Polarizability of a Spherical Particle in an Anisotropic Media

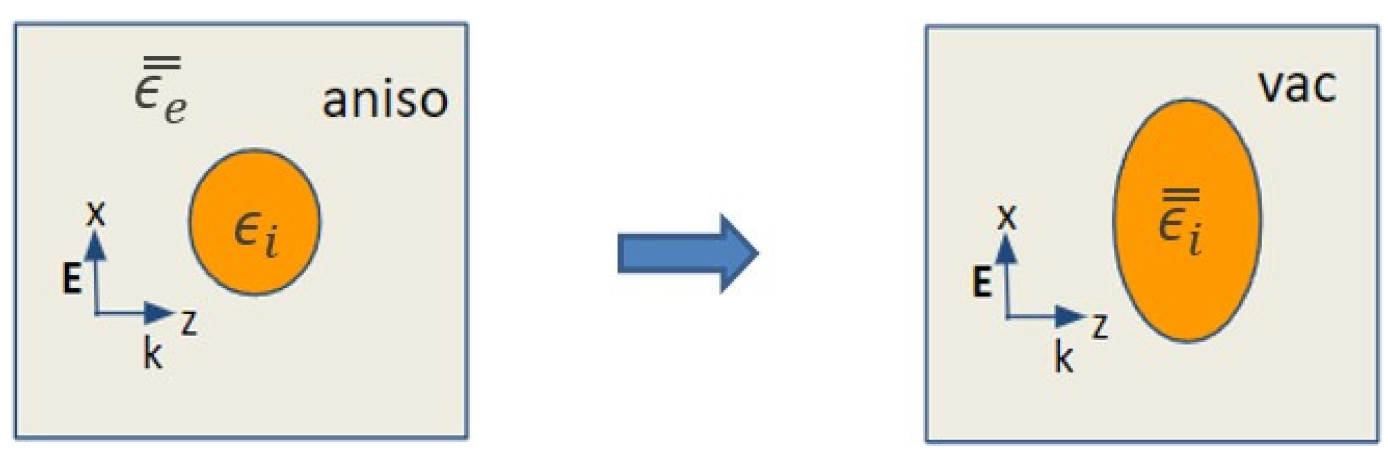
As a part of our primary research, we explore the phenomenon of non-radiative resonance energy transfer (RET) between a pair of dipoles positioned within a hyperbolic metamaterial (HMM). Our investigation reveals that the presence of an HMM can fundamentally alter these non-radiative dipole-dipole interactions, leading to strong coupling between the dipoles. Due to the anisotropic nature of HMM, it is crucial to obtain the correct expression for the polarizability of a finite sized particle placed within such a medium.

G. Bansode, K. Sasihithlu

Indian Institute of Technology Bombay, Powai, India

Introduction

A Sihvola showed that polarizability of a spherical particle in an anisotropic medium cannot be analytically determined without accounting for the depolarization effect caused by the ellipsoidal shape (see fig.2&3). In our study, we aim to demonstrate, through rigorous numerical simulations, that the effective medium approximation proposed by Sihvola provides a satisfactory estimation for this problem. To analyze this, we consider a gold (Au) nanosphere with a radius of 10 nm as a dipole emitter placed in an arbitrary anisotropic medium. By comparing the effective permittivity extracted from the simulations with analytically obtained results, we can assess the accuracy of the approximation.



Transformation of problem for isotropic spherical particle in an uniaxial anisotropic media

Extraction of effective permittivity of particle in a homogenous medium

RI seen from the incidence port → $n = \frac{1}{kd}\cos^{-1}\left[\frac{1}{2S_{21}}(1 - S_{11}^2 + S_{21}^2)\right]$

Impedance seen from the incidence port → $z = \sqrt{\frac{(1+S_{11})^2 - S_{21}^2}{(1-S_{11})^2 - S_{21}^2}}$

Symmetric configuration ⇒ $\epsilon_{eff,k} = \frac{n}{z}$

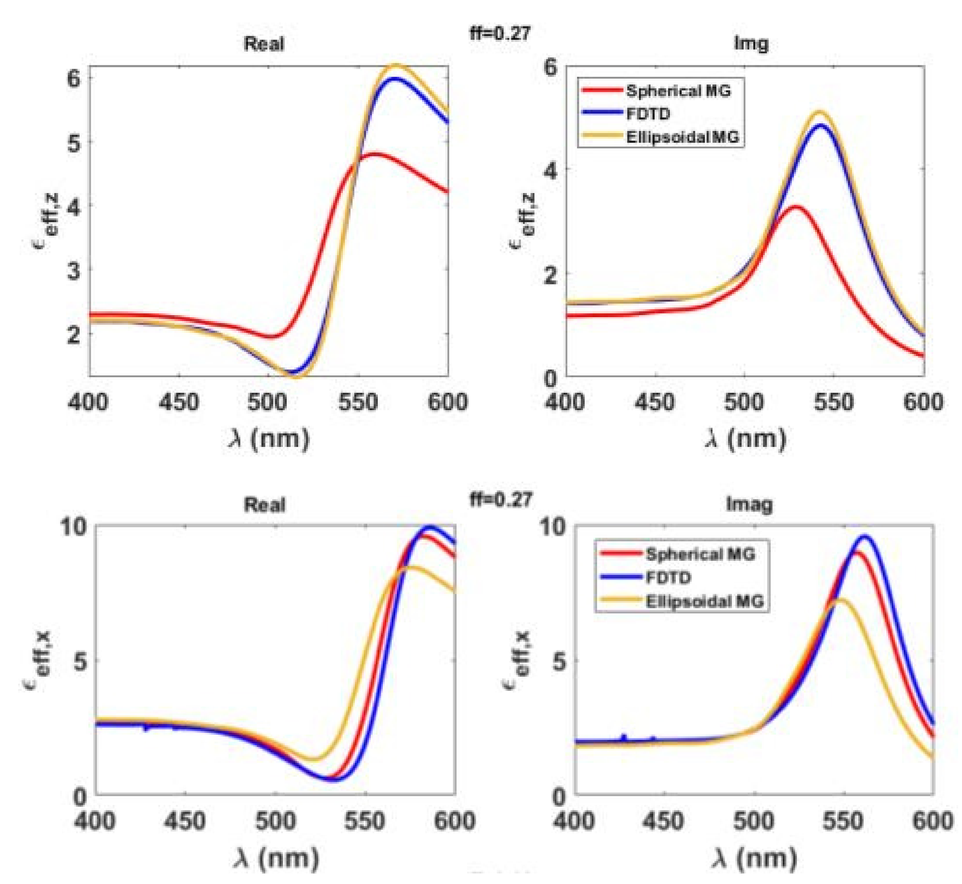
Results

The generalization of the Maxwell Garnett rule to the spherical isotropic mixtures in anisotropic follows:

$$\epsilon_{eff,z} = \epsilon_z + 3f(\epsilon_{Au} - \epsilon_z)\frac{\epsilon_z}{\epsilon_{Au} + 2\epsilon_z - f(\epsilon_{Au} - \epsilon_z)}$$

The generalization of the Maxwell Garnett rule to the spherical isotropic mixtures in anisotropic when ellipsoidal depolarization is considered follows:

$$\epsilon_{eff,z} = \epsilon_z + f(\epsilon_{Au} - \epsilon_z)\frac{\epsilon_z}{\epsilon_z + (1-f).N_z(\epsilon_{Au} - \epsilon_z)}$$



Effective permittivity component comparison for negative uniaxial anisotropic media

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