CONSTRUCTION OF SR MONITOR FOR PHOTON FACTORY ADVANCED RING

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Abstract

An optical diagnostics system using visible synchrotron radiation has been installed in the PF advanced ring. This system is capable of imaging measurements, SR interferometory measurements, and longitudinal profile measurement via streak camera. The interferograms are processed automatically, and the results of beam size measurements are displayed on a CRT panel for the continuous real-time measurements of beam size. Some free ports are also available for performing machine studies.

INTRODUCTION

The Photon Factory Advanced Ring (PF-AR) was originally constructed as a booster for the TRISTAN project. The ring was partially used as an X-ray source. The ring has been upgraded, and reborn as a dedicated pulse X-ray source [1]. In the upgrade project, several systems (vacuum ducts, BPM, etc.) were improved in order to achieve a good performance as a dedicated SR source. Since monitoring the beam profile or beam size using synchrotron radiation improves the efficiency of the commissioning of the ring, we decided to construct a new synchrotron radiation (SR) beam monitor system by the use of as a part of the upgrade project of the PF-AR. In this paper, it is described that design and construction of the new SR monitor for PF-AR.

SR EXTRACTION AND OPTICAL PATH TO MONITOR HUT

The visible part of SR beam radiated from the NW5-bending magnet is extracted by a water-cooled beryllium mirror. A metal O-ring-sealed optical glass window is used to separate the ultra high vacuum of the ring and the outside air [2]. Downstream of the extraction mirror, the SR beam is divided into two beams by a beam splitter. Since the focusing system doesn't need intense beam, we supply 2% of the total beam to the focusing system (beam line No.1). The remaining 98% of the beam is supplied to the SR interferometer, streak camera and the other instruments for machine studies (beam line No.2). The SR beams are relayed to the end of the optical path by several mirrors. The total length of the optical path is about 19m and closed by aluminum tubes and boxes (not evacuated) to reduce the turbulence effect of the air. The mirrors in the beam lines are aligned by an auto-collimation method using a He-Ne laser. The outline of the arrangement of optical paths is shown in Fig 1. At the end of the optical path, the SR monitor hut is set on the ground floor.

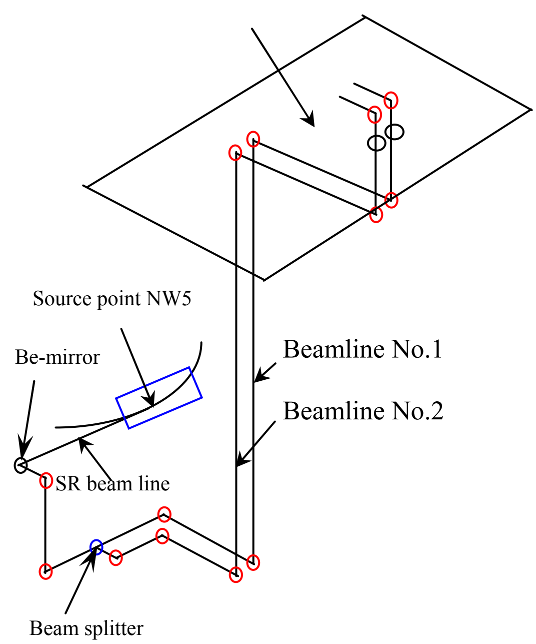

Figure 1 : Outline of optical path.
Circles denote flat mirrors.

IMAGING SYSTEM FOR PROFILE MEASUREMENT

A conventional beam profile monitor based on a focusing system [3] is set at the end of beam line No.1. A typical image of the beam profile is shown in Fig 2. This profile is observed at a beam energy of 6.5GeVand a beam current of 50mA.

Figure 2 : An example of observed beam profile taken at 50mA, 6.5GeV.

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SR INTERFEROMTER FOR MONITORING BEAM SIZE

The SR interferometer is used to monitor the beam size. Two independent SR interferometers are set at the end of branch beamline No.2 for measurements of both vertical and horizontal beam sizes. We use an aplanatic Fizeau type double-slit SR interferometer for the horizontal beam size measurement [4] as illustrated in Fig 3.

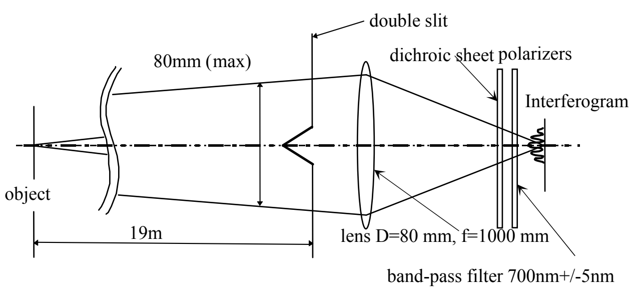

Figure 3: Aplanatic Fizeau type double-slit SR interferometer for the horizontal beam size measurement.

For the vertical beam size measurement, we use a nonaplanatic Michelson type SR interferometer [4] as illustrated in Fig 4.

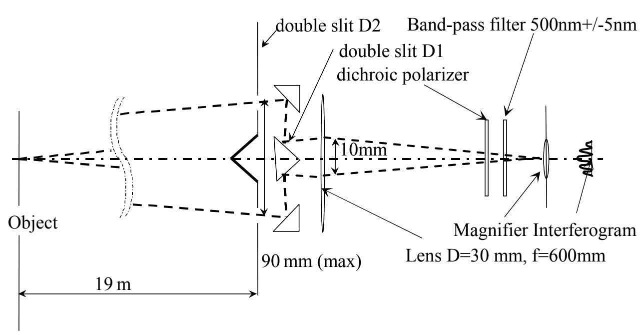

Figure 4:Nonaplanatic Michelson type SR interferometer for vertical beam size measurement.

By this design, the interferogram is given by,

$$I(y,D_2)=(I_1+I_2)\cdot\left\{\frac{\sin\left(\frac{\pi\cdot a\cdot y}{\lambda\cdot f}\right)}{\frac{\pi\cdot a\cdot y}{\lambda\cdot f}}\right\}\cdot\left\{1+\gamma(D_2)\cdot\cos\left(k\cdot D_1\cdot\left(\frac{y}{f}+\psi\right)\right)\right\}$$

where D_2 denotes the separation of the double slit, and D_1 is the fixed separation between the two rays [4]. With this configuration of the SR interferometer, the spatial frequency of the interferogram is a function of D_1 and the modulation of the interferogram is a function of D_2. Since we can choose a fixed small separation of D_1, and a movable large separation of D_2 in this configuration, we can easily measure the modulation of the interferogram in the vertical small beam size measurement.

OBSERVATION OF WAVEFRONT DISTORTION AND CALIBRATION OF SR INTERFEROMETER

To observe the thermal deformation of the beryllium extraction mirror, we set the Hartmann-screen type wavefront sensor next of the extraction mirror [5]. We used a 100-hole square-array screen. The hole diameter is carefully optimized by diffraction analysis at the observation point in the hut. Since, a hole smaller than 1mm gives a spread projection pattern, we adopt a 1mm hole diameter. This hole gives a Fraunhofer-like diffraction pattern and has a sharp peak in the center. The interval of the holes should be also small to have a sufficient number of sampling points on the wave front, but not so small that the interference fringe pattern between surrounding holes stands out. We use a hole interval of 5mm. The square-array screen is fixed on a moving stage, and is removed from the beamline during operation of the instruments.

In the SR interferometer measurement, the actual separation of the double slit of the interferometer is changed by deformation of the mirror. To find the ideal separation between the two rays at the location of the double slit, we use a single-hole screen. We can probe the paths of two ideal rays by scanning the single-hole screen in the plane which is perpendicular to the optical axis as illustrated in Fig 5.

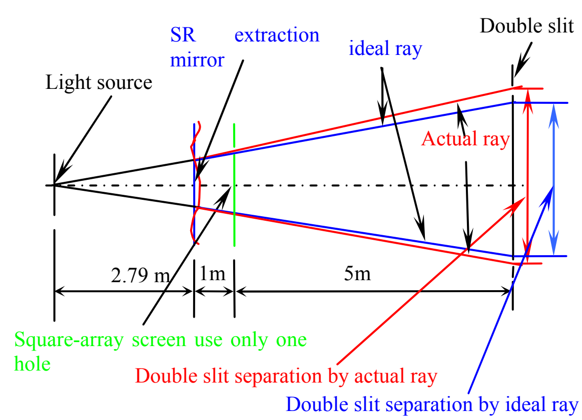

Figure 5: Setup to find the ideal separation of double slit by scanning a single-hole screen.

AUTOMATIC BEAM-SIZE MEASUREMENT SYSTEM

Using a Gaussan beam profile approximation, we can measure the RMS beam size from one measurement of visibility from an interferogram [4], which is measured at a fixed separation of the double slit. 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. To find the visibility γ from the interferogram, we use the standard Levenberg-Marquart method for non-linear fitting [6]. After processing of the interferogram, the results are displayed on a CRT panel. Figure 6 shows an example of the display panel. The interferogram, best fit curve and beam size trend graphs are shown in the panel.

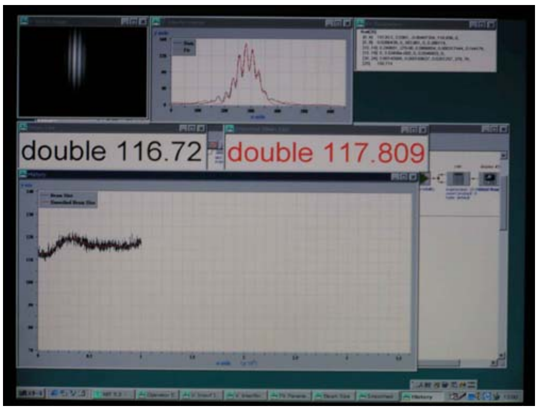

Figure 6: Display panel for automatic beam size measurement. This example shows a panel for vertical beam size measurement.

PORTS FOR MACHINE STUDIES

We prepared some extra ports for machine studies at beam line No.2. White, monochromatic ($\Delta\lambda/\lambda$: 10^{-1} to 10^{-5}), and polarized beams are available for optical measurements. Two of the machine study ports are always occupied by a streak camera and a fast gated camera. By combining these two instruments, we are capable of measuring the instantaneous transverse and longitudinal beam profiles simultaneously.

REFLECTIVE OPTICS FOR STREAK CAMERA

In the time-domain measurement using the streak camera, it is important to design an incidence optical system which has an optical path difference (OPD) as small as possible. In ordinary use of the streak camera such as for a laser, the incident light is almost monochromatic. Because we need an intense light pulse for the streak camera, we prefer to avoid using a band-pass filter, instead using white light. For this reason, we designed incident optics using reflective optics which have no chromatic aberration. Figure 7 shows an illustration of incident optics based on reflective optics. The design of the incident optics consists of two stages; the first stage is a Cssegrain-type objective [7] and the second stage is Offner-type relay system [7].

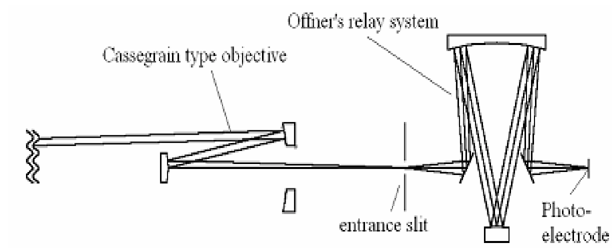

Figure 7 Illustration of incident optics design based on the reflective optics.

The Cassegrain type objective makes an image of the beam on the entrance slit of the second stage. The light is sampled at the entrance slit then relayed onto the photo electrode of the streak camera by the Offner-type relay system. A photograph of the Offner-type relay system with the streak camera is shown in Fig 8.

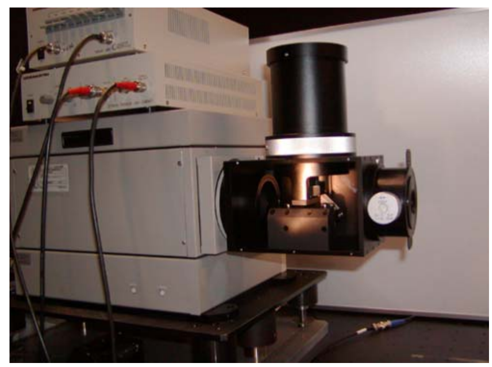

Figure 8: A photograph of the Offner-type relay system with the streak camera. The cover of the Offner-type relay system is opened to show the inside.

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