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Characterization of output circular polarization degree in low-cost asymmetric metasurfaces

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Abstract. Addition of asymmetry in plasmonic nanostructures can lead to chiro-optical phenomena, usually monitored as different absorption of left and right polarization, i.e. circular dichroism. Moreover, interesting features arise when the nanostructure changes the polarization state of the input beam. In this work, we perform extrinsic chirality characterization in a widely tuneable near-infrared range, by monitoring both polarization of the input and of the transmitted beam. We characterize low-cost metasurfaces based on polystyrene nanospheres asymmetrically covered by Ag, by exciting them at different angle of incidence with left, right and linear polarization. We then resolve the circular polarization degree of the transmitted beam, demonstrating resonance-governed circular polarization degree in the output, showing the interplay of both intrinsic and extrinsic chirality.

1 Introduction

Metasurfaces with asymmetric features can present chiro-optical behaviour with consequences in both near- and far-field. Nowadays, symmetry of metasurfaces can be easily broken even with low-cost, self-assembling methods, e.g. by tilting the deposition of the plasmonic layer [1-3]. We previously proposed metasurfaces based on polystyrene nanospheres and covered by metal for various chiro-optical effects governed by extrinsic chirality. Namely, we measured different absorption [4], extinction [5] and diffraction [6] of impinging circular polarizations of opposite handedness. In these works, we excited the nanostructures with left or right circular polarizations (LCP and RCP, respectively), and monitored the total intensity of the transmitted or absorbed light. We used conventional (transmission) methods [5], as well as highly sensitive photothermal effects [4,6]. Another interesting degree of freedom is the control of the polarization state in the output light, after the beam interacts with the metasurface.

In this work, we present experimental approach where we study wavelength, spin, and angle-of-incidence dependent circular polarization degree in the transmitted field from asymmetric metasurfaces. We use a low-cost nanosphere lithography to fabricate dielectric metasurface based on self-assembled polystyrene nanospheres, and then asymmetrically cover them with 55 nm of Ag. Additionally, we introduce the in-plane tilt, which has been shown to give intrinsic planar chirality [7]. We investigate the influence of the incident polarization on the circular polarization degree map in the output. In particular, when we shine the metasurface with linear polarization, left and right circularly polarized output exhibit interesting, resonant features with the influence of both intrinsic and extrinsic chirality. Moreover, to characterize the circular polarization conversion, we repeat this mapping with LCP or RCP input. Previous works give us the confidence of numerical model which we use to gain insight into near-field confinement and behaviour of the nanoshell and nanohole arrays at the nanoscale. The implementation of this model will be a subject of future work.

2 Experimental set-up

The experimental set-up scheme is shown in Fig. 1. We use a near-infrared laser (Chameleon Ultra II by Coherent Inc.) to excite the nanostructures with a broad range of the incident field wavelengths, from 700 nm to 1000 nm. This wave impinges on a linear polarizer (LP) and a rotating quarter wave plate (QWP), which define the polarization state of the incident beam. In this work, we first investigate the excitation by linear polarization, and then LCP and RCP excitation. We can further rotate the sample in the xz plane to investigate chiro-optical behavior at oblique incidence (from -45° to +45°). After the interaction with the sample, the zeroth order transmission passes through another set of QWP followed by LP, in order to resolve the circular polarization degree in the output. Finally, the intensity is monitored by a Si photodiode (PD).

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In the inset of Fig. 1 we show a Scanning Electron Microscope (SEM) image of the investigated sample. In the experimental set-up, the y-axis of the experimental coordinate system as aligned with the direction of the tilted deposition projection on the xy-plane. All the measurements are done at room temperature and the transmission data are normalized with respect to the transmission of light without the sample.

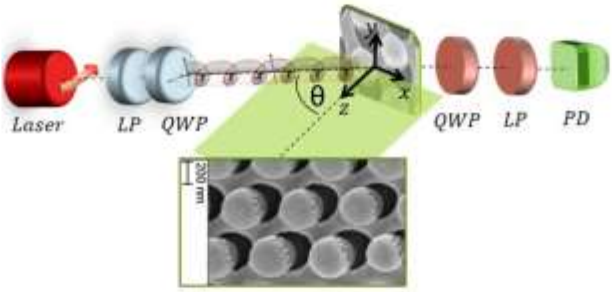

Fig. 1 Set-up of the chiro-optical characterization with both input and output beams resolved in polarization. Inset : SEM image of the investigated sample.

3 Results

In Fig. 2, we show the wavelength-incidence angle maps when the metasurface is excited with linearly polarized light; we plot the transmission maps at different output QWP angles, where T_0, T_{LCP} and T_{RCP} denote transmission into linear, LCP and RCP polarized light. Being in a highly reflecting region, transmission intensity is low, but the resonant features which appear could be due to lattice resonances [5]. Moreover, the sample positioned in this way shows intrinsic chiral features, with different LCP/RCP ratio at normal incidence across broad wavelength range. Next, by changing the incident polarization to LCP or RCP, we were able to almost completely extinct one polarization state in the output. Numerical analysis is next needed for detailed analysis of the nanoshell asymmetry on the polarization state in the transmitted beam.

4 Conclusions

In conclusion, we performed thorough chiro-optical characterization of low-cost asymmetric metasurfaces by measuring wavelength, incidence angle and polarization-dependent transmission, and resolving the circular polarization degree of the output beam. Many degrees of freedom of such characterization could pave the way to new interesting resonant chiro-optical effects in this low-cost nanoscale geometry.

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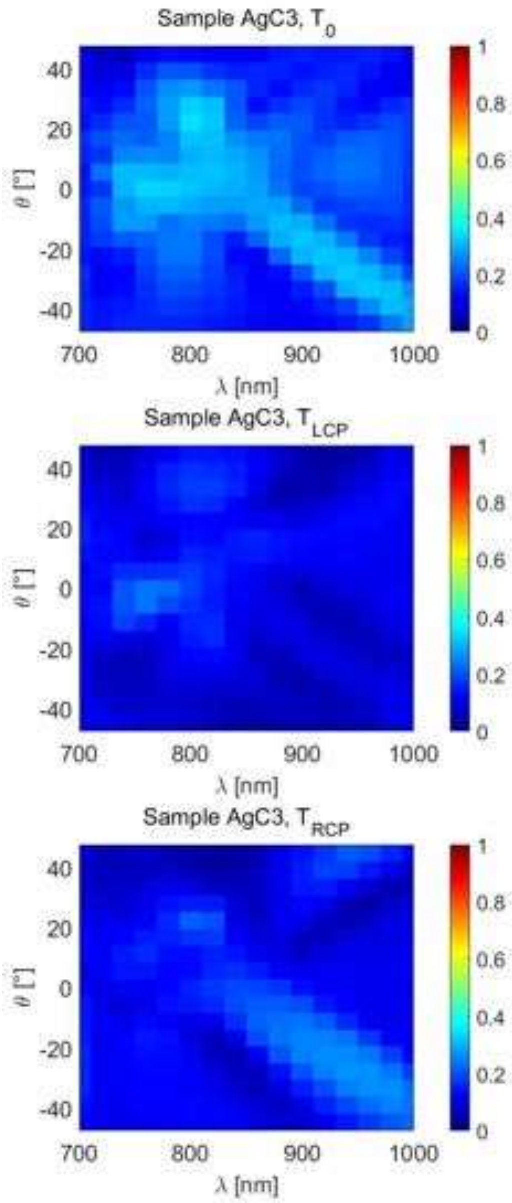

Fig. 2 Circular polarization resolved response of the sample when it is excited with linearly polarized laser beam, widely tunable in wavelength and angle of incidence. T_0, T_{LCP}, and T_{RCP} denote the output QWP angle of 0°, -45° and +45°, respectively.