Diffraction from polarisation filtering axicons

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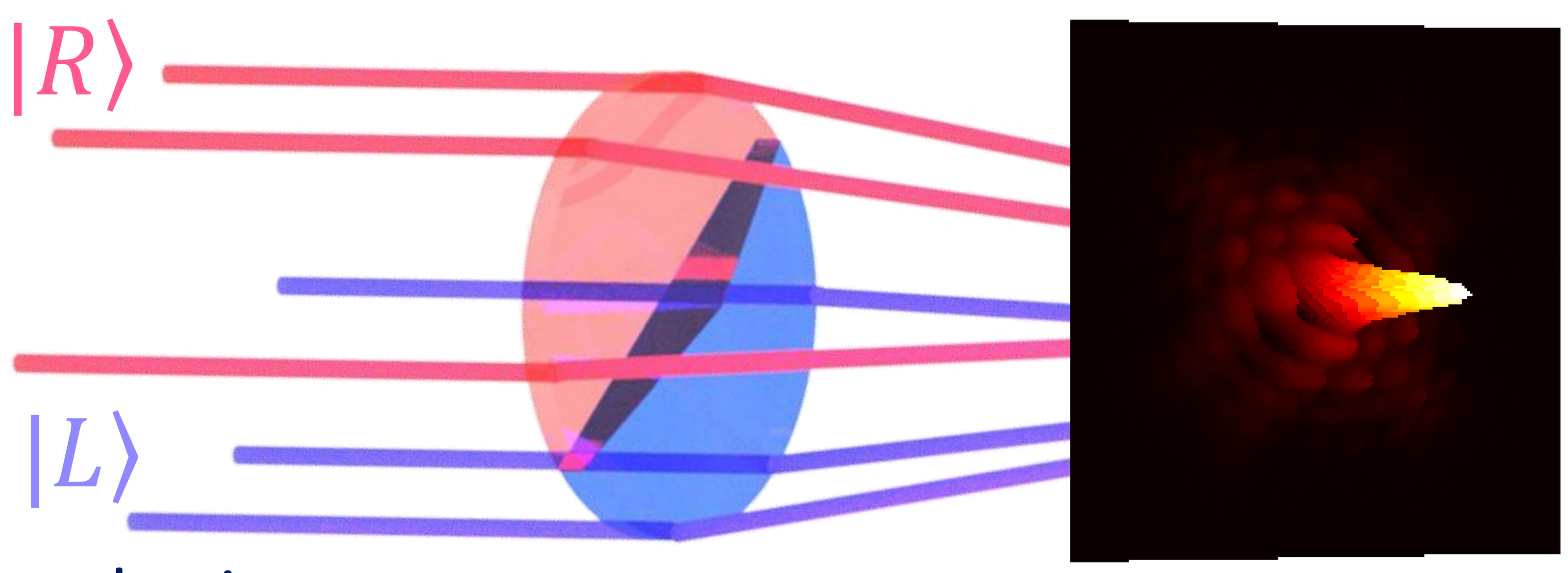
Abstract

Non-diffracting optical fields have exhibited numerous interesting properties, including self healing and radial acceleration, in addition to their propagation invariant intensities. Naturally, these properties have proven desirable in applications such as optical trapping, communication and metrology. One class of these fields is the set of Bessel-Gaussian modes which can be generated through the interference of conical waves from an axicon lens. Vectorial realisations of such fields have led to the observation of further interesting properties such as periodic acceleration and deceleration of local Stokes vectors [1]. We investigate how the diffraction of orthogonal polarisation components across cylindrically asymmetric axicons recovers conical interference behavior along the line of asymmetry. Total intensity sections as well as orthogonal polarisation projections along lines of interest present proportionality to squared Bessel functions while orthogonal lines reveal no such structures. Total intensities maintain qualitative resemblance to parabolic non-diffracting beams, while the introduction of azimuthally varying phases associated with orbital angular momentum perturb the distributions. The results provide new insights into the nature of propagation invariant optical fields.



Introduction

Axicons are conical lenses which are used to create so-called Bessel-Gaussian (BG) beams which have radial intensity fringes which occur due to the path length difference of light interfering on a conical path. Therefore, interference plays an integral role in the functioning principles of these interesting optics. The structuring of lights polarisation degree-of-freedom (DoF) has revealed new avenues for improvement in applications ranging from communications to microscopy and even laser machining – while BG beams present their own plethora of useful properties such as self-healing and non-diffracting propagation. This may lead one to ponder what would happen if polarisation interference laws were introduced into axicons. Here we present an investigation of how the polarisation DoF affects the functionality of axicons.

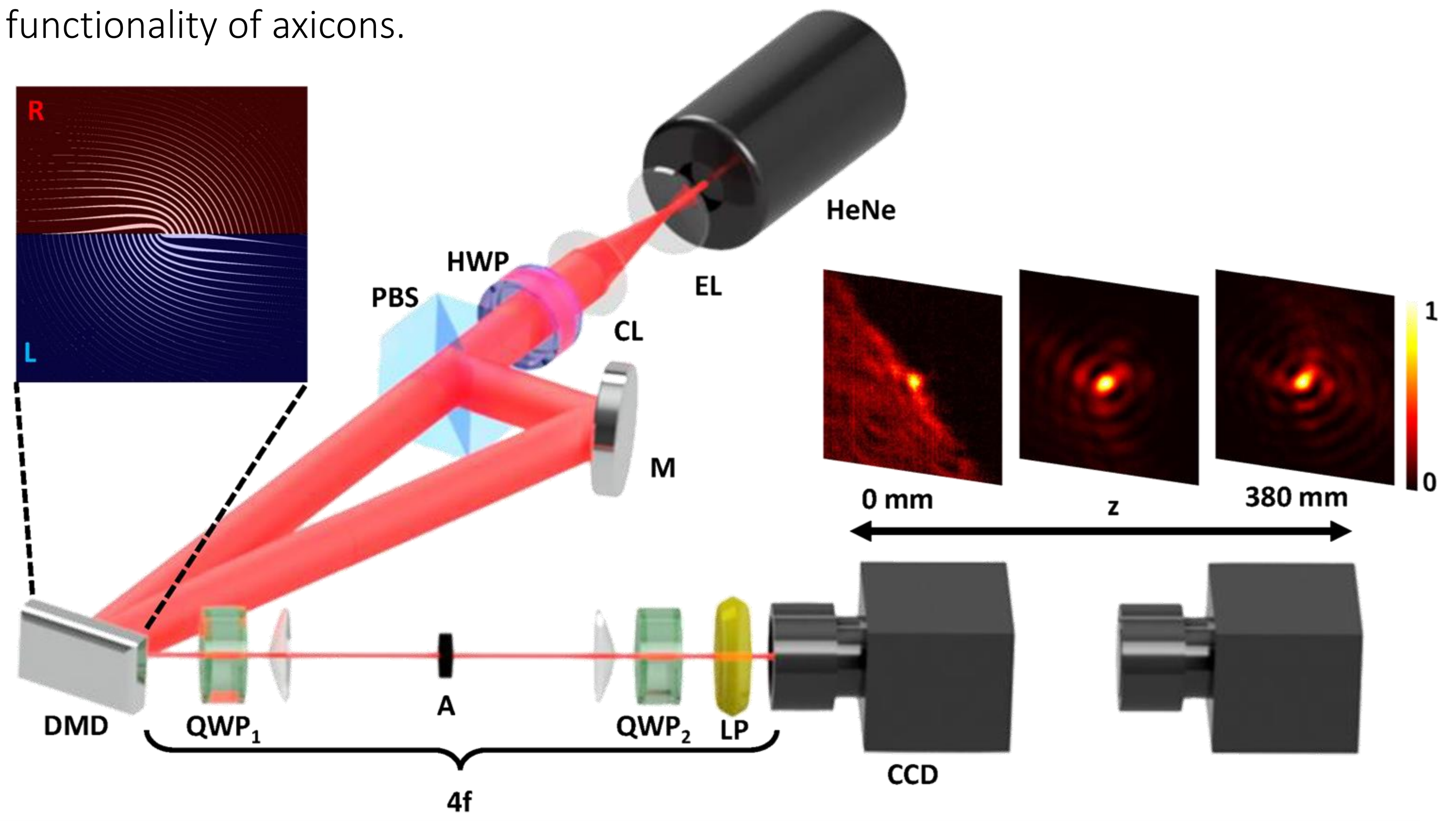


Figure 1: The experimental arrangement used to mimic and investigate the diffraction from a vectorial axicon. An expanded beam from a helium-neon source was separated into orthogonal polarisations which were holographically shaped and recombined using a digital micro-mirror device. A Stokes polarimeter consisting of a quarter-wave plate (QWP) and linear polariser (LP) was used to capture Stokes intensity measurements at a range of planes using a rail mounted CCD.

The Arago-Fresnel laws

In order to understand the structures (shown in Figs 2 & 3) created by our holographic vectorial axicon (shown in Fig. 1), we need to consider the interference of polarised light. Arago and Fresnel observed how the polarisation of light affects its ability to interfere, they collected their observations into four laws:

I. Light polarised in the same plane will interfere.
II. Light polarised in orthogonal planes will not interfere.
III. Orthogonally polarised light derived from unpolarised light, when brought into the same plane will not interfere.
IV. Orthogonally polarised light derived from polarised light, when brought into the same plane will interfere.

These laws show how interference behaviour changes when polarisation is take into account [2]. The vector beam created by our polarisation split axicon simultaneously demonstrates three of these laws (as shown in Fig. 3). Law (I) is observed in the presence of Bessel intensity fringes along the splitting line, law (II) is observed in the lack of intensity fringes perpendicular to the splitting line, while law (IV) manifests in the polarisation fringes revealed by the Stokes intensity projections [3].

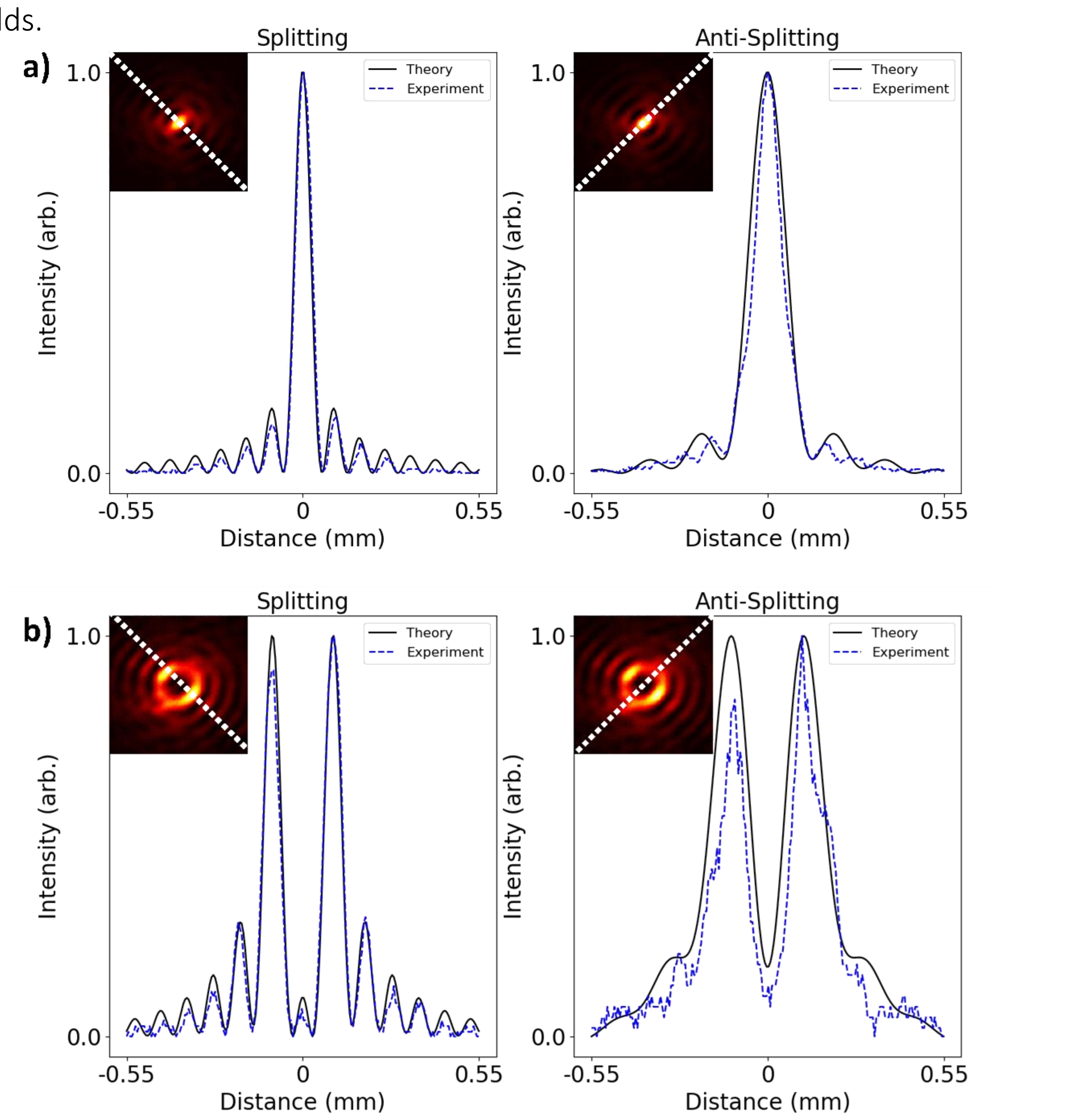


Figure 2: a) Experimental results showing the Bessel intensity distribution along the splitting line, as well as the lack of such a distribution along the perpendicular direction, b) results showing how orbital angular momentum (OAM) perturbs the intensity distributions.

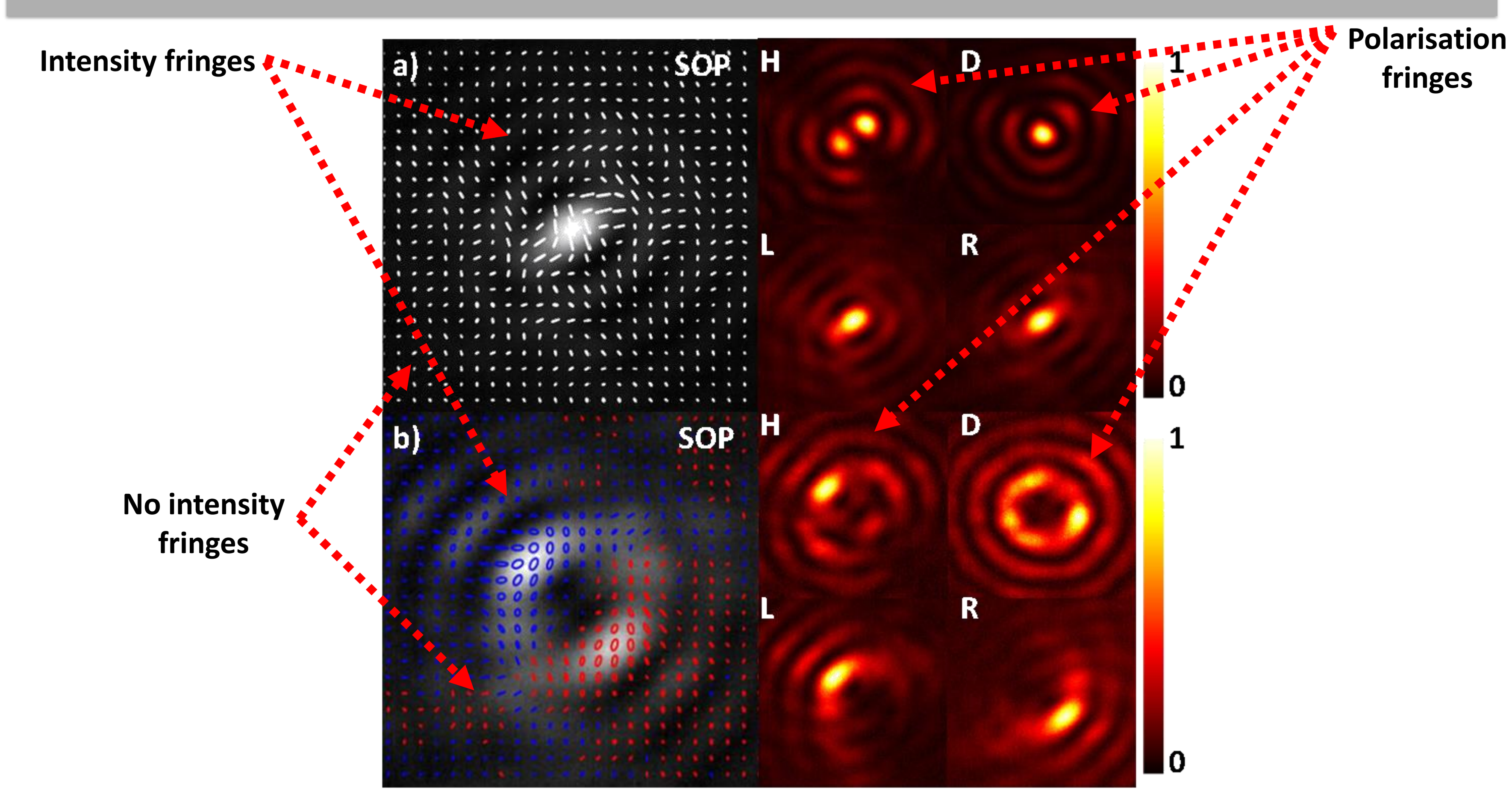


Figure 3: Results showing the state-of-polarisation (SOP) of vector beams generated from a polarisation filtering axicon, and the Stokes intensity projections used to reconstruct the SOP. Top and bottom rows show results without and with OAM respectively.

Conclusion

In conclusion, we have demonstrated how the Arago-Fresnel laws manifest in vector beams generated by a polarisation filtering axicon. These beams have, embedded in them, one dimensional scalar and vector Bessel structures as well as polarisation fringes. We have shown how introducing a vectorial aperture to axicons can add to the growing range of non-diffracting optical fields, which continue to display a range of interesting properties.

References

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