샤냑간섭계를 이용한 레이져빔의 Spatial Coherence Function 측정

Measurement of Spatial Coherence Function of laser beam by using a Sagnac Interferometer

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The spatial coherence function of laser beam was measured by using a Sagnac interferometer and self referencing technique. For laser beam passing through a narrow slit, absolute value of measured spatial coherence function becomes more symmetric as the slit size is reduced. For diverging beams, the spatial coherence function shows fast oscillations in its real and imaginary parts. We explain this by using a Gaussian Schell-model. One can use this measurement method to study and characterize the property of light field coming out of small sample.

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I. INTRODUCTION

Optical techniques are often used to characterize properties of samples in many areas of science and technology. Especially, a non-destructive optical measurement is often preferred for analysis of organic materials and bio-medical samples. For instance, optical coherence tomography is now intensively used for skin disease diagnostics [1,2]. For revealing the internal structure of biological sample and obtaining tomographic image of the sample, which is often a highly scattering media, coherence of light should be taken into account [3].
Two-point spatial coherence function (SCF) is related to the structure of the medium where light beam propagates and scatters, and it gives rich information of the medium. Several studies have been made recently to measure the coherence function using different approaches. One attractive approach is to measure the spatial coherence function directly using a Sagnac type interferometer [4], without using a separate reference beam. One can measure spatial Wigner function of optical field by using a Sagnac interferometer[5], and SCF can be obtained from the measured Wigner function. The Wigner function gives us information about the light field in terms of both space and spatial frequency and thus reveals propagation property of light beam in an optical sample under investigation [6]. We found that the SCF measured for optical field coming out of small slit shows more symmetric distribution of its absolute value as the slit size is reduced, and rapid oscillations occur in its real and imaginary part for fast diverging beam. Our technique may be used to measure the spatial coherence function of light beam with unknown characteristics emanating from a small optical samples and for optical coherence imaging of samples in real time.

Ⅱ. DISCUSSION

Because we are dealing with two replicas of the same beam that rotates 180^o with respect to each other, the larger value of SCF along the $x_1 = -x_2$ line means that the relative phase between the two counter-propagating beams are well kept constant. Along the$x_1 = x_2$ direction, the SCF shows coherence within the original laser beam [4]. We observed experimentally that the SCF becomes broader i.e., the SCF value increases along the $x_1 = x_2$ line, for smaller width slit. Considering the fact that the laser beam waist is about $300\mu m$, The $400\mu m$ slit does not affect the propagation of the laser beam much. The $50\mu m$ slit makes smaller beam cross section that increases the coherence area in the detection plane and therefore the SCF becomes broader. The real and imaginary parts of the SCF becomes more symmetric along the two diagonal lines too. Theoretically, we could write the SCF for a Gaussian Schell-model beam at z=constant plane as [16]

$$\Gamma(x_1,x_2) = \frac{A}{2\pi\sigma_I^2}\exp[-\frac{1}{4}\frac{x_1^2+x_2^2}{\sigma_I^2}]\exp[-\frac{1}{2}\frac{(x_1-x_2)^2}{\sigma_g^2}]\times\exp[-\frac{ik(x_1^2-x_2^2)}{2R}] \quad (5)$$

for the field that has Gaussian intensity distribution with variance σ_I^2 and the normalized degree of coherence g is given as

$$g(x_1-x_2) = \exp[-\frac{|x_1-x_2|^2}{2\sigma_g^2}]. \quad (6)$$

The absolute value of the SCF indicates the spatial degree of coherence. When $\sigma_g \rightarrow \infty$, the laser beam is a perfectly coherent Gaussian beam and the absolute value of SCF should be a completely symmetric function $\exp[-(x_1^2+x_2^2)/(2\sigma_I)^2]$ with respect to $x_1 = x_2$ and $x_1 = -x_2$. One can find that the measured data in Fig. 4 is more symmetric than the data in Fig. 6. $R = R(z)$ is the radius of curvature for the Gaussian wave front. $R > 0$ ($R < 0$) for diverging (converging) beam. The real and imaginary parts becomes highly oscillatory for highly divergent (convergent) beam ($|R| \rightarrow 0$), because of the factor $ik/2R$. One can also see this from the measured data from Fig. 4 to Fig. 6. Thus our experimental results show good agreement with the theory qualitatively.

Ⅲ. CONCLUSION

We have shown a method to directly measure the SCF by using a self referencing Sagnac interferometer technique. The optical field coming out of micro-size slits can be magnified and imaged onto a steering mirror and the SCF can be measured. We showed that, because the Wigner distribution function contains not only the information of wavefront but also that of beam divergence, the SCF obtained from the Wigner function contains such information in its absolute value, real and imaginary parts. This technique does not need a stable reference beam so that it can be used for the field that varies slowly in time. The inverse Fourier transform algorithm is very straightforward and it does not need any extra assumptions about the degree of coherence of light or source symmetry. This experimental set-up might be attached to the conventional optical microscope to measure the coherence function of a micro size biological samples in real time.