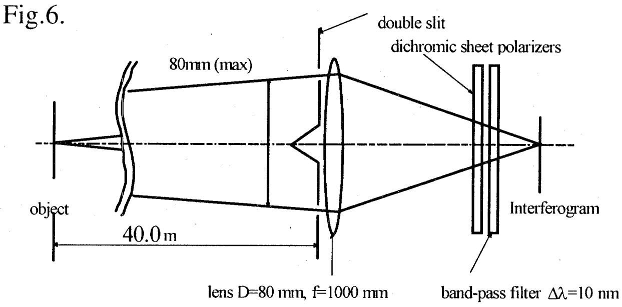
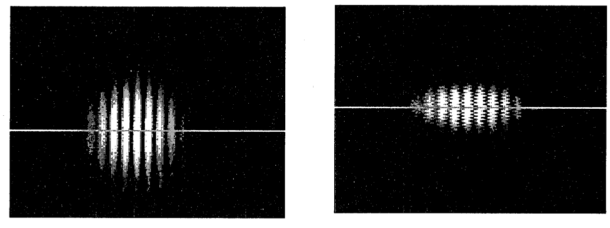



Fig.6 A set up of SR-interferometer for B-factory.

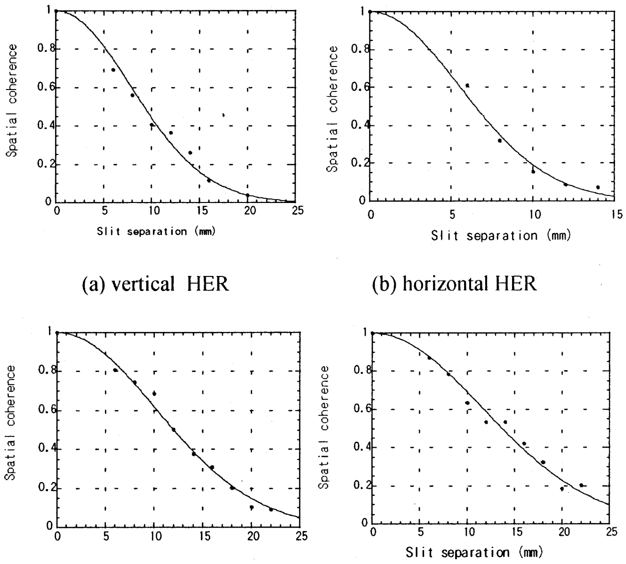
Right now, one SR interferometer is shared to vertical and horizontal beam sizes measurements. For the independent measurement for the vertical and the horizontal beam sizes, we are preparing one more SR interferometer in this summer. Observed typical interferograms of the vertical direction at the HER and the LER are shown in Fig.7



(a) HER (b) LER

Fig.7 Observed interferograms for the vertical direction at the HER and the LER.

The absolute value of the complex degree of spatial coherence is evaluated from the visibility of the observed interferograms. The results are shown in Fig.8.




(a) vertical HER (b) horizontal HER

(a) vertical LER (b) horizontal LER

Fig. 8 Absolute value of the complex degree of spatial coherence plots for HER and LER.

Under a Gaussian beam profile approximation, we can evaluate a RMS width of beam size by using the least-squares analysis of the spatial coherence[2]. The RMS beam size $\sigma_{beam}$ is given by the RMS width of the spatial coherence curve $\sigma_\gamma$ as follows:

$$\sigma_{beam} = \frac{\lambda \cdot R}{2 \cdot \pi \cdot \sigma_\gamma} \qquad (1)$$

where $R$ denotes the distance between the beam and the double slit. Least-squares fitting of spatial coherence calculated by the Gaussian beam profile approximation for the measured spatial coherence are also shown in Fig. 8. We can evaluate the RMS beam size by $\sigma_\gamma$ obtained from this fitting. The results those measured in the early stage of the ring commissioning are listed in Table 1.

Table 1 Results of beam size measurement

| | | RMS width γ (mm) | magnification due to deformation of SR extraction mirror | beam size (μm) |
|---|---|---|---|---|
| LER | horizontal | 11.64 | 0.481 | 538 |
| LER | vertical | 10.32 | 0.885 | 361 |
| HER | horizontal | 5.86 | 0.800 | 689 |
| HER | vertical | 8.31 | 0.918 | 437 |

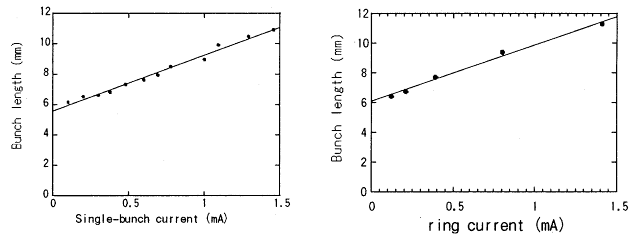
We can also measure estimate the RMS. beam size from one data of visibility, which is measured at a fixed separation of double slit. The RMS beam size $\sigma_{beam}$ is given by ,

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

where γ denotes the visibility, which is measured at a double slit separation of D[2]. By using this method, we can measure the beam size by analysing an interferogram taken at fixed D automatically. The measured results of beam size are relayed back to the control room for a continuous real-time beam size measurement [3].

## 5 MEASUREMENT OF BUNCH LENGTH BY STREAK CAMER

The bunch lengths in the HER and the LER are measured by the use of the streak camera. T results of the bunch lengths as a functions of ring current are shown in Fig. 9.




(a) HEL (b) LER

Fig.9 Results of bunch length measurements.

We can estimate natural bunch length by extrapolating the data to zero current, and results are 5.5mm for the HER and 6.0mm for the LER.

## 6 CONCLUSIONS

A synchrotron radiation(SR) monitor for KEK B-factory has been designed and constructed. The beam profile and size measurement systems are performed well to deliver continuous real-time data. The bunch length measurement system via streak camera is also available at the interferometer beam line. Further refinements to the measurement systems such as independent mesurements for the vertical and the horizontal beam size are under preparation.

## 7 ACKNOWLEDGMENTS

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