Properties of resonant photonic lattices at the lattice-particle Mie scattering wavelength

Nasrin Razmjooei and Robert Magnusson*
Department of Electrical Engineering, University of Texas at Arlington, Arlington, Texas 76019, USA
**magnusson@uta.edu*

Abstract: We address differentiation of Mie resonance and guided-mode resonance in mediating perfect reflection by periodic particle assemblies. With clear examples, Mie scattering is precluded as the operative effect.
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1. Introduction

Resonant reflection by periodic structures has been known for decades. In the subwavelength regime, resonant reflection leads to perfect reflection as no radiated power resides in non-zero-order propagating waves. The physical cause of the resonance originates in lateral Bloch modes excited by evanescent diffraction orders [1-5]. A descriptive term summarizing the dominant physics is "guided-mode resonance (GMR)" which was coined 30 years ago [3]. Whereas perfectly reflecting periodic structures are indisputably operating under guided-mode resonance, in recent years an unfortunate misunderstanding has arisen where the perfect reflection observed with 1D and 2D metasurfaces is explained by Mie or Fabry-Perot (FP) resonance [6-8]. Here, we differentiate GMR and Mie scattering resonance. Related work was done by Ko et al. [9] in which perfect reflectance arose even though the Mie cavity was destroyed [9,10]. In the present contribution, the cavity is maintained.

2. Resonance properties of periodic arrays of cylindrical rods

We treat photonic lattices with cylindrical rods with two materials. Total scattering cross section (TSCS) of the single rod as well as the reflectance spectra of the periodic arrays are calculated. Example results are shown in Fig. 1. In Fig. 1(a), there are two resonances in the TSCS spectra which locate near λ=0.77 μm and λ=1.77 μm for both polarizations. Setting the period Λ = 1000 nm, we get resonance reflectance for the periodic rod array at λ=1.55 μm and λ=1.28 μm for TE and TM polarization, respectively, as shown in Fig 1(b). It is concluded from these two figures that the photonic lattice resonances have no correlation with Mie resonances in the isolated rods.

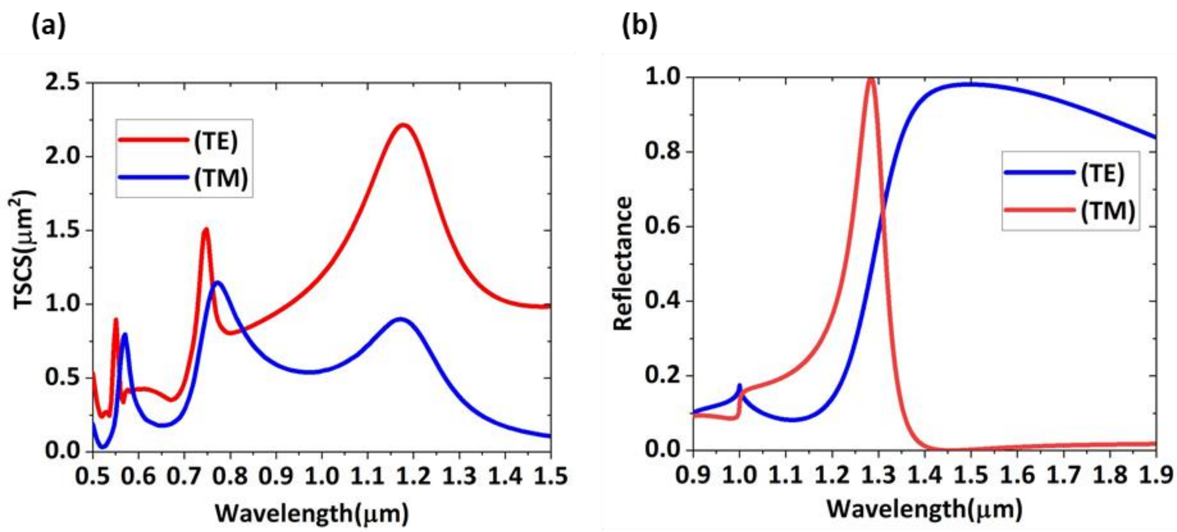

Fig 1. a) Total scattering cross section spectra of a single Si cylindrical rod with diameter D=250 nm and refractive index n=3.5. Mie resonances locate near λ=0.77 μm and λ=1.17 μm for both polarizations. b) Reflectance spectra for a 1D array of Si rods for a period of 1000 nm. Resonance peak for TE polarization is near λ=1.55 μm while for TM polarization it is at λ=1.28 μm.

We treat another example structure with Si_3N_4 rods with n=2. The TSCS spectra for the range of wavelengths of interest exhibit a Mie resonance at λ=0.63 μm for TE polarization and no Mie resonance for TM polarization as depicted in Fig 2 (a). Again, taking period Λ = 1000 nm, the periodic lattice with the new material exhibits perfect reflectance at λ=1.15 μm for TE polarization and λ=1.006 μm for TM polarization shown in Fig 2 (b). There is no correlation between the single-particle Mie spectra in Fig. 2(a) and the resonances in Fig. 2(b). The weakly modulated medium exhibits weak Mie scattering and yet produces resonance reflection of R=1.

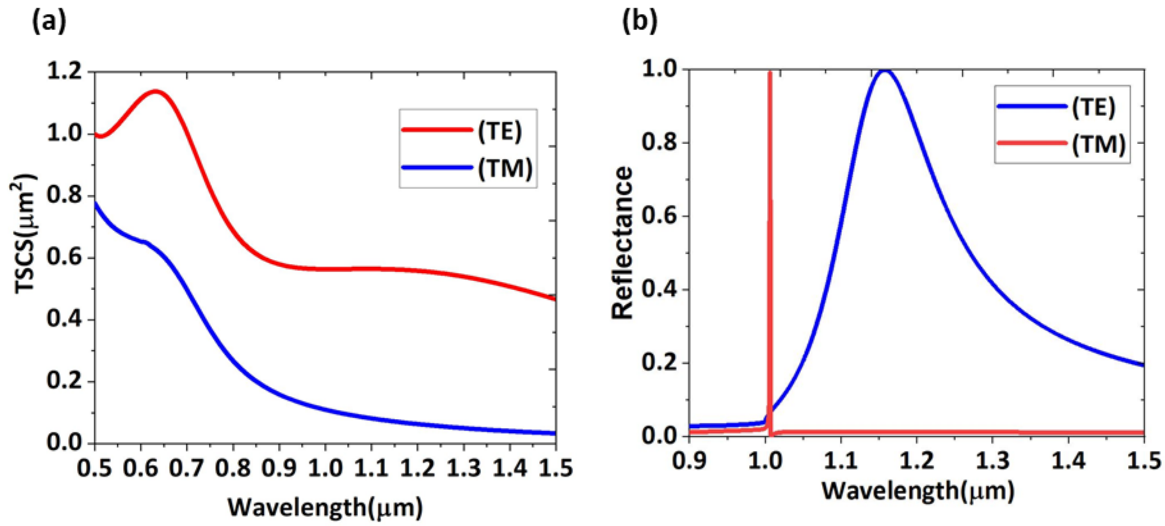

Fig. 2. a) TSCS spectra of an isolated Si_3N_4 cylindrical rod with D=250 nm showing a Mie resonance peak at λ=0.63 μm for TE polarization and no resonance for TM polarization. b) Peaks of reflectance for TE polarization at λ=1.15 μm and for TM polarization at λ=1.006 μm for a cylindrical Si_3N_4 array with Λ =1 μm and n=2.0

3. Conclusion

Perfect reflection exhibited by periodic photonic lattices is caused by the guided-mode resonance effect. This is due to lateral leaky Bloch modes excited by evanescent diffraction orders in the subwavelength regime. With simple examples, we show that localized Mie resonances do not govern the resonance properties of photonic lattices. In one case to be presented, the resonance can be tuned by the period to the lattice-particle Mie resonance wavelength; however, this has no effect on reflectance.

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4. References

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