Experimental investigation on the spatial anti-correlation structure in wander vortex beams

Yang Zhang

5 de diciembre de 2022

Resumen

In optical imaging and optical communication, orbital angular momentum (OAM) photons that possess an additional angular freedom for optical operation, attract a lot of attention. However, as the coherence of the light field decreases, the randomness from environment has an increasing impact on the OAM of the photon. A perfectly coherent optical vortex degenerates to a wander vortex with partial coherence, and the OAM signal embedded therein suffers a loss or distortion. Exploring a new scope for OAM signal demonstration in the wander vortex is of practical importance. In this manuscript, we report that in the low-coherence environment, an anti-correlation structure exists in the second-order correlation function of wander beams. This special correlation structure has positive effects on a lensless ghost imaging. The experimental results show that utilizing the anti-correlated vortex beam as illumination the lensless ghost imaging can break the Rayleigh diffraction limit and realize super-resolution.

1. Introduction

Light fields with a spiral phase structure possess an additional angular freedom due to the orbital angular momentum(OAM) of photons, and have become one of the hot spots in varous optical applications . In optical communication, the freedom of OAM can be used as a multiplexed information carrier to increase communication capacity . In optical imaging, using optical vortices as illumination exhibit an ability to break the Rayleigh limit in imaging . In optical interferometry sensing, a coherent OAM state exhibits an ability to suppress the shot noise and improve the precise of the phase estimation. However in reality, turbulence and fluctuations always exist in environment, which influence the information embedded therein and result in a reduction in the quality of imaging and communication .

In the manuscript, we experimentally convert an optical vortex to a Rankine vortex beam by controlling the randomness of the light field. The measured second-order correlation function and the OAM spectrum of the Rankine vortex field show that there is an anti-correlation spatial structure existing in the picture of second-order correlation. As an application example, we applied the anti-correlated light filed to a lensless ghost imaging (GI) system. Results show that not only the OAM state but also the correlation structure of the optical Rankine vortex play an important role in breaking the Rayleigh diffraction limit for imaging. This manuscript provides a new point of view for multi-dimensional light field control.

2. Main Content

2.1. Part of the theory

In turbulence physical systems, the rotational motion of a vortex is usually characterized as a Rankine vortex, which consists of two parts: solid body rotation and ideal fluid rotation[20]. In optics, a wander vortex is a partially coherent vortex beam, which propagates in z direction meanwhile the central axis varies randomly with positions at the cross section plane [19]. The wander vortex can be regarded as an optical Rankine vortex, and its OAM is composed of a rigid body rotator and a fluid rotator [20,25].

2.2. Part of the experimental

In the experiment, the composite field is a superposition of N=500 vortex beams. One thousand CGH frames have been prepared in advance. Fig. 1(b) is one of the CGH frames used to generate

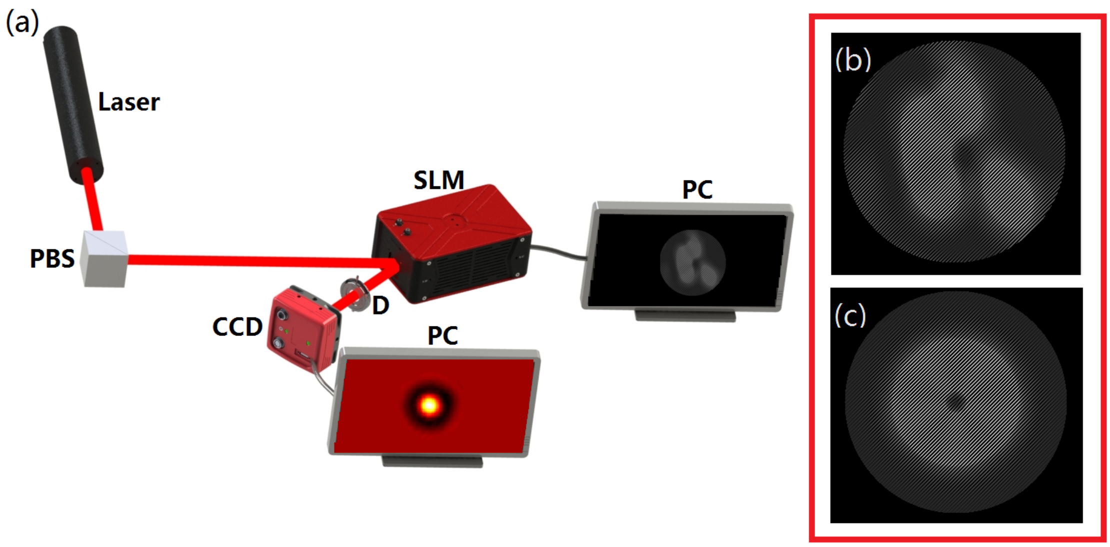

Figura 1: (a) Experimental setup for generating a wander vortex beam. Laser, He-Ne laser; PBS, polarization beam splitter; SLM, spatial light modulator; D, aperture stop; CCD, scientific camera; PC, personal computer.

A	B	C	D
a	1	2	3
b	4	5	6
c	7	8	9

Cuadro 1: Table learning.

the wander vortex beam. When the CGH frames are periodically displayed on the SLM at a rate of 20ms/frame, the camera takes photographs of the light field at a shooting rate 49.5HZ. In order to guarantee the incoherent superposition of the light intensities at the camera, the shooting rate of the camera should be equivalent or slower than the displaying rate of the SLM. This experimental setup is also capable for the production of coherent vortex beams by replacing the CGHs. As an example, we show in Fig. 1(c) the CGH used to generate a completely coherent vortex beam.

2.3. Table learning and related issues

As shown in the following table, how to add a vertical line between B and C.How to align 1 and B.

2.4. Add Comments and Track Changes

I haven't seen 'Add comment' yet.

2.5. Follow up improvement of classroom research

Finally, the following work needs further research

1. The partially coherent vortex optical model mainly studied in this paper is drift beam, and the partially coherent beam with Rankine vortex like vortex structure is not unique, so it is meaningful to explore what characteristics of the beam model can have two-component.

2. The environmental background studied in this paper is mainly in the case of low coherence, whether the anti correlation drift beam has advantages in atmospheric turbulence, underwater environment, and complex optical systems remains to be studied.

3. In the application of correlation imaging, this paper mainly regulates the topological charge carried by the beam itself and the superposition mode of the light field. There can be further research on the regulation means and regulation objects. Secondly, the correlation imaging

objects involved in this paper are only binary objects, and the imaging of phase objects and even complex objects need to be studied.

2.6. Write Mathematics

LaTeX is great at typesetting mathematics. The wave function of the wander vortex beam can be written in the following form

$$\mathrm{E}(r) = \epsilon(r_1) + \phi(r_2)$$

where $\epsilon(r_1)$ represents the wave function of the rigid body rotator, $\phi(r_2)$ is the wave function of a fluid rotator. Since the beam wander occurs in the spatial domain, this manuscript focuses on the spatial correlation of the light field, and does not consider the influence from time variables .

2.7. Add Citations and a References List

[Gre93] [HT02] [DCB11]

Referencias

[DCB11] Y. Dong, L. Chen, and X. Bao. Time-division multiplexing-based botda over 100km sensing length. *Optics Letters*, 2011.

[Gre93] George D. Greenwade. The Comprehensive Tex Archive Network (CTAN). *TUGBoat*, 14(3):342–351, 1993.

[HT02] T. Horiguchi and M. Tateda. Botda-nondestructive measurement of single-mode optical fiber attenuation characteristics using brillouin interaction: theory. *Journal of Lightwave Technology*, 7(8):1170–1176, 2002.