Broadband Optical Chirality Using Ultrathin Metasurface

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Abstract: A metasurface layer of λ/50 thickness is developed to produce the optical rotation effect of chiral media through the use of a plasmonic nano-antenna array that generates a phase-shift between helical components of incident light.
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1. Introduction

Optical chiral media are typically used to rotate the plane of a linearly polarized light about the direction of propagation by introducing a phase shift between right hand (RHC) and left hand circularly (LHC) polarized components of light. The angle of optical rotation is equal to half the value of the introduced phase shift between these helical components.

This work aims to achieve the chirality effect through plasmonic metasurfaces. In the following section, a metasurface structure is implemented to split incident linearly polarized light into its helical components and introduce an optical path delay between them. This results in the chirality effect of optical rotation. The theory behind the structure and experimental results are demonstrated below.

2. Theory and Implementation

Metasurfaces control light beams by engineering the wavefront of light across the surface. They have been used for light bending [1,2] and other applications. Wave-front control is also applied in [3] for deflection of circularly polarized light, through the rotation of an anisotropic nano-antenna structure across the metasurface. An interesting property of the structure in [3] is that it causes light to deflect to the angle of opposite sign if polarization of incident light is switched from RHC to LHC. Therefore, if this structure is used for a linearly polarized incident light, its two helical components will be deflected in different directions as shown in Fig 1(a). In order to retrieve the linear polarization in the deflected beam, a metasurface structure is proposed in which each unit consists of two sub-units of anisotropic nano-antennas rotating in opposite directions as shown in Fig 1(b). This will cause the RCP obtained from one sub-unit to be directed parallel to the LCP obtained from other sub-unit, and the two rays effectively retrieve a linear polarization. The output ray is deflected at an angle $\theta = \sin^{-1}(\lambda / p)$ where p is the repetition period of the array structure. An offset distance $d = p / 4$ is introduced between the two sub-units to cause a π/2 phase delay between RCP & LCP, leading to 45^o rotation of the output beam. The technique of the offset distance between two sub-units to create a phase shift has been used in [4] for another application. If the offset distance is changed, the angle of optical rotation is changed accordingly.

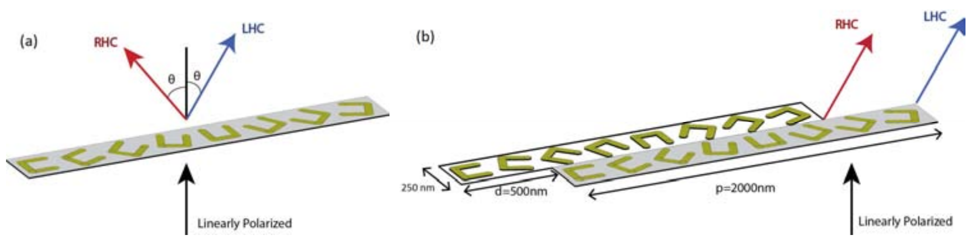

Fig. 1. (a) An array of rotated anisotropic c-antenna structure causing splitting of helical components in different directions. (b) Unit cell of the metasurface structure.

The structure used is an array of c-shaped plasmonic gold nano-antennas of three sides. Each side is 150 nm long, 40 nm wide, and 30 nm thick. The array is fabricated on top of an ITO-coated glass substrate using electron-beam lithography. Fig 2(a) is a scanning electron microscope (SEM) image of the sample. Fig 2(b) shows the measured output power versus deflection angle θ for various wavelengths in the near infrared (NIR) range. Fig 2(c) shows the normalized polar plot of the output beam, for each wavelength, for both horizontally and vertically polarized incident light, measured at the angle of maximum output power for each. These polar plots clarify that the chiral effect of optical rotation is achieved.

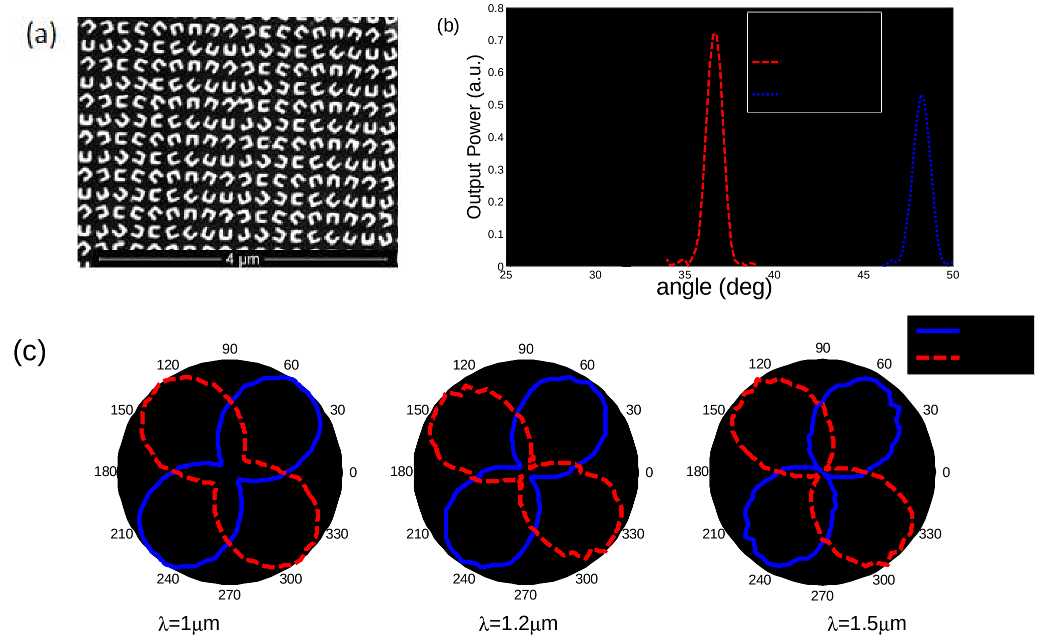

Fig. 2. (a) SEM image of fabricated metasurface. (b) Output power Vs deflection angle for different wavelengths in NIR. (c) Polar plot of normalized power at different wavelengths for horizontal input (solid blue) and vertical input (dashed red)

3. Conclusion

In this work, the chirality effect is being introduced in metasurfaces. A 30 nm (λ/50) thick nano-antenna array structure was designed and fabricated which produces the optical effect of a chiral medium over a broadband NIR wavelength range (1– 1.5μm) causing an optical rotation by a specific angle. This effect is observed for any orientation of incident linearly polarized light. Future work could include varying the angle of optical rotation by involving micro-electro-mechanical system (MEMS) techniques to control the offset distance d between the two subunits in Fig 1(b).

4. Acknowledgement

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5. References

[1] N. Yu, P. Genevet, M. A. Kats, F. Aieta, J. P. Tetienne, F. Capasso, and Z. Gaburro, "Light propagation with phase discontinuities: generalized laws of reflection and refraction," Science **334**, 333–337 (2011).

[2] X. Ni, N. K. Emani, A. V. Kildishev, A. Boltasseva, and V. M. Shalaev, "Broadband light bending with plasmonic nanoantennas," Science **335**,427–427 (2012).

[3] M. Kang,T. Feng, H. T. Wang, and J. Li, "Wave front engineering from an array of thin aperture antennas," Optics Express **20**, 15882-15890 (2012).

[4] N. Yu, F. Aieta, P. Genevet, M. A. Kats, Z. Gaburro, and F. Capasso, "A broadband, background-free quarter-wave plate based on plasmonic metasurfaces," Nano Letters **12**, 6328–6333 (2012).