Phase-change spatial light modulators with amplitude-only control

J. Shields[1*], C. R. de Galarreta[1],[2], H. Penketh[1], J. Bertolotti[1] and C. D. Wright[1]

1. College of Engineering, Mathematics and Physical Sciences, University of Exeter, U.K.
2. Instituto de Optica (IO-CSIC), Madrid, Spain
*corresponding author: j.shields@exeter.ac.uk

ABSTRACT

Current spatial light modulator (SLM) technology allows for the spatial control of the phase of light, but amplitude control is more limited. The realisation of a SLM that can efficiently modulate amplitude without altering the phase of the light would enable the development of devices that can perform full wavefront control. Here we discuss the design, fabrication and characterisation of such modulators using a phase-change material layer as the active component. These devices allow for the modulation of the amplitude of a reflected wave with near-zero change to its phase., providing a potential route to ultra-fast, solid-state wavefront control.

Key words: amplitude-only modulation, thin-film, phase-change materials, wavefront control.

1. INTRODUCTION

The full wavefront control of light would provide an indispensable tool for applications across a wide range of fields such as lithography, optical computation and imaging through scattering media for biological diagnostics. Good spatial phase control of light is currently available using liquid-crystal-on-silicon SLM's, but there is a lack of technology for controlling the spatial amplitude of light. Digital micromirror devices can control amplitude in binary on/off states, but these are relatively slow (milliseconds to hundreds of microseconds range, typically), are relatively bulky and are required to be permanently powered. To allow for full wavefront control a device is required that can perform amplitude-only modulation in a fast and reliable manner.

Here we present the design, fabrication and characterisation of a phase-change material (PCM) based thin-film SLM that has a large modulation in amplitude of the reflected wave whilst having a near-zero modulation of the optical phase of the reflected light. Figure 1 (a) shows a schematic of the device's operation. The amplitude modulation is enabled using the high electro-optical contrast of GeTe between its amorphous and crystalline states in the visible [1]. The device has a simple 3-layer structure: Ti (70 nm), GeTe, (30 nm), ITO (5nm) and, for characterisation puposes, spatially varying crystalline patterns are written to the devices using a laser writer.

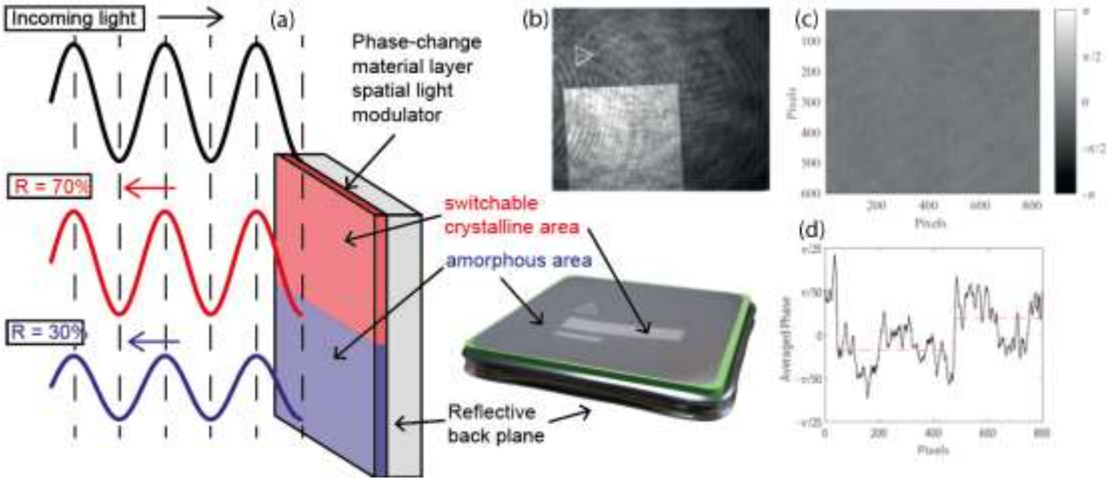

Figure 1. (a) Schematic of device operation and 3D render showing an example of spatial crystalline patterning. (b) Measured reflection intensity and (c) phase distribution across a sample with amorphous and crystalline sections. (d) Averaged phase distribution across the crystalline/amorphous boundary, showing less than $\pi/50$ phase difference between crystalline and amorphous sections.

2. RESULTS & DISCUSSION

The devices were simulated and optimised using both COMSOL and the transfer matrix method. Devices where fabricated using magnetron sputtering. To inspect the operation of the devices an off-axis digital holography system [2] was designed and implemented in order to measure the spatial phase variation of the reflected light from amorphous and crystalline sections. Typical results can be seen in figure 1 (b), (c) and (d), which record information about the amplitude and the phase of the reflected light from amorphous and crystalline sections. The devices were found to perform as intended showing a high reflectance contrast ($\Delta R(\%) = 220\%$) between amorphous and crystalline sections and a small phase modulation ($\Delta\phi < \pi/50$ rad) at the wavelength of interest (632.8 nm).

4. CONCLUSIONS

These results show a viable route to amplitude-only spatial light modulation. Switching of the PCM layer is potentially possible using in-situ electrically controllable embedded microheaters (as can be seen in [3]). Here, the use of a PCM as the active layer allows us to exploit the properties of PCM’s such as their non-volatile nature, fast switching capability and robustness against cycling. This could enable a potential avenue to the development of an ultra-fast, lower power solid-state SLM.

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