3rd URSI AT-AP-RASC, Gran Canaria, 29 May – 3 June 2022

Active scatterers with non-positive extinction cross section

Ari Sihvola*(1), Rashda Parveen(1)(2), Henrik Wallén(1), and Pasi Ylä-Oijala(1)
(1) Department of Electronics and Nanoengineering, School of Electrical Engineering, Aalto University, Finland
(2) Department of Electronics, Quaid-i-Azam University, Islamabad, Pakistan

This presentation discusses the electromagnetic response of isotropic spherical scatterers with active dielectric material response. A dielectrically active material means that the imaginary part of the relative permittivity ε'' is negative, using the notation for the permittivity $\varepsilon = \varepsilon' - \mathrm{j}\varepsilon''$ with the time-harmonic convention $\exp(\mathrm{j}\omega t)$ for temporal field variation. Using both analytical Mie scattering expansions and numerical surface-integral-equation computations, we can determine the scattering, absorption, and extinction cross sections of spherical scatterers with arbitrary material parameters and diameters (although computational expenses grow as the scatterer size increases).

Allowing scatterers to be active opens up interesting phenomena in their electromagnetic response. In [1], we have pointed out the enhanced backscattering effect that homogeneous dielectric scatterers composed of active material can display. In the present contribution, we will focus on the balance between the different cross sections of active scatterers.

For lossless dielectric materials, $\varepsilon'' = 0$. The absorption efficiency Q_{abs} for a sphere made of lossless material also vanishes, and the scattering and extinction efficiencies Q_{sca} and Q_{ext} are equal. This is a consequence of the fact that the extinction cross section of a scatterer amounts to the sum of scattering and absorption cross sections [2]. Lossy (dissipative) scatterers have $\varepsilon'' > 0$ in which case $Q_{\mathrm{abs}} > 0$ and $Q_{\mathrm{ext}} > Q_{\mathrm{sca}}$. However, for active scatterers, for which $\varepsilon'' < 0$, the balance between the efficiencies is more complicated: the absorption efficiency is negative while the scattering efficiency remains always positive. Depending on their relative amplitudes, the extinction efficiency Q_{ext} can be negative, positive, or zero. We define three classes of active objects: positive extinction (PEO), zero extinction (ZEO), and negative negative (NEO) objects. Figure 1 displays domains which these objects occupy in the parametric space of the scatterers and illustrates how the three scatterer types populate themselves into a fractal-like varying landscape.

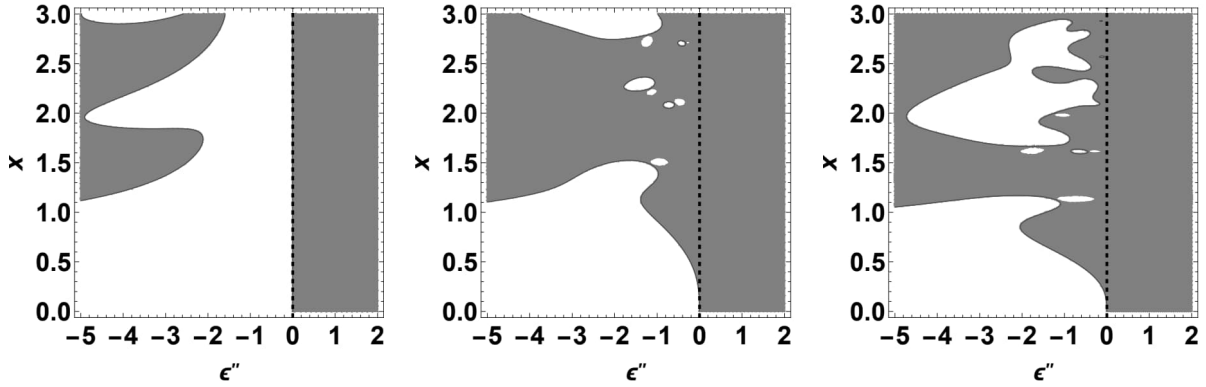

Figure 1. The sign of the extinction efficiency of dielectric spherical scatterers depicted as gray (PEO, $Q_{\mathrm{ext}} > 0$) and white (NEO, $Q_{\mathrm{ext}} < 0$) in the plane with axes of the imaginary part of the relative permittivity ε'' and the size parameter of the sphere x. The real part of the permittivity is different in the figures: $\varepsilon' = 1.1$ (left); $\varepsilon' = 4$ (center); $\varepsilon' = 7$ (right). Note the rich structure of extinction variation on the active side ($\varepsilon'' < 0$).

References

[1] A. Sihvola, R. Parveen, H. Wallén, and P. Ylä-Oijala, "Enhanced backscattering for dielectrically active scatterers," *Radio Science Letters*, 2021, to appear.

[2] C.F. Bohren and D.R. Huffman, *Absorption and Scattering of Light by Small Particles,* Wiley, New York, 1983.