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All-fiber focused optical vortex array generator

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Abstract. We report a focused optical vortex array (FOVA) generator prepared by printing a Dammann spiral zone plate on the composite fiber facet using femtosecond laser two-photon polymerization. The generation of FOVA is verified by simulation and experiment. The all fiber generator of FOVA exhibits high flexibility and compactness, making it a suitable candidate for applications in fields such as optical manipulation and optical communications.

1 Introduction

Optical vortex array (OVA) has been proposed to achieve more complex spatial distributions compared to individual vortex beams. Conventional methods of free-space optics can produce OVA, such as spatial light modulation-holography [1], laser interferometry [2], and the Talbot effect method [3]. It is worth noting that the system for generating OVA consists of numerous complex optical components, and in order to couple with the back-end system it is necessary to introduce additional objective lenses to post-focus the OVA. The stringent optical path requirements and the large system size make the traditional OVA generation method is facing the challenge of low compactness and low flexibility.

In this paper, we present a fiber facet-based focused optical vortex array (FOVA) generator, composed solely of optical fiber and a Dammann Kinoform spiral zone plate (DKSZP) fabricated on the fiber facet using femtosecond laser two-photon polymerization. The proposed approach offers enhanced flexibility and stability compared to traditional bulky optical components.

2 Numerical simulation and experiment results

The DKSZP were designed by combining the beam splitting function of the Dammann grating and the vortex beam excitation function of the vortex phase grating based on the Kinoform lens. We have designed three types of DKSZP with phase distribution as shown in

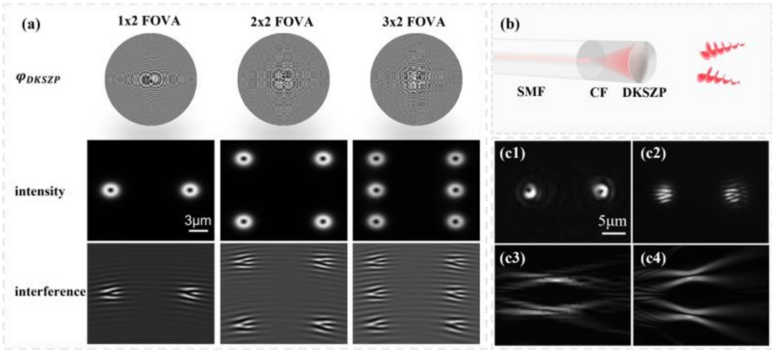

Fig.1. (a) Simulated phase functions φ_{DKSZP} of DKSZP for 1×2, 2×2 and 3×2 types, and the corresponding focal plane intensity distributions and interference patterns;(b) The Schematic diagram of the FOVA generator;(c1) Measured normalized intensity distribution of the focal plane;(c2) Interference pattern of 1×2 FOVA with reference light;(c3), (c4) Experimental and simulated light intensity distribution in the longitudinal plane.

Fig.1(a) for generating 1×2, 2×2 and 3×2 FOVA respectively. These DKSZPs have the same focal length f = 50μm and topological charge l = 1. The Propagation of the output light from the DKSZP was simulated based on angular spectrum transmission theory. The intensity distribution at the focal length f = 50μm as designed via simulation. It is evident that the diameter of the vortex beams of FOVA is 3.8μm. Additionally, it can be observed that the interferences patterns of vortex light arrays with plane waves demonstrate a single-forked-shaped fringes. The results of the simulation match the results of the design.

As Fig. 1(b) illustrates, the generator utilizes a single mode fiber (SMF) for transmitting input light, and a section of coreless fiber (CF) is fused at the end of the SMF for expanding Beam Diameter. The DKSZP is printing onto the end face of CF using femtosecond laser two-photon polymerization printing system. We experimentally prepared a 1×2 type DKSZP As shown in Fig.1(c1), the focal spot diameters of the two vortex beams generated by the DKSZP were found to be 4.01μm and 3.86μm, respectively. The interference patterns of FOVA and plane waves are shown in Fig. 1(c2). It can be observed that both interference patterns exhibit single-forked patterns, thereby confirming that both beams of light output from the DKSZP carry orbital angular momentum, with a topological charge l = 1. The longitudinal plane light intensity distributions of the DKSZP are shown in Fig. 5(c3), and the numerical calculation is shown in Fig. 5(c4). The focal length obtained by experiment is 48 μm, and numerical calculation is 50μm. From the results, the output light field of the DKSZP closely resembled the experimental and simulated results, and confirming the successful generation of FOVA from the all fiber generator.

In conclusion, we investigated the design and preparation of all fiber FOVA generator. The FOVA generation was verified by experimental and simulated results of the generator. The all-fibre FOVA generator has the capacity to be utilized in optical pump and complex optical tweezers with invasive requirements.

References

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