3D printed photonic structure for generation to zeroth- and high-order Bessel beams from a single-mode optical fiber

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Bessel beams have gained prominence due to their diffraction-free propagation and self-healing properties [1]. The zeroth-order Bessel beam has maximum intensity at its center and has found many applications, including optical trapping and bio-imaging. On the other hand, higher-order Bessel beams have a node due to a phase singularity and carry orbital angular momentum (OAM). Over the past years, Bessel beams have been generated by using different approaches, namely by Fourier transforming a narrow circular beam with a lens, by using axicons and with holographic beam shaping techniques. The need to miniaturize optics has led to efforts towards the on-fiber generation of Bessel beams. The successful attempts include the fabrication of a customized annular-core fiber along with a polymer lens [2], or modifying the end of the fiber to an axicon profile with chemical or lithographic methods [3]. These techniques have limited capability on generating Bessel beams with on-demand optical parameters and are only focused on creating zeroth-order Bessel beams from optical fibers.

We present a new method for the generation of Bessel beams from optical fibers that utilizes stacked miniaturized optical elements 3D printed in a single step on the fiber facet with a commercial two-photon lithography based printer (Nanoscribe). The design allows for the generation of both zeroth- and high-order Bessel beams and a fully controllable tailoring of the beams' parameters, such as their propagation distance or the width of their central peak or node. Our structure includes a segment with a longitudinally varying annular-core photonic crystal fiber (PCF) design [4] used to transform the fundamental mode from the single-mode fiber into an annular beam, which is subsequently Fourier transformed with a microfabricated lens (Fig. 1). By designing the longitudinal variation of the annular-core PCF segment, the fundamental mode of the fiber is transformed into a beam ring of desired parameters. The structure includes also a PCF taper, used to modify the beam width output from the fiber to match the ring mode size in the annular-core PCF. For the generation of higher-order Bessel beams, a spiral phase plate (SPP) with the needed topological charge is also fabricated on the output face of the annular-core PCF. Finally, a microlens is fabricated to generate the desired Bessel beam at its focal plane. We demonstrate the generation high-quality Bessel beams with order starting from zero-order until 20 (Fig. 1).

Figure 1: Rendered cross-section of the presented structure. In the insets, SEM images of the fabricated structure. On the right side, collected images of the generated 0-th and high-order Bessel beams.

References

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