Generation of Perfect Vortex Beam Arrays Using Axicon Embedded in Singular Almost Periodic Phase Structures

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Abstract

This work presents an experimental method for generating circular arrays of Perfect Vortex Beams (PVBs) with distinct topological charges. The arrays are produced by modulating a Gaussian beam with a singular almost-periodic phase structure (SAPPS) embedded with an axicon, followed by a Fourier transform lens. This structured light platform holds significant potential for optical trapping, parallel particle manipulation, and light-matter interaction studies.

Introduction & Theory

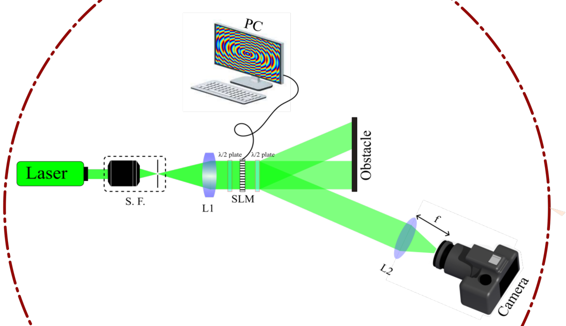
Optical vortices carry orbital angular momentum (OAM), useful in numerous applications. In Laguerre-Gaussian and Bessel-Gaussian beams, the ring size depends on topological charge (TC). Perfect Vortex Beams (PVBs) have a constant ring radius, independent of TC, enabling uniform performance.

We propose using a Singular Almost-Periodic Phase Structure (SAPPS). Its transmittance function is given by:

$$t_{SAPPS}(\mathbf{r}) = \frac{1}{2} + \frac{1}{4N}\sum_{n=1}^{2N} \exp(i2\pi \mathbf{f}_n . \mathbf{r})\, e^{-i2\pi \frac{r}{r_0} + il\varphi}$$

where N defines the symmetry order (number of beams in the array), and φ is the azimuthal coordinate.

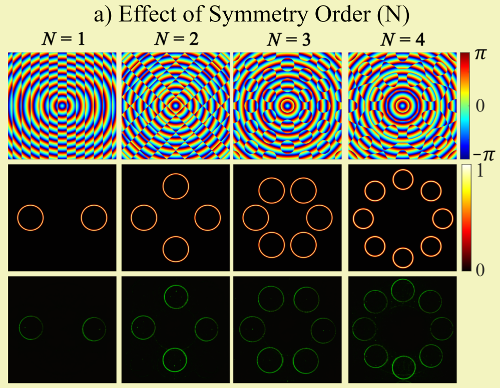
Experimental setup



A Gaussian laser beam is spatially filtered, collimated, and directed onto a Spatial Light Modulator (SLM). The SLM is programmed with the hybrid phase pattern (SAPPS + Axicon). Two half-wave plates optimize polarization. The beam is Fourier transformed by a lens (L2),

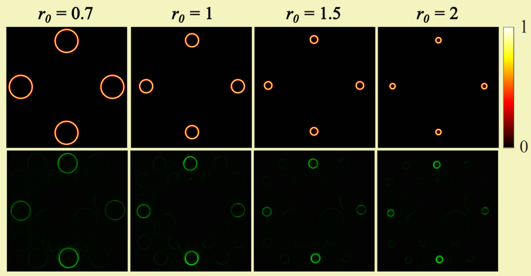
Results & Discussion

a) Effect of Symmetry Order (N)



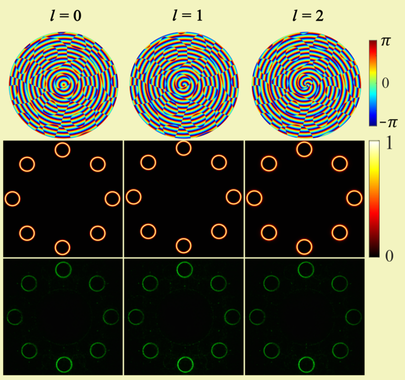
Top row: Phase masks for N=1, 2, 3, 4. Middle/Bottom rows: Simulated and experimental intensity profiles for TC=0. Successful generation of circular PVB arrays with 2N beams, confirming the design principle.

b) Effect of Radial Scaling Parameter



Top/Bottom rows: Simulated and experimental results for N=2 array with varying radial scaling (0.7, 1.0, 1.5, 2.0 mm). The ring diameter and thickness of individual PVBs can be precisely controlled by adjusting this parameter, without affecting the array structure.

c) Effect of Topological Charge (TC)



Top row: Phase masks for different TCs.Middle/Bottom rows: Simulated and experimental results for arrays with TC = 0, 1, 3. The diameter of the PVBs remains constant regardless of the topological charge, validating their "perfect" vortex nature. Only the internal phase structure changes.

Conclusion

We demonstrated a robust method for generating customizable arrays of Perfect Vortex Beams. Control Parameters: 1) Sets the number of beams in the array. 2) Controls the size and thickness of each PVB. 3) Controls the OAM without changing the size. This work provides a versatile tool for advanced applications in multi-particle manipulation, quantum optics, and optical communications.

Acknowledgments

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Reference:

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