Measuring the topological charge of ultra-broadband optical-vortex beams with a triangular aperture

Matthew E. Anderson  
San Diego State University, USA

Heath Bigman  
University of Northern Colorado, USA

Luis E.E. de Araujo  
Universidade Estadual de Campinas, Brazil

Jan L. Chaloupka  
University of Northern Colorado, USA

Abstract

A technique for determining the topological charge of supercontinuum optical vortices is presented. Spatial dispersion is compensated with a unique double-pass arrangement, and charge is consistently measured across a wide range of colors by observing diffraction through a triangular aperture.

Spiral Phase Plates for Vortex Generation

In order to generate optical vortex beams [1-2], a spiral phase ranging from 0 to 2πm (a) is applied to the near field of an incident laser beam. This phase is encoded modulo 2πm (b) on a spatial light modulator (SLM) to maximize the dynamic range of the device. In this example, the pinwheel structure with five 0-2πm segments represents a spiral phase with a topological charge of Δ. A uniform phase tilt (c) is also applied to steer the modulated beam away from the unshifted background, say, due to reflections off of windows or other interfaces. When encoded modulo 2πm, the phase tilt resembles a Blazed diffraction grating (d). The sum of the spiral phase and the Blazed grating results in the total phase applied to the SLM (e).

Calculations Confirm Dispersion Compensation

The propagation of a broadband optical beam through our experimental arrangement is calculated by evaluating the Kirchoff-Fresnel integral for each path segment. The cross-sectional profiles for charge 3 vortices are shown below. The doubly dispersed case (a) demonstrates the effect on the diffraction order that would be ordinarily discarded, showing large spatial separation between the green (550nm), orange (580nm), and red (619nm) light. The corrected case (b) shows excellent spatial overlap for all of the colors.

Experimental Results Demonstrate Excellent SuperContinuum Vortices & Topological Charge Measurement

The combination of an applied spiral phase and Blazed grating along with the dispersion-correcting double-pass arrangement results in high-quality optical vortices across a broadband width. Inspection of the doubly dispersed case generated by a triangular aperture allows for a straightforward method to reliably measure the topological charge of these super-continuum vortices.

Charge 3 vortices (below) are generated in the doubly dispersed arrangement for continuous-wave (a), femtosecond (b), and super-continuum (c) beams. The ultra-broadband SC vortices are severely distorted by spatial chirp. The dispersion corrected vortices, CW (d), FS (e), SC (f), are all formed perfectly, regardless of spectral bandwidth.

True-color images of doubly dispersed (left column) and dispersion-corrected (right column) vortices are shown for 550nm (a,e), 580nm (b,f), 619nm (c,g) and the full spectrum (d,h). The full-spectrum case clearly demonstrates the severe spatial chirp in the doubly dispersed case and the excellent overlap in the dispersion-corrected case.

False-color diffraction patterns through a triangular aperture for the doubly dispersed case (left column) and dispersion-corrected case (right column) for CW (a,d), FS (b,e) and SC (c,f) beams. While the patterns are still discernable for the CW and FS beams in both cases, the extreme bandwidth in the SC beams makes the dispersion correction essential in order to measure the vortex charge (equal to m = n-1, where n is the number of spots along each edge).

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