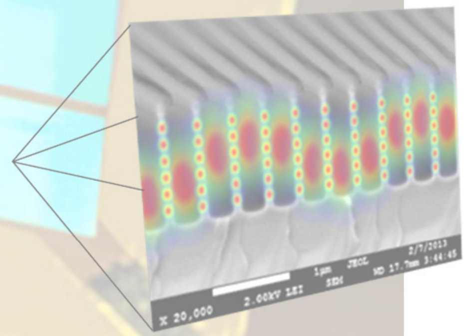
Properties of Photonic and Plasmonic Resonance Devices



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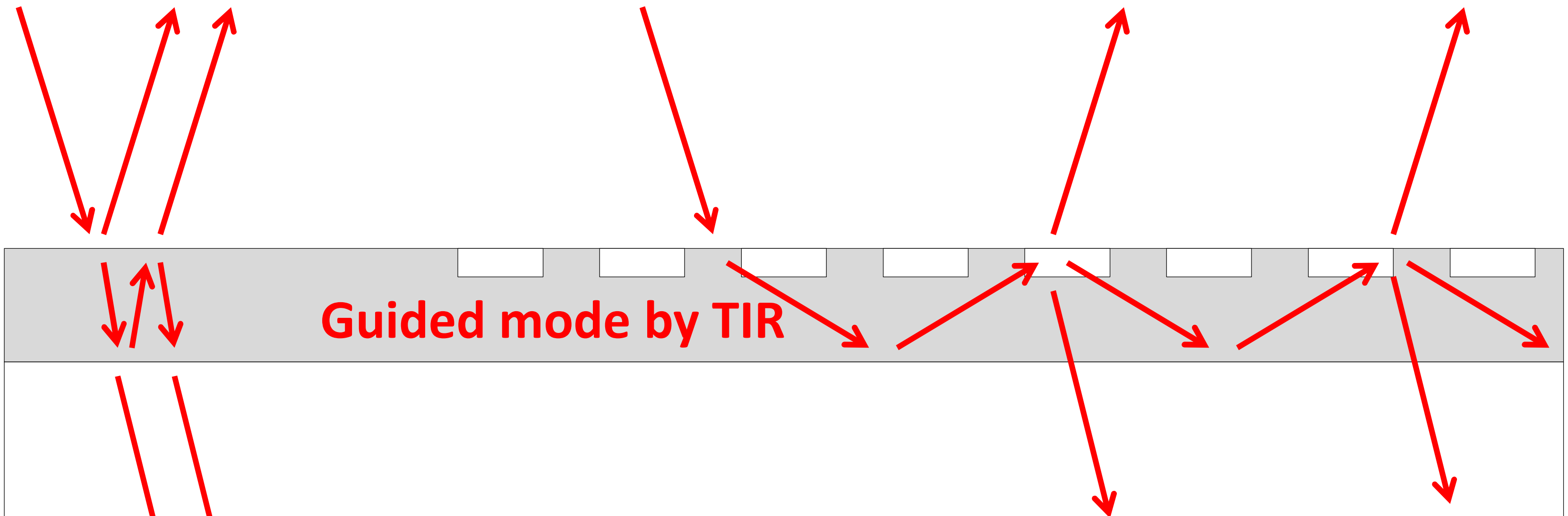
Outline

- Introduction
- Guided-mode resonance bandpass filters.
- Broadband omnidirectional Si grating absorbers.
- Transmission resonances in metallic nanoslit arrays.
- Gain-assisted ultrahigh-Q SPR in metallic nanocavity arrays.
- Conclusion

Photonic Resonances in Periodic Thin Films

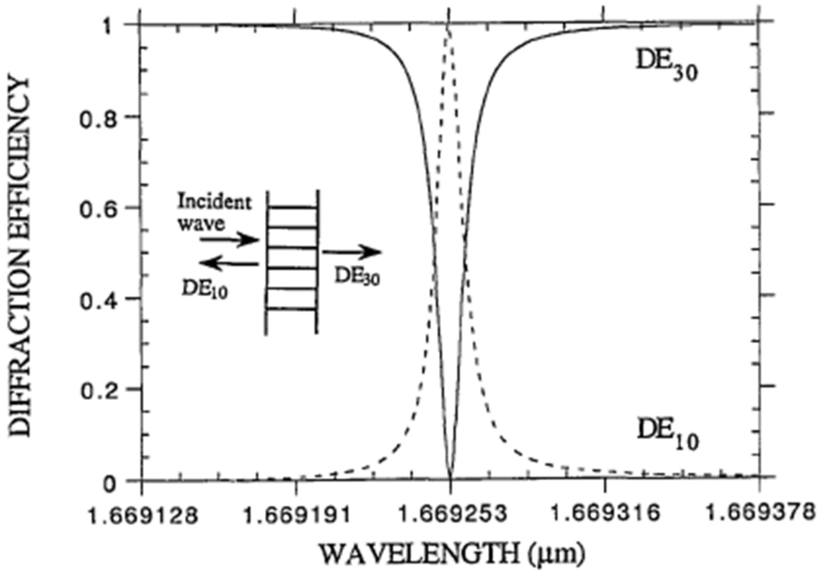
Thin-film interference **Guided-mode resonance**



- Highly controllable with the pattern's geometry.
- Spectral engineering by blending of multiple guided modes.

Guided-Mode Resonances in Dielectric and Semiconductor Thin-Film Gratings

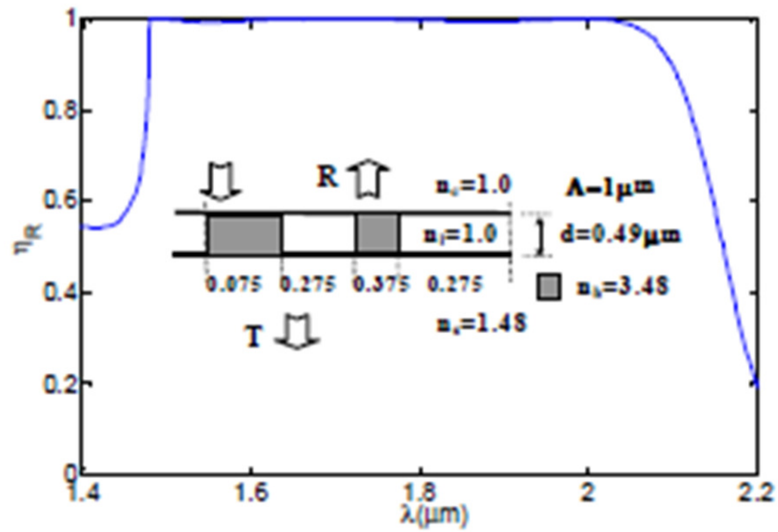
Low index-contrast gratings



[Wang and Magnusson, Appl. Opt. 32, 2606 (1993)]

- High-Q, narrow band resonances.
- Primarily reflection peaks.
- Optical notch filters, biosensors, and so on.

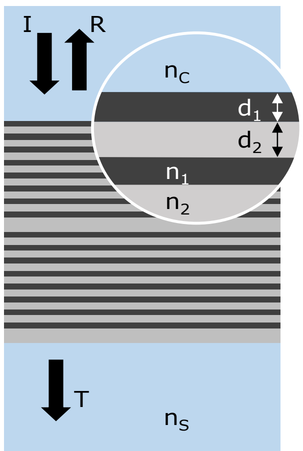
High index-contrast gratings



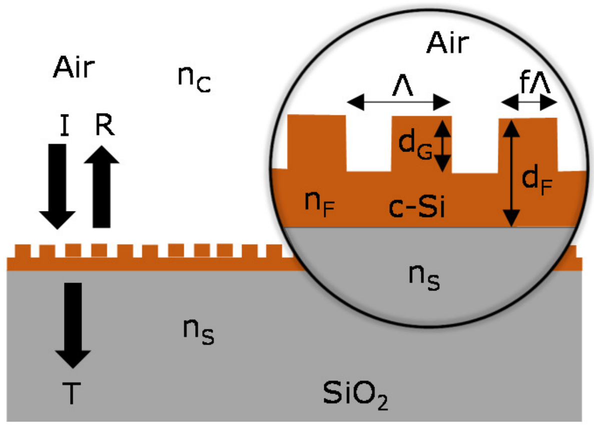
[Ding and Magnusson, Opt. Express 12, 5661 (2004)]

- Both broadband + narrow-band effects.
- Versatile spectral engineering.
- Lossless mirrors/polarizers, flat microlenses, bandpass filters, broadband resonant absorbers, and so on.

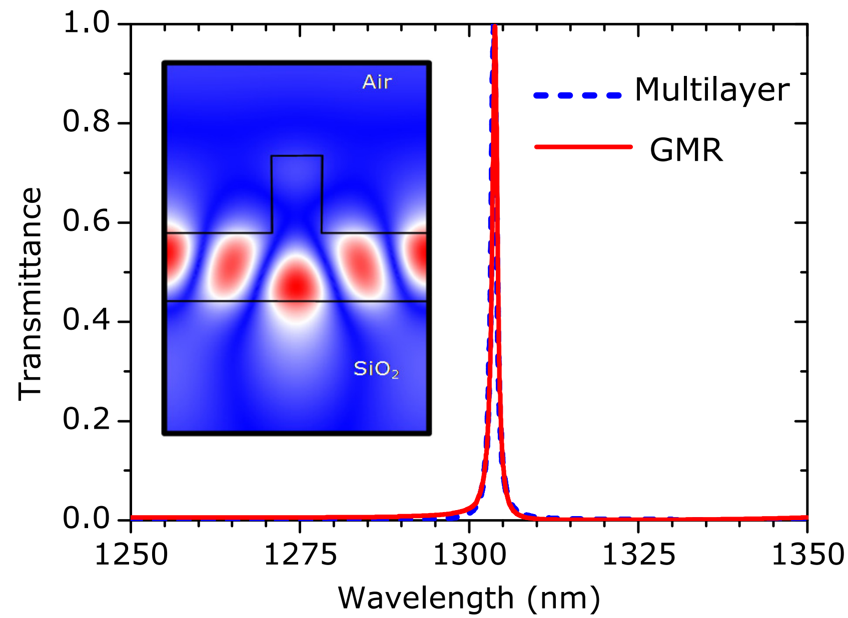
Bandpass Filters: Theoretical



Conventional multilayer



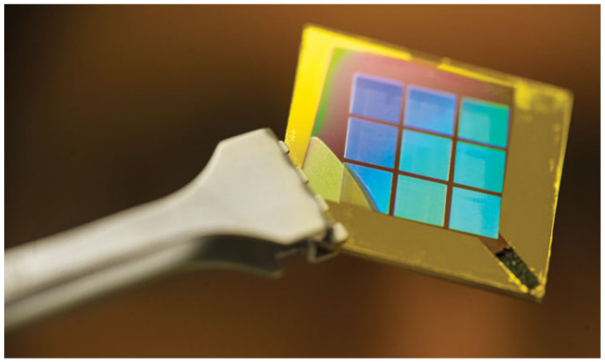
Single-layer GMR structure



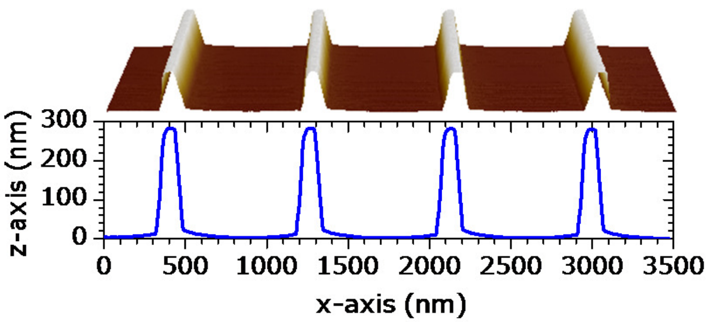
Major advantages

- Simple fab. processes (involves less fabrication errors).
- Stop-bands and pass-line are determined by geometry of the surface texture.

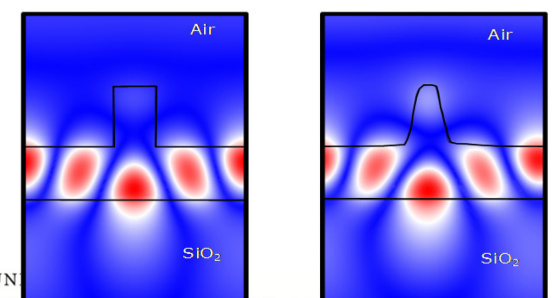
Bandpass Filters: Experimental

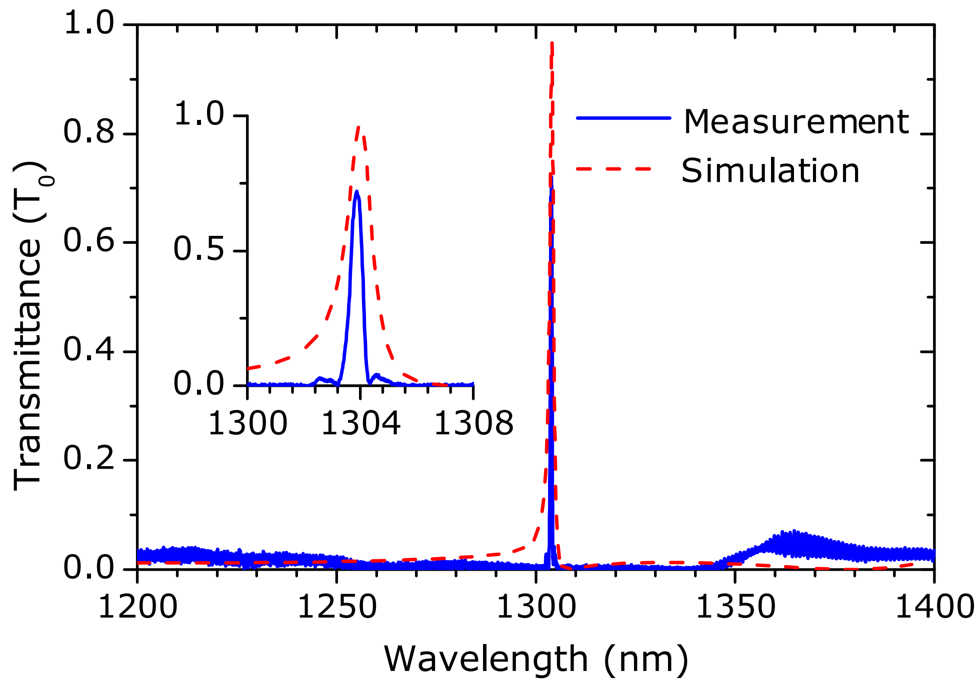


Surface profiles (AFM)



Design Fabricated





Performance Parameters

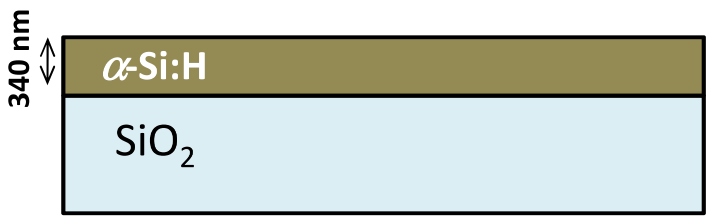
- Pass-line (peak): 0.4 nm FWHM, 83% efficiency.

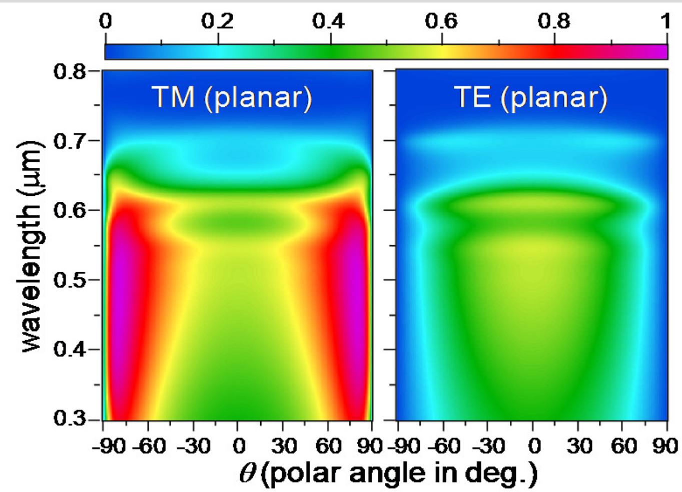
- Stop-band: < 1% over 100 nm bandwidth.

- Angular tunability = 6 nm/deg.

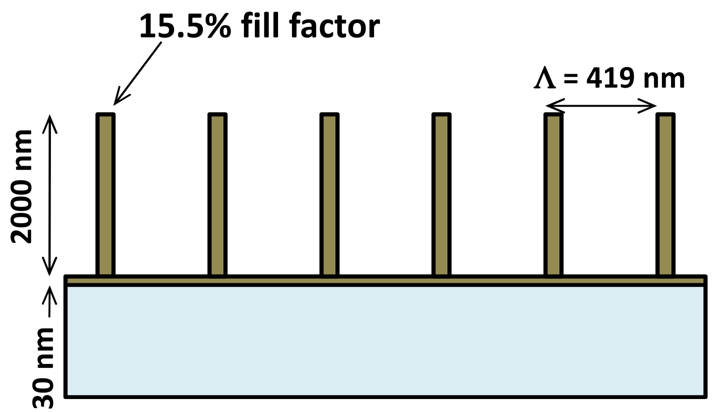
Broadband Omnidirectional Absorbers: Theoretical

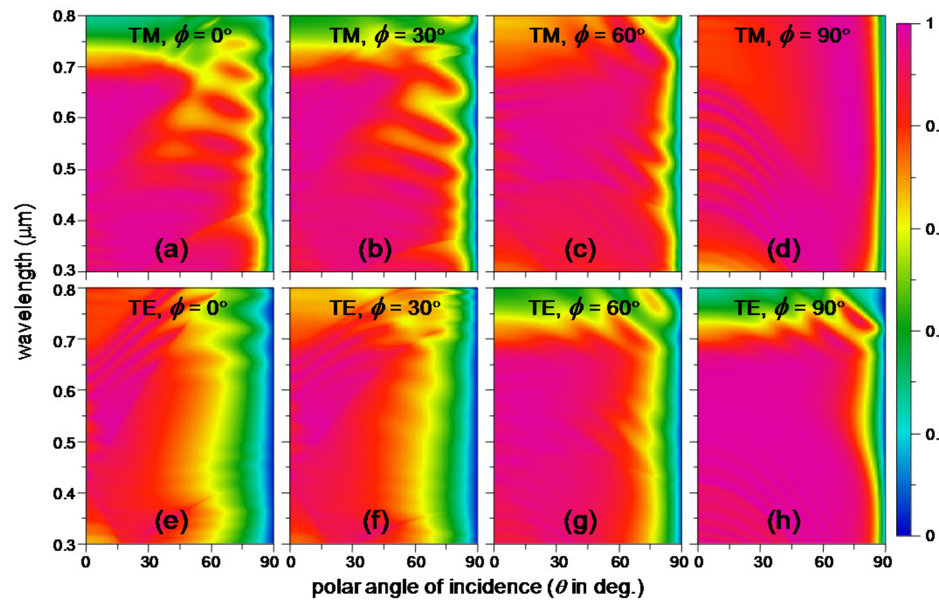
Planar absorber





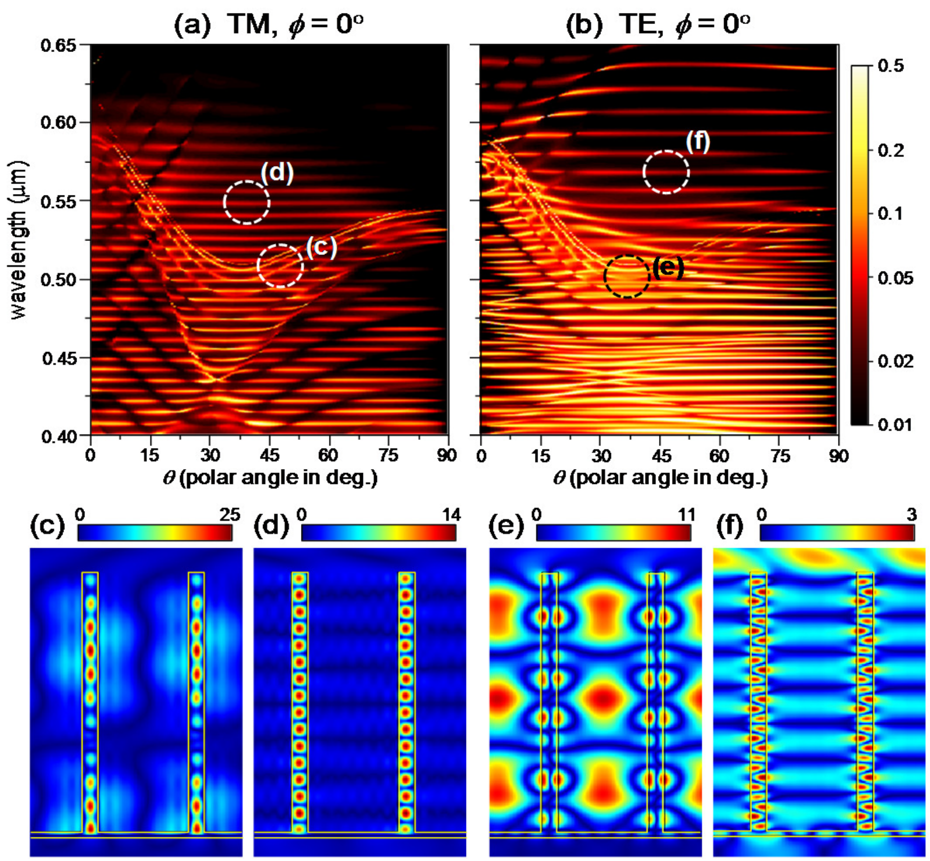
GMR absorber



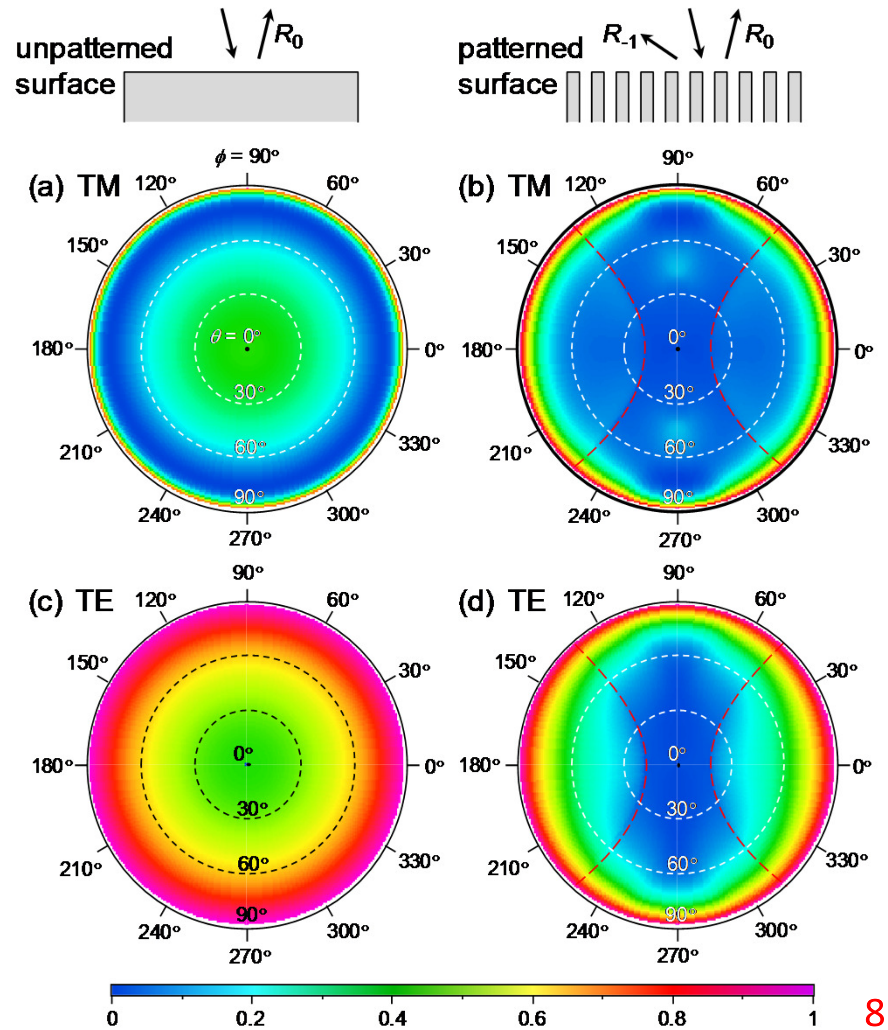


Broadband Omnidirectional Absorbers: Theoretical

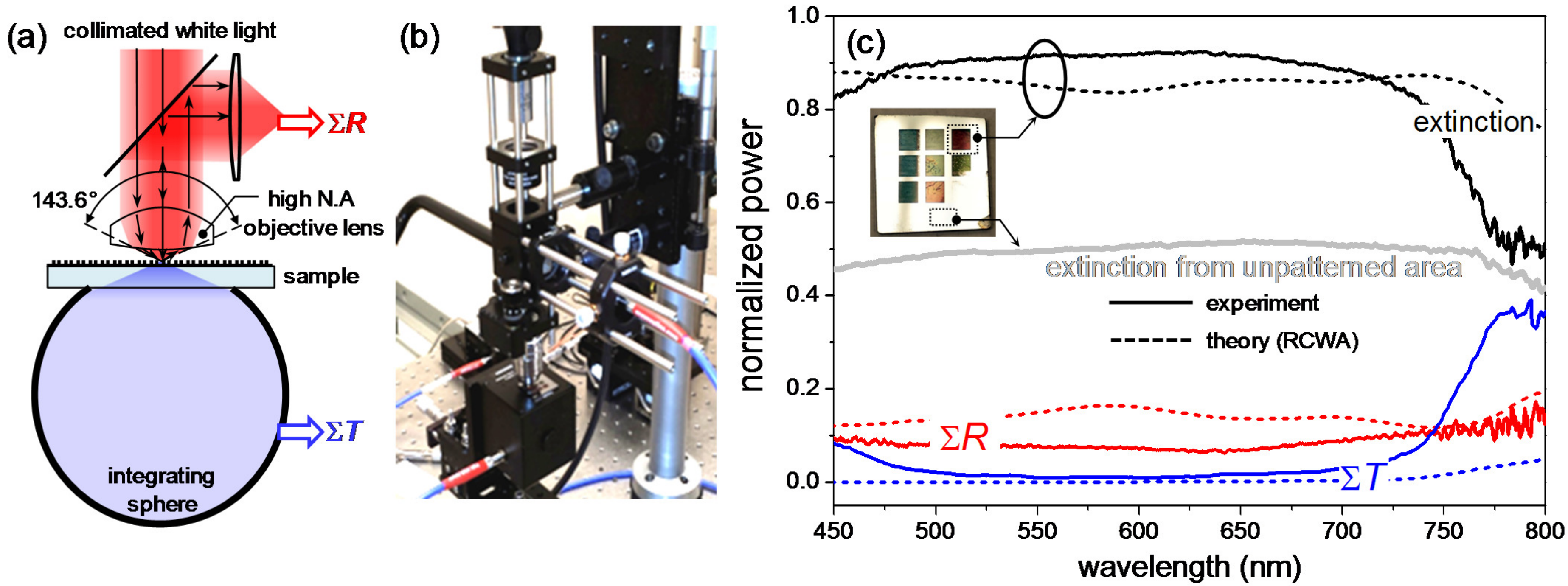
Resonant Light Trapping

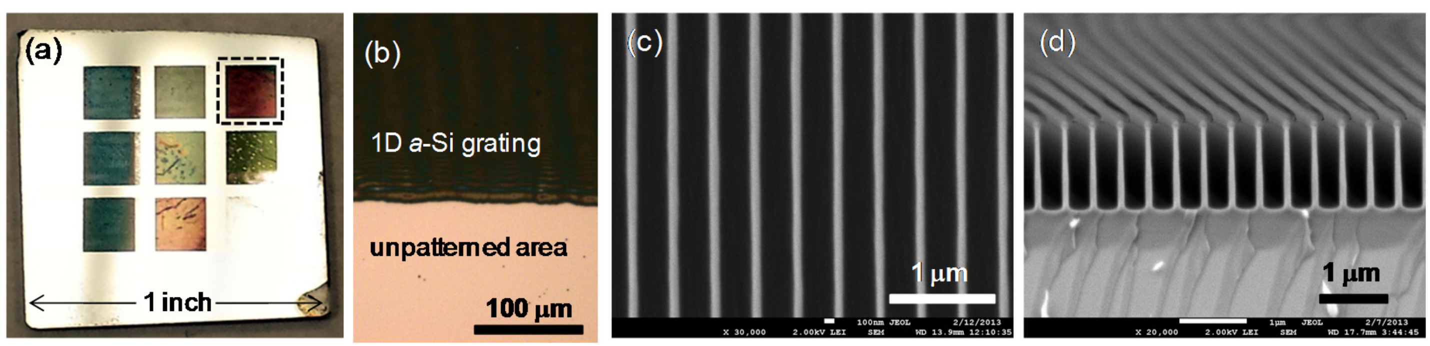


Anti-Reflection Effect



Broadband Omnidirectional Absorbers: Experiment





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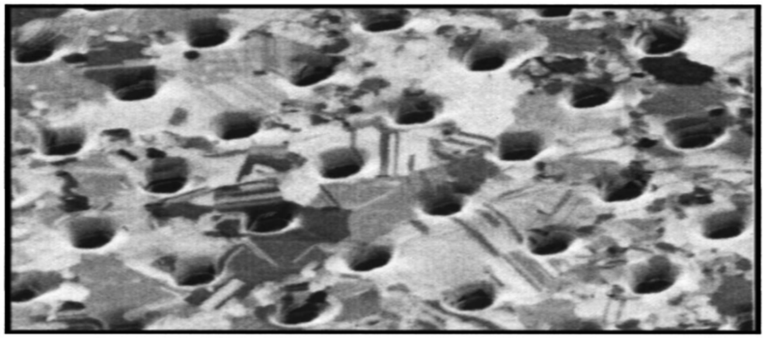
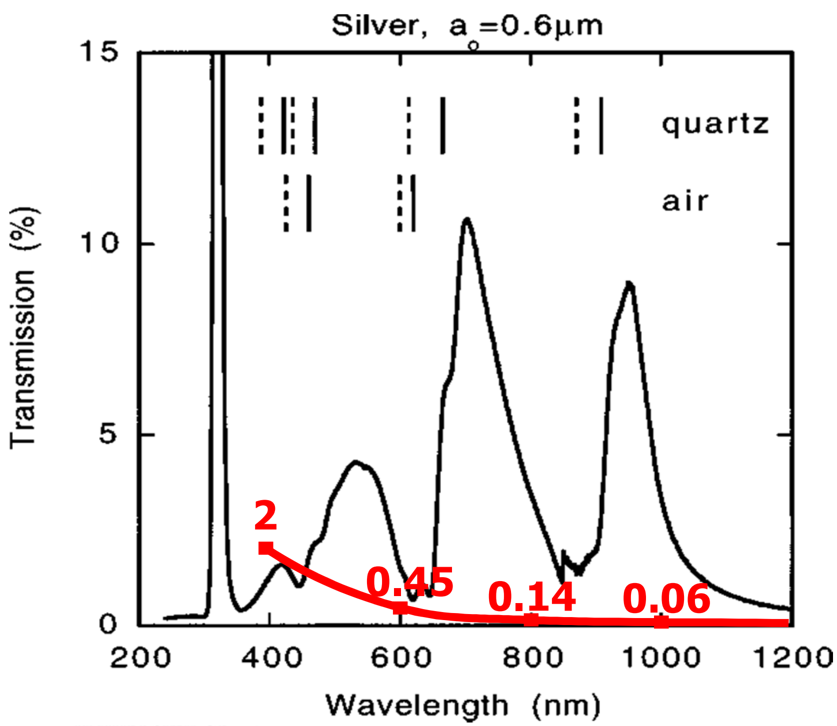
Surface Plasmon Resonances in Metallic Nanostructures

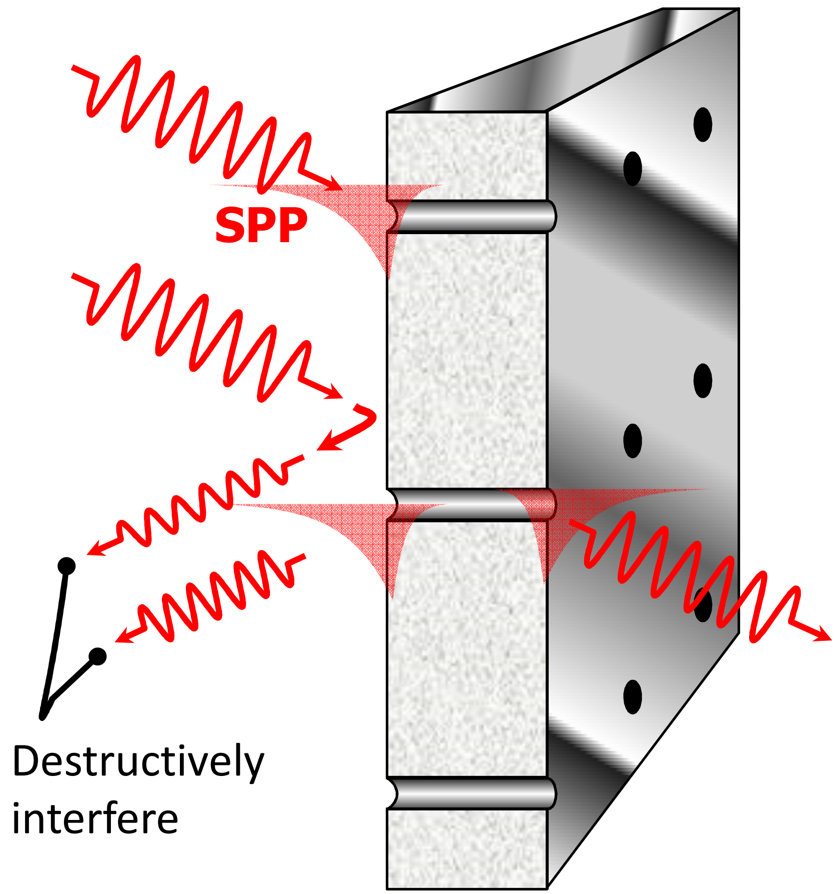
- Collective oscillation of surface free electrons.
- Deep subwavelength confinement:
  - Metallic metamaterials.
  - Optical communication with nanoscopic objects.
  - Quantum optical effects.
- Highly lossy due to ohmic damping.
- Primarily absorption and transmission resonances. (↔ Photonic resonances)

Extraordinary Optical Transmission

Nature 391 667; Phys. Rev. B 58 6779.



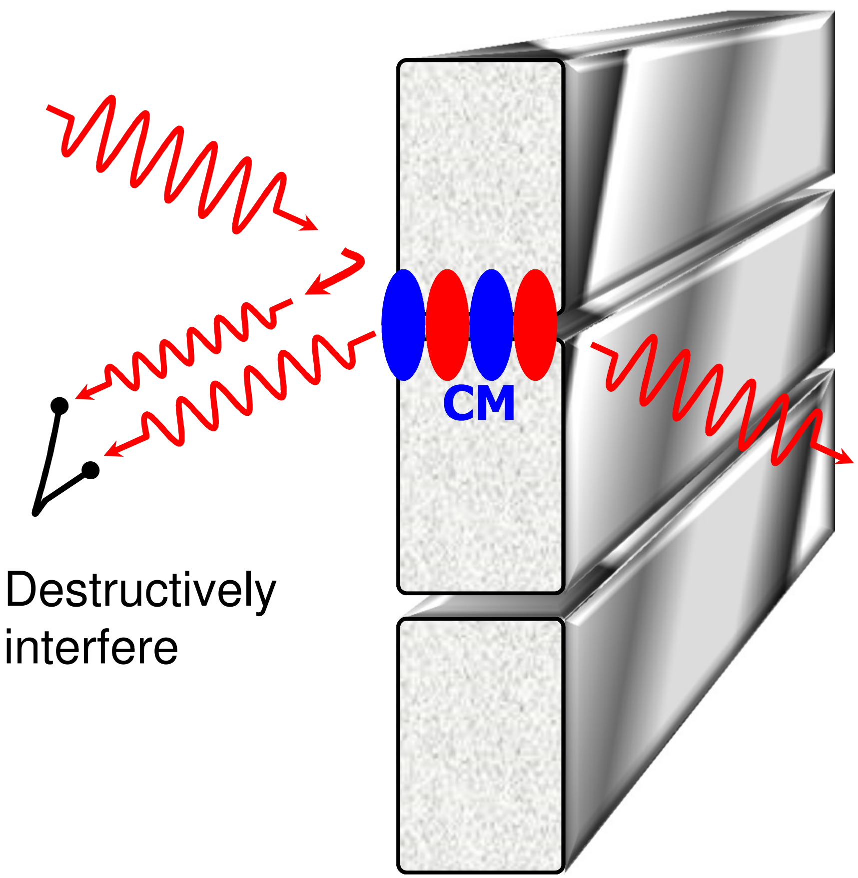


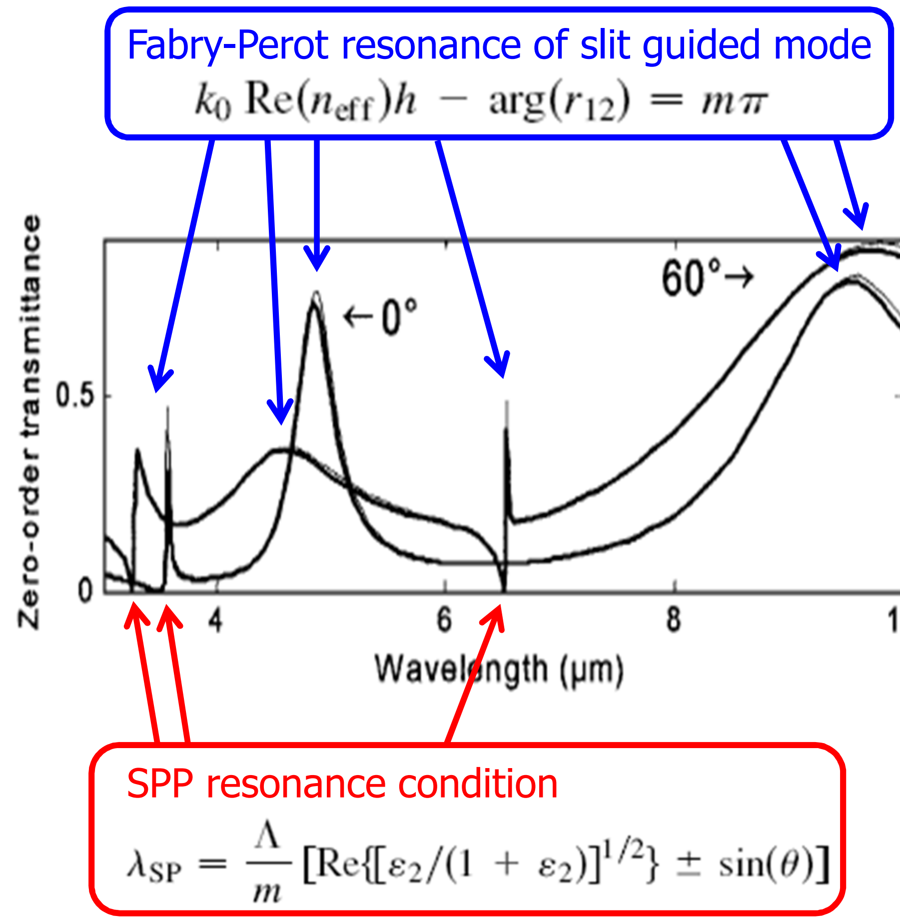


Extraordinary Optical Transmission

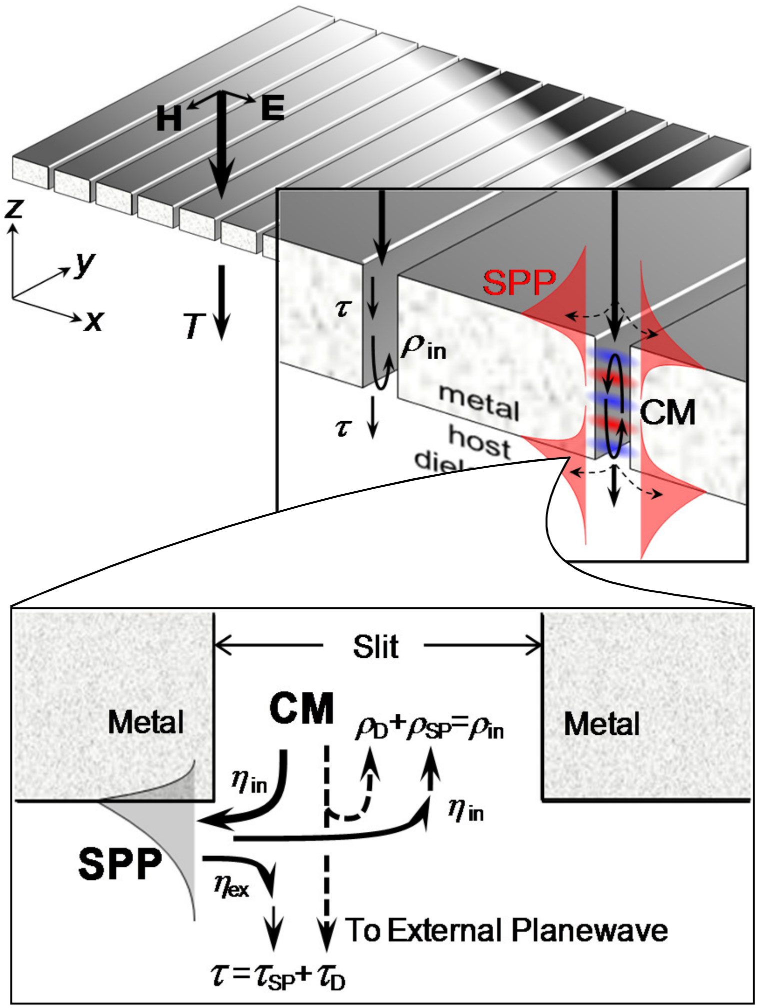
Cao et al., Phys. Rev. Lett. 88 057403 (2002)

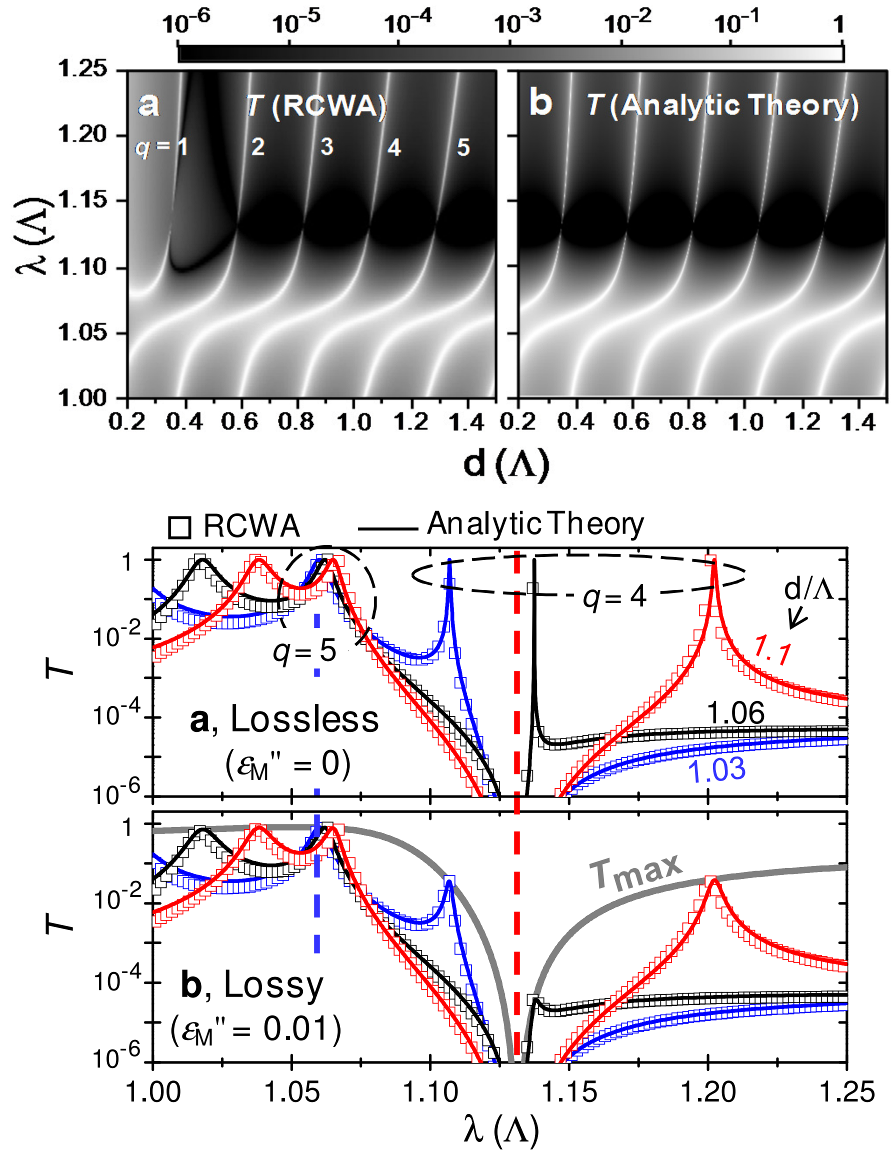
"Negative role of surface plasmons in the transmission of metallic gratings with very narrow slits"



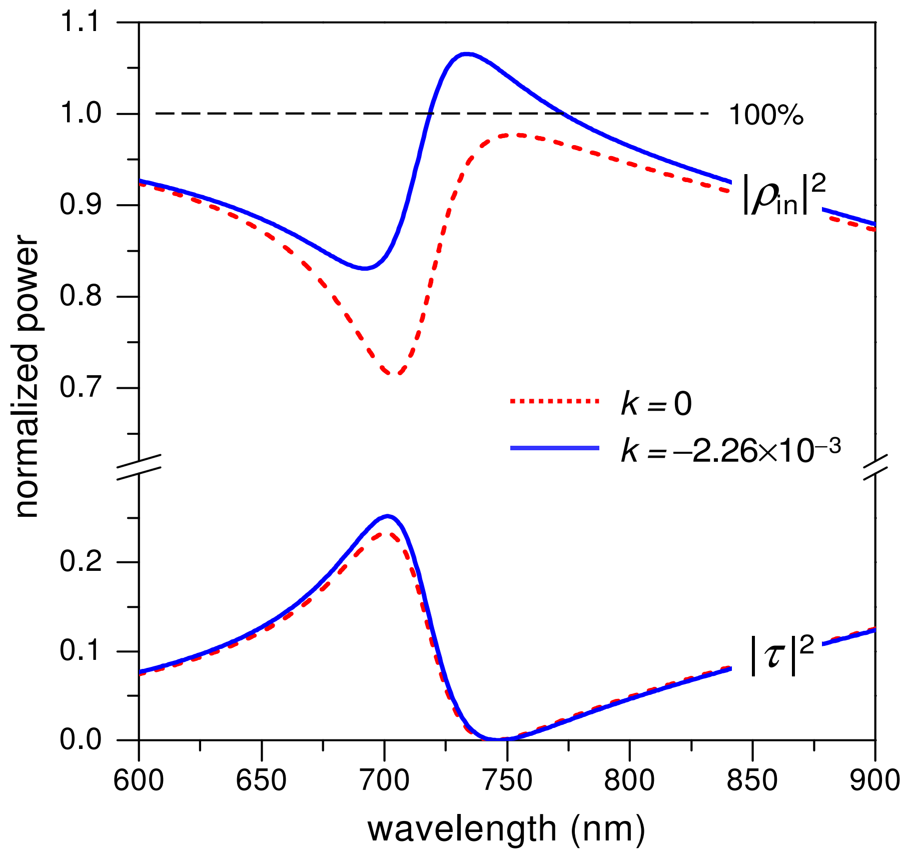


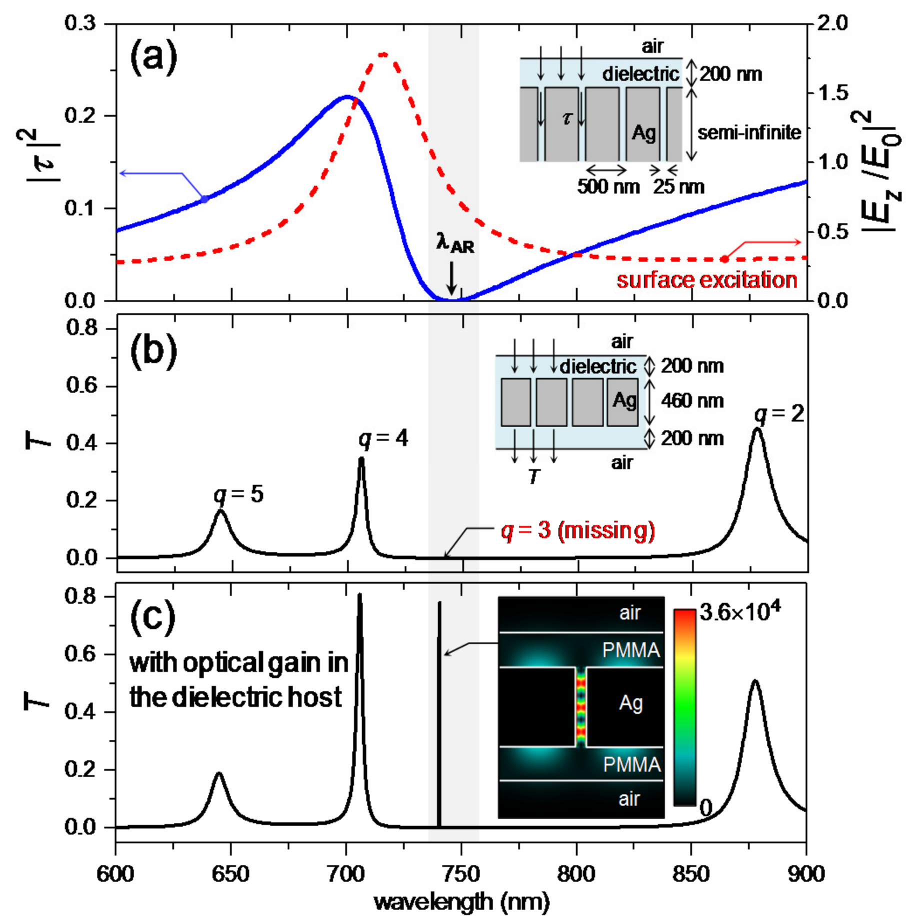
Surface and Cavity Plasmonic Resonances in Metallic Nanoslit Arrays





Toward Ultrahigh-Q Metallic Nanocavity Resonances





Conclusion

- Demonstrated optical bandpass filters and broadband absorbers based on high-index contrast subwavelength waveguide gratings.
- Explained complex resonance effects in metallic nanoslit arrays with a simple model of an optical cavity with Fano-resonant reflection boundaries.
- The theory predicts efficient room-T ultrahigh-Q plasmonic nanocavity resonances with the externally amplified intracavity feedback mechanism.

ACKNOWLEDGEMENT

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Publications with these works:

[1] J. W. Yoon, K. J. Lee, W. Wu, and R. Magnusson, "Wideband omnidirectional polarization-insensitive light absorbers made with 1D silicon gratings", Adv. Opt. Mater. 2014; doi:10.1002/adom.201400273.

[2] J. W. Yoon, J. H. Lee, S. H. Song, and R. Magnusson, "Unified theory of surafce-plasmonic enhancement and extinction of light transmission through metallic nanoslit arrays", Sci. Rep. 4, 5683 (2014).

[3] J. W. Yoon, S. H. Song, and R. Magnusson, "Ultrahigh-Q metallic nanocavity resonances with externally-amplified intracavity feedback", Sci. Rep. 4, 7124 (2014).