Scattering phases and its radiation distributions of nano-antennas in evanescent waves excitation

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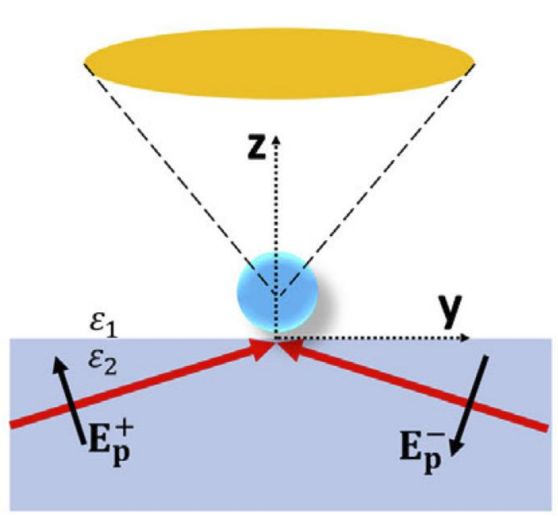
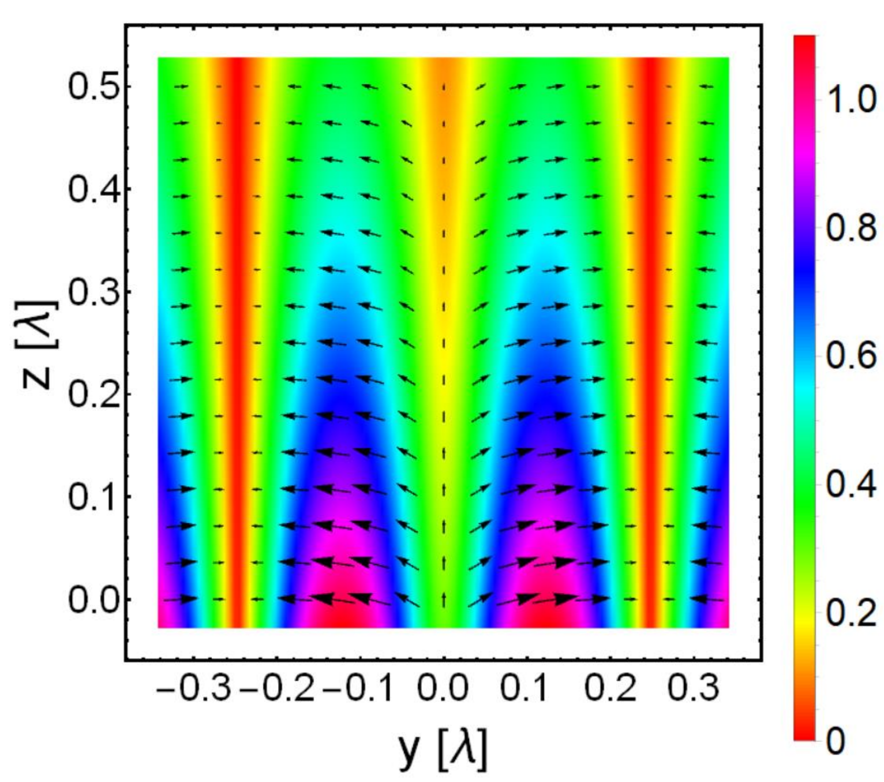
Abstract

Two counter-propagating evanescent waves could create an imaginary Poynting vector field, meaning no net energy transportation. However, there still have oscillating electric and magnetic fields, but with a phase difference. Complied with phase diagram of scattering coefficients for nanoantennas, we investigate general conditions to form a Fourier scattering zero in far-field regime. The phase and amplitude distributions can provide a means to excite various multipole mode resonances with different weights and phases relation, leading to kerker's conditions. Furthermore, we can mark the dark scattering signature to locate the position of nanoantennas in nano scale, overcoming diffraction limit.

Introduction

Evanescent wave is exploited to detect the position of nanoparticles by probe the differential scattering distribution
1.When the EM wave propagates from high refractive index to low one.
2.Snell's law could predict it.
3.No energy transport in less-dense refractive index as importing two counterpropagating waves! But there still has a electromagnetic field! Some kind of "optical tunneling"!





For two TM waves excitation, the total would be

$$\vec{H} = \hat{x} H_0 e^{-\gamma_z z}\{e^{i\frac{\Delta\phi}{2}} e^{ik_\parallel y} + C.C\} = \frac{2E_0}{Z_0} e^{-\gamma_z z}\cos[k_\parallel y + \frac{\Delta}{2}\phi]\hat{x}$$

$$\vec{E} = 2iE_0 e^{-\gamma_z z}\{-\hat{y}\frac{\gamma_z}{k_0}\cos[k_\parallel y + \frac{\Delta\phi}{2}] + \hat{z}\frac{k_\parallel}{k_0}\sin[k_\parallel y + \frac{\Delta\phi}{2}]\}$$

Energy transportation would be

$$\vec{S} = \frac{1}{2}\vec{E}\times\vec{H}^* = \frac{2iE_0^2}{Z_0} e^{-2\gamma_z z}\{\hat{z}\frac{\gamma_z}{2k_0}[1+\cos(2k_\parallel y + \Delta\phi)] + \hat{y}\frac{k_\parallel}{2k_0}\sin(2k_\parallel y + \Delta\phi)\}$$

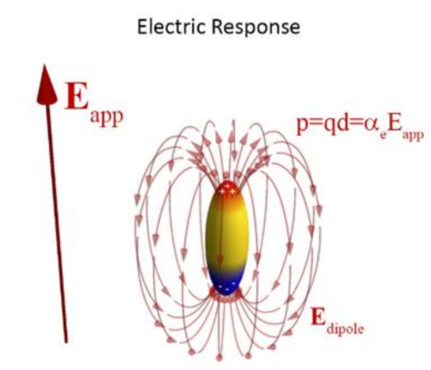
We find there would be no net energy transport.

Fermi-Golden rule to describe the interference between electric and magnetic dipoles

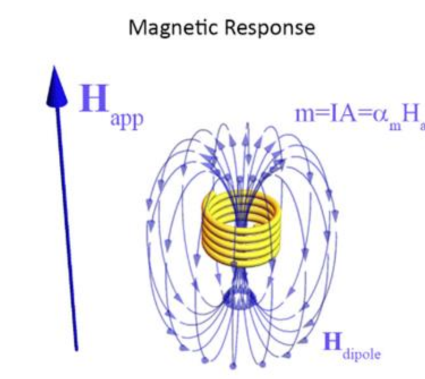
$$|\vec{p}^* \cdot \vec{E}_k + \mu_0 \vec{m}^* \cdot \vec{H}_k|^2$$

Nanoparticles support electric and magnetic resonances

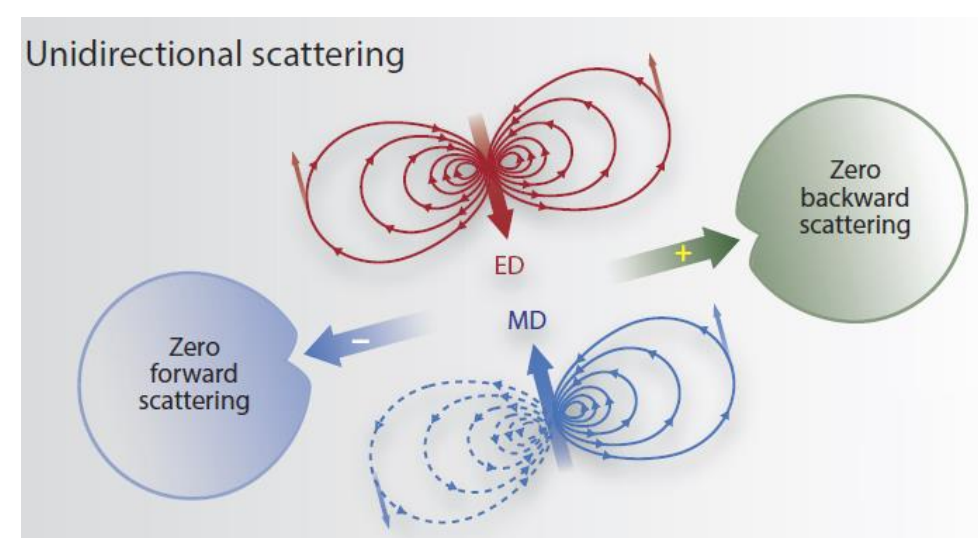
$$\vec{p} = \alpha_e \vec{E} \qquad \alpha_e = \frac{i6\pi\epsilon_0}{k_0^3} a_1$$



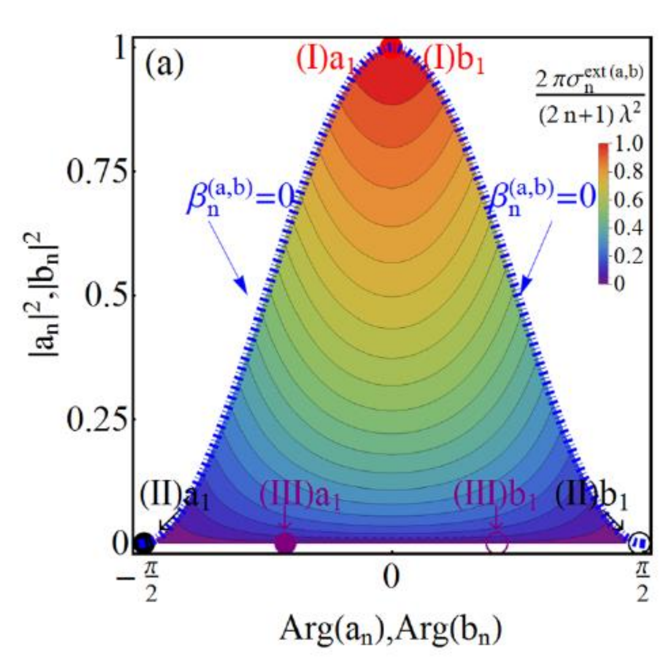
$$\vec{m} = \alpha_m \vec{H} \qquad \alpha_m = \frac{i6\pi}{k_0^3} b_1$$



[1]. Here a1 and b1 are Mie scattering coefficients for electric and magnetic responses. A nanoparticle supports electric and magnetic dipoles resonance would produce kerker's conditions as follows [2].



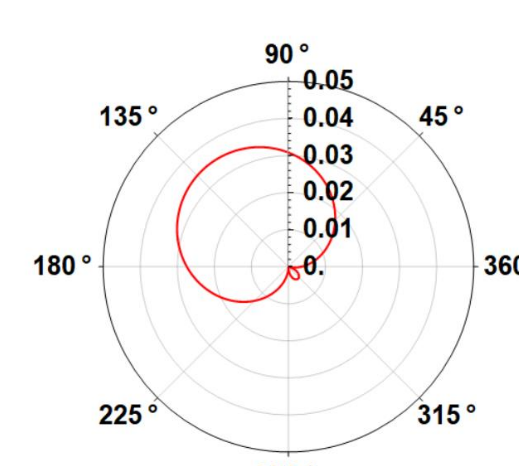
Complied with our developed phase diagram: energy conservation. So there has a constraint for a1 and b1 [3].

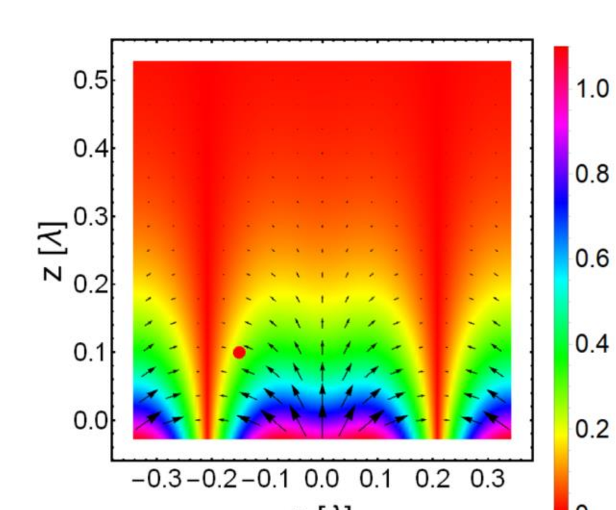


$$a_n = \frac{1}{1 + i(\alpha_n^a + i\beta_n^a)},$$

$$b_n = \frac{1}{1 + i(\alpha_n^b + i\beta_n^b)}.$$

$$a_1 = (-ik_0/\gamma_z) b_1$$





Conclusion

1.Structured wave provides a non-trivial electric and magnetic field distribution to affect the scattering responses.
2.By using phase diagram for scattering coefficients, we could find out all possible combination of electric and magnetic resonances to form a variety of kerker condition, which could not happened by conventional illumination.

Reference:
1.Phys. Rev. Lett. 84, 4184 (2000); App. Phys. Lett. 90, 263504 (2007).
2.Opt. Photonics News 28, 24 (2017).
3.Opt. Express 24, 6480 (2016).