Measurement of Spatial Coherence Function of multy-mode beam by using a Sagnac Interferometer

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The spatial coherence function of multy-mode beam was measured by using a Sagnac interferometer and self referencing technique.
For leaner polarization laser beam passing through a multy-mode fiber, its change value of spatial mode and polarization from stress of faber and input coupling angle. And each spatial mode have each polarizations, when we simulation Wigner distribution function and Spatial Correlation function of spatial multi-mode beam by using Hermit Gaussian modes leaner sum.
We measured spatial coherence function of using by multy-mode fiber.
One can use this measurement method to study and characterize the property of multy-mode light field coming out of GRIN multy-mode fiber.

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 multi-mode optical field that passing through grin index multi-mode fiber. Our technique may be used to measure the spatial coherence function of light beam with unknown characteristics emanating from a optical samples and for optical coherence imaging of samples in real time.

Ⅱ. DISCUSSION

The two-point spatial coherence function, $\Gamma(x_1,x_2)$, gives us the information of coherence between two points x_1 and x_2 in space. For propagating light, the SCF obeys wave equation and the coherence of field can be changed during the propagation [7]. We can obtain SCF by making a inverse Fourier transform of the spatial Wigner distribution function, which is a joint function of both position and propagation vector. The Wigner distribution function gives us information about the wavefront and propagation property [8,9]. We can use a Sagnac interferometer to measure the SCF without the need of stable reference light [10-12]. Phase-space tomography for retrieval of phase information from an optical field has been reported [13], and the direct measurement of a two-point correlation function has been reported also by using a similar technique [4].

A Wigner distribution function of a scalar field, $\phi(\boldsymbol{r},z)$, $\boldsymbol{r}=(x,y)$, at a plane z=constant can be defined as [14,15]

$$W(\boldsymbol{r},\boldsymbol{p})=\int d\boldsymbol{r}' e^{i\boldsymbol{r}'\cdot k\boldsymbol{p}}\phi(\boldsymbol{r}+\boldsymbol{r}'/2)\phi^*(\boldsymbol{r}-\boldsymbol{r}'/2). \qquad (1)$$

Here, $k=2\pi/\lambda$. The $\boldsymbol{p}=(p_x\ ,p_y)$ is called the spatial frequency and it is a canonical conjugate to $\boldsymbol{r}$. The spatial coherence function of the field $\Gamma(\boldsymbol{r}_1,\boldsymbol{r}_2)=<\phi(\boldsymbol{r}_1)\phi^*(\boldsymbol{r}_2)>$ can be obtained from the relation

$$\phi(\boldsymbol{r}_1)\phi^*(\boldsymbol{r}_2)=\frac{k^2}{4\pi^2}\int d\boldsymbol{p}\,W(\frac{\boldsymbol{r}_1+\boldsymbol{r}_2}{2},\boldsymbol{p})\exp[-i(\boldsymbol{r}_1-\boldsymbol{r}_2)\cdot k\boldsymbol{p}], \qquad (2)$$

after taking the ensemble average. For a strong and stable CW laser light, the product $\phi(\boldsymbol{r}_1)\phi^*(\boldsymbol{r}_2)$ does not change much from one measurement to another, so a single measurement is often enough to obtain the SCF. In the case of optical field, the scalar field is often a cartesian component of electric field vector of the light wave, and the Wigner function is a function of the position $\boldsymbol{r}$ and the wave-vector $\boldsymbol{k}$,

$$W(\boldsymbol{r},\boldsymbol{k})=\frac{1}{\pi^2}\int d\boldsymbol{s}E(\boldsymbol{r}+\boldsymbol{s})E(\boldsymbol{r}-\boldsymbol{s})^*e^{2i\boldsymbol{s}\cdot\boldsymbol{k}}. \qquad (4)$$

The experimental set-up to measure the Wigner function is shown in Fig. 1. It is similar to the experimental set-up used in previous studies [4,5], with some improvements. In the experiment, we varied only the x and k_x, that is, $\boldsymbol{r}=x$ and $\boldsymbol{k}=k_x$ here.

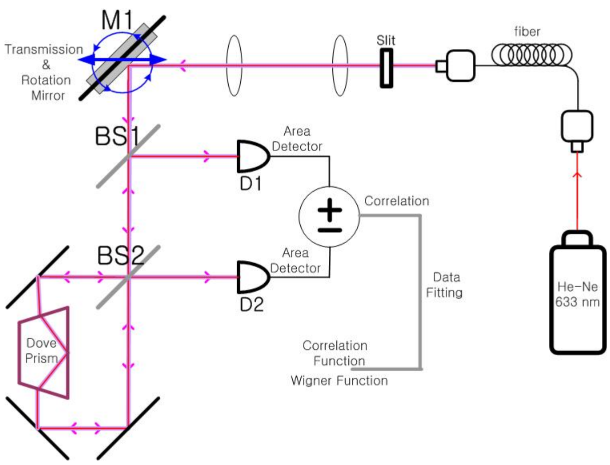

FIG. 1. Experimental set-up of the shift-and-tilt Sagnac interferometer. The fiber acts as a spatial filter.

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 spatial multi-mode light source.

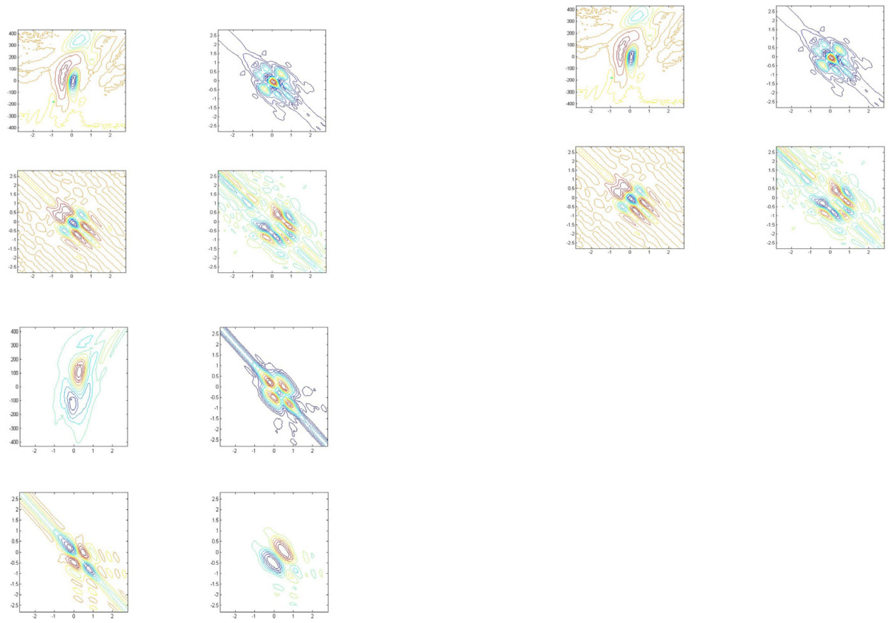

FIG. 2. Experimental data

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 multi-mode fiber 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.