META 2023
Metamaterials, Photonic Crystals and Plasmonics

University of Exeter
Centre for Metamaterial Research and Innovation

Switching of Phase-Change Optical Metasurfaces via Remote Thermal Sources

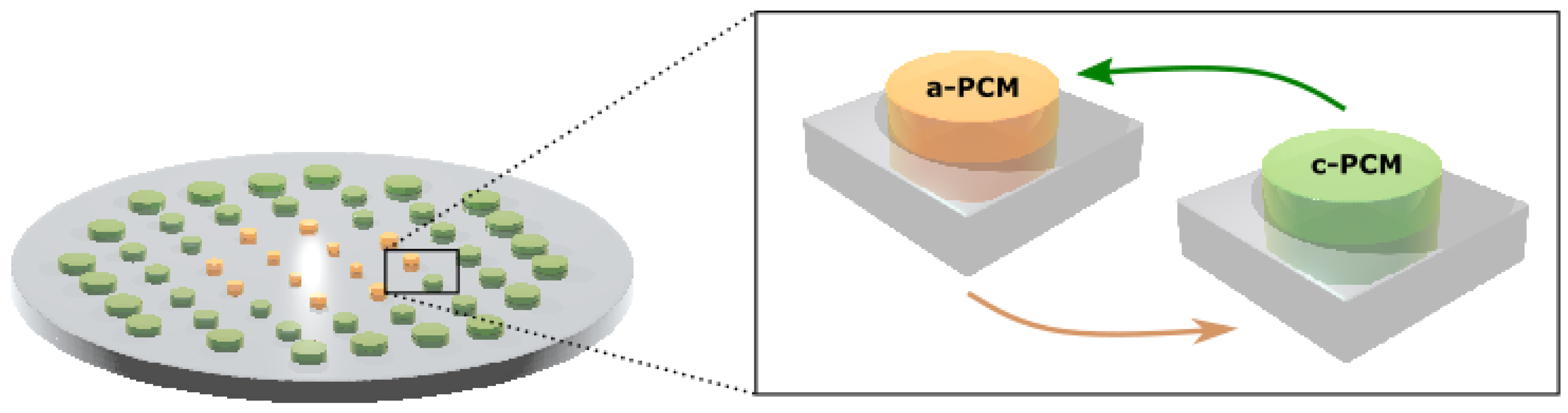
G. Braid[1], C. Ruíz de Galarreta[1,2], A. Comley[3], J. Bertolotti[1], C. D. Wright[1]

[1]Centre for Metamaterial Research and Innovation, University of Exeter, Exeter EX4 4QF, UK
[2]Instituto de Óptica, IO-CSIC, Madrid 28006, Spain
[3]AWE Aldermaston, Reading RG74PR, Berkshire, UK

Introduction

Metasurfaces offer control of optical wavefronts, with an extended range of applications possible if the metasurface can be actively controlled [1,2]. This can be achieved by incorporating chalcogenide phase-change material (PCM) in the design. PCMs have two solid phases—amorphous and crystalline—with very different optical properties. Each phase can be switched to the other by a thermal stimulus, but switching is not always feasible by conventional methods in many optical metasurfaces. So, we here explore switching via a simple and physically remote thermal source.

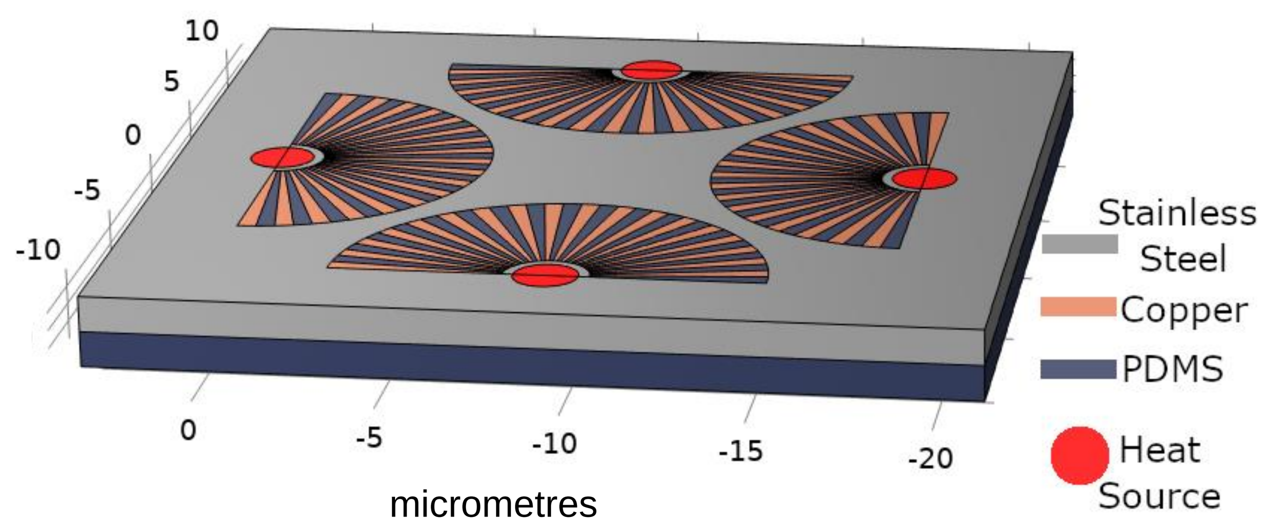
Schematic of generic phase-change based metasurface



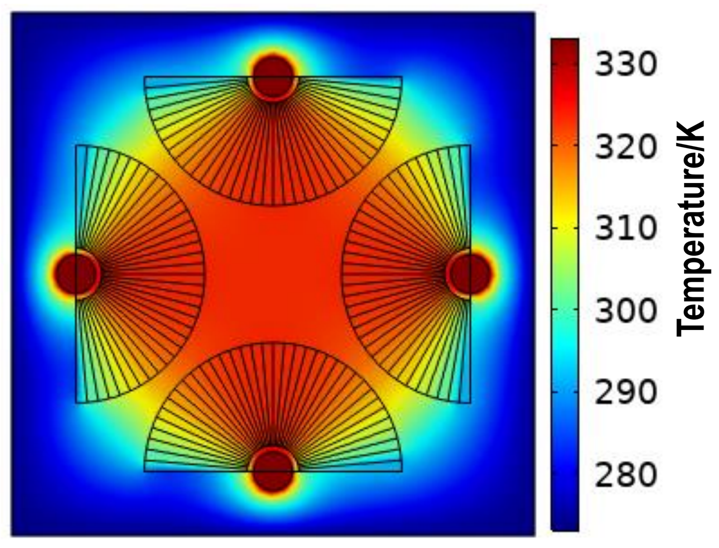
Design

Han et al. recently demonstrated thermal metamaterial structures to provide near-uniform heating over extended regions [3]. An adaption of Han's approach for use on the microscale is shown in the figure to the right.

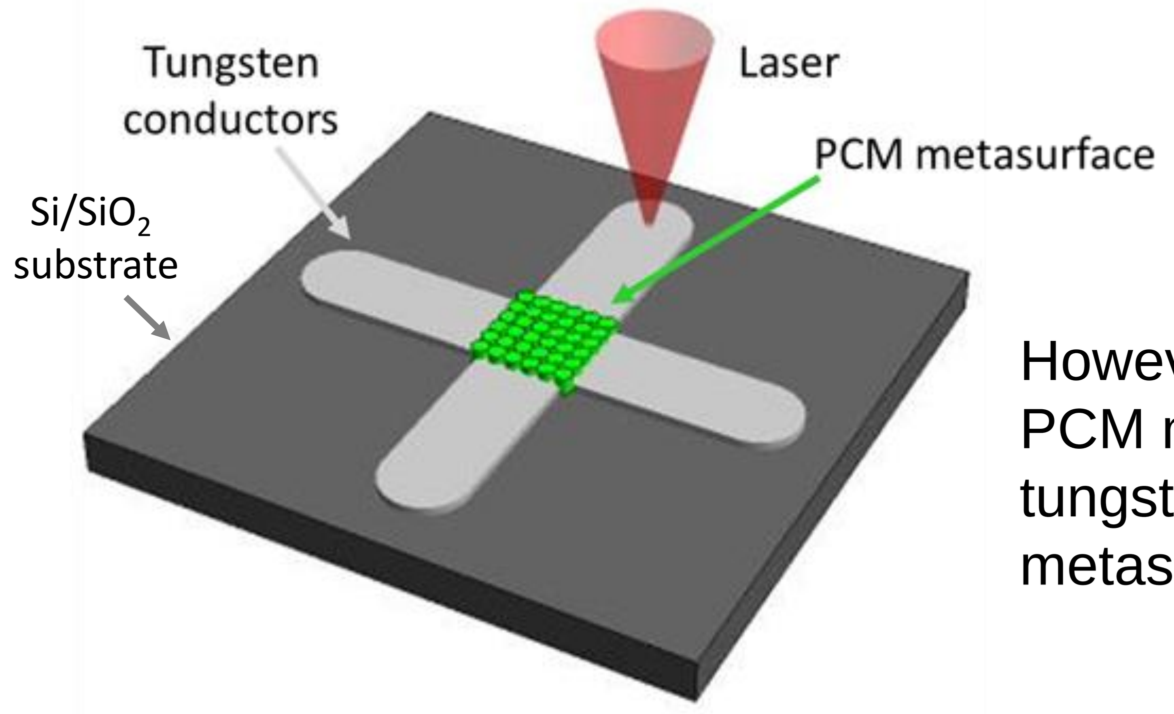
Han's thermal metamaterial design for uniform heating via remote sources



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



Simplified remote heating design for use with PCM optical metasurfaces



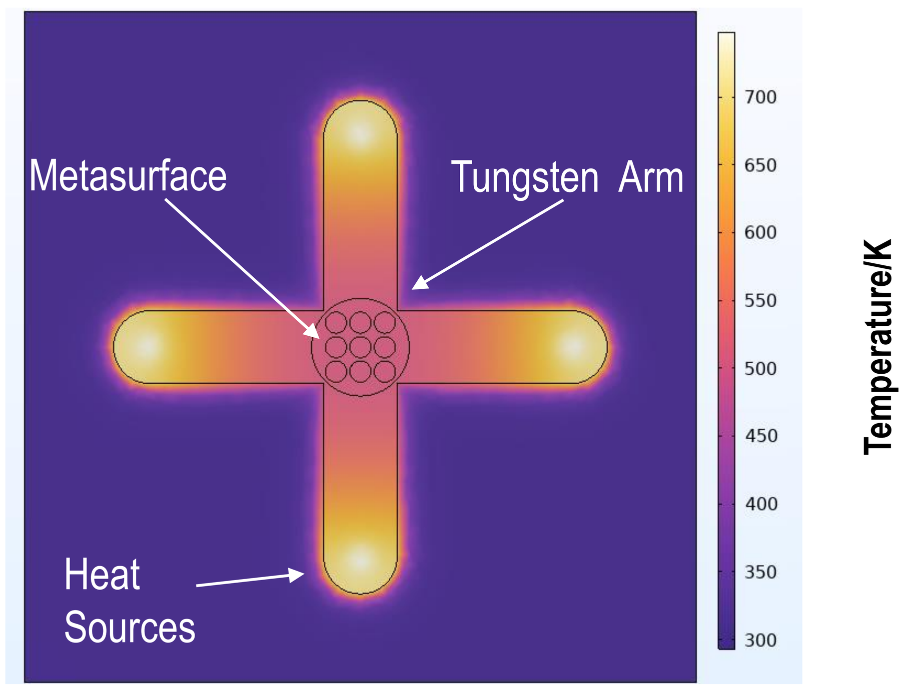
However, similar control of heat can be obtained using simpler structures more suited to use with PCM metasurfaces. Such a design is shown on the left. Here heat sources are linked by straight tungsten arms to a central metasurface. Upon laser excitation of one or more of these arms, the metasurface can be heated and the PCM layers switched.

Results

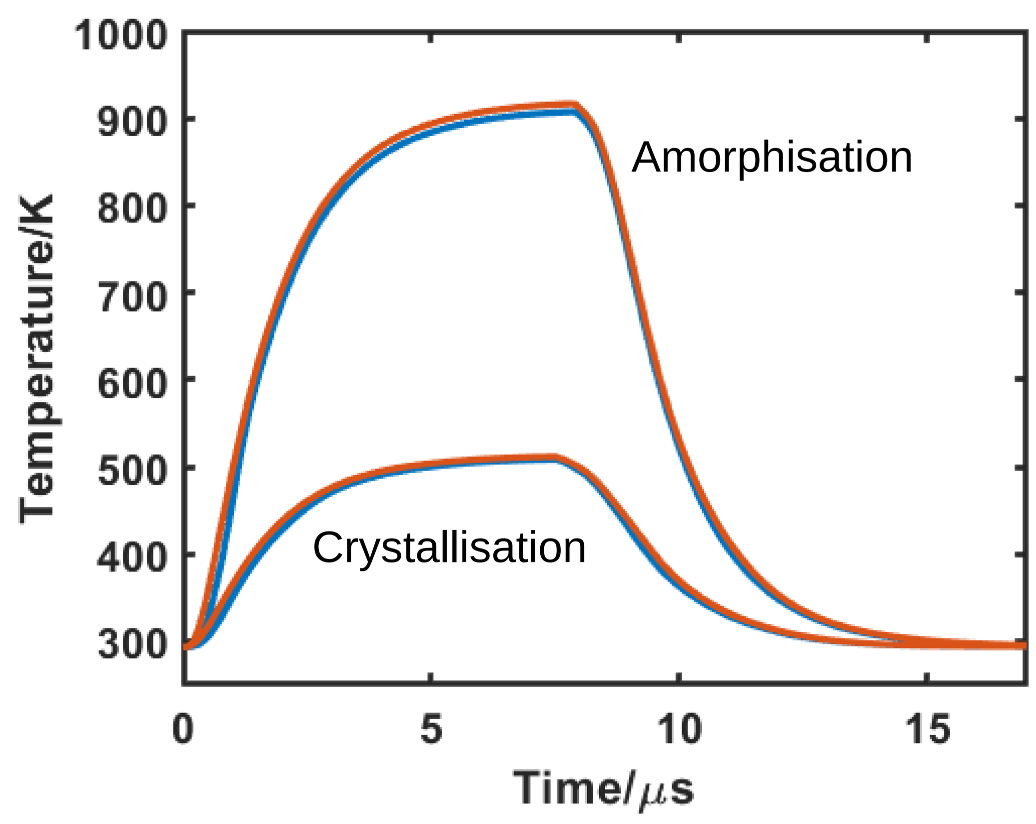
We here simulated the remote switching of a $Ge_2Sb_2Se_4Te_1$ (GSST) PCM-metasurface (of the type used in [2]) using the simple remote heating design discussed above. Excitation was via 400 nm laser pulses (powers in tens of mW range) focused onto the end of each of the tungsten conductor arms.

- Steady state thermal simulation showed that a near uniform temperature distribution over the metasurface could be achieved.
- Dynamic thermal simulations showed that suitable temperatures and cooling rates could be achieved for successful crystallisation and amorphisation of the PCM layers in the metasurface.

Temperature distribution in remote heating structure (steady-state)



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



Conclusion

In cases where direct heating of a PCM metasurface is not straightforward, we have shown that switching of the PCM layer can be achieved by heat conducted from remote thermal sources. Various PCM metasurface devices based on this remote thermal switching concept are currently in the process of fabrication and experimental characterisation.

References

[1] Ruiz de Galarreta C et al., "Tunable optical metasurfaces enabled by chalcogenide phase-change materials: from the visible to the THz", Journal of Optics, Vol. 22, No. 11, 114001, 2020.
[2] Braid, G. et al., "Optical and Thermal Design and Analysis of Phase-Change Metalenses for Active Numerical Aperture Control," Nanomaterials, Vol. 12, No. 15, 2689, 2022.
[3] Han, T. et al., "Manipulating Steady Heat Conduction by Sensu-shaped Thermal Metamaterials," Sci Rep, Vol. 34, 10242, 2015.

Acknowledgments and Contact Details

Funding is acknowledged from EPSRC (EP/L015331/1) and AWE Ltd.

UKRI Engineering and Physical Sciences Research Council

AWE

C. David Wright

Centre for Metamaterials Research and Innovation,
Exeter, EX4 4QF

UK Tel: +44 1392 723614
Email: david.wright@exeter.ac.uk
Web: https://emps.exeter.ac.uk/engineering/staff/dwright0
http://emps.exeter.ac.uk/metamaterial-cmri/