Space-Variant Polarization-State Manipulation with Computer-Generated Subwavelength Gratings

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Subwavelength gratings have opened up new methods for the formation of beams with sophisticated phase and polarization distributions. Such gratings are usually used to form homogeneous space-invariant polarizers or wave plates. When the period of the grating is much smaller than the incident wavelength, only the zeroth order is a propagating order, and all the other orders are evanescent. Such gratings behave as layers of uniaxial crystal. Therefore by using space-variant (transversely inhomogeneous) subwavelength gratings we can generate complex vectorial wave fronts with a different polarization state at each location. Such nonuniformly polarized beams are useful for polarization coding of data, neural networks, optical encryption, tight focusing, imaging polarimetry, material processing, atom trapping, and optical tweezers.

We recently developed a novel method for designing and realizing nonuniformly polarized beams using computer-generated space-variant subwavelength gratings.[1] Our design is based on determination of the local period and direction of the grating at each point, formation of space-varying polarizers or wave plates that convert uniformly polarized light into any desired space-variant polarization. Our gratings are continuous, thereby guaranteeing the continuity of the electromagnetic field. We realized the gratings for CO_2 laser radiation at a wavelength of 10.6 μm on GaAs and ZnSe substrates utilizing advanced photolithographic and etching techniques.

Figure 1(a) shows the intricate geometry of a subwavelength metal stripe grating designed to convert circularly polarized light into radial polarization. The experimental measurement of the local azimuthal angle at each point is shown in Fig. 1(b). The manipulation resulted in high-polarization purity in the desired direction of greater than 98%.[2] We also realized a beam with azimuthal polarization and a beam whose local azimuthal angle varied linearly in the x direction, demonstrating the flexibility of our approach.[3]

Our space-variant polarization state manipulations are accompanied by a space-variant phase modification resulting from the Pancharatna–Berry phase. This phase modification results solely from the polarization manipulation[4] and is purely geometric in nature. We found that this phase could be understood by projecting the resulting polarization onto a Poincare sphere. Figures 1(c)–1(e) show the instantaneous real part of the electric field in two beams with radial polarization. Figure 1(c) illustrates the beam that results directly from the grating of Fig. 1(a), whereas Fig. 1(e) shows the beam when the Pancharatnam–Berry phase has been canceled with an appropriate spiral phase element [an element with phase function exp (iθ)]. The symmetry of the beams differs, and therefore they exhibit different propagation. Figure 1(d) shows the far-field image of the beam in Fig. 1(c). The image shows a clear bright center, as compared with Fig. 1(f), which shows the far-field image of Fig. 1(e). In this case a dark center is clearly observable. We therefore conclude that the Pancharatnam–Berry phase plays an important role in the propagation of space-variant polarized beams.

Recently we demonstrated a unique method for rapid polarization measurement based on a subwavelength space-variant polarization grating.[5] The Stokes parameters of the incident beam are determined by spatial Fourier analysis, and the method enables real time polarization measurement.

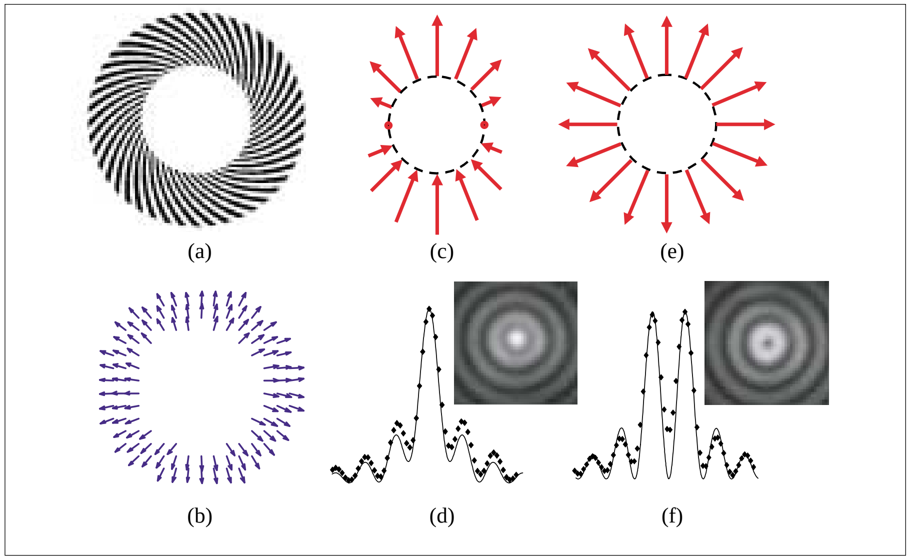

Figure 1. (a) Magnified geometry of the grating for converting circularly polarized light into radial polarization and (b) experimental measurement of the local azimuthal angle. (c) Illustration of the instantaneous real part of the electric field vectors including the Pancharatnam–Berry phase, as well as (d) the far-field image and cross section (both measured and calculated) of this beam. (e) Illustration of the instantaneous real part of the electric field vector for radial polarization in which the Pancharatnam–Berry phase has been canceled, as well as (f) its far-field image.

References:

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