A MEASUREMENT OF BEAM SIZE OF AURORA BY THE USE OF SR-INTERFEROMETER AT SR CENTER OF RITSUMEIKAN UNIVERSITY

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Abstract

A vertical beam size of the AURORA at SR center of Ritsumeikan University was measured by the use of SR-interferometer. A spatial coherence of the visible SR beam was measured at the region of spatial frequency from 15 to 41 mm^{-1}. The result of the beam size is 16.5μm and it is good agreement to the estimated beam size of 10μm by means of tousheck life time measurement. The beam size is also measured for large beam mode which is used for normal operation of the facility.

1. INTRODUCTION

The principle of object-profile measurement by means of the spatial coherency of the light is known as the van Citterut-Zernike's theorem(1). It is well known that A. A. Michelson was measured the angular diameter of stars by his famous stellerinterferometer. Recently, this principle was applied for the measurement of vertical electron beam profile in the storage ring by one of the authors by the use of SR-interferometer(interferometer for synchrotron radiation)(2). Since this method is based on spatial coherence of the SR beam, it is suitable to measure a small electron beam size having a good spatial coherence. The beam size of AURORA at SR center of Ritsumeikan University was estimated about 10μm by means of tousheck life time measurement(3). In this time, we measured this small beam size by the use of SR-interferometer.

2. SPATIAL COHERENCE AND BEAM PROFILE AND SIZE

According to van Cittert-Zernike's theorem, the profile of the object is written by Fourier Transform of the complex degree of spatial coherence. Let f denotes beam profile as a function of angular diameter Θ ,and γ denotes the complex degree of spatial coherence as a function of distance of double slit of the interferometer D, γ is given by the Fourier transform of f as follows;

$$\gamma(D) = \int f(\Theta)\exp(-ikD\Theta)d\Theta \quad \text{-1)}$$

Then the interferogram which observed with the SR-interferometer as shown in Fig.1 is given by the use of γ;

$$I(\theta) = (\sin c(\theta))^2\left\{\left[1 + |\gamma(D)|\cos[kD(\theta+\varphi)]\right]\right\} \quad \text{-2)}$$

where θ denotes the observation angle of the interferogram, sinc function denotes a diffraction of one silt in the interferometer and φ denote a phase of the interference fringe. Using the equation 2), we can measure degree of spatial coherence from the interferogram, and using the equation 1), beam profile will be obtained from the degree of spatial coherence. Furthermore, to assume a Gaussian profile of the beam, we can measure the rms beam size from one interferogram.

3. SR-INTERFEROMETER

The SR-interferometer designed by one of the authors(2) was used for the measurement. The SR-interferometer is basically a wavefront division type two beam interferometer by the use of polarized quasi-monochromatic rays. A schematic drawing of the SR-interferometer is shown in Fig.1.

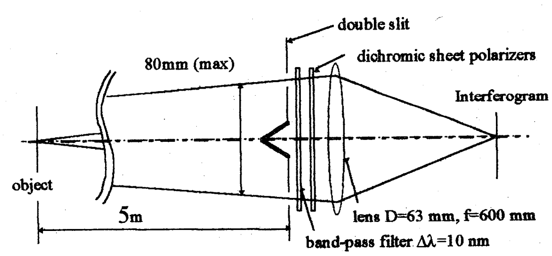


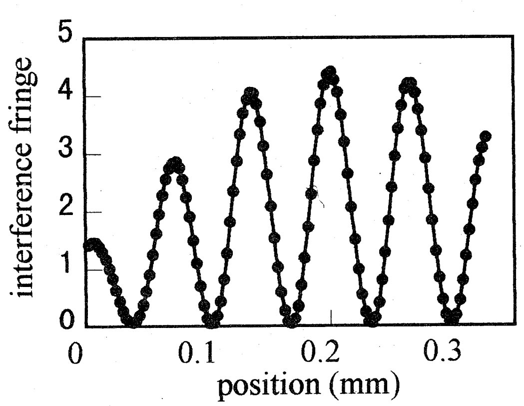
Fig.1 Outline of the SR-interferometer.

An aperture of $1x1mm^2$ was used in the double slits assembly. A diffraction limited doublet-lens having a diameter of 63mm and focusing length of f=600mm was used as an objective lens of the interferometer. A band pass filter of 10nm band width was used to obtain a quasi-monochromatic ray. A magnifier lens, CCD (plinix,TM765) and image processor (spilicon,LBA-100A) were used for the observation of interferogram.

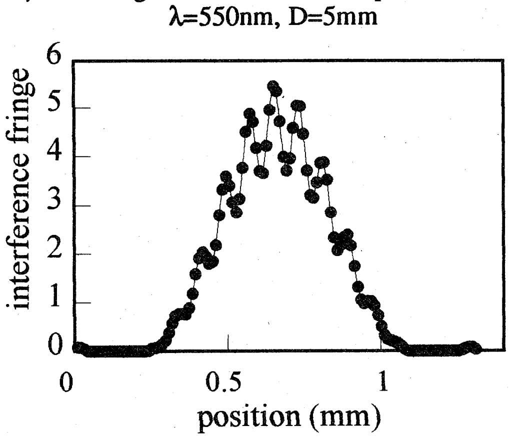
The SR-interferometer was set at 5m apart from the source point.

4 . MEASUREMENT OF SPATIAL COHERENCE OF THE SR BEAM

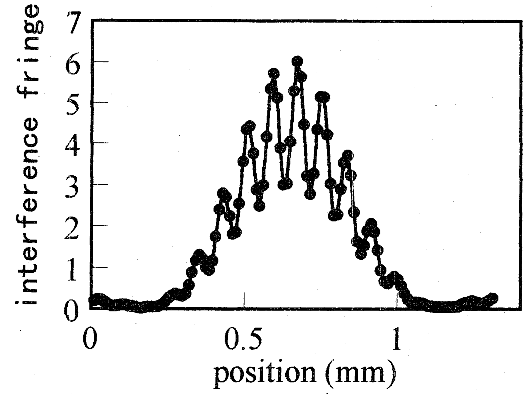
The absolute value (visibility) of complex degree of spatial coherence was measured at SR monitor beamline of AURORA. The opening angle of SR monitor beamline was limited by the dimension of the extraction mirror for SR beam and it was 2.7mrad. This opening angle limits the measurement of interferograms in the larger region of spatial frequency. Under this condition, the interferogram was measured by changing the distance D of the double slits from 5mm to 13.5mm by 0.5mm step. Corresponding spatial frequency region ($D/f\lambda$) is from 15 to 41mm^{-1}for the wqavelength of 550nm. The interferograms are measured for three operation modes of the AURORA. One is small beam operation mode(beam size is estimated to 10μm by means of the tousheck lifetime measurement). Second is lager beam operation mode No.1. Third is Large beam operation mode No.2. Large beam mode No.1 is the operation mode having a fat beam obtained by means of beam-ion scattering which realized by willingly ion trapping. Large beam mode No.2 is the operation mode having a fat beam obtained by the use of RF kicker. The results of interferograms for these three operation mode are shown in Fig.2.



a) interferogram for small beam operation mode. λ=550nm, D=5mm



b) interferogram for large beam operation mode No.1. λ=700nm, D=5mm



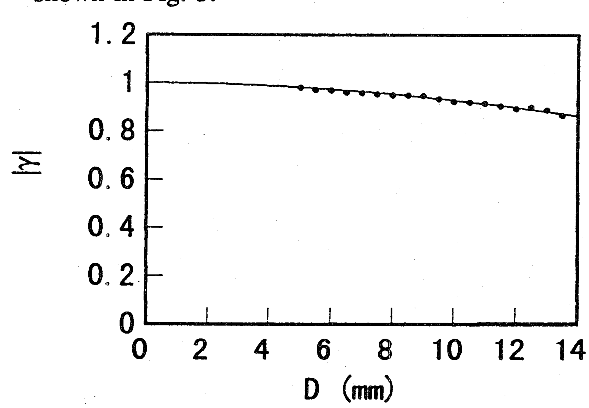
c) interferogram for large beam operation mode No.2. λ=700nm, D=5mm

Fig. 2 The results of interferograms for these three operation mode

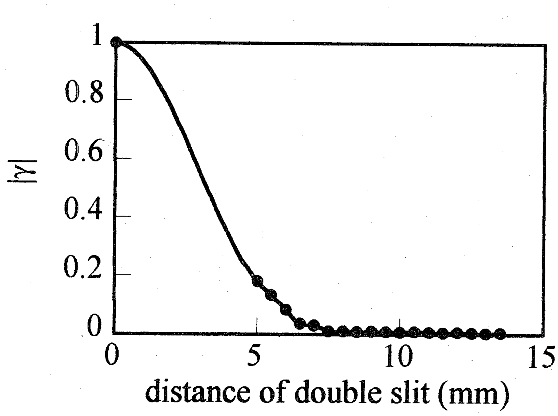
These interferograms are measured at the distance of double slits of 5mm

5. EXPERIMENTAL RESULTS OF DEGREE OF SPATIAL COHERENCE

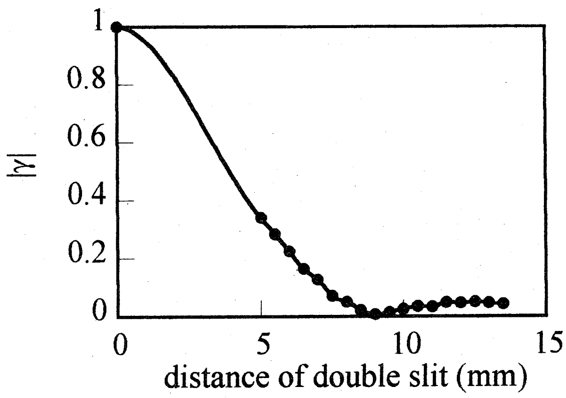
The absolute value of complex degree of coherence is evaluated from the visibility of the measured interferogram. The results for three operation modes are shown in Fig. 3.



a) small beam operation mode. The solid line denotes a least square fitting curve by Gaussian beam profile.



b) large beam operation mode No.1



c) large beam operation mode No.2

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

AS shown in figures 3-a) and 3-b), the absolute value of complex degree of coherence for small beam operation mode is still 0.9 at the spatial frequency D=13.5mm and the absolute value of complex degree of coherence for large beam operation mode No.1 is almost zero at D=7.5mm. As shown in Fig.3-c), the absolute value of complex degree of coherence for large beam mode No.2 becomes one time zero at D=9mm. This sinc function like distribution of the degree of coherence suggest us a trapezoidal distribution of the beam profile.

6 RESULT OF VERTICAL BEAM SIZE AND PROFILES

To assume the gaussian beam profile, we can evaluate the beam size of small beam operation mode from degree of spatial coherence data as shown in Fig.3-a). Least squire fitting of degree of the spatial coherence by gaussian beam profile is shown in Fig.3-a). The result of the beam size from this fitting is 16.5μm.

According to the van-Cittert-Zernike's theorem (1),(2), the profile of the object is obtained by Fourier transform of the complex degree of spatial coherence. To assume the central symmetry for the beam profile, Fourier transform of the complex degree of spatial coherence reduces Fourier cosine transform of absolute value of the complex degree of spatial coherence(2). For two of the large beam operation modes, we make a Fourier cosine transform of absolute value of the complex degrees of spatial coherence as shown in figures 3-b) and 3-c). The result of beam profiles for large beam operation modes 1 and 2 are shown in figures 4 and 5. The beam profile of the large operation mode No.1 is Gaussian like and this profile of the beam is obtained by means of beam-ion scattering which realized by willingly ion trapping. In the case of Large beam mode No.2 ,the beam profile is little bit trapezoidal and it is obtained by the use of RF kicker. We can consider the trapezoidal distribution in the beam profile is due to a sinusoidal potential of the RF kicker. The rms beam sizes are 202μm for mode No.1 and 176 μm for mode No.2.

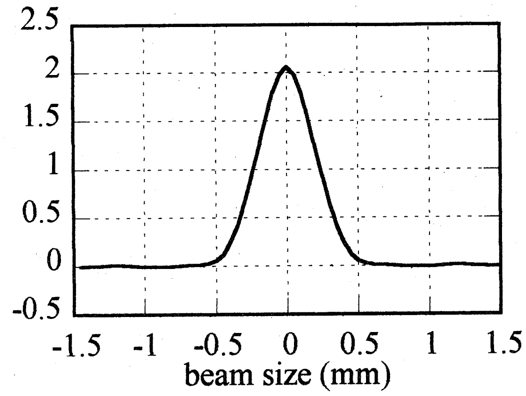


Fig.4. beam profile of large operation mode No.1

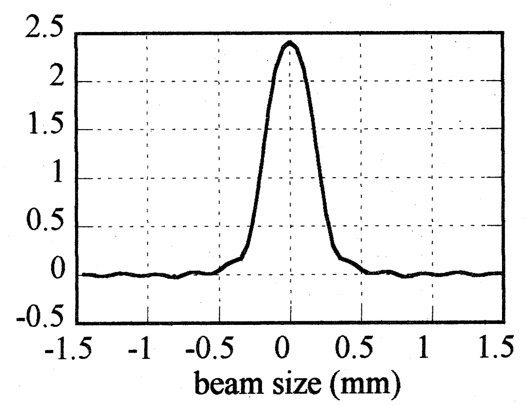


Fig.5. beam profile of large operation mode No.2

7 CONCLUSIONS

The beam size of the small beam operation mode and the beam profile of the large beam operation mode of the AURORA was measured by SR-interferometer. We conclude the beam size in the small beam operation mode is measured to 16.5μm and it is agree with the beam size estimated from Toushecks life time measurement(3). The beam profile for large beam operation modes are Gaussian like distribution for the beam of mode No.1 which obtained by means of beam-ion scattering which realized by willingly ion trapping and trapezoidal distribution for the beam of the mode No.2 which obtained by the use of RF kicker. The of rms beam sizes are 202μm for mode No.1 and 176μm for mode No.2.

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