

## Limits on Electromagnetic Scattering

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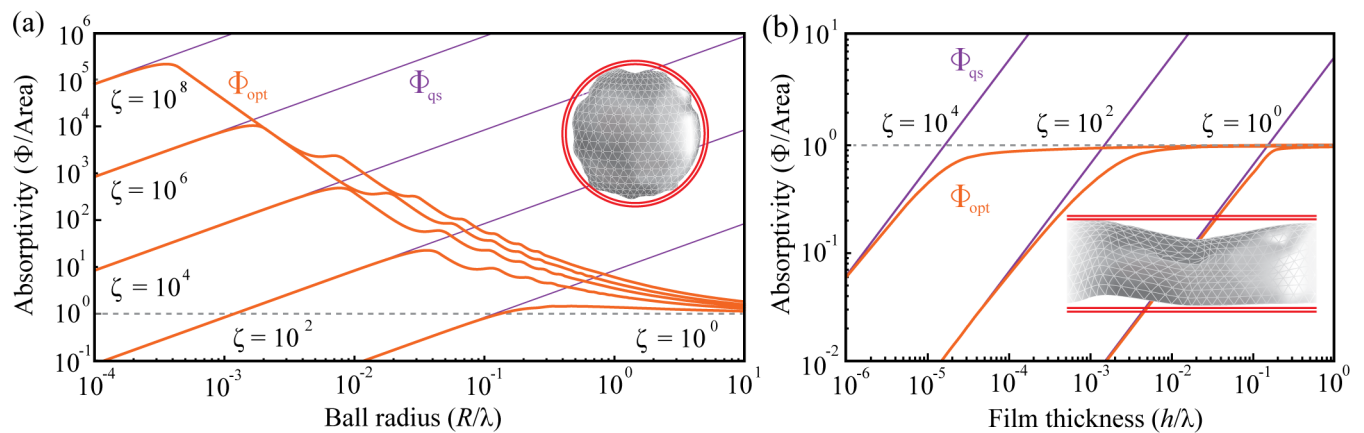
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### Abstract

Much of the continuing appeal and challenge of electromagnetism stems from the same root: given some desired objective (enhancing radiation from a quantum emitter, the field intensity in a photovoltaic cell, the radiative cross section of an antenna) subject to some physical constraints (material compatibility, fabrication tolerances, or system size) there is currently no method for finding or assessing uniquely best wave solutions. While improvements in nanofabrication and computational methods have driven dramatic progress in expanding the range of achievable optical characteristics, they have also greatly increased design complexity [1]. These developments have led to heightened relevance for the study of fundamental limits on optical response. Here, we review recent progress in our understanding of these limits with special focus on an emerging theoretical framework that combines computational optimization with conservation laws to yield physical limits capturing all relevant wave effects [2]. Results pertaining to canonical electromagnetic problems such as thermal emission (Fig. 1), scattering cross sections, Purcell enhancement, and power routing are presented.



**Fig. 1. Representative maximum scattering bounds for integrated absorption and incoherent emission.** Both panels display upper bounds on area-normalized absorptivity  $\Phi_{\text{opt}}$  (orange lines) for several values of the material efficacy figure of merit  $\zeta = |\chi|^2/\text{Im}[\chi]$  at a fixed wavelength  $\lambda$ . These quantities are shown as a function of the wavelength normalized radius  $R$  of an enclosing sphere (left) or thickness  $h$  of an enclosing slab (right).

### References

[1] Sean Molesky, Zin Lin, Alexander Y Piggott, Weiliang Jin, Jelena Vuckovic, and Alejandro W Rodriguez. Inverse design in nanophotonics. *Nature Photonics*, 12 (2018) pp. 659–670.

[2] Pengning Chao, Benjamin Streckha, Rodrick Kuate Defo, Sean Molesky, and Alejandro W. Rodriguez. Physical limits on electromagnetic response. *arXiv:2109.0566* (2021).