PB10

A DESIGN OF THE BEAM PROFILE MONITOR FOR THE HIGH BRILLIANCE LATTICE OF THE PHOTON FACTORY

Toshiyuki MITSUHASHI
Photon Factory, National Laboratory for High Energy Physics,
Oho,Tsukuba,Ibaraki, 305 Japan

Abstract

A beam profile monitor by means of an imaging the visible part of synchrotron radiation beam was designed for the high brilliance lattice of the Photon Factory. The design consists extraction mirror for SR beam, adaptive optical system, and focusing system. A Fourier optical analysis of the system has been done. A preliminary result of the monitor will be described.

1. Introduction

The beam profile monitor based on an imaging of the synchrotron radiation will give a visible beam profile, which greatly improves the efficiency of the commissioning of the new high brilliance configuration of the Photon Factory. By digitizing the image data, transverse beam size can be obtained, and with the knowledge of the lattice parameters, various beam parameters such as beam emittance and horizontal- vertical coupling can be deduced. The dependence of the beam size measured with this device on the beam current gives some information on the collective effects. Furthermore, by using a streak camera or photon counting system, the longitudinal profile of the beam bunch can be observed. in this paper presents the design of the optical beam profile measurement system for high brilliant configuration of the Photon Factory. A preliminary result of the system is also described.

2. Extraction of the visible synchrotron light and correction of the thermal deformation of the extraction mirror by use of corrective mirror

Since the focusing system will be placed in the atmospheric environment, which is separated from the accelerator, the visible synchrotron light must be extracted from the ring through a vacuum-tight optical quality window. The window system consist of two optical grass windows those place in series. The windows are made of BK7 and SF11,those having a surface quality of $\lambda/10$ (λ=500nm now). The first window separates ultra-high vacuum of the ring and next high vacuum room of 10^{-6}Pa. The second widow separates high vacuum room and atmospheric environment.

The extraction mirror must withstand the maximum angular power of the synchrotron lights given in Table 1.

Table 1
Parameters of the bending magnet and angular power of the SR light

Bend radius	8.66m
Dipole field	0.96T
Angular power of SR	13.2W/mrad at 350 mA
Beam size (90deg latice)	σ_x: 450μm, σ_y: 95 μm

An optimum design of a water-cooled Be mirror has been designed and constructed. The outline of the Be-mirror is shown in Fig.2. Nevertheless, a thermal deformation of the optical flatness of the mirror can exceed the tolerance of the diffraction-limited optics such as Rayleigh's criterion(about wave front error < $\lambda/8$).

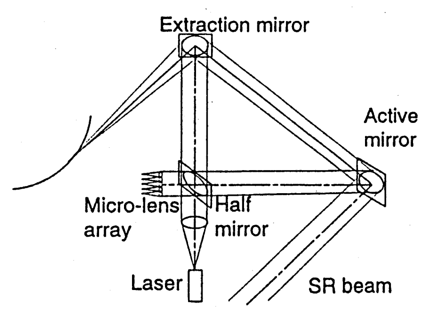

Fig.1 The schematic design diagram of the corrective system

There may be also the mirror deformation caused by the mechanics of mounting and cooling water. To correct such errors corrective optical system is designed[2]. It is basically a feedback system based on an active(corrective) mirror that makes the point response function of the two-mirror system as correct as possible. A schematic diagram of the corrective system is shown in Fig.1. Because of the wave front of the SR light is spherical, the point response between two mirror must be modified by distance of tow mirrors.

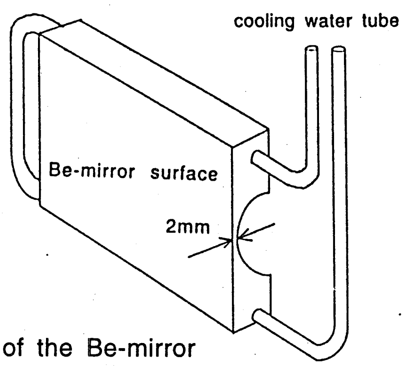

Fig.2 Design of the Be-mirror

3. Focusing system

The optical image of the beam is produce by a diffraction limited focusing system placed in the experimental room under the accelerator tunnel. The focusing system consists a ED doublet lens having a diameter of 80mm and focusing length of 1000mm which optimized to the wave length of 550nm. The theoretical remaining longitudinal aberration and modulation transfer function (MTF) on axis are shown in Figures 2 and 3. The designed wave front error is about less than $\lambda/100$. So the geometrical aberration by this lens is negligible small and image will be diffraction limited near by on axis. Transverse magnitude is designed to 0.141.

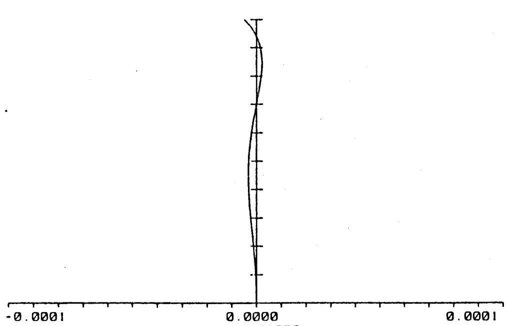

Fig.2 The expected longitudinal aberration of the lens

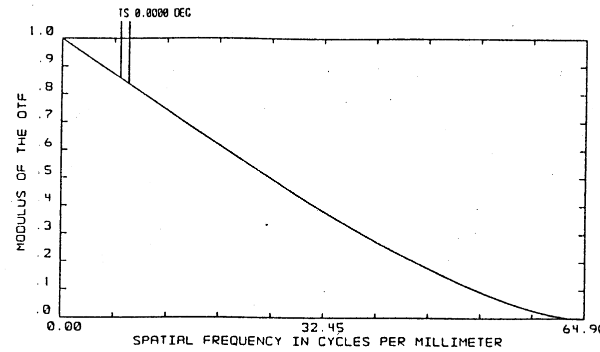

Fig. 3 The calculated MTF of the lens

4. Fourier optical analysis of the focusing system

4-1 Transverse diffraction effects

The finite aperture of the entrance pupil of the focusing system produce a diffraction. With the Fresnel approximation of the diffraction theory and the paraxial lens transfer function, the point spread function (PSF) of the system is a Fourier transform of the generalized pupil function of the system[1].

A wave front error of the lens or mirrors are treated by means of wave front aberration in these approximation, but now they will be negligible small after the corrective system. An amplitude transmittance of the generalized pupil function is modified by a vertical angular intensity distribution of the SR. To create a simple generalized pupil function, an apodization[2] for the entrance pupil of the system is required. The apodization filter must have an anti-amplitude transmittance which corresponds to the vertical intensity distribution of the SR light. This apodization filter will create a flat intensity distribution on the entrance pupil, and the pupil will give a increase of the higher components of spatial frequency. Results of calculation of a PSF with the apodization for the system is shown in Fig.4. The optical parameters of the focusing system are given in Table 2.

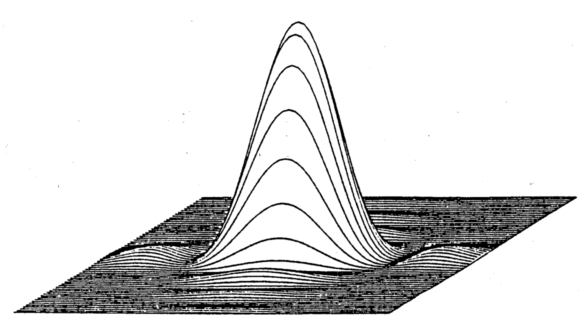

Fig.4 The PSF of the focusing system. The side length of the 3-dimensional plots is 119μm.

Table 2
Optical parameters of the focusing system.
All the unit is in mm

Surface nunber	Radius of surface	thickness	glass
source point		7763	
1	573.36	8.00	FPL52
2	-222.3936	-1.00	
3	-226.5498	5.00	ZSL7
4	-1212.2	1126.00	

The rms widths of the central peak of the PSF are 5.9μm in vertical and 12.8 μm in horizontal. The image of the beam is given a convolution of the PSF and the geometrical image. Very small vertical beam size as in table 1 must analyzed by lest square fitting method for the observed image by use of PSF. The PSF of the real system must be measured for this analysis.

4-2 longitudinal diffraction and the field depth

The field depth of the diffraction limited focusing system is dominated by the longitudinal diffraction along the optical axis[1]. Figure 5 shows the calculated longitudinal diffraction pattern on axis of the focusing system. From this figure, the field depth around image plane to be 500μm. Effect of the longitudinal aberration as discussed in section 3 is small enough for this lens. The system appears to be diffraction limited also in the longitudinal axis. The curvature effect in the horizontal beam size of the beam trajectory by the this field depth will to be.

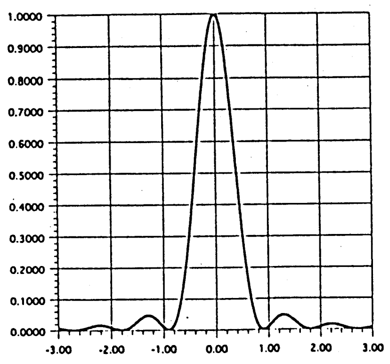

Fig.5 Longitudinal diffraction pattern of the focusing system.

5. Performance of the Be mirror and preliminary experiment at present Photon Factory

The surface quality of the Be-mirror before mounting to the holder was λ/4. After the mirror was mounted to the mirror holder and applying two times of 150deg backing, the mirror surface was bent permanently as like as a parabola in vertical (no distortion in horizontal). The extraction mirror was installed in the BL-27 in the Photon Factory. Maximum difference between center and edge was about 5μm. The corrective mirror system for the correction of the extract mirror and the focusing system are now under construction.

A preliminary measurement of a beam profile without corrective system has been done. The nomal doublet lens MELLES GRIOT LAO366 is used for focusing system. A result of observed beam image is shown in Fig.6.

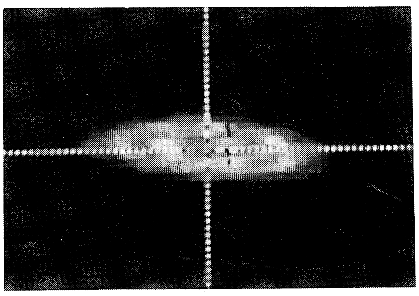

Fig.6 A beam image of the Photon Factory beam current is 2mA.

references

1)M.Born and E. Wolf,"Principles of Optics, Pergamon press. (1974).
2)R.K.Tyson, "Principles of Adaptive Optics, Academic press.(1991).