OPTICAL DIAGNOSTIC SYSTEM FOR THE KEK B-FACTORY

Toshiyuki MITSUHASHI, John W. FLANAGAN and Shigenori HIRAMATSU
High Energy Accelerator Research Organization, Oho, Tsukuba, Ibaraki, 305-0801 Japan

Abstract

A set of optical-diagnostics systems utilising visible synchrotron radiation has been installed at the KEK B-factory. These systems are capable of both imaging measurements and SR interferometory measurements. The focused images and interferograms are processed automatically, and the results are relayed back to the control room for continuous real-time measurements of beam size.

1 INTRODUCTION

Monitoring to measure the beam profile or beam size based on a using the synchrotron radiation was undertaken to improve the efficiency of the commissioning of KEKB project. A beam monitor system based on synchrotron radiation (SR) for the KEK B-factory was designed and constructed. The visible SR beam for the monitor is produced by a dedicated weak bending magnet and is extracted by a mirror system which has a real-time mirror-surface flatness measurement. The extracted SR beam is transferred to an SR monitor hut above ground by a 40m long optical path system. An image of the electron (positron) beam is observed by the use of a focusing system. The SR interferometer is applied to measure both the horizontal and the vertical beam sizes. A few extra branch beam lines are available for other types of measurement such as streak camera, fast gated camera, etc. The beam images for the HER and the LER are continuously displayed in the control room and an automatic analysis system for the interferogram via SR interferometer is running on the control computer [4].

2 SR SOURCE AND EXTRACTION SYSTEM

We inserted dedicated 5mrad weak bending magnets into both the HER and the LER as SR beam sources in order to minimize the hard X-ray component. The bending radii are 65m for the LER and 650m for the HER, respectively. The total angular radiation powers of the SR beams are 55.9 W/mrad for a 2A beam in the LER and 76.3 W/mrad for a 1A beam in the HER. The SR beams from the weak bending magnets are extracted by water-cooled beryllium extraction-mirrors. The surface temperature is estimated to be 60°C for maximum power input by a thermal simulation. To monitor the thermal deformation of beryllium extraction-mirror, we use a the Shack-Hartmann wavefront sensor [1]. The outline of the extraction mirror system is shown in Fig. 1. The mirror chamber has a double structure, i.e. an inner duct and a surrounding chamber. The inner duct is carefully designed to reduce the collective effects. The water-cooled Be mirror is inserted into the side of the duct. The duct has a surrounding chamber to maintain vacuum. The chamber has two ports seeing the Be-mirror. One is for the extraction of the visible SR beam, and the other is for monitoring the thermal deformation of the mirror surface as shown in Fig.1. Two holes are also made on the inner duct. These holes on the inner duct are covered with 5mm thickness optical-quality Quartz windows. Since the inside of the quartz windows face the electron or positron beam, we applied 500nm thickness Ti coating. This coating behaves like a neutral density filter as far as the optics design of the system are concerned.

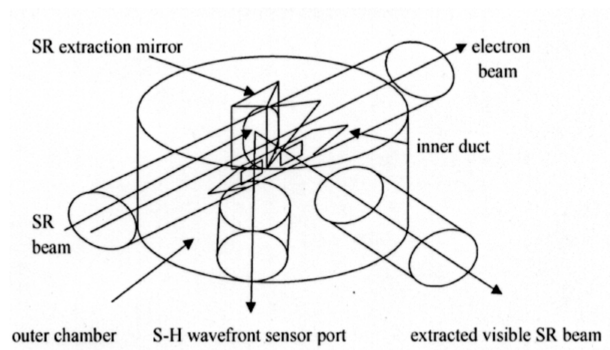


Figure 1: Outline of the SR extraction mirror system.

The temperature of the chamber rises from 25°c to 47°c with a ring current of 500mA. This temperature rise is linearly proportional to the ring current. Since we did not observe a non-linear temperature rise, the design of the chamber is apparently functioning well to prevent collective effects. An electric fan is used to cool the chamber.

3 OPTICAL PATH TO MONITOR HUT

After the extraction mirror, the SR beam is divided into two beams for two branch beamlines by a beam splitter (2:98). Since the focusing system doesn't need intense beam, we supply 2% of the total beam for the focusing system (beamline no.1). The remaining 98% of the total beam is supplied to the SR interferometer other instruments for machine studies (beamline no.2). The beamline for the focussing system incorporates a relay lens system to reduce the conjugation ratio of the focussing system. The total length of optical path is about 40m and is enclosed by aluminium tubes and boxes (not evacuated). Each beamline was aligned with an auto-collimation method using a He-Ne laser. The outline of the optical path is shown in Fig.2 [2].

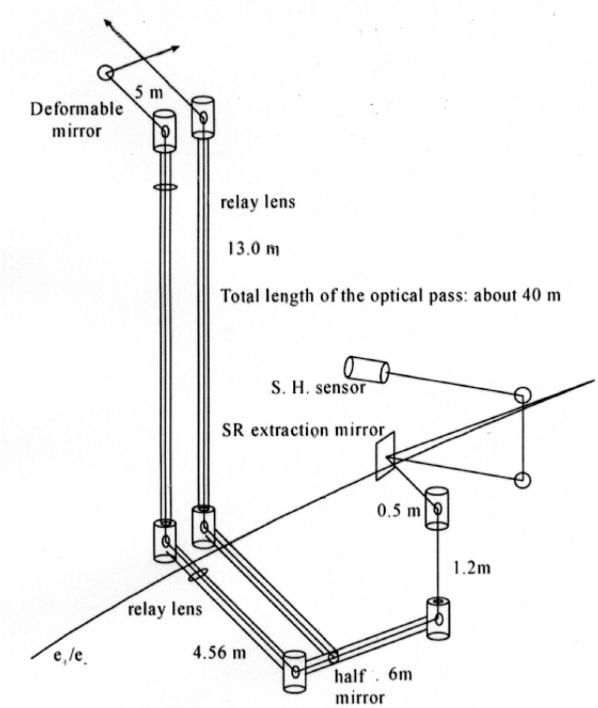
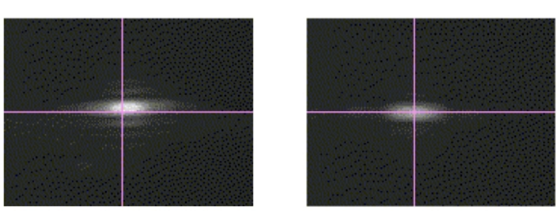


Figure 2 : Outline of optical path.

At the end of the optical path, two SR monitor huts are set on the ground level. One is dedicated to the SR interferometer to monitor the vertical and the horizontal beam sizes. The other hut has the focusing system and apparatuses for machine studies

4 IMAGING SYSTEM FOR PROFILE MEASUREMENT

A conventional beam profile monitor based on a focusing system is set at the end of beamline no.1. Figure 5 shows typical examples of the beam profiles for the HER and the LER.



(a) HER (b) LER

Figure 3: Observed beam profiles

The focussing system consists of a relay lens system (set in the beamline), a diffraction limited doublet lens (F=1000mm) for the objective, a magnifier lens and a CCD camera. The conjugation ratio of the objective including the relay lens is 0.025.

5 SR INTERFEROMETER FOR MONITORING BEAM SIZE

To monitor the beam size, SR interferometers [3] are installed at both the HER and the LER. Two branch beamlines are cut from beamline No.2 by totally reflective mirror. Two independent SR interferometers are set end of these branch beamlines for measurements of both vertical and horizontal beam sizes. The set up of the SR interferometer is shown in Fig.6. We use fixed slit separation for beam size monitoring.

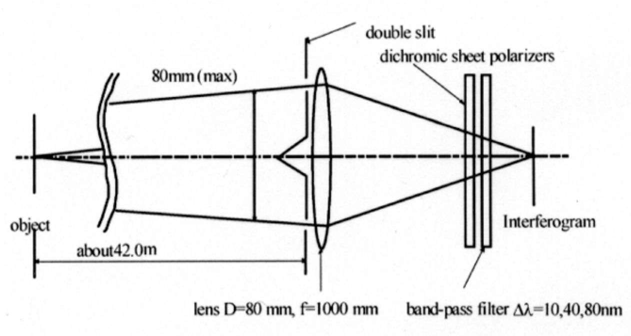


Figure 4: Set up of SR-interferometer

6 AUTOMATIC BEAM-SIZE MEASUREMENT SYSTEM

Using a Gaussan beam profile approximation, we can estimate the RMS beam size from the visibility of one interferogram, which is measured at a fixed separation of the double slit [3]. The RMS beam size σ_{beam} is given by ,

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

where γ denotes the visibility, which is measured at a double slit separation of D and R is the distance between the beam source point and the double slit [3]. We can easily measure a beam size automatically from an analysis of the interferogram taken at fixed separation of double slit D [4]. To find the visibility γ from the interferogram, we use the standard Levenberg-Marquart method for non-linear fitting. After the image processing of the interferogram, the results are displayed in a display terminal in the control room. Fig. 9 shows an example of the display panel for the LER. A similar panel is also displayed for HER. The interferogram, best-fit curve and beam size trend graphs for vertical and horizontal directions are shown in the panel. With this automatic beam-size measurement system, we can measure the vertical and horizontal beam size every 0.5 seconds for beam tuning.

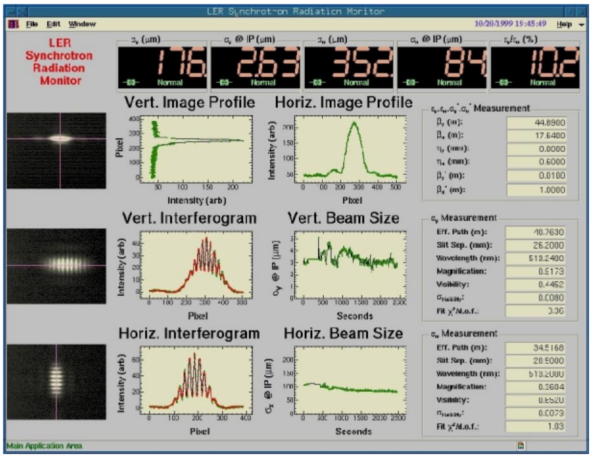


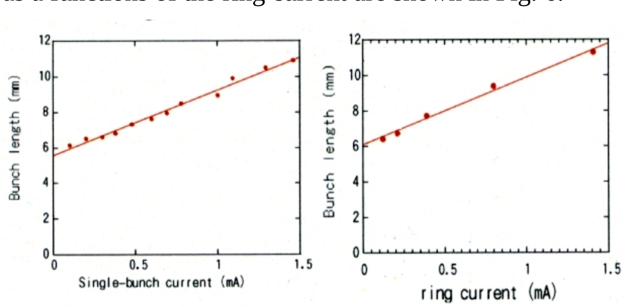
Figure5: SR Monitor panel in control room, showing LER vertical and horizontal beam sizes.

7 APPARATUSES FOR MACHINE STUDIES

Some apparatuses are set the end of branch beamline No.2 for machine studies. In here, we introduce a bunch length measurement by streak camera and instantaneous beam profile measurement by high speed gated camera.

7-1 Bunch length measurement by streak camera

The bunch lengths in HER and LER are measured by the use of a streak camera. Results of the bunch lengths as a functions of the ring current are shown in Fig. 6.



(a) HER (b) LER

Figure 6: Results of bunch length measurements.

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

7-2 High speed gated camera

To observe the instantaneous beam profile bunch by bunch, we used a high-speed gated camera (Hamamatsu C7244) [5]. With this camera, we observed blow up of the bunch by bunch vertical beam-size along a bunch train in the LER. A typical result is shown in Fig.7.

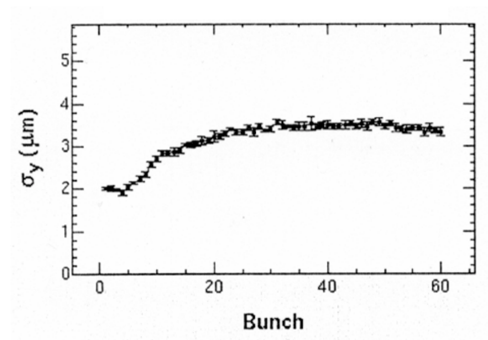


Figure 7: Blow up of the bunch by bunch vertical beam-size along the bunch train in the LER

8 CONCLUSIONS

The optical-diagnostics systems have been installed at the KEKB factory. The beam profile and size measurement systems are performing well. The online SR interferometry analysis system is developed and it is working well to deliver continuous, real-time measurement of the beam sizes. Machine studies such as vertical beam size blow up etc. are being actively performed with the system. The system is successfully operating and used to improve the efficiency of the commissioning of KEKB.

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