Tight focal spots using azimuthally polarised light from a Fresnel cone

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Abstract

A simple glass cone can be used to structure the polarisation of light in such a way that allows focussing below the conventional diffraction limit, enhancing resolution in scanning microscopy. Conversely, not only can these glass cones be used to generate useful polarisation structures [1] but can also be used to measure light's polarisation in single-shot polarimetry [2]. When considering the polarisation of light in a high numerical aperture system, a longitudinal electric field component emerges, and interesting effects can be observed. For example, focal spots below the conventional diffraction limit have been predicted for certain radially and azimuthally polarised beams [3–5]. There are numerous ways to generate these special polarisation structures, however, setups can be expensive and rely on birefringent components making broadband operation difficult. We show a passive, low-cost technique using a simple glass cone to generate beams with structured polarisation and their predicted focussing properties. When uniformly polarised light is incident in a glass cone, a phase-shift occurs upon total internal reflection between orthogonal s and p polarisation components. This phase-shift depends on the refractive index and the azimuthally varying angle of incidence with respect to the initial polarisation, resulting in a spatially varying polarisation structure in the reflected beam. Using this we can generate azimuthally polarised vector vortex beams, predicted to focus below the conventional diffraction limit. Importantly, refractive index does not vary significantly with wavelength, allowing broadband operation. The polarisation of light can contain information about its source and interactions, from biological samples to distant stars. Polarimeters can recover this information, but reliance on birefringent or rotating optical elements limits their wavelength range and stability. We additionally show that a solid glass cone can be used in a passive, single-shot, broadband polarimeter device, analogous to the popular rotating quarter-wave plate technique.

References

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