Image Processing Using Coherent Absorption

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Abstract: We demonstrate logical operations with two images using coherent interaction of optical beams on thin films and metasurfaces. The new coherent image processing is illustrated by mode selection and deletion for spatial mode multiplexing.

Metasurfaces and other thin films provide access to all sorts of unusual and novel static optical properties. Recently, it has been demonstrated that the interaction of two coherent waves of arbitrarily low power on a functional material of sub-wavelength thickness can provide ultrafast control over the material excitation and thus over the expression of the film's functionality [1]. While temporal control over the expression of material properties is interesting, a whole new level of functionality would be achieved by simultaneous control over material properties in time and space.
Here we demonstrate for the first time simultaneous spatial and temporal coherent control of light with light on thin films. Coherent material excitation is achieved by splitting a 785 nm laser beam into coherent control and signal beams illuminating front and back of chromium and metamaterial thin films (Fig. 1(a)). Spatial control is realized by imaging masks onto the absorptive thin film, while phase modulation of the control beam provides temporal control.
Below, we illustrate coherent image processing using mode separation for space-division multiplexing as an example. Space-division multiplexing increases the information carrying capacity of optical fibres by using higher order modes as additional information channels. Such a multimode optical signal beam is simulated using a mask with 5 holes (Fig. 1(b)). A control signal for deleting or enhancing the fundamental mode is simulated using a mask with a single hole (Fig. 1(c)). Depending on the relative phase of the control and signal beams, simultaneous illumination of the thin film with both control and signal beams leads to four-fold coherent enhancement of the fundamental mode (mode selection, Fig. 1(d)) or its deletion (mode removal, Fig. 1(e)) from the signal beam.
Beyond image processing and mode selection, this concept allows the spatially resolved ultra-fast modulation of the expression of all sorts of optical properties a metasurface or thin film may exhibit as well as massively parallel all-optical polarization and intensity modulation.

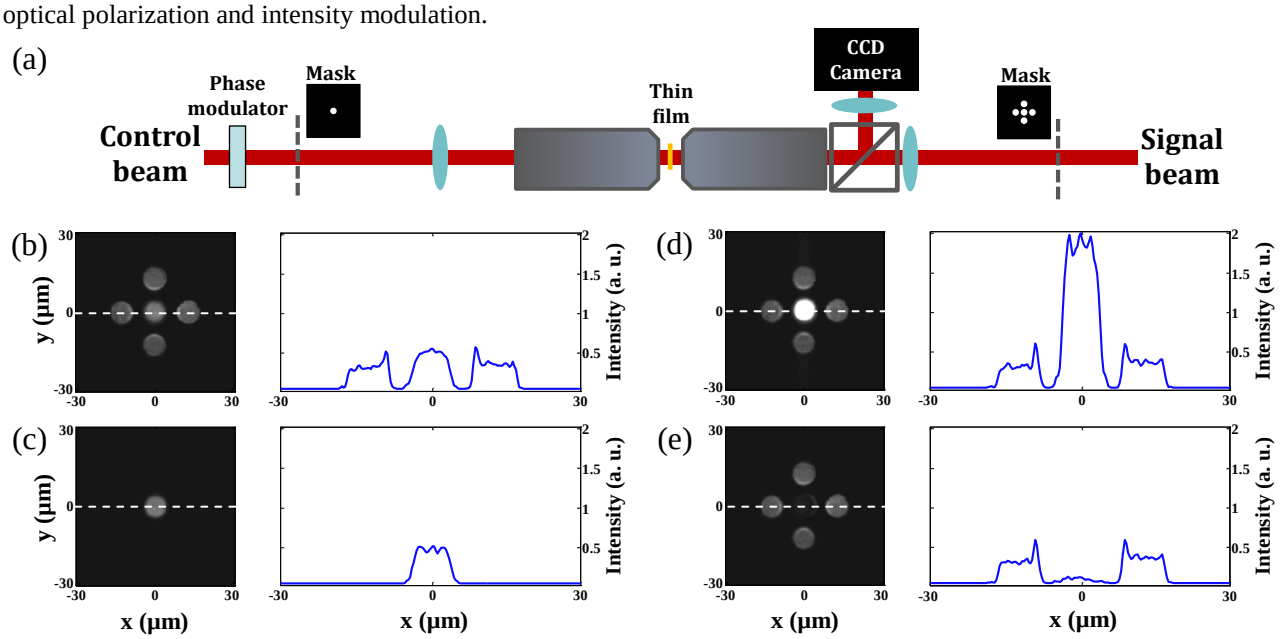

Fig. 1: (a) Schematic of the experimental setup where spatial modulation of the coherent control and signal beams is provided by masks and temporal modulation is provided by a phase modulator. Images and cross sections of a chromium thin film illuminated by (b) signal beam only, (c) control beam only, (d) signal and control beams with coherent enhancement (mode selection), (e) signal and control beams with coherent cancellation (mode deletion).

[1] J. Zhang, K. F. MacDonald, and N. I. Zheludev, "Controlling light-with-light without nonlinearity," Light: Science and Applications 1, e18 (2012).