Temperature Invariant Metasurfaces

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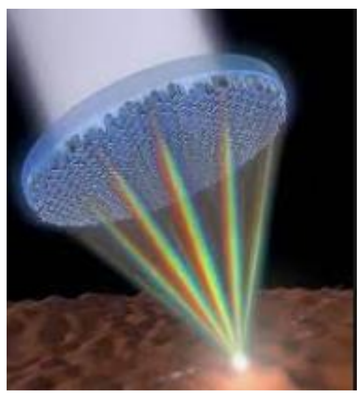
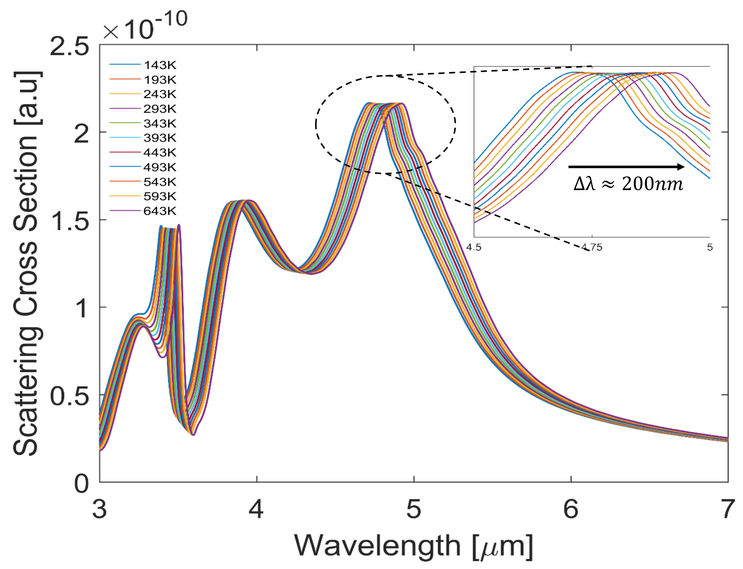
Introduction

- Metasurfaces are optical frequency analogs of phased array radar [1]. The thermo-optic (TO) effect is one of the most common mechanisms used for tunable optical devices including metasurfaces[2].
- Most applications require fixed and stable response and TO induced index shifts lead to undesirable behavior. **Applications with extreme temperature gradients include, space applications, thermophotovoltaic cells, photodetectors and spectroscopic systems.**
- Si disk metasurface array exhibits strong temperature dependency. Resonances shift by $200nm$ in the temperature range $143\ K - 643\ K$. As a result, such devices are unstable and optimized to a specific temperature



Visible metalens.
Adapted from ref [3]



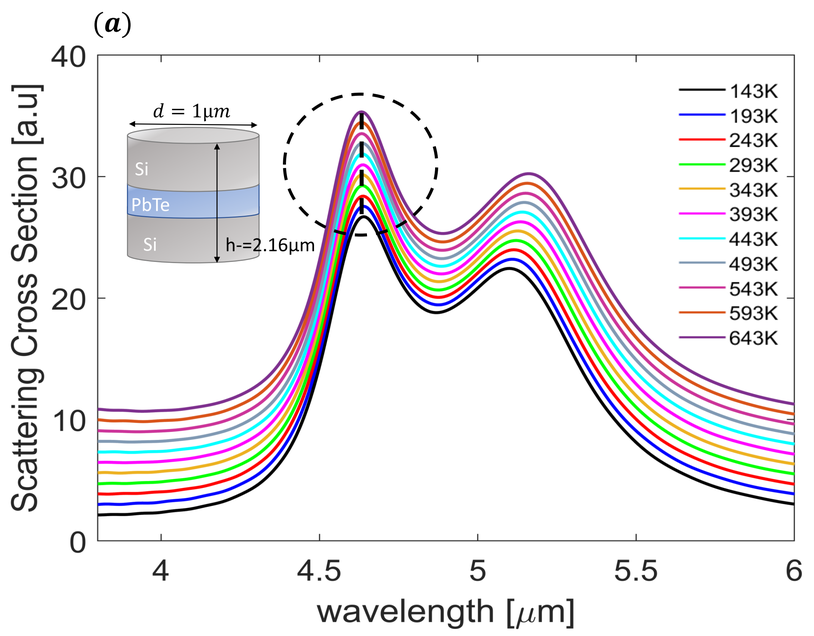
Proposed Method

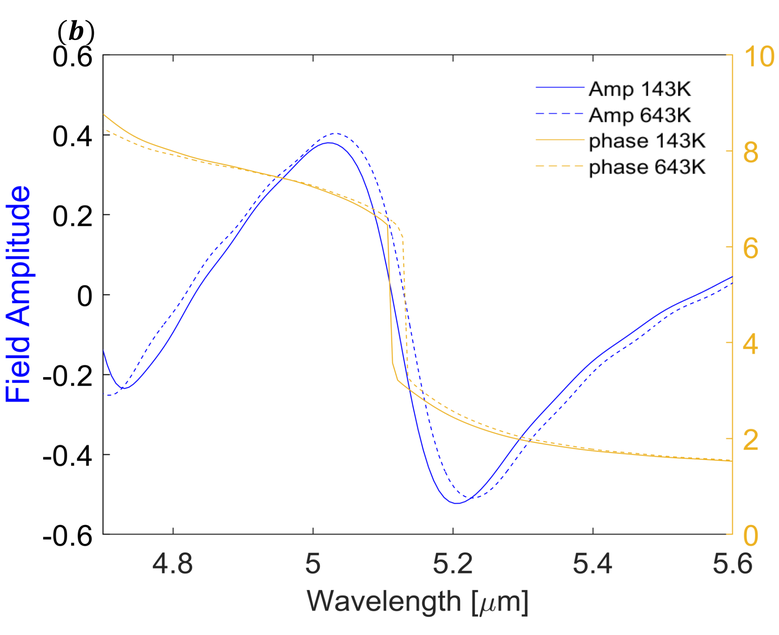
- Constructing metasurface arrays comprised of hybrid unit-cell resonators from Si and PbTe
- By coupling negative (dn/dT<0) and positive (dn/dT>0) thermo-optic materials these hybrid structures lead to $\frac{dn_{eff}}{dT} \approx 0$
- These hybrid metasurfaces are engineered to achieve temperature invariant frequency, amplitude and phase response

Step 1 – Designing the unit cell

- Disk geometry
- Alternating layers of $Si - PbTe$
- Temperature Invariant performance is achieved

(a) Scattering cross section vs wavelength demonstrating fixed resonances with temperature (b) Reflection amplitude and phase vs wavelength demonstrating temperature independent phase response

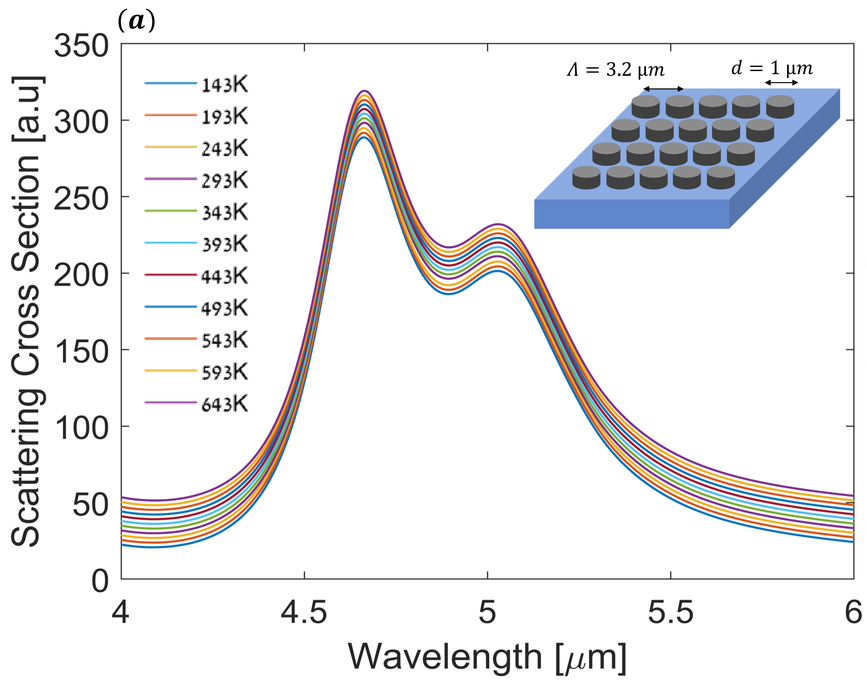


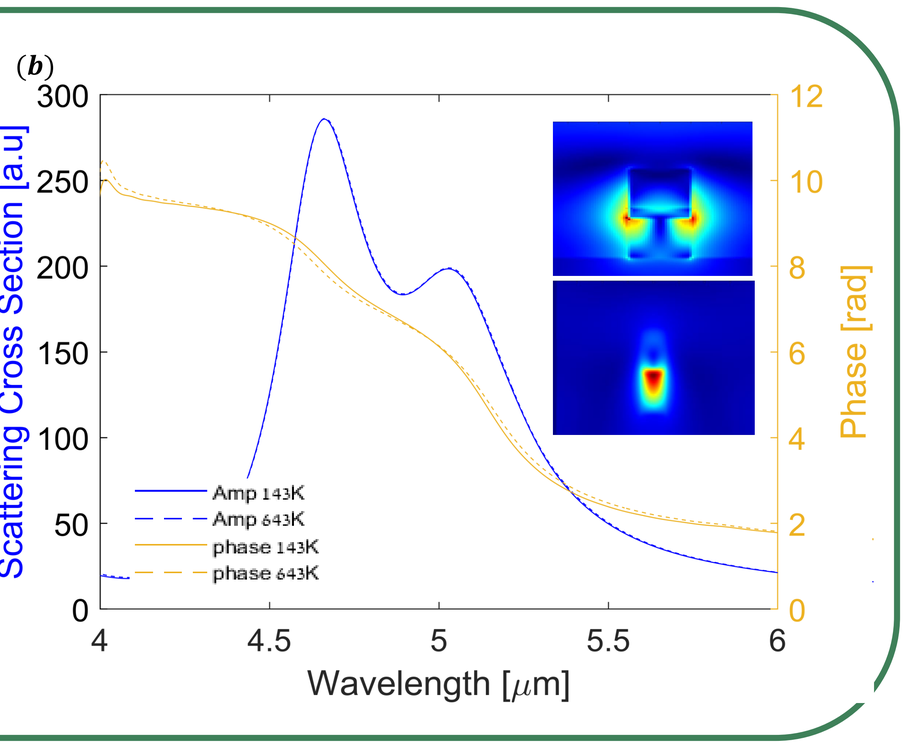


Step 2 - Expanding to a Full Metasurface

- By careful design, hybrid disk metasurfaces were simulated. **Temperature invariant response is maintained across the spectrum of both the scattering as well as phase**
- **Full phase coverage of 2π is achieved**

(a) Scattering cross section vs wavelength demonstrating pinned resonances with temperature (b) Reflection amplitude and phase vs wavelength demonstrating temperature invariant full phase coverage





References

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2. Tomer Lewi, Nikita A.Butakov, Jon A. Schuller, "Thermal tuning capabilities of semiconductor metasurface resonators". Nanophotonics 2019
3. Wei Ting Chen, Alexander Y.Zhu, Vyshakh Sanjeev, Zhujun Shi, Eric Lee, Federico Capasso, "A broadband achromatic metalens for focusing and imaging in the visible". Nature Nanotechnology 2018

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