Metasurface-based high-order vector beam generation for polarization rotation measurement

Fuyong Yue* (1), Vincenzo Aglieri(1), (2), (3), Riccardo Piccoli(1), Roberto Macaluso(3), Andrea Toma(2), Roberto Morandotti(1), (4) and Luca Razzari(1)
(1) Institut national de la recherche scientifique, Centre Énergie Matériaux Télécommunications, 1650 Boulevard Lionel-Boulet, Varennes, Quebec J3X 1S2, Canada, e-mail: fuyong.yue@emt.inrs.ca; vincenzo.aglieri@emt.inrs.ca; riccardo.piccoli@emt.inrs.ca; morandotti@emt.inrs.ca; razzari@emt.inrs.ca
(2) Istituto Italiano di Tecnologia, Via Morego 30, 16163 Genova, Italy; andrea.toma@iit.it
(3) Università degli Studi di Palermo, Viale delle Scienze, 90128, Palermo, Italy; roberto macaluso@unipa.it
(4) Institute of Fundamental and Frontier Sciences, University of Electronic Science and Technology of China, Chengdu 610054, Sichuan, China; morandotti@emt.inrs.ca

Metasurfaces, i.e., arrays of nanoantennas with size smaller than the free-space wavelength of light, have emerged as a promising paradigm to fully control light's properties on a subwavelength scale. Especially, "geometric metasurfaces" [1] consisting of nanoantennas with identical geometry, provide the opportunity to manipulate the phase and polarization of light by engineering the space-dependent orientation angles of the nanoantennas. Here, we present the generation of a high-order vector beam via a plasmonic metasurface and demonstrate its application in the characterization of polarization rotation with high dynamic range and precision (down to ~10^{-2} degrees) [2].

The nanoantennas constituting the plasmonic metasurface (Fig. 1 (a)) were arranged with an azimuthally-dependent rotation angle $\alpha(\varphi) = (\ell\varphi)/2$ ($\ell = 30$) to add a $e^{\pm i\ell\varphi}$ phase term to the wavefront of an incident right- or left-handed circularly polarized beam through its conversion into a beam of opposite handedness. For the case of linear polarization, corresponding to the superposition of two circularly polarized beams with opposite handedness, the metasurface generated a vector beam with azimuthally dependent polarization distribution (Fig. 1 (b)) and a donut-shaped intensity profile (top image of Fig. 1 (c)). The intensity profile resulted in $2\ell = 60$ lobes after propagating through a linear polarizer (bottom image of Fig. 1 (c)). As the input linear polarization of the incident beam was rotated, a relative phase difference arose between the two circular polarization components, which in turn caused the rotation of the overall multi-lobed intensity profile. Therefore, by tracking the displacement of only two of these lobes on a camera, the rotation of the input polarization state could be retrieved with high precision. As a proof-of-principle, we demonstrated the capability of sensing rotation angles in the range of -45° to 45° with a sensitivity down to ~10^{-2} degrees (Fig. 1 (d)).

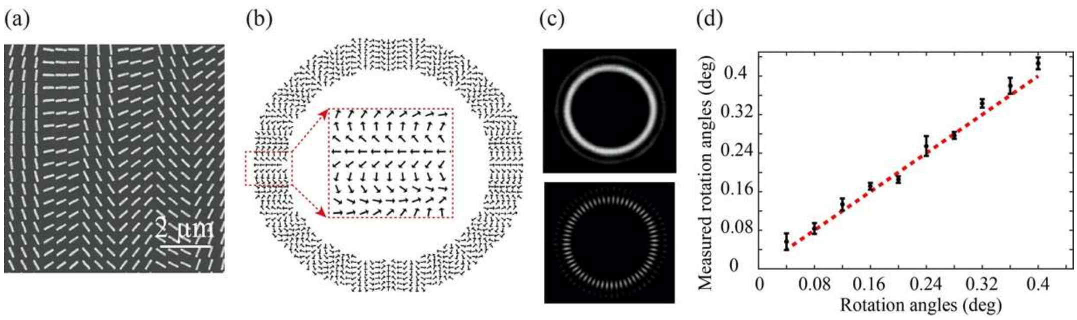

Figure 1. (a) SEM image of the fabricated metasurface. (b) Polarization profile of the generated high-order vector beam. (c) Recorded intensity profiles of the vector beam before (top) and after (bottom) passing through a linear polarizer, respectively. (d) Measured polarization rotation angles, ranging from 0.04° to 0.44° with steps of 0.04°.

References

[1] L. Huang, X. Chen, H. Mühlenbernd, G. Li, B. Bai, Q. Tan, G. Jin, T. Zentgraf, and S. Zhang, "Dispersionless Phase Discontinuities for Controlling Light Propagation," *Nano Lett.*, vol. 12, no. 11, pp. 5750-5755, Oct. 2011.

[2] F. Yue, V. Aglieri, R. Piccoli, R. Macaluso, A. Toma, R. Morandotti, and L. Razzari, "Highly Sensitive Polarization Rotation Measurement through a High-Order Vector Beam Generated by a Metasurface," *Adv. Mater. Technol.*, vol. 5, no. 5, Jan. 2020, Art. no. 1901008.