PEROVSKITE METASURFACE LIGHT-EMITTING TRANSISTOR

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Introduction

- The advancement of hybrid organic-inorganic perovskites has led to their applications in optoelectronic devices such as perovskite light-emitting transistors (PeLETs). However, it suffers from low-brightness of unpolarized electroluminescence [1].
- Metasurfaces consisting of optically resonant nanostructures allow for shrinking of light confinement down to the nanoscale and effectively manipulating light, through excitation of highly confined optically resonances. Electroluminescence at the resonances can be enhanced because the spontaneous emission is accelerated due to the Purcell effect [2].
- In this project, for the first time, we integrate a PeLET with metasurfaces patterned directly onto the perovskite film, between source and drain electrodes. The performance (e.g., intensity enhancement and polarization control) of the perovskite metasurfaces light emitting (PemLET) transistor are predicted and optimized through Lumerical FDTD simulation. We report improvement of electroluminescence by using a dipole light source when nanograting is imprinted onto transistor.

Finite-Difference Time-Domain Method

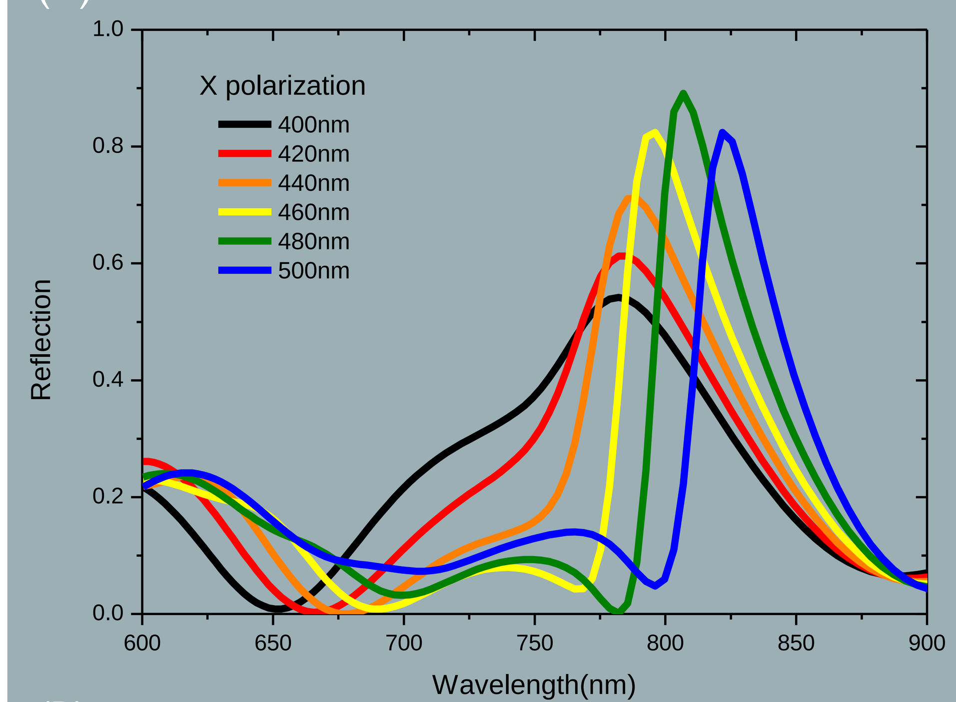
The Finite-Difference Time-Domain (FDTD) method is a method for solving Maxwell's equations in complex geometries [3].

- A direct time and space solution.
- Obtaining the frequency solution by exploiting Fourier transforms
- Calculating the complex Poynting vector, the transmission and the reflection of light.

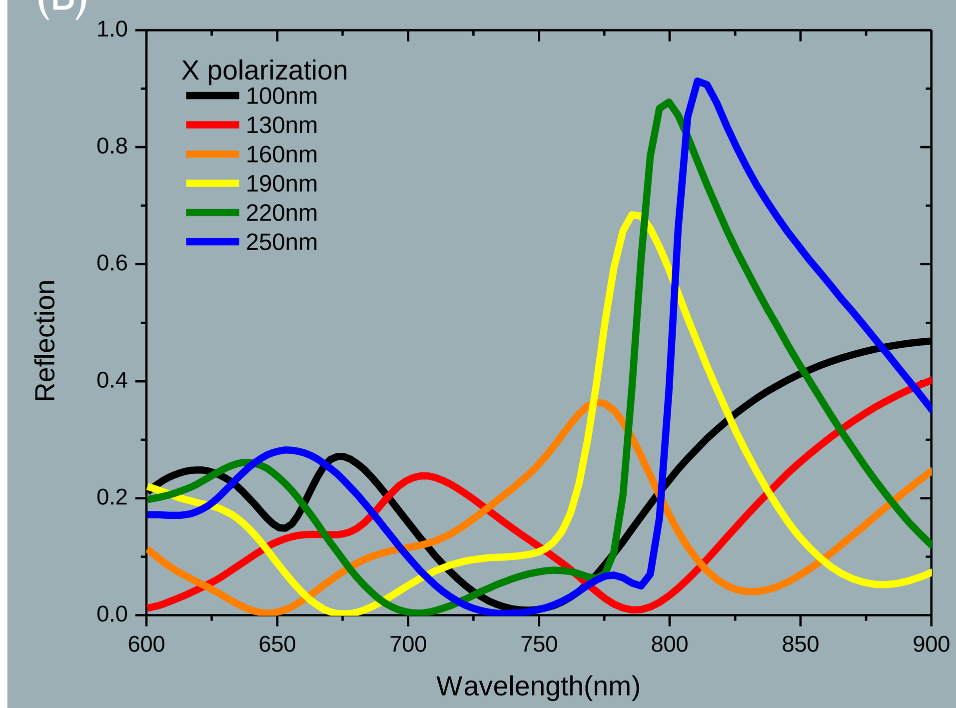
Tunability by Varying Geometric Parameters

A: Period dependence B: Thickness dependence
C: Gap Dependence

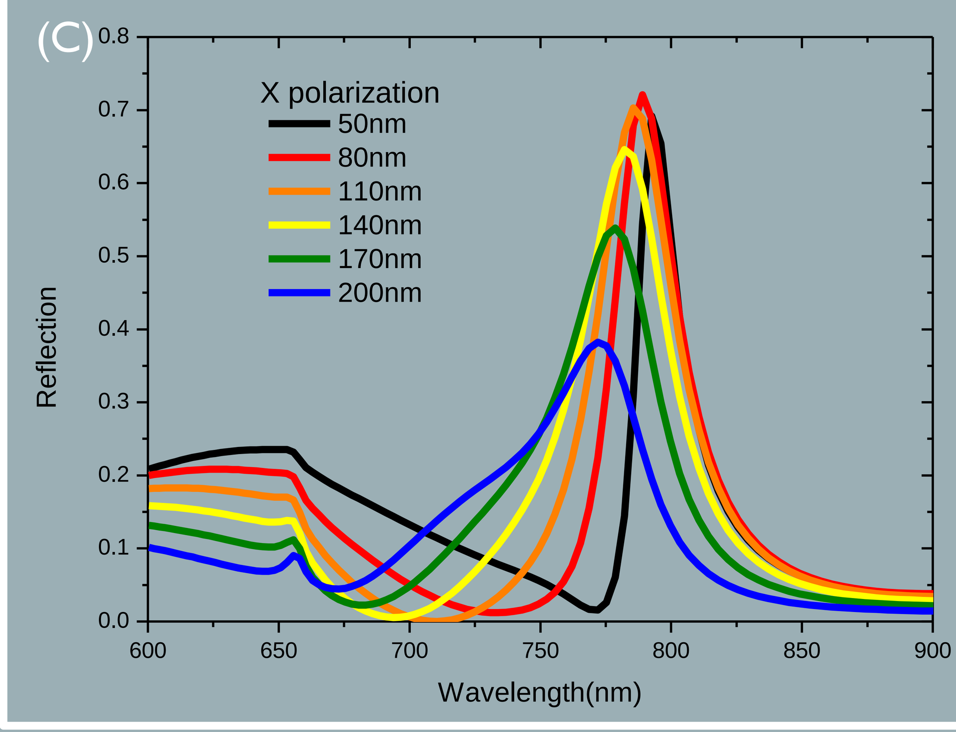
(A)



(B)

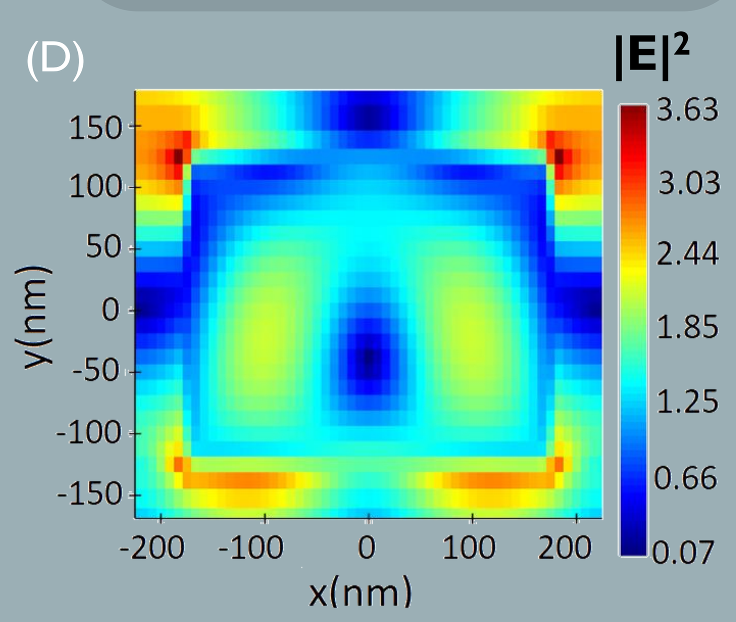


(C)



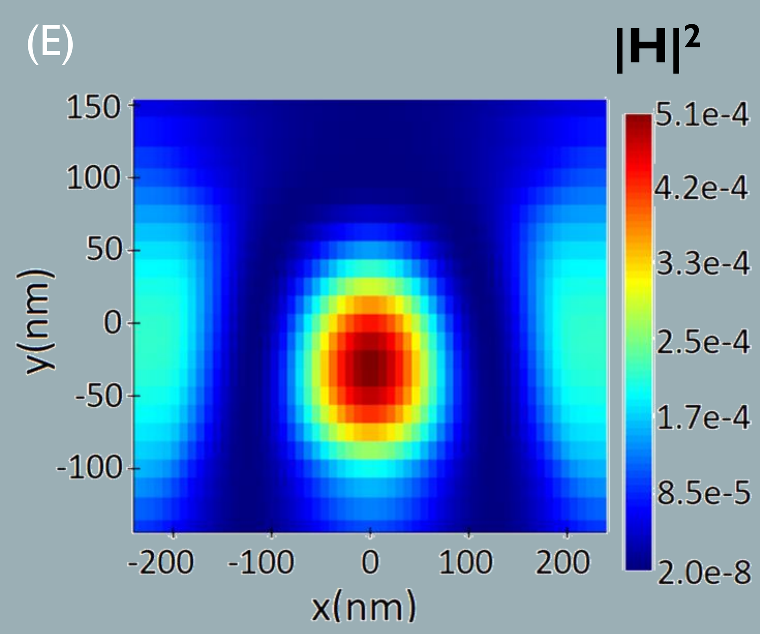
D: Normalized E-field distribution, field enhancement for fundamental mode TM1

(D)



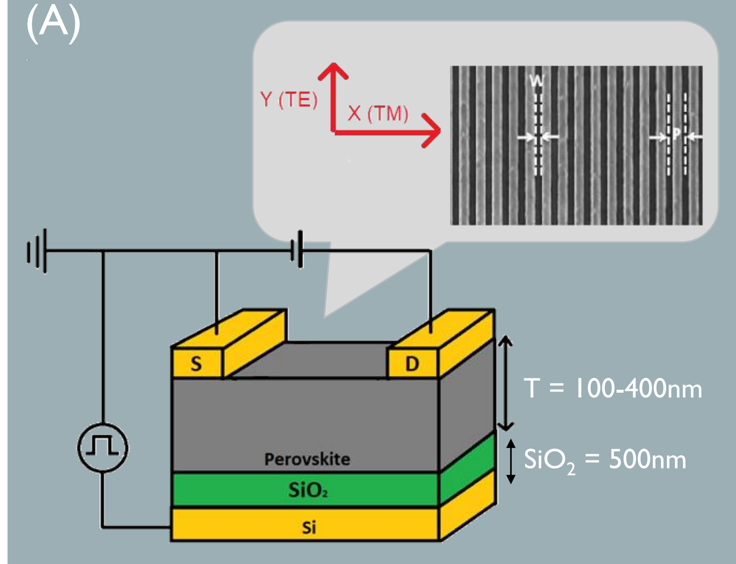
E: H-field distribution, field enhancement for fundamental mode TM1

(E)

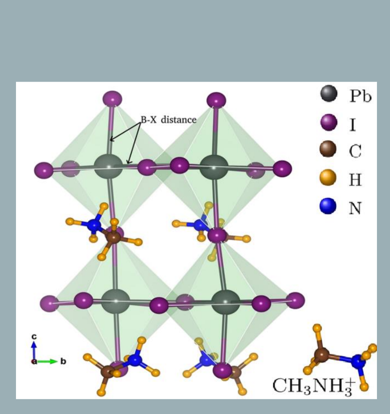


Device Structure

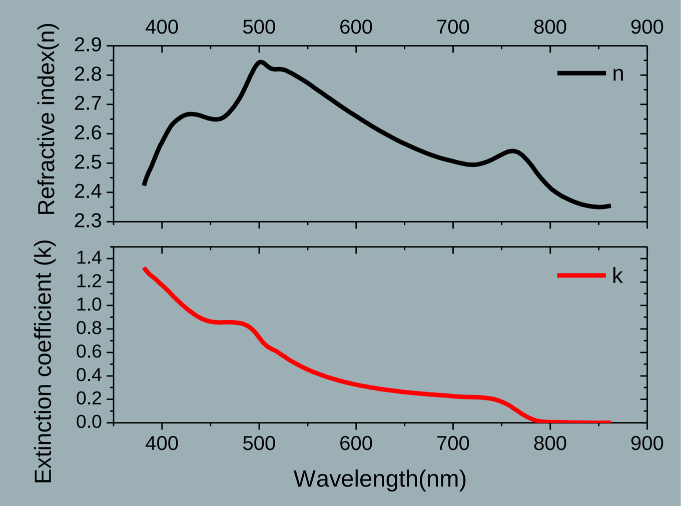
(A)



(B)

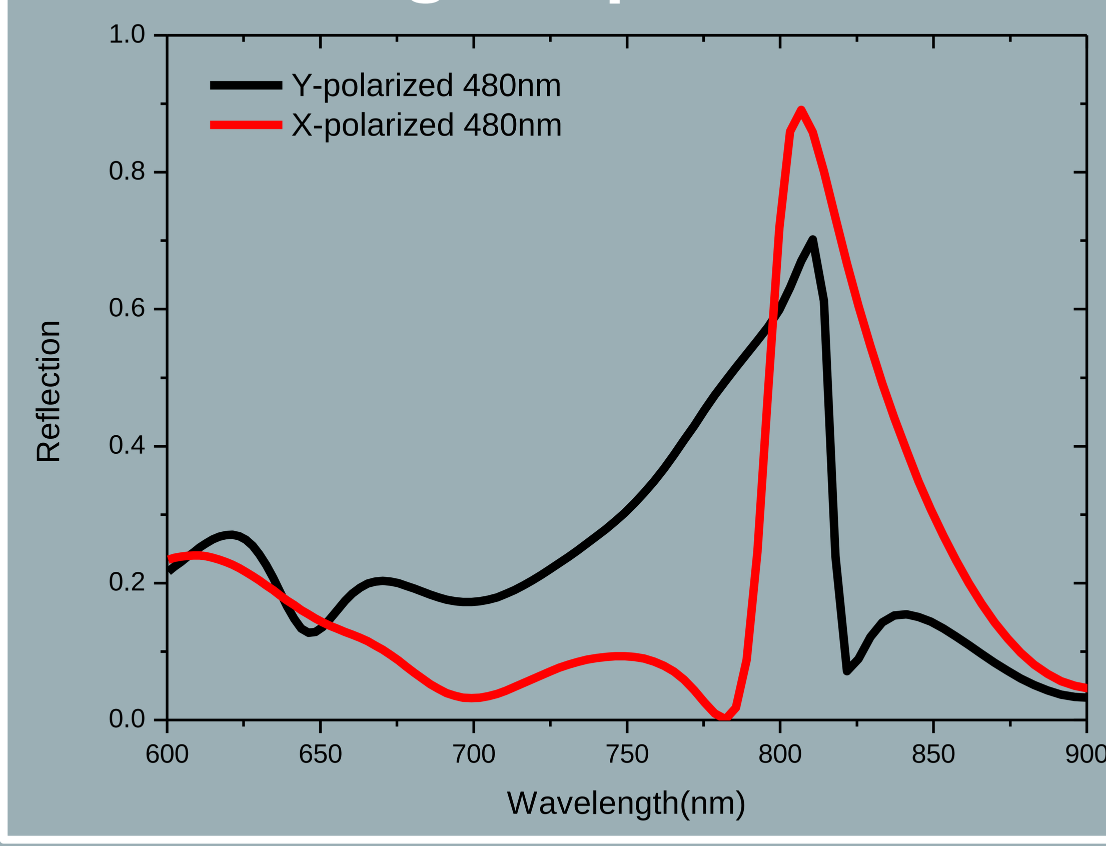


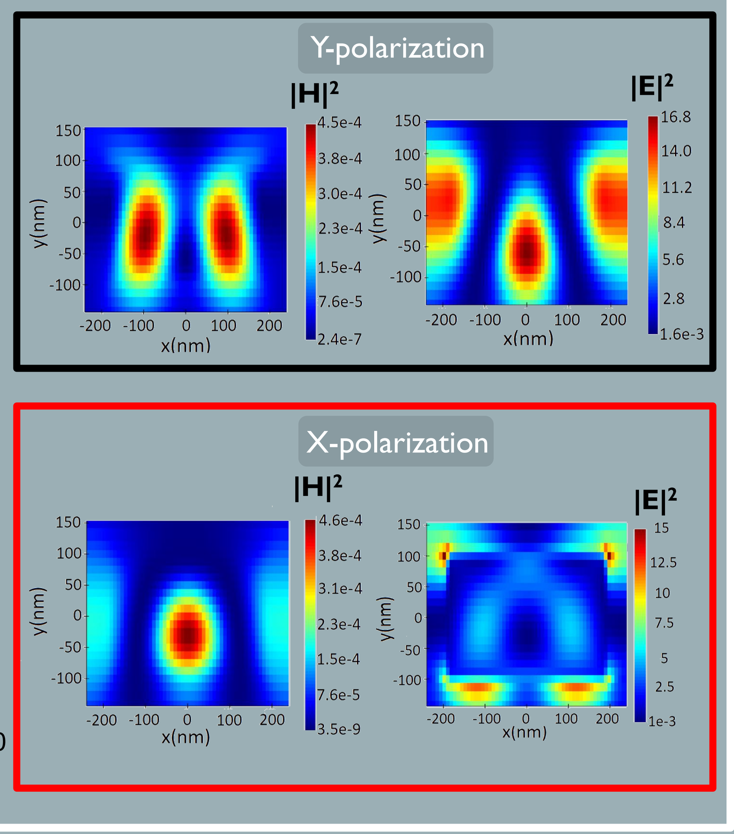
(C)



A:Transistor Schematic inset: Optical microscope image of nanograting B: $MAPbI_3$ crystal structure [4] C: Optical constants of $MAPbI_3$ at 300 K

Switching of Optical Resonances by Polarizations

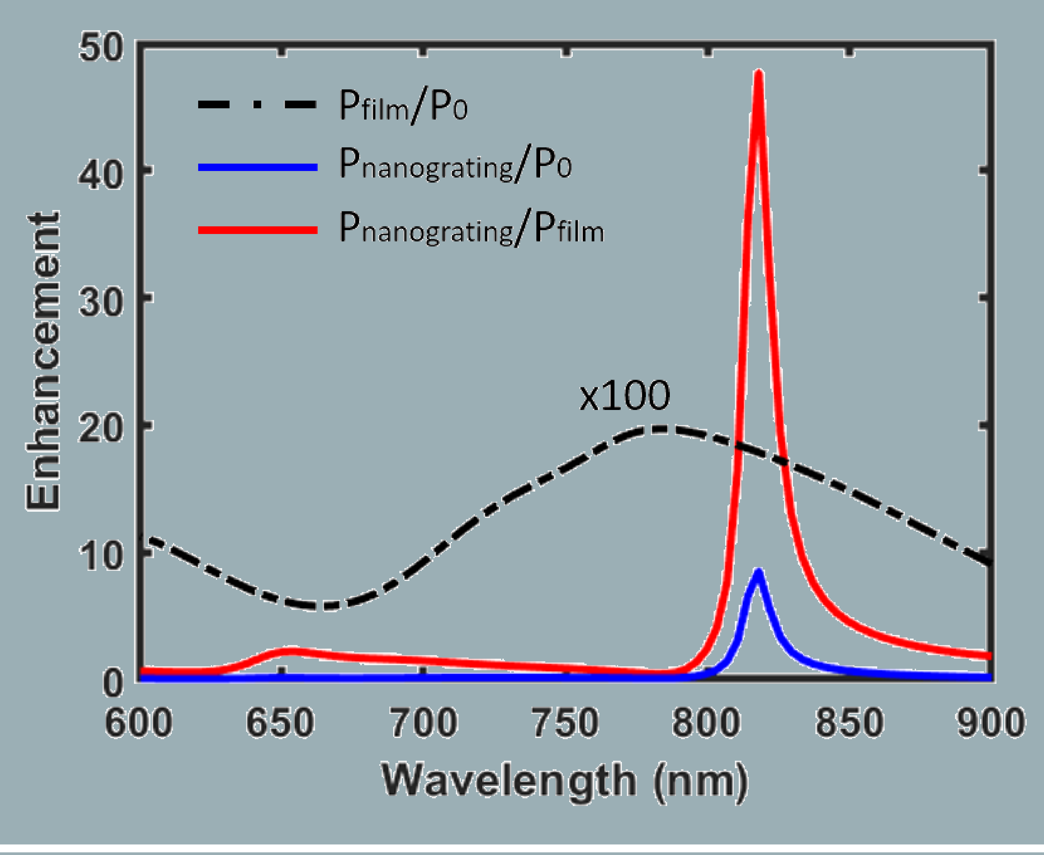




Enhancement of EL via Purcell Effect

$$F = \frac{P_t}{P_o} = \frac{\Gamma}{\Gamma_0}$$

Purcell Factor (F) indicating power ratio of dipole in metasurface over free space [5]



Conclusions

- The reflection spectra of transistor nanograting can be effectively tuned by varying the geometric parameters.
- In the anisotropic nanograting metasurfaces, the optical response is highly sensitive to polarization and the optical resonances can be efficiently switched by changing the polarization of incident light.
- We report improvement of electroluminescence of approximately 48 times compared to perovskite thin film transistor by using a dipole light source when nanograting is imprinted onto transistor.
- Fabrication of the aforementioned parameters have been taken into consideration during the modelling phase to realize a physical PemLET. Experimentation of PemLET would dramatically increase electroluminescence. This project paves the way for developing a new electro-optical device concept for lighting, future integrated displays, and optical communications.

References

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