Modeling of Metasurfaces

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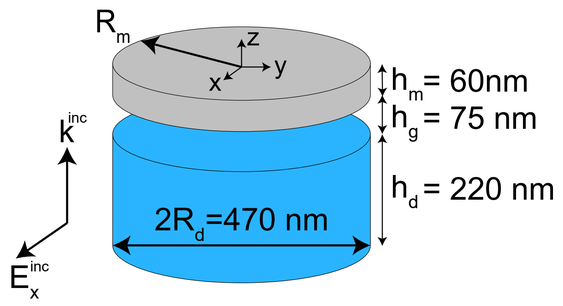
1 Introduction

Hybrid metasurfaces demonstrate effects that are not possible with either dielectric or plasmonic metasurfaces. They consist of meta-atoms from both dielectric and plasmonic materials. For modeling such structures, we resort to the surface integral equation. We perform a detailed study of different hybrid metasurfaces built from aSi combined with different plasmonic metals (Ag, Al, Pt). To obtain a significant optical response, it is important that electric and magnetic resonances overlap spectrally, which requires adjusting the metal. Using multipoles expansions obtained from the full-field electromagnetic calculations, we highlight the interplay between different modes that lead to an extremely rich spectral response, which includes narrow spectral features.

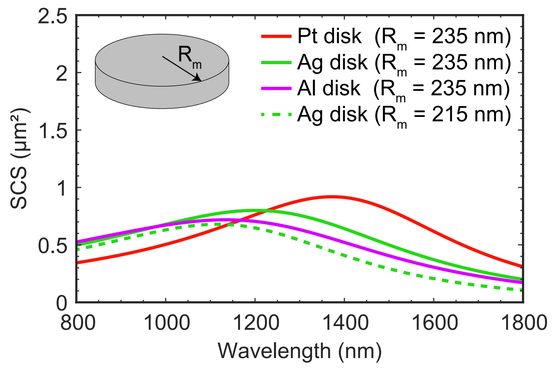
2 Geometry

Plasmonic metal disk over dielectric cylinder in air:

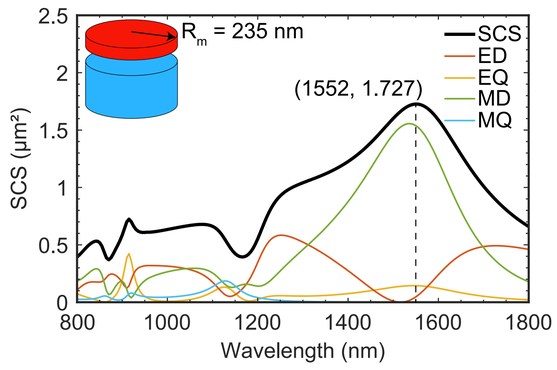


3 Multipole Analysis

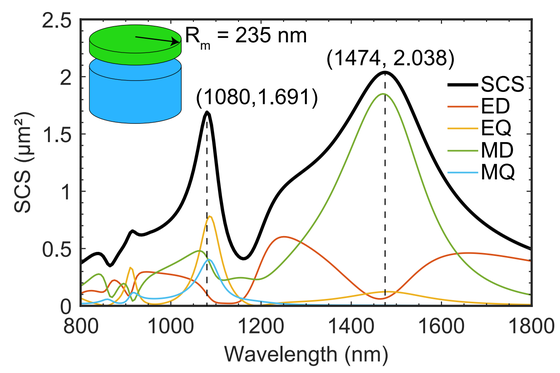
- Isolated metal disks responses:



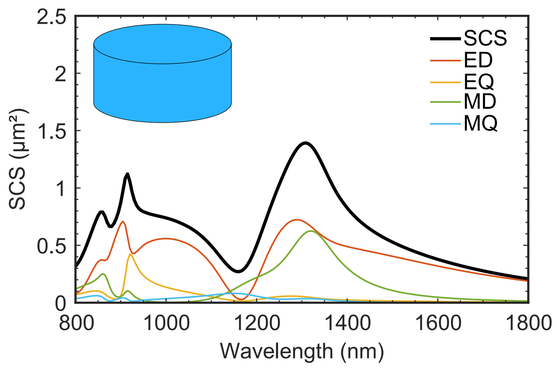
- Pt metal disk:



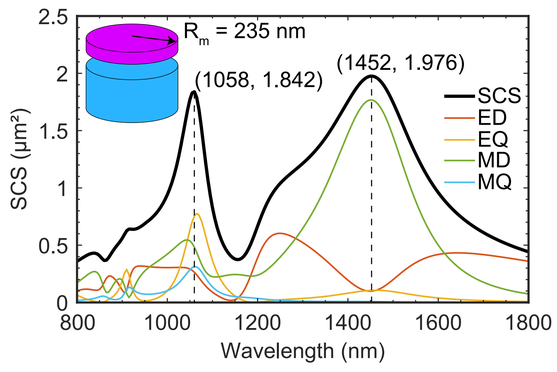
- Ag metal disk:

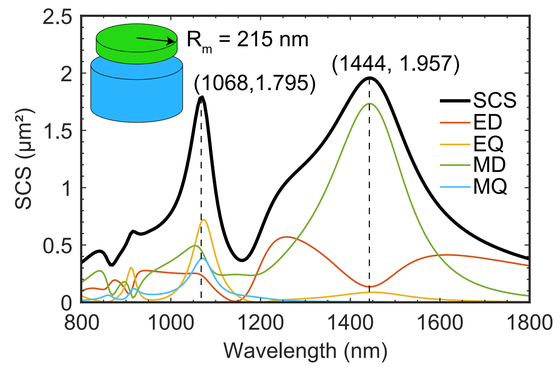


- Isolated aSi cylinder response:



- Al metal disk:

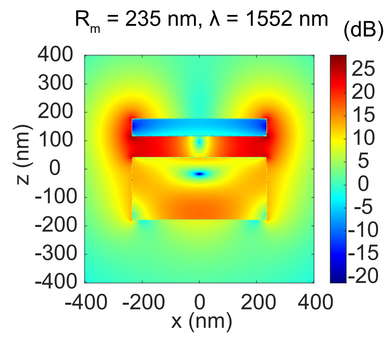




- The short wavelength resonance can be manipulated via the plasma frequency of the plasmonic metal (Drude model) and the radius of the disk.
- The long wavelength resonance is broad and more stable but with differences in amplitude, which depend on the aforementioned parameters.

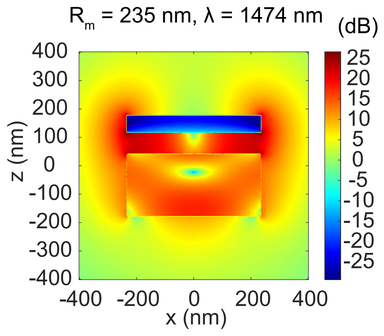
4 Scattered Electric Field Intensity

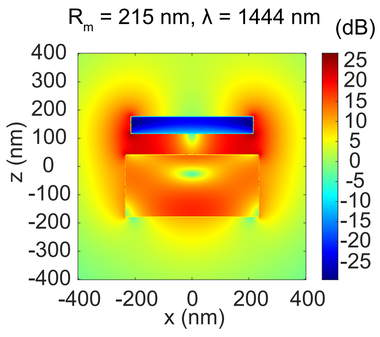
- Pt metal disk:

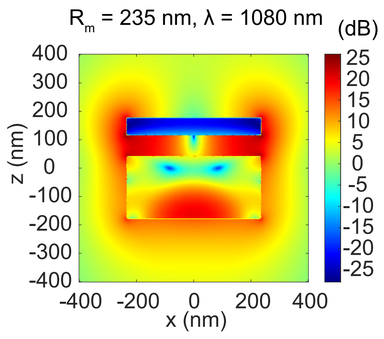


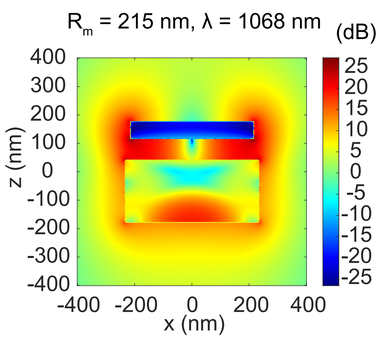
- At the short wavelength resonance, the distribution of the scattered electric field intensity inside the aSi cylinder is localized towards the bottom.
- Very strong scattered electric field intensity values are present around the adjacent edges of the plasmonic metal disk and the dielectric cylinder.

- Ag metal disk:

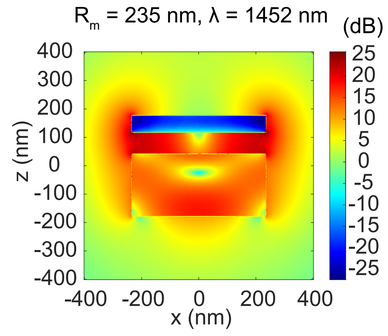


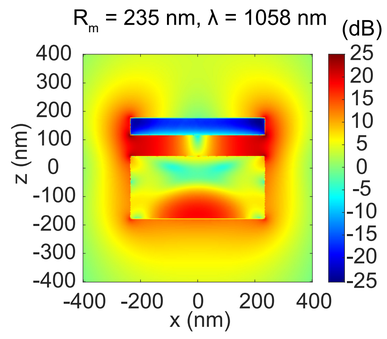






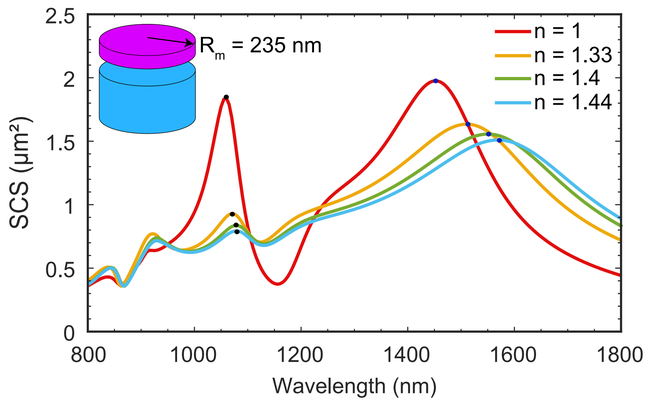
- Al metal disk:





5 Refractive Index Sensing

- Al-aSi cell response for different backgrounds



- Backgrounds:
  air (n = 1), water (n = 1.33), water with 42% mass glucose (n = 1.40), water with 60% mass glucose (n = 1.44).
- Short wavelength resonance:
  Sensitivity is equal to 175 nm/RIU.
- Long wavelength resonance:
  Sensitivity is equal to 620.45 nm/RIU.

6 References

[1] D. Ray, A. Kiselev, and O. J. F. Martin, “Multipolar scattering analysis of hybrid metal-dielectric nanostructures”, Opt. Express 29, 24056 (2021).

[2] D. Ray, T. V. Raziman, C. Santschi, D. Etezadi, H. Altug, and O. J. F. Martin, “Hybrid metal-dielectric metasurfaces for refractive index sensing”, Nano Lett. 20(12), 8752–8759 (2020).

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