Creating Cylindrical Vector Beams Using Spatially-varying Birefringent Elements

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Background

Polarized light is light with an electric field that oscillates in a specific way. Cylindrical vector beams are formed when the oscillation of the field is dependent on position within the beam and varies with angle. These beams are of interest for high-resolution microscopy because of their focusing properties.

Theory

This study focused on the creation of polarized vector beams using stress-induced spatially varying birefringence. In a birefringent plastic, the index of refraction depends on the direction of polarization and can be modified by applying pressure. Birefringence causes retardance, which is a phase delay between different directions of polarization. A waveplate is an optical device that utilizes retardance to modify the polarization of an incident beam.

Experimental Methods

We utilized an element that consisted of a Plexiglass cylinder encased in copper. Since a specific pattern of retardance was necessary for this work, and this pattern can only be observed within a small radius, the element first had to be tested for birefringence contours. This was achieved through the following setup:

1. First-Surface Gold Mirror
2. Collimating Lens
3. A/4 Waveplate
4. Iris Aperture
5. Achromatic Lens (f=333 mm)
6. Birefringent Stress Optical Element
7. Iris Aperture
8. Achromatic Lens (f=333 mm)
9. Circularly Polarizing Filter
10. Desktop Computer
11. CCD Camera

After isolating the center of the stress, linearly polarized light was used to analyze the potential of the device to create cylindrical vector beams.

Results

Rings delineate the boundaries between regions where the optical element has no retardance and regions where it acts as a λ/2 waveplate. In both pictures, the center region exhibits no birefringence. The waveplate area exhibits lobes with their centers aligned with the polarization axis of the filter as in a radially polarized beam.

Conclusions

- Striations observed in the image are likely caused by inadequate polishing of the Plexiglass element
- Near the center of the device, birefringence, and therefore also retardance, increases with radius
- Stress-engineered devices can be utilized in conjunction with a λ/2 waveplate to create cylindrical vector beams
- Further study could include working with plastics having “frozen-in” birefringence

References


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Spatially-varying waveplates can change polarization non-uniformly to create inhomogeneous beams.