Coherent Spectroscopy of Optical Activity

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Control of light with light is at the heart of optical information processing. Here we demonstrate for the first time, optical control of light polarization without nonlinearity by exploiting the coherent interaction of light waves on optically active metasurfaces. This polarization effect is ultrafast, compatible with arbitrarily low intensities and offers new opportunities within long-established polarization spectroscopy and sensing techniques.

Coherent electromagnetic waves form standing wave patterns of nodes and anti-nodes. A functional medium of sub-wavelength thickness, e.g. a metasurface, may be selectively positioned within such a standing wave leading at nodes to suppression, and at anti-nodes to enhancement of light matter interactions and expression of the metasurface's effect on the waves. Recently, it was shown that this allows for all-optical switching via enhancement and suppression of absorption in absorptive thin films [1] and that it enables novel electric/magnetic excitation-selective spectroscopic techniques [2]. Here we study polarization effects for a freestanding metasurface consisting of a gold film of 60 nm thickness perforated with an array of asymmetric split ring apertures with period of 310 nm. The metasurface exhibits optical activity (circular birefringence and circular dichroism) at oblique incidence, when the experimental arrangement becomes different from its mirror image; this is known as extrinsic 3D chirality [3-4].

In our experiments, coherent 640 nm "signal" and "control" beams are incident on opposite sides of the metasurface and co-polarized perpendicular to the metamaterial's symmetry axis (as illustrated in Fig. 1a), such that any polarization change in reflection or transmission must be due to optical activity. We observe that the polarization of the output signal beam depends strongly on the relative phase of the incident beams. Both the polarization azimuth rotation (circular birefringence) and ellipticity angle (circular dichroism) of the beam oscillate as a function of this phase with period of 360° - see Fig. 1(b-c). Notably, input phase control allows both the complete suppression and sign reversal of polarization azimuth rotation.

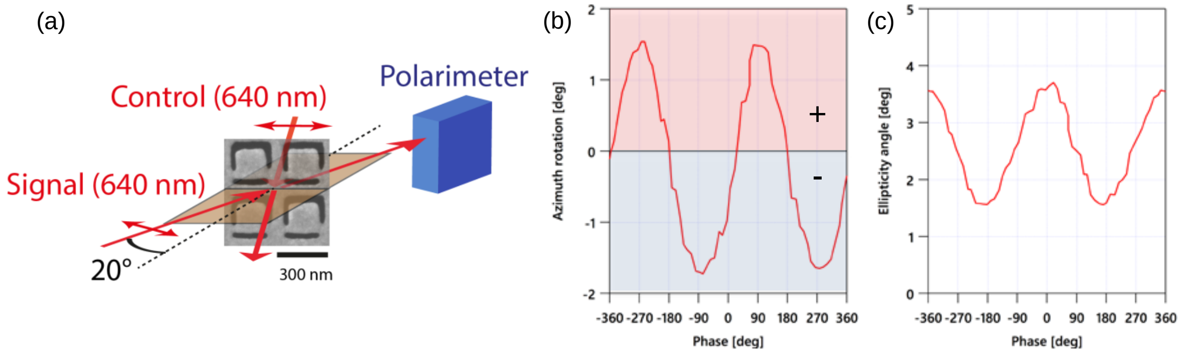

Fig. 1: Coherent control of polarization of light with light. (a) Extrinsically 3D-chiral experimental arrangement consisting of metasurface and incident beams that cannot be superimposed with their mirror image. Optical activity in terms of (b) polarization azimuth rotation and (c) ellipticity angle of the output signal beam as a function of the mutual phase of the input beams.

In summary, we demonstrate for the first time that the expression of optical activity of metasurfaces can be controlled by the interaction of two coherent light waves on the metasurface. This allows both ultrafast polarization modulation and highly sensitive detection of optical activity using lock-in techniques.

References

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