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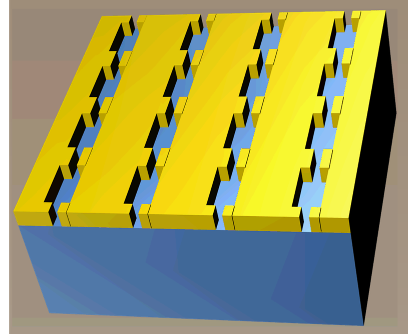

Nonresonant, Broadband Funneling of Light via Ultrasubwavelength Channels

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Motivation

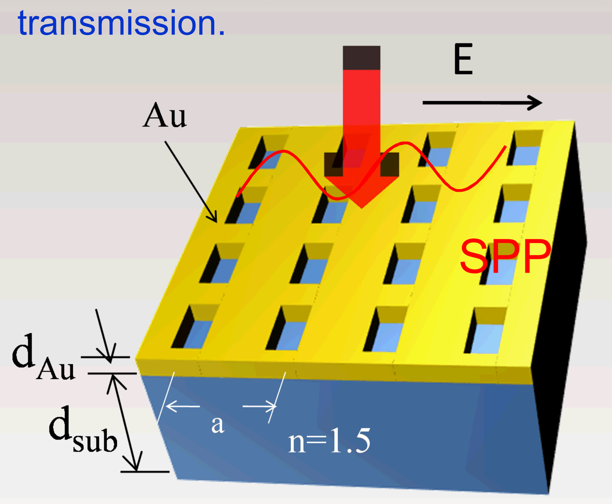
There is great demand for light funneling into very small , deep sub-wavelength volumes!

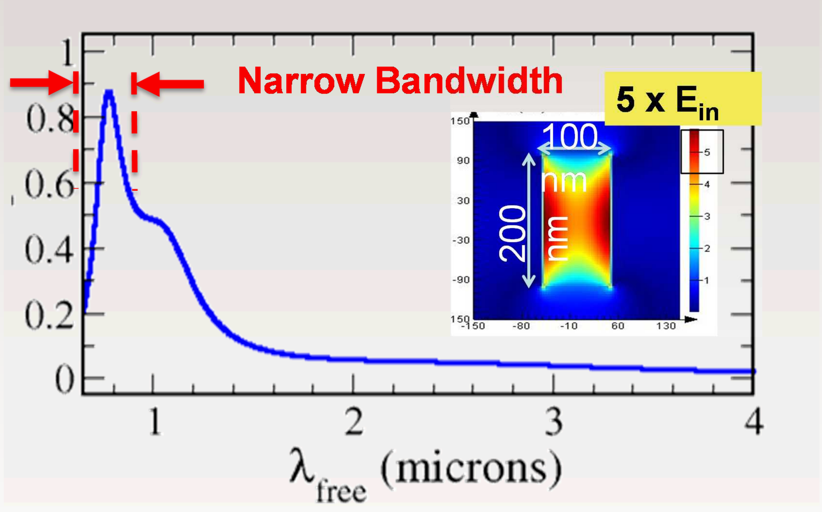
➢ **Important for photonic and optoelectronic device miniaturization e.g. sensors, detectors**

• **Small size** • **High efficiency** • **High sensitivity** • **Broad bandwidth**

Current approach : EOT (Enhanced Optical Transmission) platforms

Impinging light excites resonant Surface Plasmon Polaritons (SPPs) on the surface of a perforated metal hole array that enables the light to squeeze through the subwavelength holes with a high transmission.





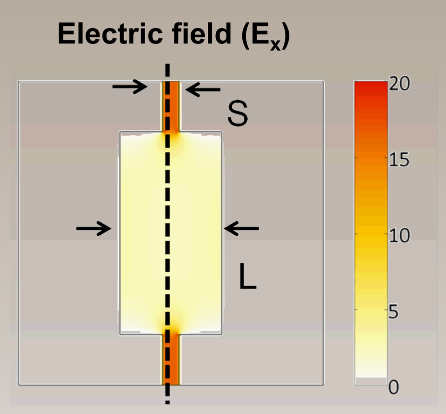
The transmission response of the structure with a= 300nm, d_{Au}=50nm and d_{sub}=500nm showing a narrow band transmission. The inset shows that the electric field distribution in the gap is enhanced 5-fold.

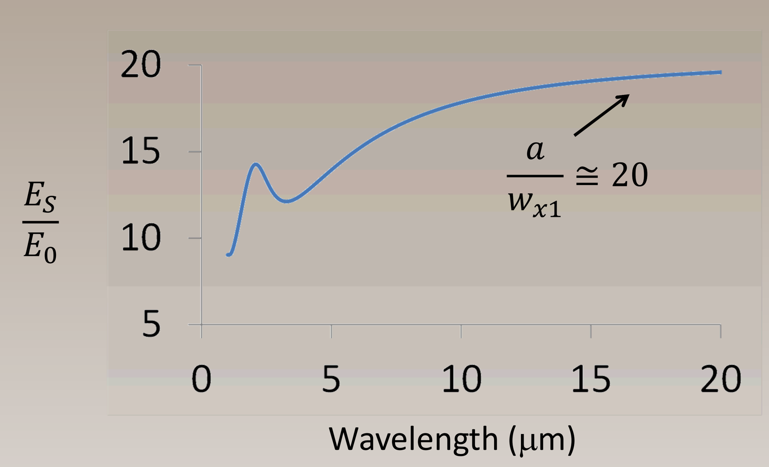
Limitations:

- Relies on resonance – so narrow operating bandwidth.
- Electric field confinement is inversely related to transmission.

Can we achieve light confinement and electric field enhancement with broad wavelength operation?

Key Features

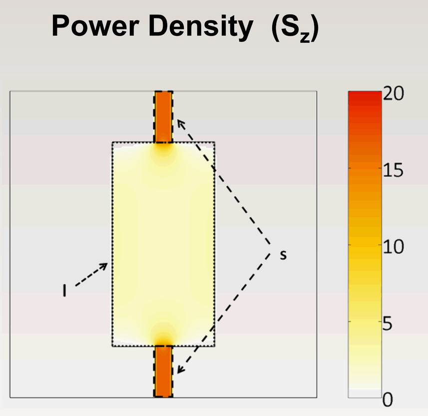


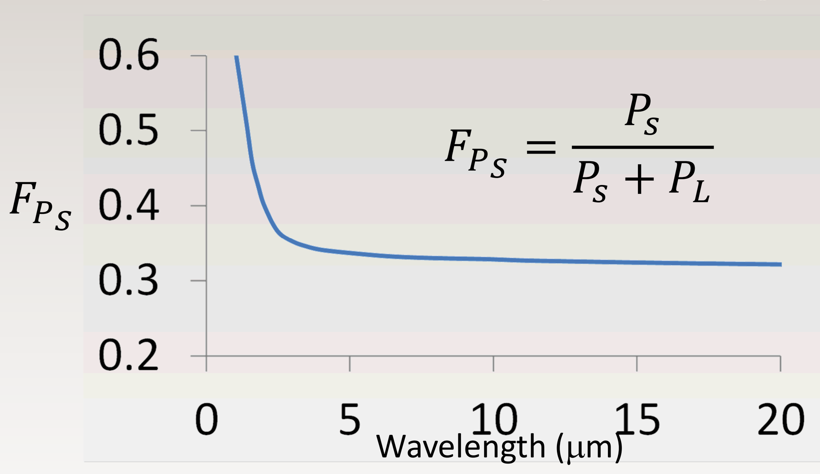


➢ **Enhancement factor exceeding 15X across broadband!**

➢ **Asymptotic value determined by the structural geometry**

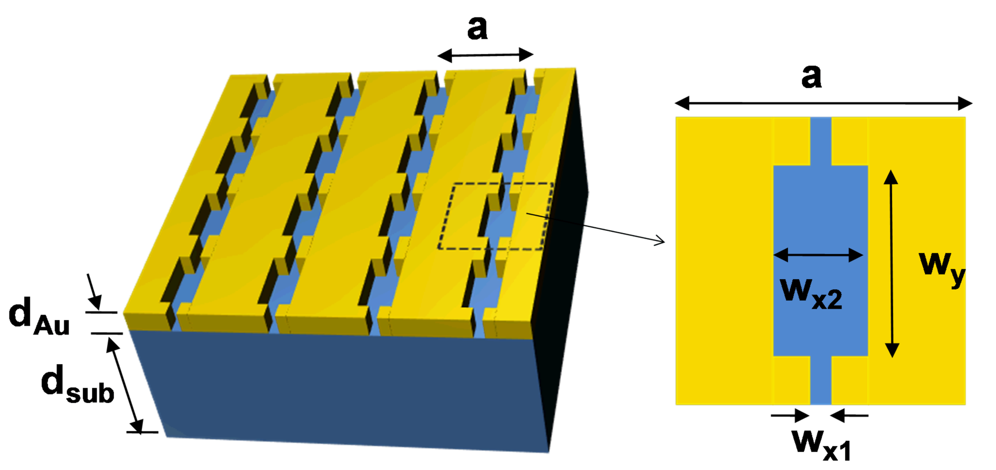
➢ **The enhancement factor can be controlled via structural geometry.**

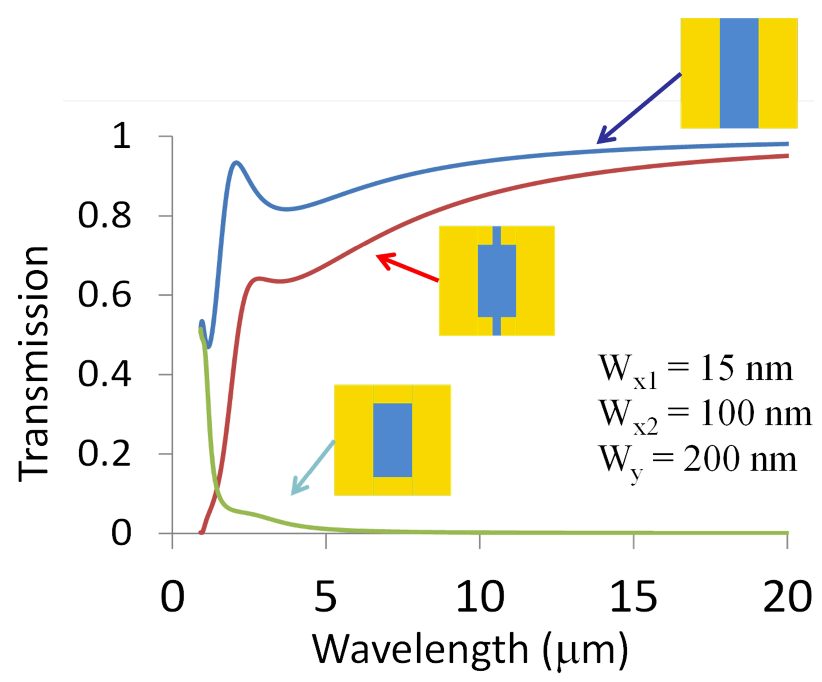




Surprisingly, nearly 30% of the transmitted power is channeled through an area ~ **(λ/250)^2** that is **1/60th** of the unit cell area across broadband.

Approach : The Double –groove structure



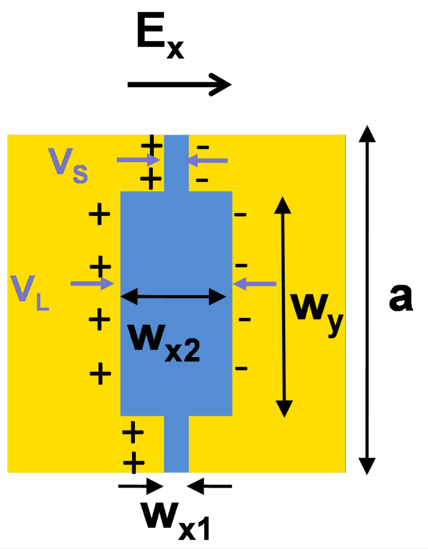


✓ **Broadband transmission**

✓ **Electric field enhancement/confinement**

Operational Principle

- **Instead of relying on resonance phenomena, this design exploits the nearly instantaneous response of the charges to the incoming electromagnetic field.**
- **The quasistatic behavior of this structure is non-resonant enabling a broadband response**



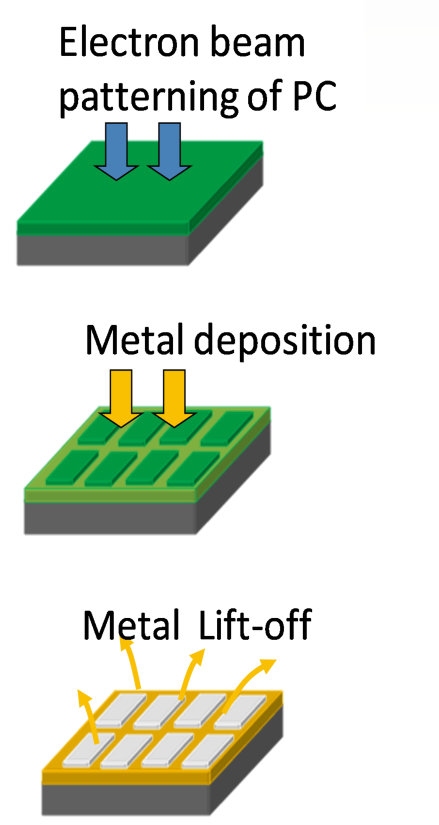
Quasistatic behavior:

- The two sides are electrically disconnected resulting in charge accumulation.
- High conductivity of metal ensures potential difference at the small gap and large gap are the same i.e., $V_S = V_L$.
- Electric field in the small gap is considerably larger than in the large gap. In fact, the ratio of the electric field obeys a simple relation

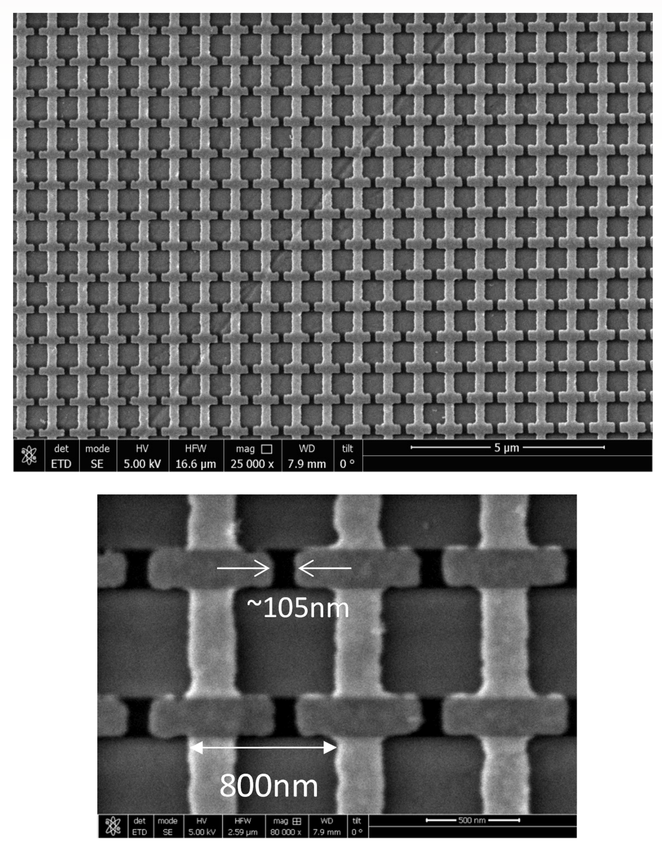
$$\frac{E_S}{E_L} \cong \frac{w_{x2}}{w_{x1}}$$

Experiment

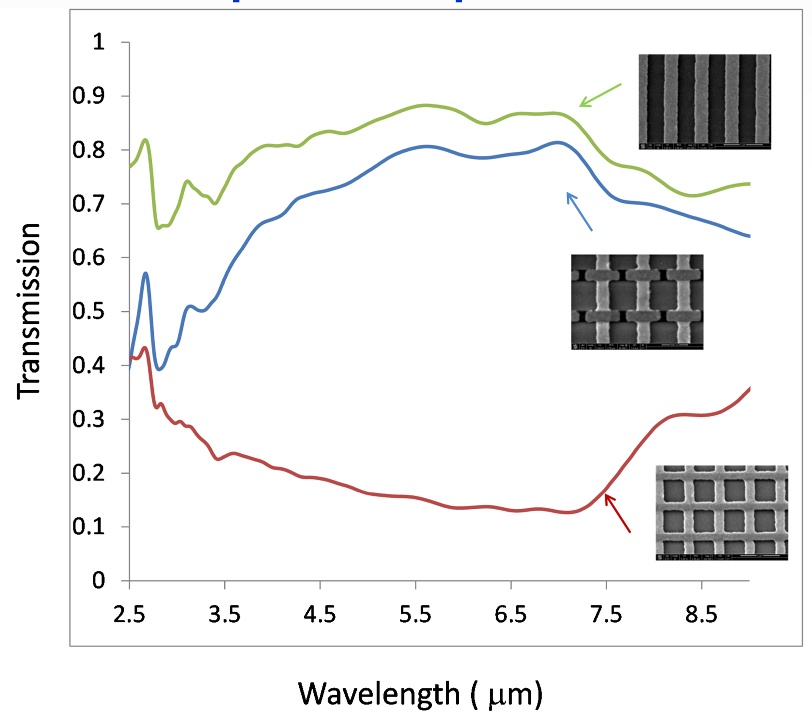
Fabrication Approach



Structural characterization



Optical Response



Optical response indicates good match to theory.

Summary

➢ **Disproportionately large amounts of incident power (~20X) can be channeled through this area also across a broad wavelength band.**

➢ **The property of this design to efficiently confine light to ultrasmall volumes across a broad wavelength range (1– 20 μm) will yield devices that are**

• **Compact** • **Highly sensitive** • **Energy efficient** • **Robust**

➢ **Proof-of-principle structures farbicated from gold thin films demonstrated with ~ 100nm gap**

➢ **Preliminary optical measurements reveal good match to theoretical predictions**

➢ **The results presented will directly impact many devices such as sensors, detectors, and light emitters operating in the infrared that are important for national security.**

References:

1.G. Subramania , S. Foteinopoulou, & I. Brener, "Nonresonant Broadband Funneling of Light via Ultrasubwavelength Channels," *Phys. Rev. Lett.* **107**, 163902 (2011).

2. "Synopsis: Light Gets into the Double Groove", http://physics.aps.org/synopsis-for/10.1103/PhysRevLett.107.163902.

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NNSA National Nuclear Security Administration

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