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Remote Thermal Sources for Switching Phase-Change Material-Based Metasurfaces

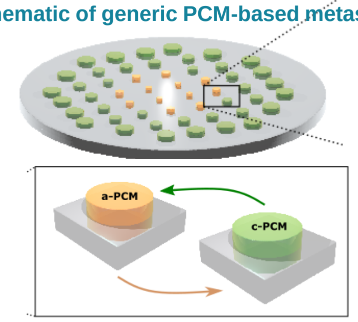
G. Braid[1], C. Ruiz de Galarreta[1,2], A. Comley[3], J. Bertolotti[1], C. D. Wright[1]
[1]CMRI, University of Exeter, UK; [2]IO-CSIC, Madrid, Spain; [3]AWE Aldermaston, Reading UK

Introduction

Optical metasurfaces are 2D arrays of resonant subwavelength nanostructures that can change the phase, amplitude, or polarisation of incident light, enabling precise control of the optical wavefront [1]. A wider range of potential applications is achieved if the metasurface optical response can be actively controlled [1,2]. We do this by incorporating a chalcogenide PCM.

The thermal impulse to switch a PCM metasurface is conventionally supplied by direct laser heating or embedded microheaters. However, these may not be feasible with all metasurfaces. We therefore here explore the switching of PCM-based metasurfaces by using remote thermal sources.

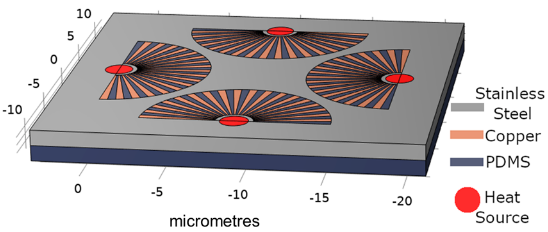
Schematic of generic PCM-based metasurface



Design

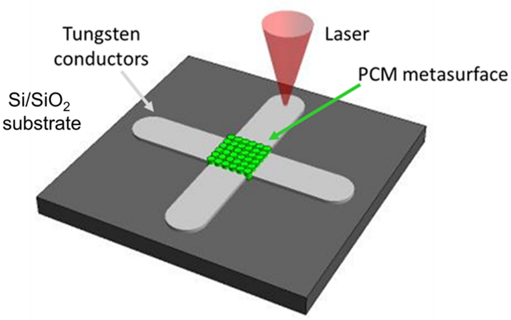
Han et al. [3] demonstrated thermal heat guide structures that can provide near-uniform heating over extended regions by conduction from a remote source. Although Han's designs were on the macroscale (sizes in the cm range), we show that the approach is readily shrunk down to the microscale.

Han's design for uniform heating via remote sources



However, similar control of heat can be achieved using simpler structures more suited to PCM metasurfaces, such as the design below. Here, heat sources are linked by straight tungsten arms to a central metasurface. Upon laser excitation of one or more of these arms, the metasurface can be heated and the PCM layers switched.

Simplified remote heating design for use with PCM metasurfaces



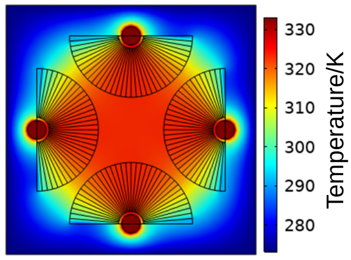
Results

We show (in simulation) that Han's structure produces a uniform temperature region on the microscale.

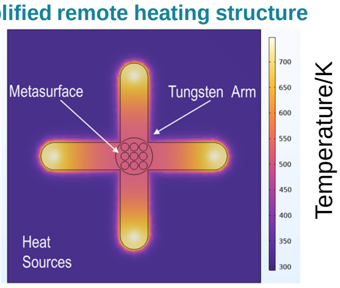
We also simulated remote switching of a $Ge_2Sb_2Se_4Te$ PCM metasurface (as in [2]) using pulsed laser excitation of each end of the four tungsten arms (400 nm laser, pulse power in tens of mW range).

Steady state thermal simulations show a near-uniform temperature distribution can be achieved over the metasurface using the simplified remote heating approach.

Simulated temperature distribution for Han's design and four remote sources

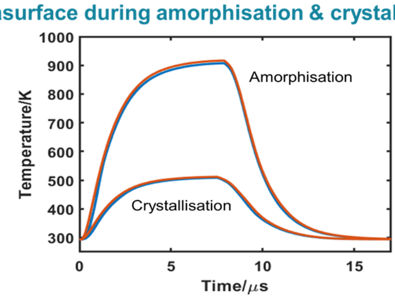


Temperature distribution in simplified remote heating structure



Dynamic thermal simulations show that the temperatures and cooling rates needed for successful crystallisation and amorphisation of the PCM layers in the metasurface can also be reached using the remote heating approach.

Max (red) and min (blue) temperatures in PCM metasurface during amorphisation & crystallisation



Conclusion

Where conventional approaches are not practicable, the switching of PCM-based metasurfaces should be possible using remote heating sources. Devices based on this concept are currently in the process of fabrication and testing.

References

[1] Ruiz de Galarreta C et al., *Journal of Optics*, 2020, **22**, 11, 114001.
[2] Braid, G. et al., *Nanomaterials*, 2022, **12**, 15, 2689.
[3] Han, T. et al., *Sci Rep*, 2015, **34**, 10242.

gb512@exeter.ac.uk
ex.ac.uk/GBraid
www.exeter.ac.uk/metamaterials

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