SPATIAL COHERENCY OF THE SYNCHROTRON RADIATION AT THE VISIBLE LIGHT REGION AND ITS APPLICATION FOR THE ELECTRON BEAM PROFILE MEASUREMENT

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Abstract

A spatial coherenceies of SR beam at visible light region were measured both σ and π-polarized components at Photon Factory. A wave-front division type polarized interferometer was designed and constructed for this experiment. Interferograms were observed clearly in the vertical direction. π phase difference of the interference fringe was observed between interferograms corresponding to σ and π-polarized components. Degree of spatial coherence was measured and by means of the van Citterut-Zernike's theorem, a vertical beam profile was obtained by the Fourier transform of the degree of spatial coherence.

1 INTRODUCTION

The measurement of profile of the object by means of spatial coherency was known as the Van Cittert-Zernike's theorem[1]. It is well known that A. A. Michelson was measured the angular diameter of stars by this theorem [2]. Recent developments in the accelerators, according to the reducing the beam emittance, the beam size becomes very small (few ten microns). The problem to observe such a small beam profile becomes as a same problem as in the measurement of angular diameter of the stars. In this time, for the purpose to measure the beam profile, I applied profile measurement of the object by means of spatial coherency. At first, basic investigation of the spatial coherence of synchrotron light in the visible light region has been performed. In the second, by means of the van Citterut-Zernike's theorem, the electron beam profile in the vertical direction was obtained by Fourier transform of the degree of spatial coherence.

2 INTENSITIES OF INTERFEROGRAMS BY THE SYNCHROTRON RADIATION IN THE VEERTICAL PLANE

In the vertical plane, elliptical polarity of the Synchrotron radiation is opposite against the medium plane of the electron beam orbit. Therefore, it is expected that π phase difference in the phase of interferogram corresponding to σ and π-polarized components. Disturbances U of the synchrotron light are written by[3];

$$u_\sigma = A_0 \frac{\eta}{(1+\theta^2)^{\frac{1}{2}}} K_{\frac{2}{3}}(\eta)$$

$$u_\pi = A_0 \frac{\eta\theta}{(1+\theta^2)} K_{\frac{1}{3}}(\eta)$$

for σ and π-polarized components. Where θ denotes observation angle and K denotes the second order Bessel function. Divided the wave front of the light beam into two beams against the medium plane of the electron beam orbit, then coupled again to make the interferogram, the intensity of the interference fringe is given by;

$$I_\sigma = (a_1^2 + a_2^2)\left\{1 + \frac{2a_1 a_2}{a_1^2 + a_2^2}\cos(\delta)\right\}$$

$$I_\pi = (a_1^2 + a_2^2)\left\{1 + \frac{2a_1 a_2}{a_1^2 + a_2^2}\cos(\delta + \pi)\right\}$$

where δ denotes optical pass difference in phase. a_1 and a_2 denote amplitude of the light beams corresponding to two optical pass of the interferometer. The phase term of the interferogram of π-polarized components is shifted by π from the phase term of σ -polarized components.

3 DESIGN OF THE INTERFEROMETOR

A wave-front division type tow beam interferometer by the use of polarized quasi-monochromatic rays was designed and constructed. A schematic drawing of the interferometer is shown in Fig.1. A double slits assembly was applied for dividing the wave-front. The distance between the tow slits can change continuously from 5mm to 80mm. A dichroic sheet polarizer was used to select σ or π-polarized component. The extinction rate of this filter for one component to the other is 10^{-4}. This filters can be rotated by 360° around the optical axis of the interferometer. A band-pass filter of 10nm bandwidth at 700nm was used to obtain a quasi-monochromatic ray. A diffraction limited doublet-lens having a diameter of 80mm and a focal length of 1000mm was used as an objective lens of the interferometer. The obtained interferogram is measured by a CCD (Plinix,TM765) and an image processor (Spiricon,LBA-100A).

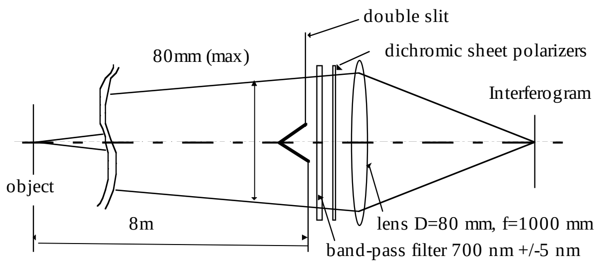
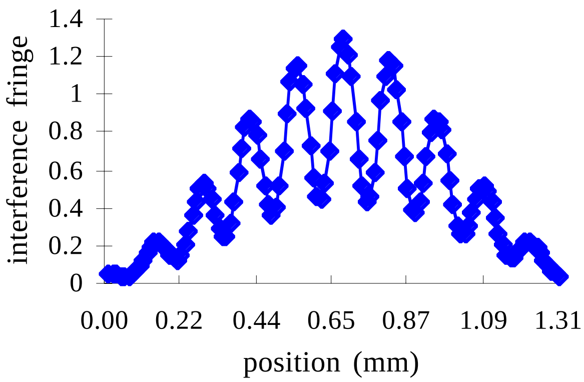


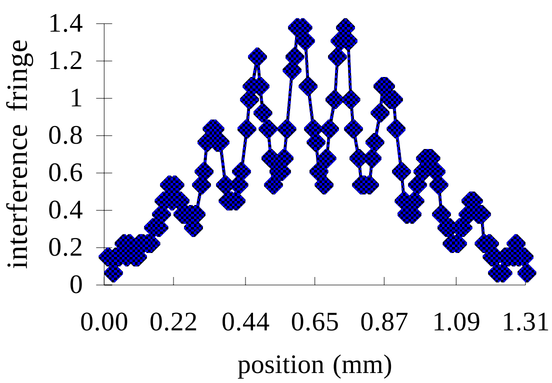
Fig.1 design of interferometer

4 EXPERIMENTAL RESULTS OF SPATIAL COHERENCY OF THE SYNCHROTRON RADIATION

Interferograms were measured both σ and π-polarized components of the synchrotron light at the optical laboratory 2 of BL-27 in the Photon Factory. Examples of observed intereferograms corresponding to σ and π-polarized components are shown in Fig.2.



a) interferogram by s -polarized components.



b) interferogram by p-polarized components.

Fig.2 results of interferograms for σ and π-polarized components. The distance of double slit is 5 mm.

Comparing these two interferograms, the phase of the interference fringe is shifted by π.

The absolute value (visibility) and phase of complex degree of spatial coherence was measured by changing the distance of the double slit from 5mm to 15mm. Results are shown in Figures 3 and 4. As in Fig.3, the visibility is almost zero at the distance of double slit of 15mm. Its means beam profile has no more higher spatial frequency parts of Fourier component.

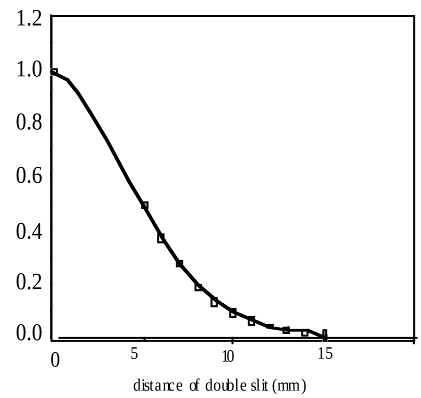


Fig.3 Absolute value of the complex degree of spatial coherence

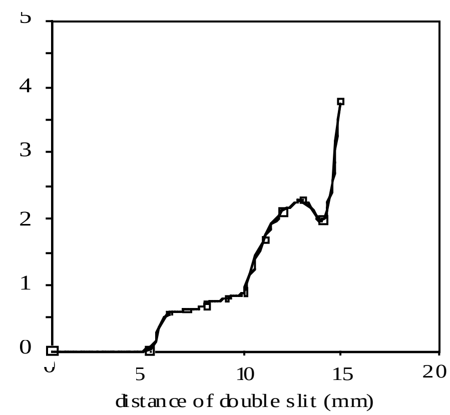


Fig.4 Phase of the complex degree of spatial coherence vertical axis is phase in radian

5 VERTICAL BEAM PROFILE

According to the van Citterut-Zernike's theorem, the profile of object was obtained by Fourier transform of the complex degree of spatial coherence. Let f(Θ) denotes beam profile as a function of angular diameter Θ and γ(D) denotes the complex degree of spatial coherence, γ is given by the Fourier transform of f as follows;

$$\gamma(D) = \int f(\Theta)\exp(-ikD\Theta)d\Theta$$

$$= C(D) + iS(D)$$

where C(D) denotes Fourier cosign transform of f(Θ) and S(D) is Fourier sin transform of F(Θ). Then interferogram is given by;

$$I(\Theta) = 1 + |\gamma(D)| \cos\{kD(\Theta + \varphi)\}$$

$$\varphi = \tan^{-1} \frac{S(D)}{C(D)}$$

Therefore, from the data of the absolute value and phase of the complex degree of spatial coherence , we can obtain the beam profile by the Fourier transform. A result of the beam profile is shown in Fig.5.

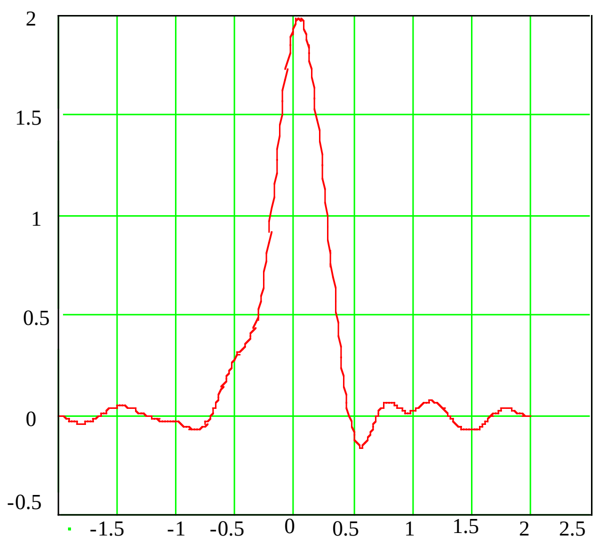


Fig.5 The beam profile obtained by a Fourier transform of the complex degree of coherence.

A least square beam size s through a second order moment is 214 µm.

According to the phase term of complex degree of spatial coherency, the beam profile has a asymmetric distribution. This asymmetry in the distribution curve is mainly caused by a deformation of the extraction mirror for SR light. A large astigmatism term was observed by the in situ measurement of the surface flatness of the mirror [4],[5]. As same technique as in the noise elimination processing in the Fourier transform of the electric signal, it is possible to eliminate asymmetric part of the Fourier components of complex degree of spatial coherency. As most easy way to do this process, we try to neglect Fourier sine transformation. The result is shown in Fig.6.

Compare with Figures 5 and 6, the asymmetric part caused by deformation of the mirror was completely eliminated. The least square beam size in Fig 6 is 202 µm. This technique is very useful for the elimination of unknown effects (asymmetric terms of the wavefront aberration) of the optical components between the object and the image plane. As demerits, we cannot use this technique for 1. optical system has a symmetric wave front error such as spherical aberration, 2.beam has asymmetric distribution.

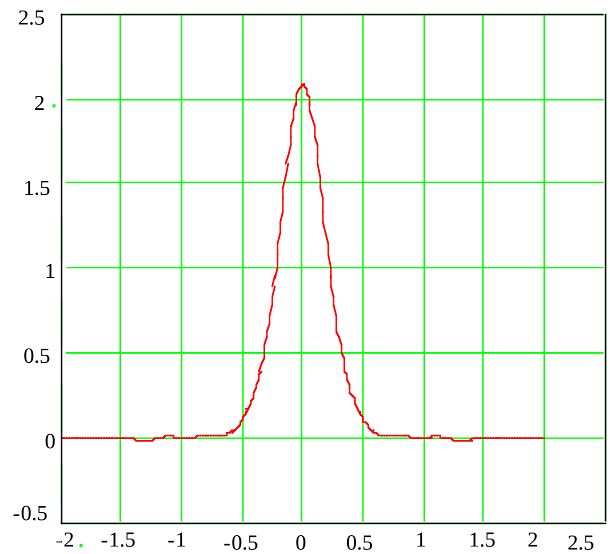


Fig.6 The beam profile obtained by a Fourier cos transform

6.CONCLUSIONS

A spatial coherenceies of SR beam at visible light region were measured both σ and π-polarized components. A phase difference of π in the interference fringes corresponding to σ and π-polarized components was observed. The Complex degree of spatial coherency was measured and by means of the van Citterut-Zernike's theorem, a vertical beam profile was obtained by the Fourier transform of the complex degree of spatial coherence. An asymmetry of the distribution curvature caused by a deformation of optical mirror was observed. This effect was eliminated by neglecting the Fourier sin transform.

7.ACKNOWLEDGMENTS

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