Light-matter Interactions in a Polarization Standing Wave

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We report on the application of polarization standing waves (PSW) to the coherent control of light-matter interactions in planar photonic nanostructures. Such waves, formed by counter-propagating (linear or circular) orthogonally polarized beams can uniquely detect polarization conversion, planar chirality and related asymmetric transmission effects.

It has recently been shown that phenomena including absorption, refraction, birefringence and optical activity in ultrathin (sub-wavelength) films and photonic metamaterials can be coherently controlled with high contrast and THz bandwidth at energy levels down to the single-photon regime by precisely positioning the media within an intensity standing wave formed by counter-propagating co-polarized light beams [1]. We now demonstrate a new dimension of coherent control based on *intensity-invariant polarization standing waves*.

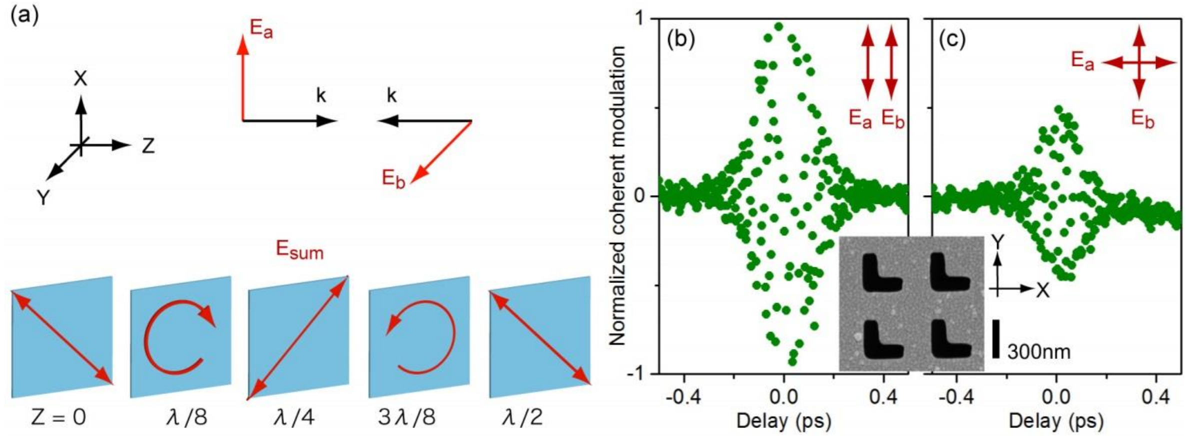

Fig. 1 (a) Polarization standing wave formed by counter-propagating orthogonally linear polarized beams. (b-c) Normalized coherent absorption modulation as a function of counter-propagating pulse delay for a gold *L*-slot array metamaterial [a section of which is shown in the inset electron microscope image] in intensity (b) and polarization (c) standing waves.

Figure 1a illustrates the PSW generated by a pair of linearly polarized travelling waves. Its local polarization is a periodic function of position along the light propagation direction, oscillating through linear, left- and right-circular states (the linear states being at ±45° to the input states), while the intensity is invariant. The electromagnetic response of any ultrathin film can be modulated by changing the local field intensity, as between the nodes and antinodes of an intensity standing wave [1], but only media able to convert light between orthogonal polarizations will be sensitive to the local variations within a PSW.

We interrogate a variety of planar photonic metamaterials (manufactured by focused ion beam milling typically in 50 nm, ~λ/16, thin Au films) under coherent intensity and polarization standing wave illumination conditions using counter-propagating 130 fs pulses at a wavelength λ=800 nm. For example, Figs. 1b and 1c show measured coherent absorption modulation for a sample comprising a square array of *L*-shaped slots in respectively standing waves of intensity (incident beams co-polarized in the *y*-direction) and polarization (crossed incident polarizations along *x* and *y*). In the former case (Fig. 1b) absorption oscillates between coherently-enhanced and suppressed levels (at intensity anti-nodes and nodes respectively) according to the time delay, i.e. mutual phase of the pulses at the sample position, within an envelope defined by their temporal overlap [c.f. Ref 2]. In a PSW a similar pattern of delay-dependent coherent absorption modulation is maintained for this sample (Fig. 1c) via the (intensity invariant) oscillation of the local polarization state.

This mode of polarization coherent control brings an additional dimension to coherent-illumination spectroscopy alongside selectivity based on the magnetic/electric nature of incident fields [3] and may be harnessed for all-optical data processing in coherent communication networks where data is encoded in the amplitude, phase and polarization of signals.

References

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