Supercontinuum optical vortices: generation, characterization, and control

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Abstract
We create coherent, ultrabroadband optical vortex beams, characterize their topological charge, and control the interaction of multiple vortices. Ultrafast laser pulses are first injected into a microstructured fiber, generating a wide spectrum of supercontinuum light. Then, a large-aperture, high-resolution, reflective spatial light modulator (SLM) is used to create single and multiple vortices across a broad range of colors. Exquisite full-color interference patterns are investigated, showing excellent agreement with numerical simulations. Also, by using different colored filters in front of the SLM, multiple single-color vortices can be generated and independently controlled simultaneously. Finally, the topological charge of broadband vortices is characterized by inspecting the diffraction pattern through a triangular aperture. Significant spatial dispersion is compensated through the use of a double-pass arrangement utilizing a single SLM, allowing for the consistent measurement of topological charge across a wide range of colors. These studies pave the way for applications in particle trapping and manipulation, imaging, and information science.

Vortex Generation

An optical vortex is created in the far field by adding a spiral phase to a coherent beam in the near field. The familiar forked phase pattern is the result of the phase on the spatial light modulator. The use of the phase tilt (equivalent to a blazed grating when displayed modulo 2\(\pi\)) ensures that only the properly converted portions of the beam are diffracted to the first-order angle. Beam quality will be excellent and only the diffraction efficiency will suffer. In the upper panel, theoretical vortex beams for a 0-2\(\pi\) forked pattern. In the lower panel, experimental results for the same conditions. Typically, the SLM is calibrated to the central wavelength of the incident light, but the calibration can be shifted to a weaker portion of the spectrum to effectively enhance that spectral region.

Supercontinuum

A Nd:YAG-pumped Ti:Sapphire oscillator generates 20-fs mode-locked pulses with a central wavelength of 800 nm. After the oscillator, the beam passes through a pulse compressor, allowing for control of the temporal chirp of the pulses. A 25x microscope objective is mounted onto an XYZ translation stage to couple the beam into the nonlinear photonic crystal fiber (NKT Photonics FemtoWhite 800), which is also mounted on an XYZ stage.

Spatial Light Modulator

The spatial light modulator (SLM) is a Hamamatsu liquid crystal-on-silicon design that eliminates pixelation and has a 100% fill factor. The reflective nature of this device is well suited for high power beams and can handle an amplified system. It has an antireflection (AR) coating at 800 nm, but with our amplification power, it performs well over a wide range of wavelengths. It has a large active area of 2mm x 2mm with 768 x 768 pixels, easily allowing for “segmentation” into at least four regions with excellent results.

Broadband Vortices

Two independent forked patterns are encoded onto the SLM, simultaneously generating two broadband vortices that interfere on the CCD. Here, the brilliant interference pattern generated with the annular phase of the opposite topological charge (±10, ±10) are captured in full color with a Nikon D70s DSLR camera (left panel). Numerical calculations (right panel) show excellent agreement.

References