Continuously Variable Topological Charge of a Vector Vortex Beam Generated by an Integrated Metasurface

Hao Peng, Yuntian Ye, Xu Fang*

School of Electronics and Computer Science, University of Southampton, Southampton SO17 1BJ, UK

**x.fang@soton.ac.uk*

We propose and numerically verify a new method for generating a vector vortex beam, in which the twist of the wavefront varies continuously along the beam axis, offering potential benefits for distance detection.

Metasurfaces provide precise control over the propagation of light, with potential applications ranging from commercially explored achromatic light focusing to the recently discovered quantum-like behavior of bound states in the continuum [1]. Integrating metasurfaces with silicon waveguides has become a significant new avenue in metasurface research, enabling advanced light manipulation in devices compatible with the mass production capabilities of silicon electronics and photonics foundries. These integrated metasurfaces have demonstrated a wide range of light manipulation functionalities, including light focusing, beam deflection, beam expansion, and the generation of vector vortex beams [2-4].

In this work, we introduce a new method of light manipulation using integrated metasurfaces, where the vector vortex beam generated by the metasurface exhibits a continuously variable topological charge along the propagation direction. This method demonstrates that the orbital angular momentum of the output light near the beam axis, which is most significant for many applications, does not need to remain constant. The light beam behaves like a probe, with each segment possessing unique properties, making it potentially useful for applications such as distance detection.

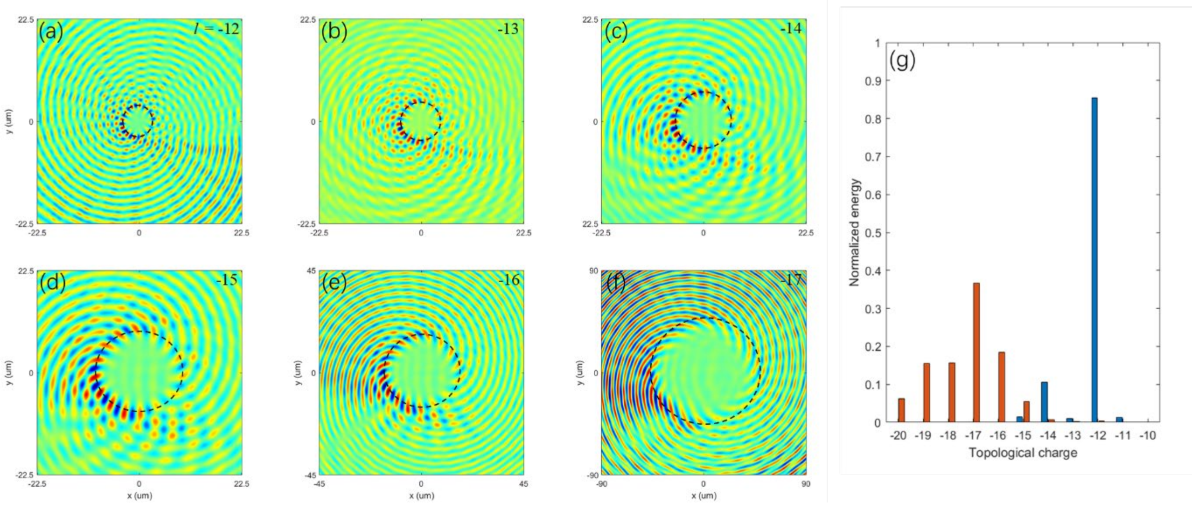

Fig. 1 Numerically simulated field distributions for an example device and the corresponding orbital angular momentum (OAM) spectra. The field distributions are shown at heights of (a) 7 μm, (b) 25 μm, (c) 43 μm, (d) 69 μm, (e) 120 μm, and (f) 335 μm. The OAM spectra for (a) and (f) are compared in (g).

Figure 1 shows the output of an example device featuring a Fermat's spiral waveguide. The waveguide's shape is defined by the Fermat's equation of $r = \pm a\sqrt{\varphi}$ in the *xy* plane, where $a = 10$ μm is the size factor, and r and φ are the polar coordinates. Nano-sized holes are aligned along the waveguide, scattering the guided mode into free space. The spiral's shape and the nanoholes each contribute to the total angular moment momentum l, resulting in an l value that depends on the height *z*. We have numerically verified this method in multiple designs. In this example, l varies continuously from -12 to -17 over a distance of approximately 300 μm.

References

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