Examining the latest developments of spatiotemporal vortices of light

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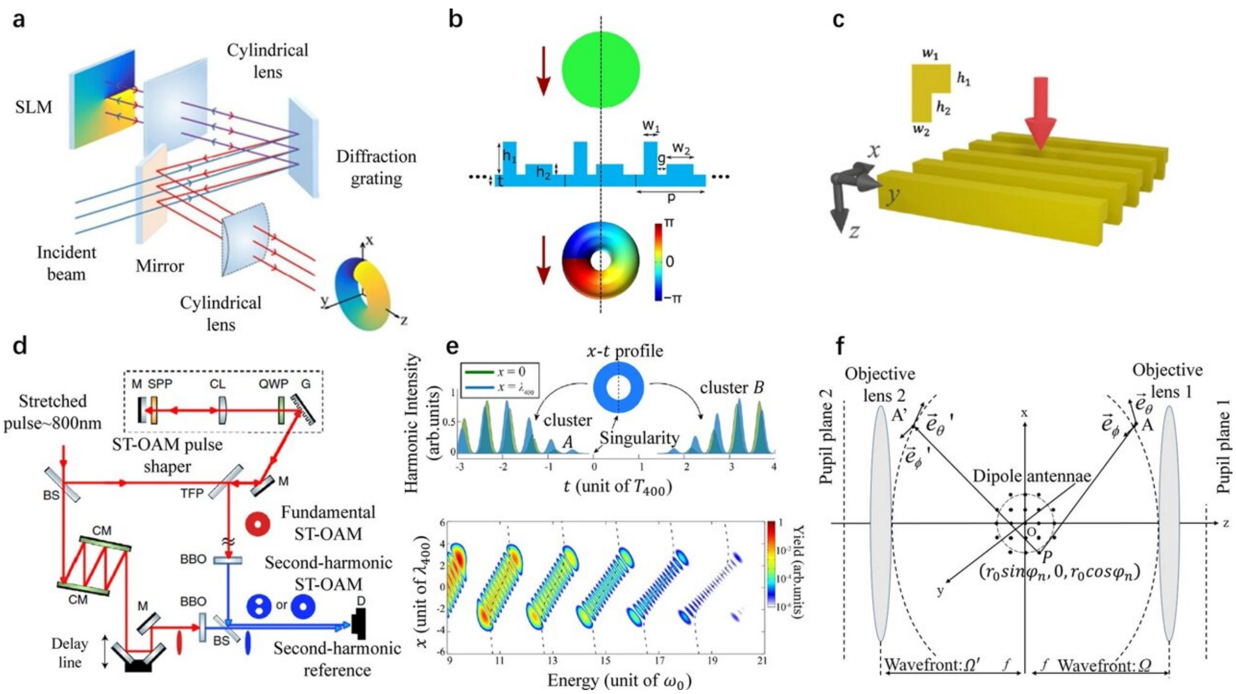

Generation, propagation and conversion of STOVs. **a** Generation of STOVs through spiral phase modulation using 2D pulse shaper. Adapted with permission from [29], copyright 2020, NPG. **b** A spatiotemporal differentiator that breaks spatial mirror symmetry is capable of generating STOVs without Fourier transform. Adapted with permission from [35], copyright 2022, WILEY. **c** A photonic crystal slab structure that possesses a custom nodal line for the generation of STOVs. Adapted with permission from [37], copyright 2021, OPG. **d** STOVs under second harmonic nonlinear process. Adapted with permission from [31], copyright 2021, NPG. **e** High harmonic generation with transverse OAM. Adapted with permission from [63], copyright 2021, APS. **f** Focusing structured light to obtain focal field with transverse SAM and OAM.

Adapted with permission from [65], copyright 2022, OPG. Credit: *eLight* (2023). DOI: 10.1186/s43593-023-00042-6

Vortices of light, null regions of intensity surrounded by spiral phases, make up the skeleton of a wavefield and influence the properties of light. Since the discovery of the tight connection of optical vortices and orbital angular momentum (OAM) of light in the seminal paper in 1992, considerable research progress has been made to unveil the beauty of vortices of light.

Numerous applications of optical OAM have been discovered in both classic and quantum optics, including optical communication, quantum entanglement and cryptography, optical tweezing, driving torque for a micromachine, rotational Doppler shift, and imaging.

In a new paper published in *eLight*, a team of scientists led by Professor Qiwen Zhan from the University of Shanghai for Science and Technology examined the latest developments of spatiotemporal vortices of light.

Optical vortices feature azimuthal phase dependence. The OAM carried by each photon is proportional to the topological charge and quantized. The spin angular momentum (SAM), associated with circular polarization states, is limited, but the OAM per photon is theoretically unbounded. The direction of angular momentum of light is usually directed along the propagation direction.

A decade ago, the interest in transverse SAM emerged and transversely spinning electric fields was discovered in strongly focused beams and evanescent waves. The word "photonic wheel" describes the orthogonal relationship between the SAM direction and the propagation direction.

Analogously, optical vortices carrying transverse OAM have attracted rapidly growing interest.

Tilted vortices of light were predicted using the special theory of relativity. A transversely moving observer sees a spatial optical vortex near the speed of light as a tilted vortex. Spatiotemporal optical vortices (STOVs), occupying a small fraction of total energy, were first observed in femtosecond filaments in the air.

Later, controllable generation of STOVs with transverse OAM was demonstrated using linear optics. The second harmonic generation (SHG) of transverse OAM was reported, and the conservation of OAM demonstrated. Rigorous calculation of transverse OAM and the coupling of transverse OAM and SAM were also accomplished.

Schemes were designed to generate STOVs using metasurfaces and photonic crystals. Undoubtedly, the experimental realization of STOVs has been driving the increasing interest in STOVs and spurring their potential applications in various optical phenomena. It should be noted that this article focuses on the very recent advances related to STOVs. Readers interested in the latest developments of more general spatiotemporal wave packets and structured waves may refer to several review articles cited in this work.

More information: Chenhao Wan et al, Optical spatiotemporal vortices, *eLight* (2023). DOI: 10.1186/s43593-023-00042-6

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