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Perovskite Optical Metamaterials

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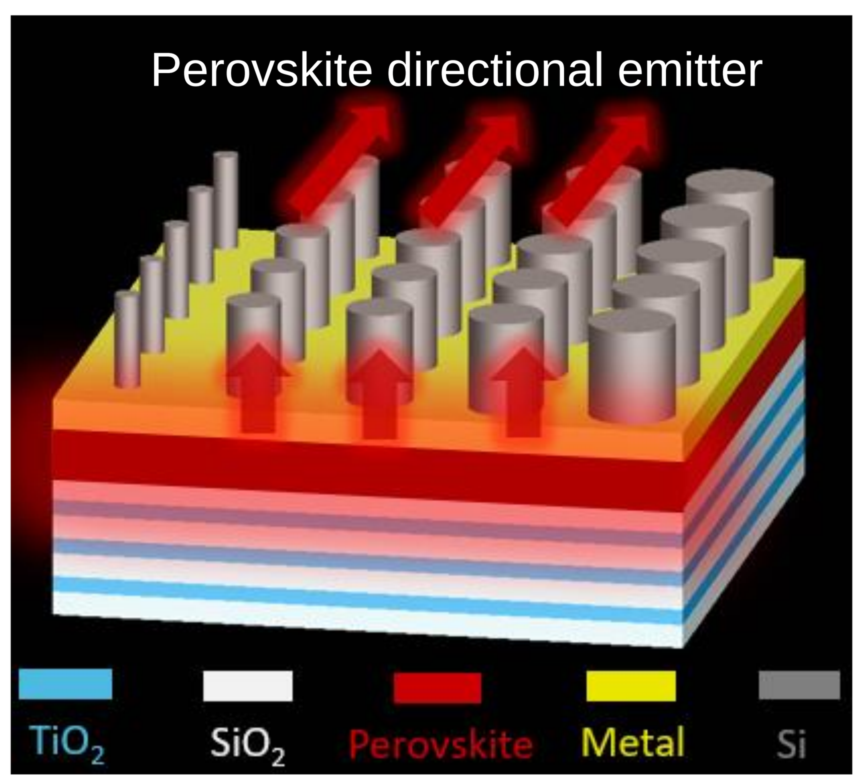
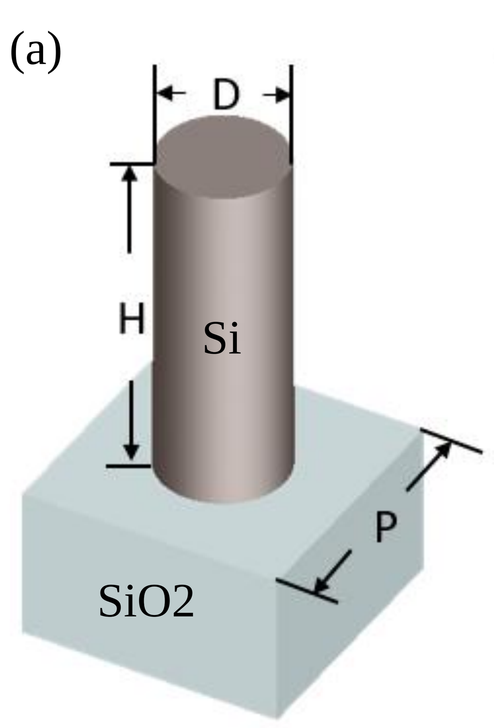
Introduction

- Perovskites are promising materials in photovoltaics, optical communications, and LiDARs.
- Controlling perovskite emission profile is critical and unsolved.
- Our perovskite optical metamaterials enable arbitrary emission phase control, facilitating directional emitter, self-focusing lens, orbital angular momentum generation, etc.

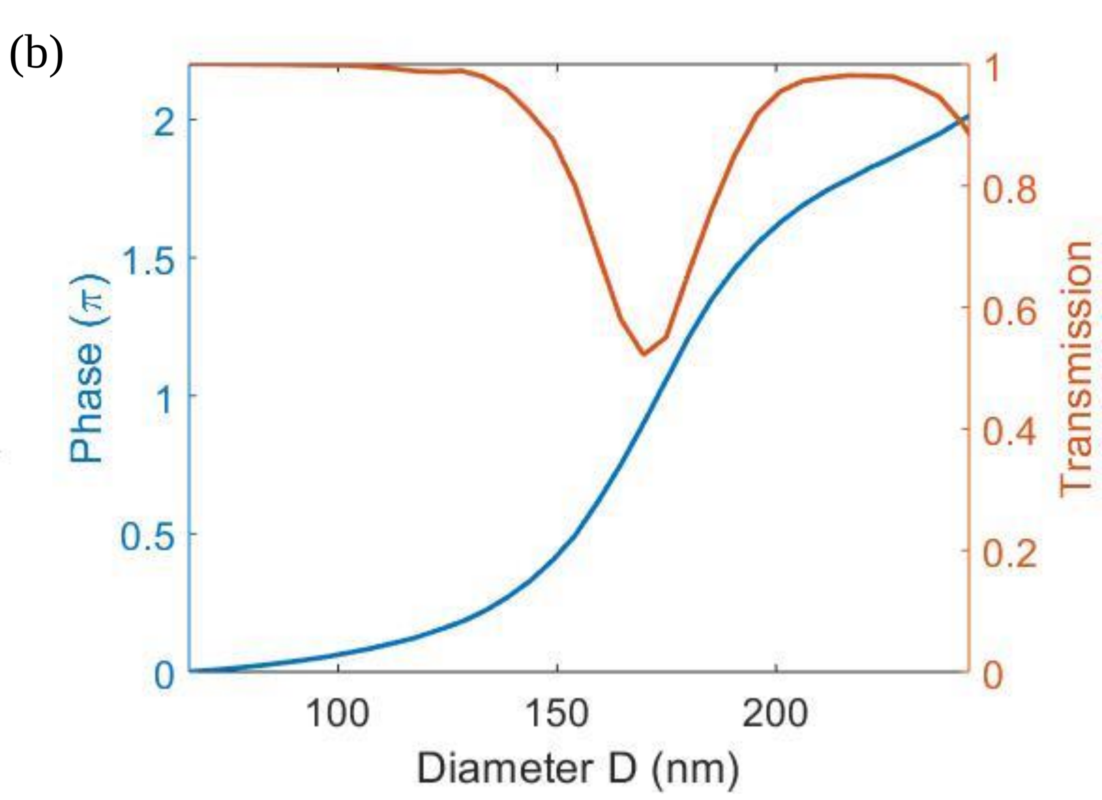
Design



- $MAPbI_3$ perovskite
- TiO2/SiO2 Bragg reflectors
- Cavity formed by Bragg reflectors and silver layer
- Non-uniform silicon metasurface on top to engineering emission phase

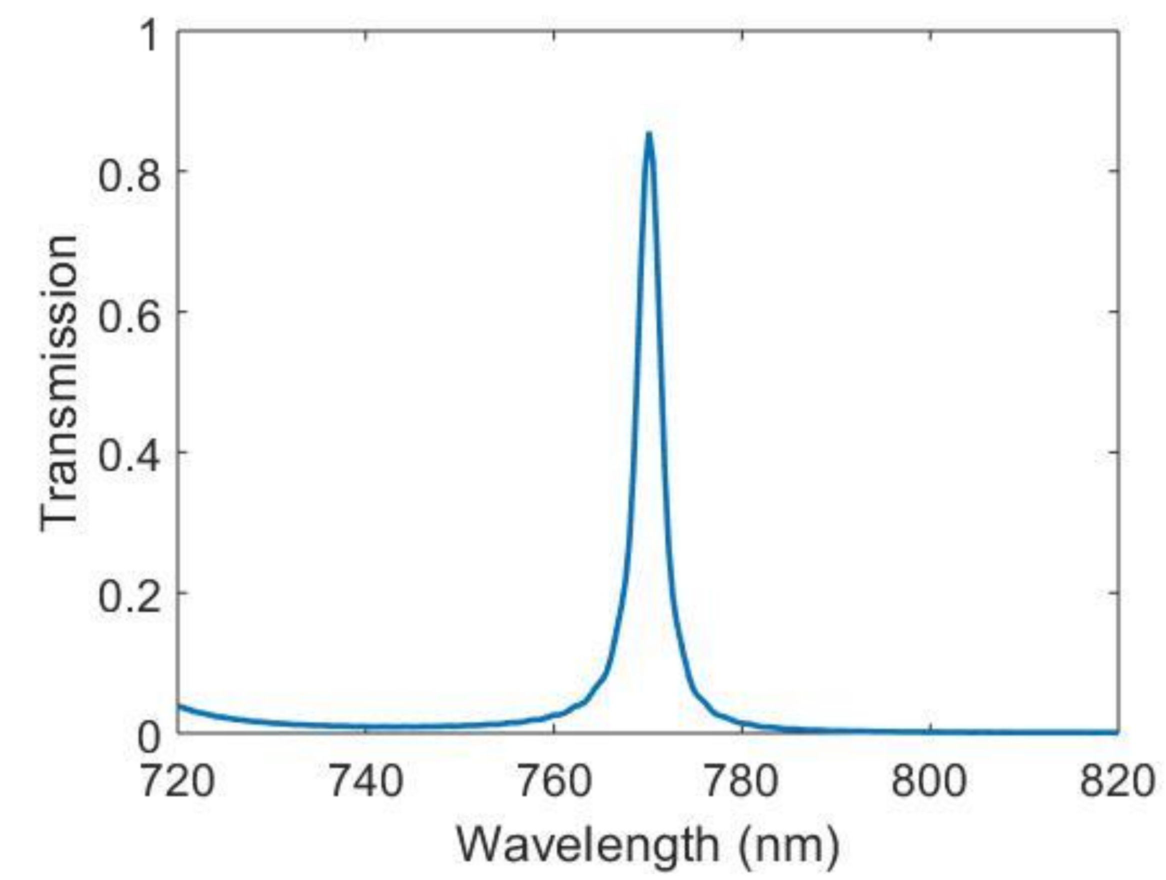


Unit cell design



Phase shift and transmission calculation

- High index (3.7) silicon non-uniform metasurface
- 2π phase shift is achieved for full phase control
- High transmission (>0.5) across diameter variation at $MAPbI_3$ emission wavelength (770 nm)

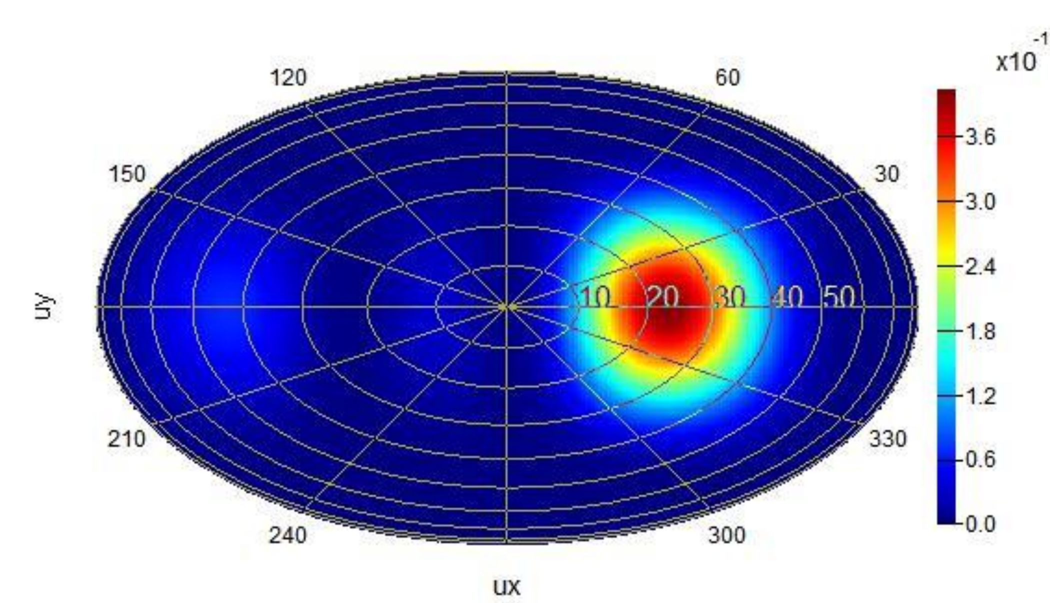


Transmission calculation of the cavity

- Cavity resonance reached at emission wavelength (770 nm)
- Amplified spontaneous emission achieved

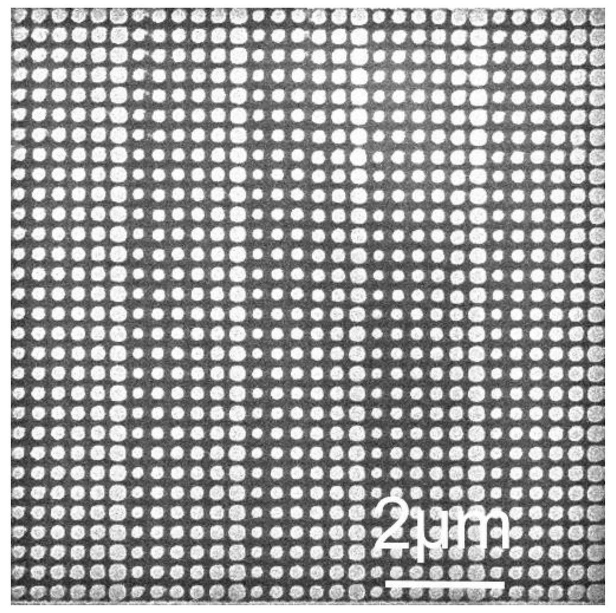
Unit cell No.	1	2	3	4	5	6
Diameter (nm)	145	162	172	185	205	244

- 6 unit cells of different diameters in one supercell
- Designed to achieve 23° directional emission at 770 nm



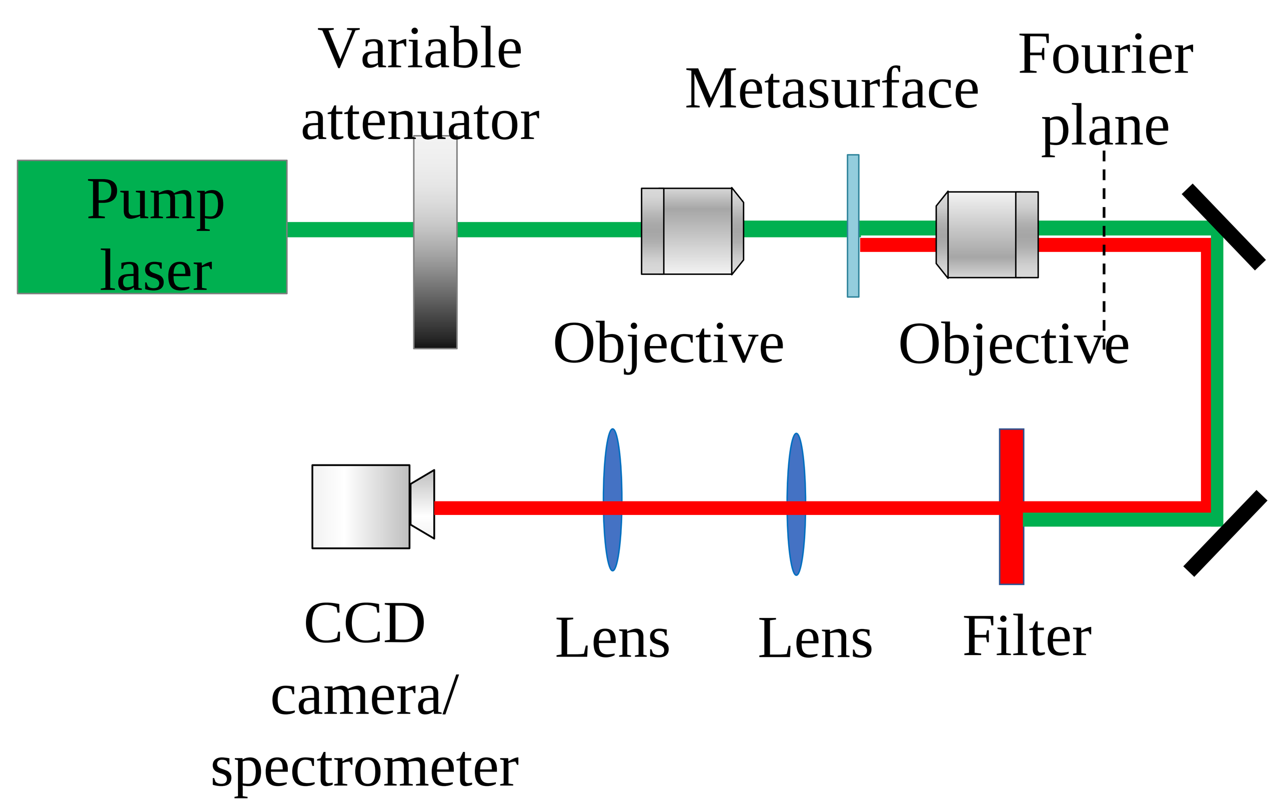
Far-field emission profile from the perovskite directional emitter (designed 23° emission)

Experiments

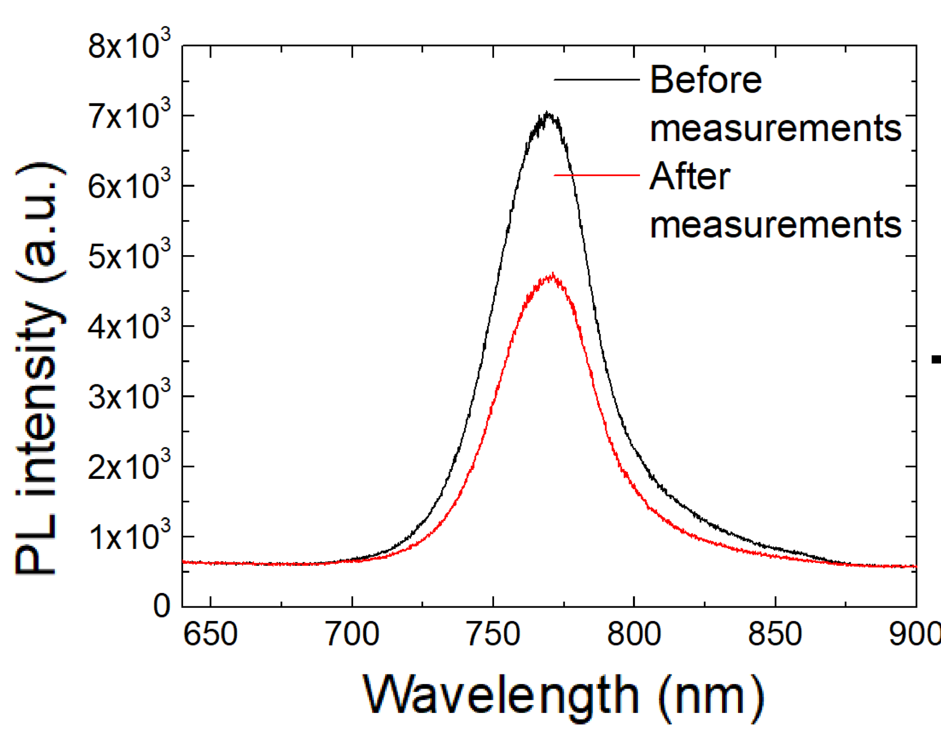


SEM image

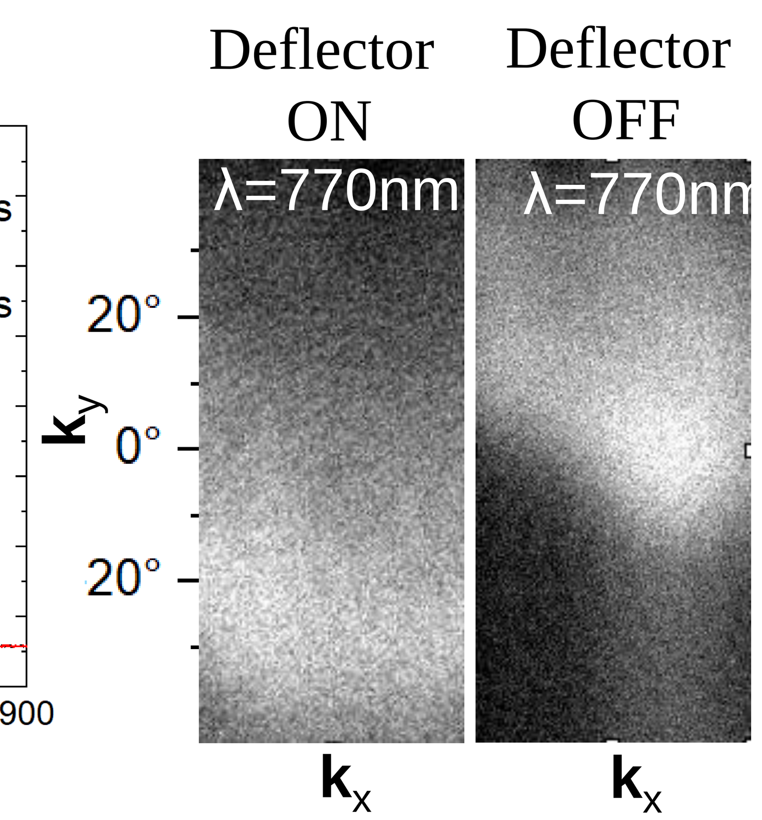
- E-beam evaporation of TiO2/SiO2
- Spin-coating of $MAPbI_3$
- E-beam evaporation of SiO2/Ag/Si
- E-beam lithography patterning of metasurface
- Etching using induced coupled plasma etching



Measurement setup



Photoluminescence spectra



Momentum space images

- Photoluminescence intensity dropped only 30% after the measurements – stable $MAPbI_3$ metamaterials.
- Directional emission from the perovskite metamaterials can be seen from momentum space images

Conclusion and outlook

- We demonstrated designed directional emission from our perovskite optical metamaterials
- The mechanism can be applied to arbitrary phase control of perovskite spontaneous emission
- More applications include self-focusing perovskite lens, perovskite orbital angular momentum generator, etc.

Acknowledgement

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