Single Shot Two-Dimensional Polarization Mapping of Birefringent Elements and Devices

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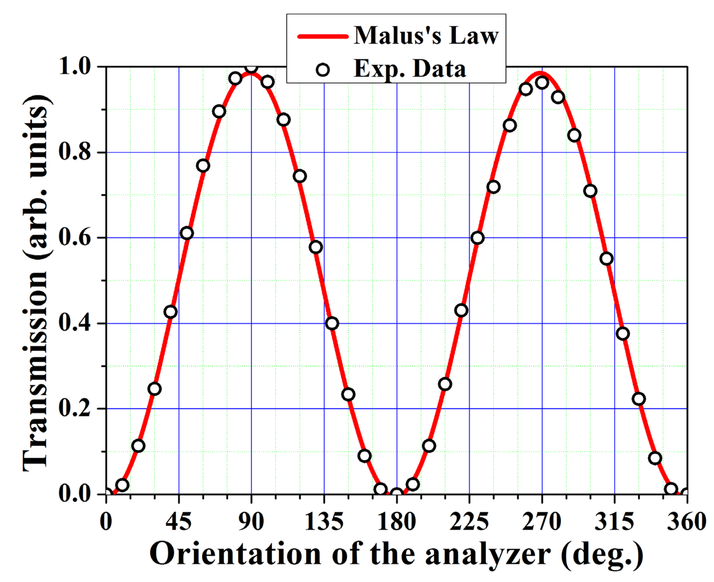
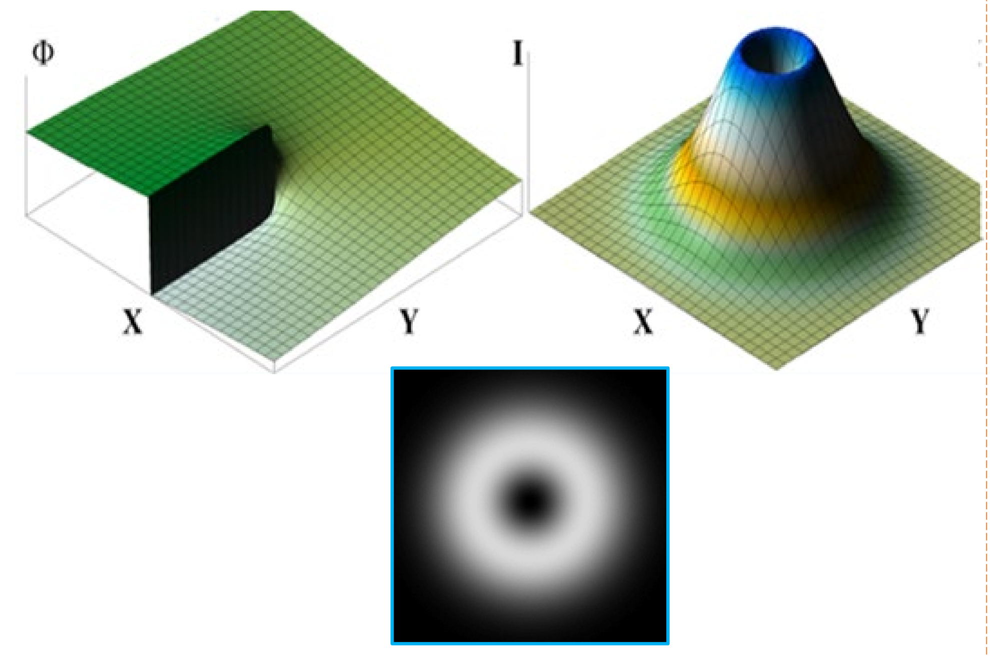
INTRODUCTION

Polarization mapping provides a spatially resolved characterization of the polarization states across an optical beam. This technique helps to identify complex distributions, including radial, azimuthal, and elliptical polarization patterns, and is particularly important for analyzing vector beams and other forms of structured light and other beams with nonuniform polarization. Such beams are often generated by elements like polarization plates or q-plates.

To determine the polarization, one can use combinations of optical elements such as rotating polarizers, wave plates and imaging detectors. [1-3].



Phase optical vortices



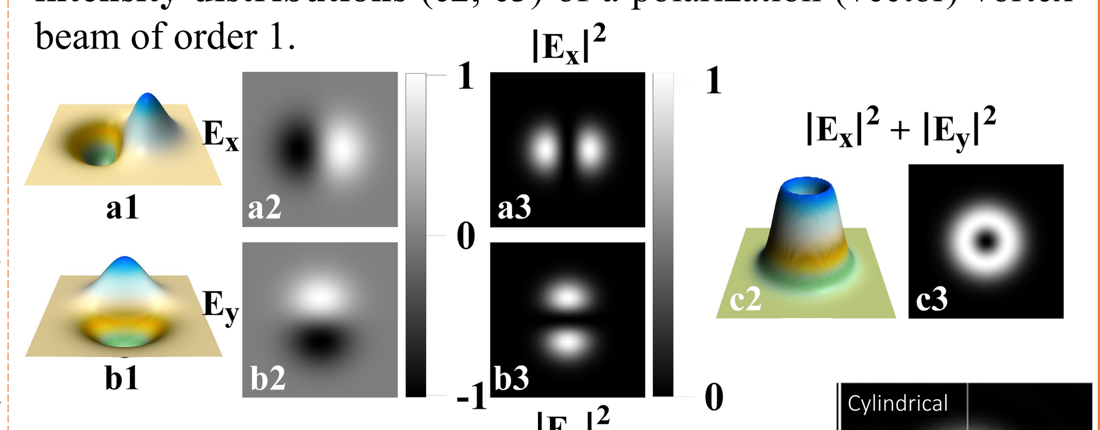
Above are shown **phase** and **intensity distributions** of an optical vortex with topological charge = 1.

Phase optical vortices (OVs) are light beams that contain a spiral phase dislocation – a point in the wavefront where the phase is undefined and the beam intensity drops to zero. Around this singularity, the phase winds continuously, producing a helical wavefront and giving the beam a characteristic doughnut-shaped intensity profile with a dark central core. They can be generated using devices such as spiral phase plates, spatial light modulators, or computer-generated holograms [4].

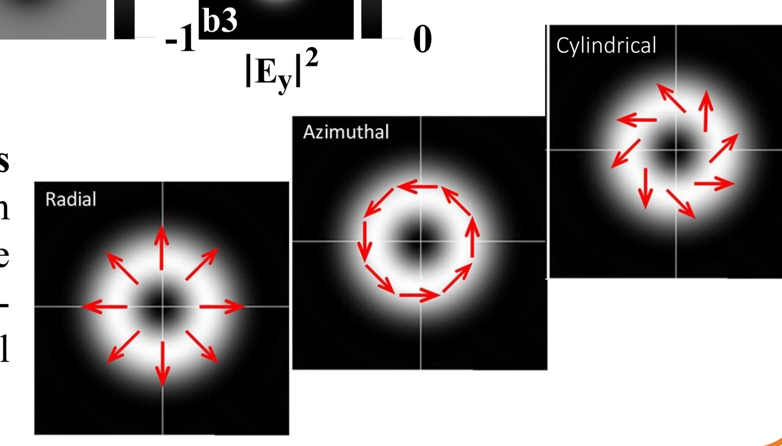
Polarization Optical Vortices

Polarization Optical Vortices (POVs) are a special class of light beams where the state of polarization varies across the beam profile, rather than being uniform. Unlike scalar optical vortices, which involve only phase singularities, POVs are vector beams, meaning their polarization, amplitude, and phase all play a role in defining their structure [5].

Below are shown **amplitudes** (a1, b1, a2, b2) and respective **intensities** (a3, b3) along the *x* and *y* coordinates as well as **intensity distributions** (c2, c3) of a polarization (vector) vortex beam of order 1.



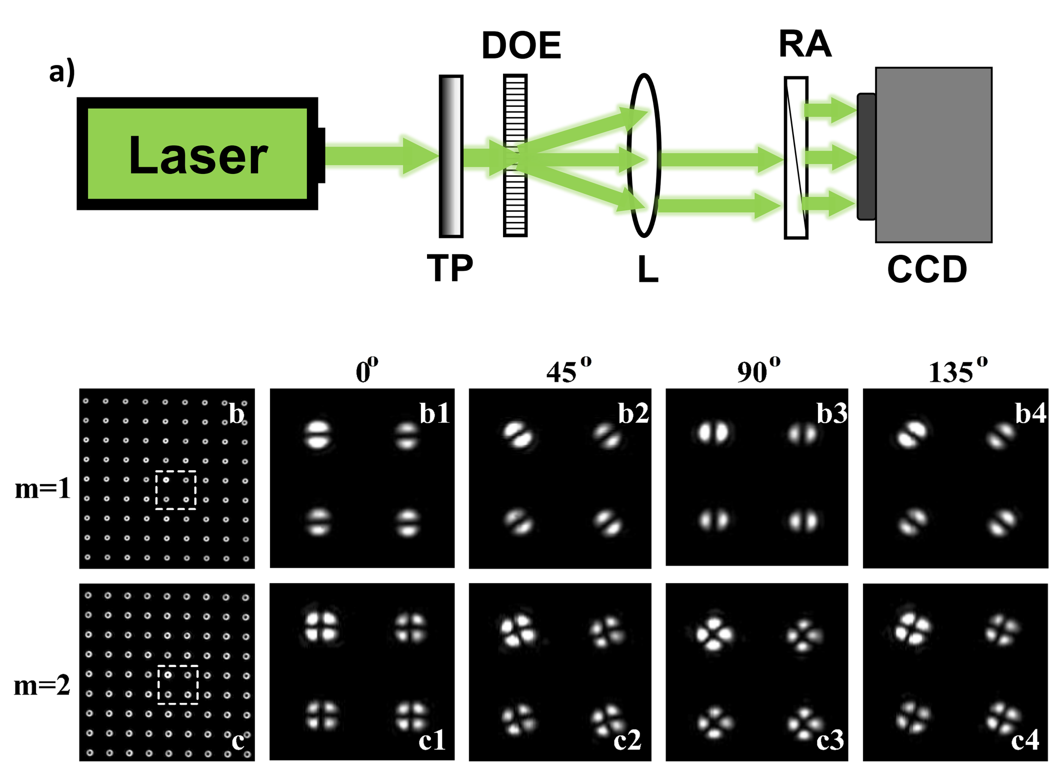
Some **examples of POVs** (shown on the right) are radially, azimuthally, cylindrical polarized beams.



Beam multiplication

(a) Experimental setup for the so-called "trivial beam multiplication". TP – test polarizing plate generation polarization OVs of orders m=1 or m=2. DOE – diffractive optical element creating an array of 9x9 secondary beams. L – thin lens. RA – Rotating analyzer. CCD-camera.

(b) and (c) – 9x9 arrays of polarization OVs of orders m=1 (b) or m=2 (c). Dashed rectangle – 4 OVs analyzed by rotating the RA. (see (b1-b4) and (c1-c4)).



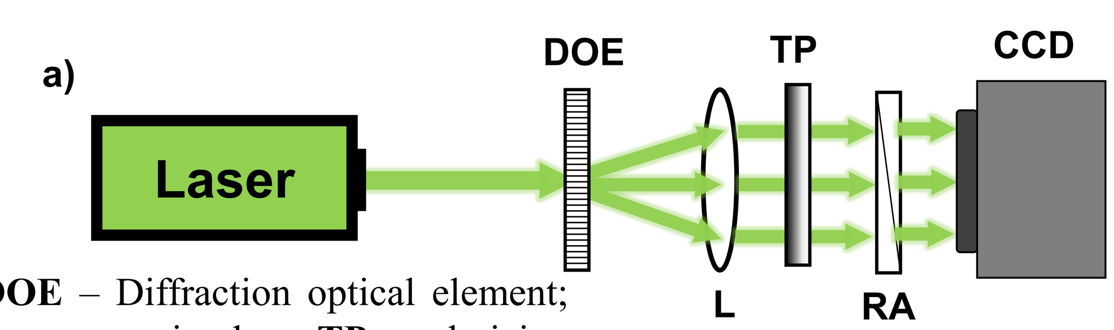
Polarization mapping of a known "test plate"

Experimental setup for the so-called "polarization mapping" of known test plate.

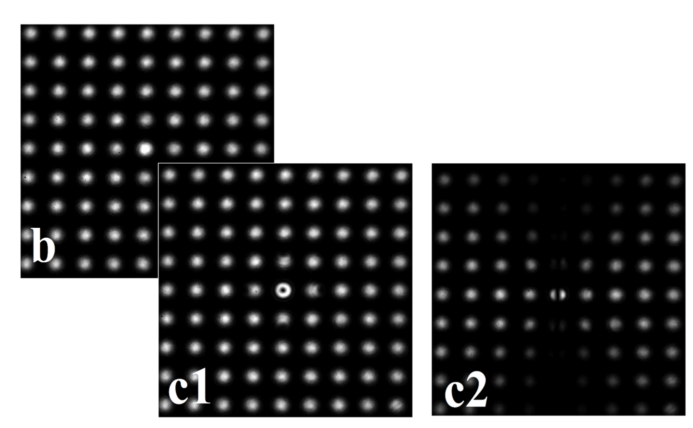
The DOE and the L create a collimated array of 9x9 identical test linearly polarized (Gaussian) beams probing different areas of the TP.

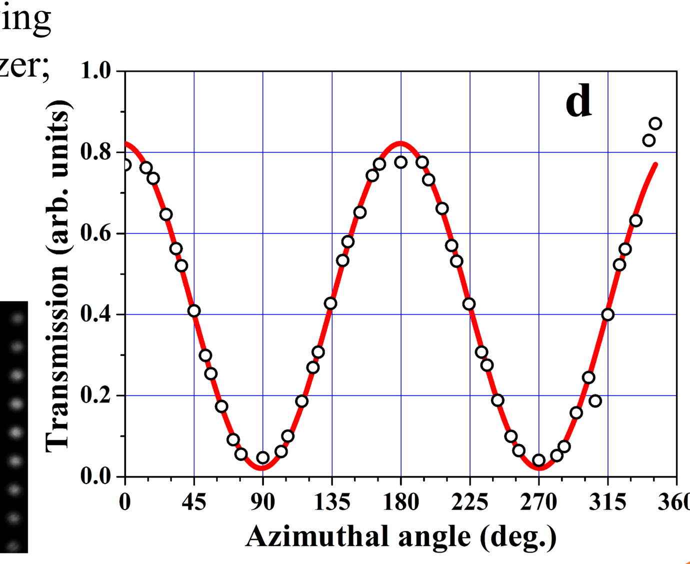
(b) The beams in the array are influenced in a different manner depending on their location on the TP **(c1).** The polarization state of all beams is determined using a single RA and is captured by the CCD camera **(c2).**

Graph (d) – Retrieved polarization dependent transmission after the RA. From (c2) and (d) is seen that the used TP is creating a polarization OV of order m=1.

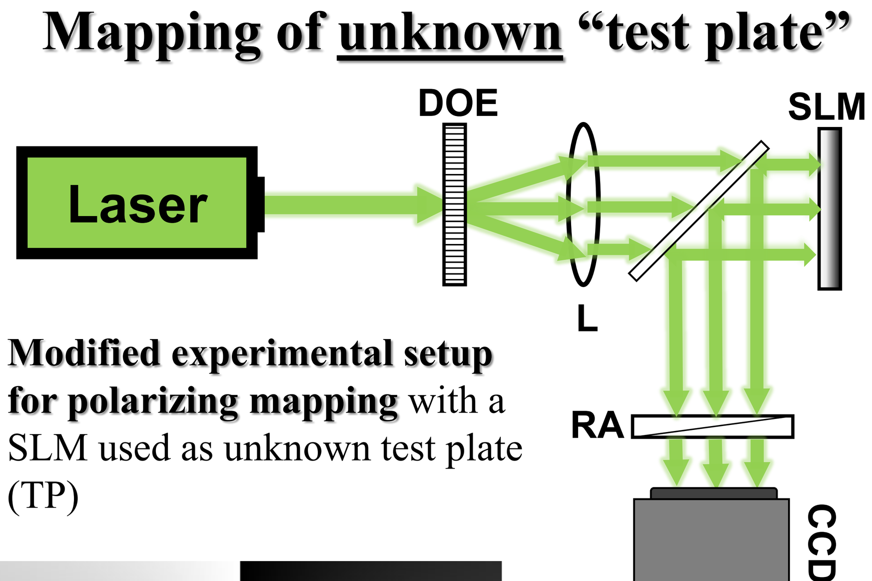


DOE – Diffraction optical element; **L** – converging lens; **TP** – polarizing test plate; **RA** – rotating analyzer; **CCD** camera





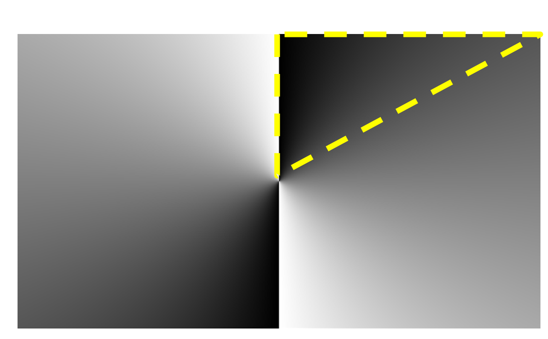
Mapping of unknown "test plate"

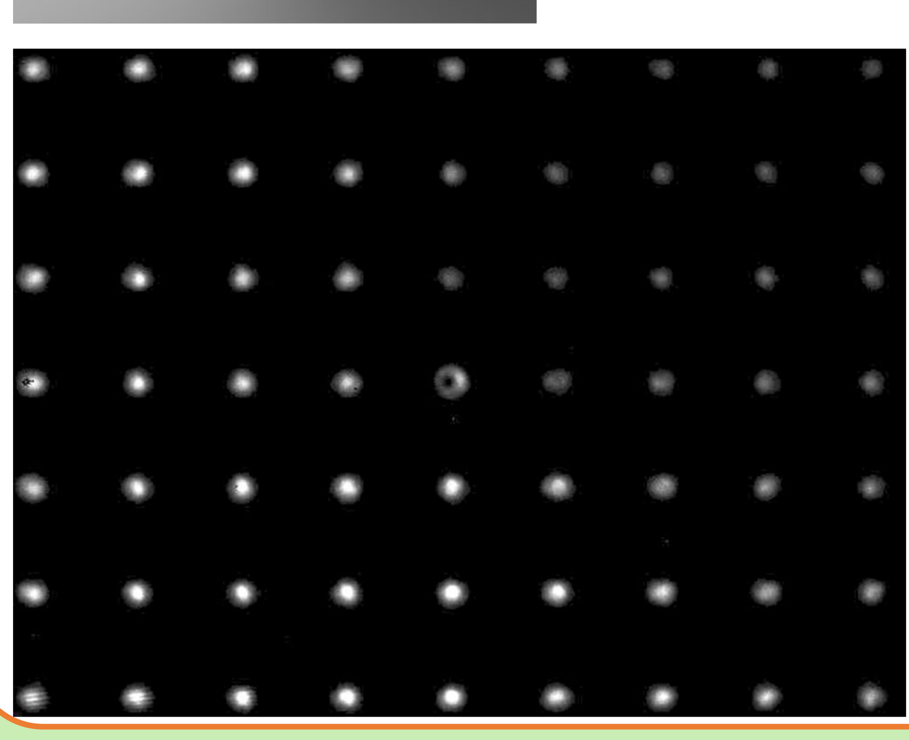


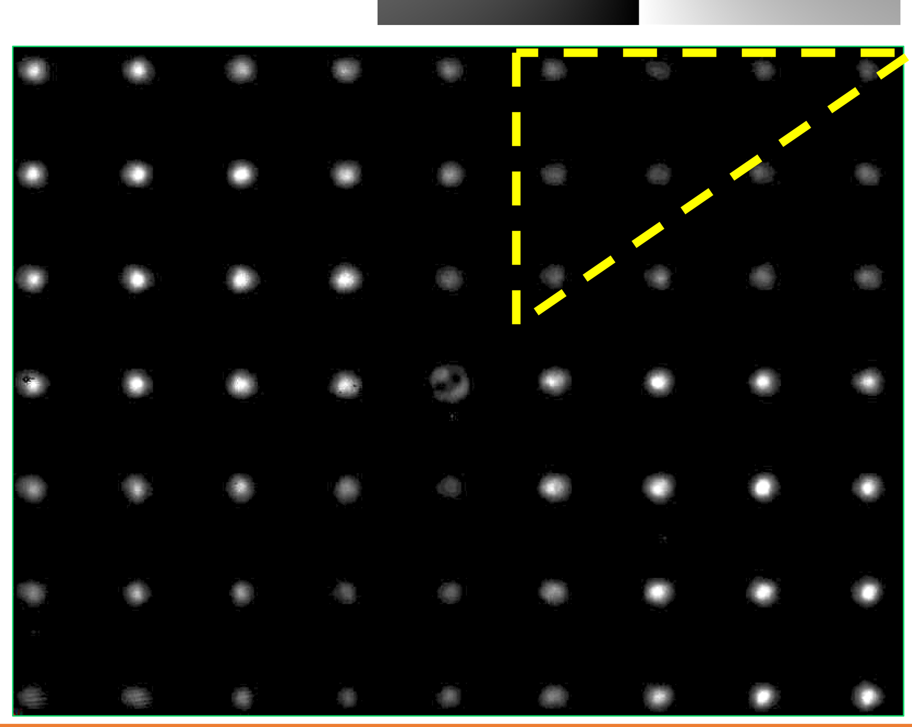
Modified experimental setup for polarizing mapping with a SLM used as unknown test plate (TP)

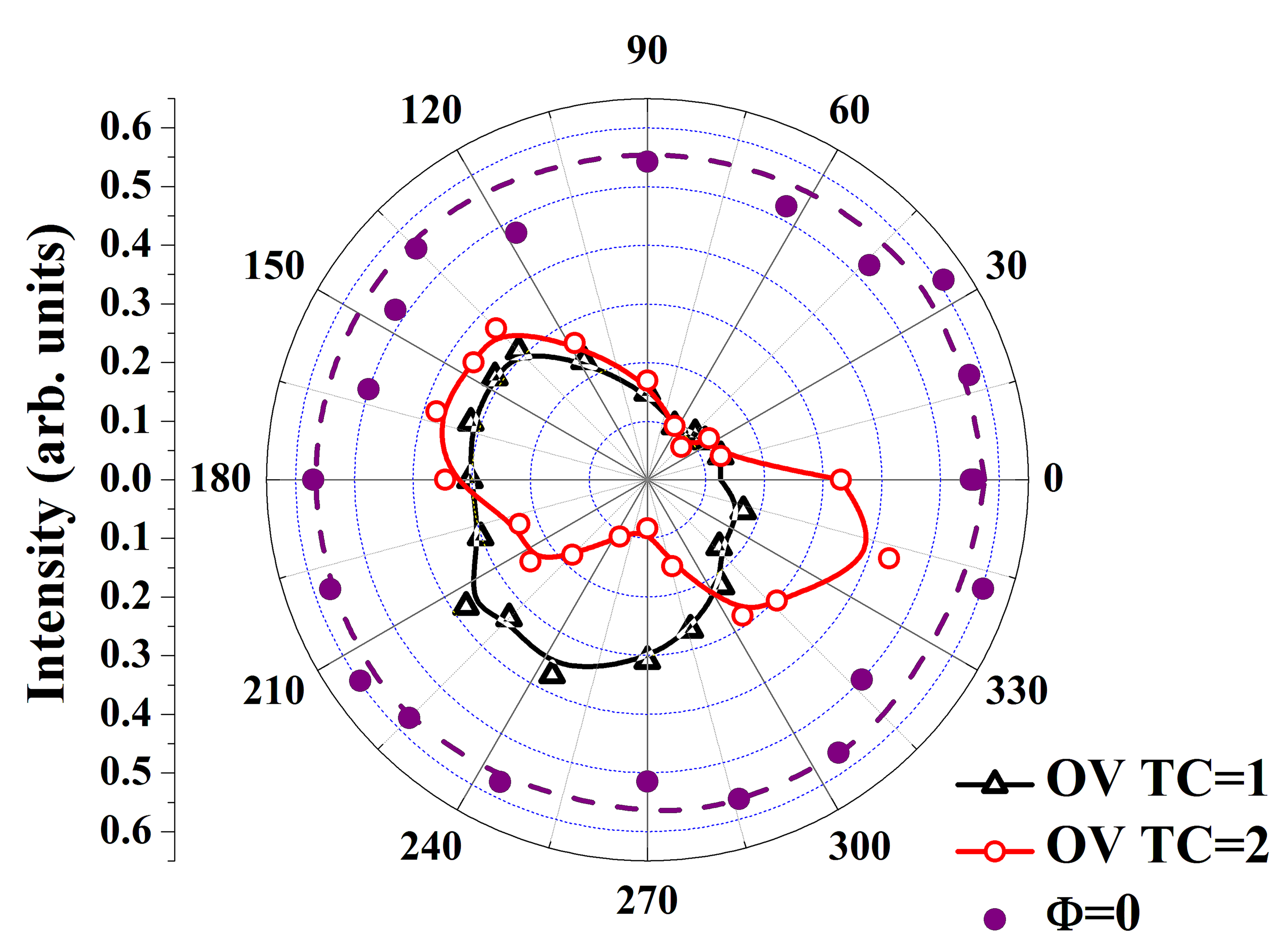
Phase distributions of singly-charged OV upper left frame) and of two-fold charged OV (upper right frame) encoded on a SLM.

Array of simultaneously reflected linearly polarized Gaussian beams (lower left and right frame) from the SLM (encoded with a singly or two-fold charged OV), as transmitted by the used analyzer (RA).









Polar plot: Same as Graph (d) above, however for phase OVs of topological charges TC=1 and TC=2 generated by a liquid crystal on silicon based spatial light modulator used as an unknown polarization influencing element.

CONCLUSION

In this study, we present a novel technique for simultaneously (single-shot) mapping of the polarization changes induced by an unknown optical element (including e.g. accurately characterizing the polarization response of spatial light modulators). This is achieved using the combination of diffractive optical generating arrays of linearly polarized Gaussian beams, analyzer and a CCD camera. As presented, the approach is applicable even for a clear determination of the polarization response of spatial light modulators.

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