Enhanced Interaction of Plasmonic Nanocylinders and Other Cylindrical Structures

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1. Introduction

Light scattering by two dimensional photonic crystal structures has been studied thoroughly using SMM (scattering matrix method) [1-2]. Periodic structures are also attracting attention [3-4]. With the development of nanoscience and nanotechnology, it becomes possible and important to investigate optical properties of nanoscaled objects. The enhancement of the near-field energy of a single plasmonic nanocylinder has been discussed in [5]. In this paper, we now study the interaction of a dielectric nanocylinder with an array of plasmonic nanocylinders; significantly enhanced energy intensity is observed. The total cross-section can also be enhanced greatly. This phenomenon happens when the incident wave is a TE-polarized plane wave. In this case, Rayleigh scattering for small arguments of the lossless scatterers cannot be used because it will theoretically allow a nanocylinder to have an infinitely large cross section which is known as the divergence problem. For low damping cases, the exact solutions, *i.e.*, Mie scattering theory should be applied to calculate the optical properties. Enhanced backscattering of a metallic nanocylinder with a random rough surface was studied using the method of stochastic functional approach [6].

2. Field Intensity Distribution of a Single Plasmonic Nanocylinder

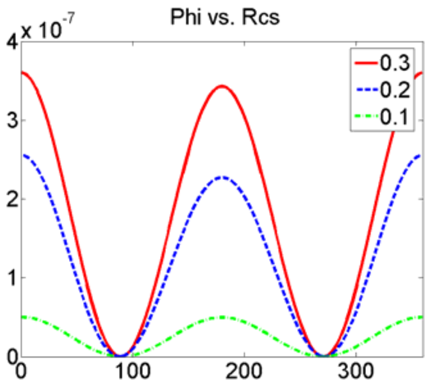
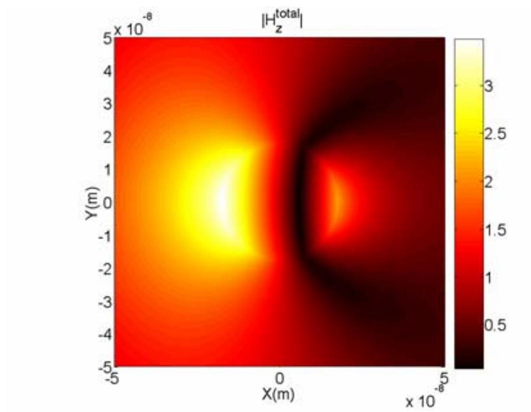


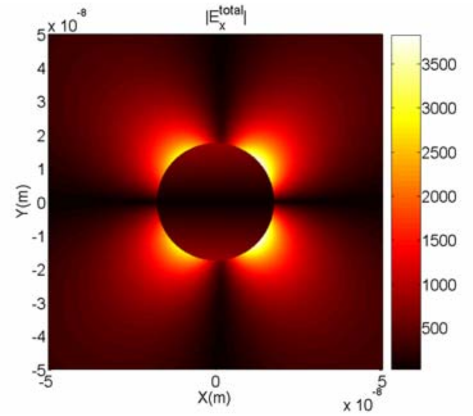
Fig. 1 Radar cross section of a single plasmonic nanocylinder with various electrical dimension *q*.

In Fig. 1, we plot the radar cross section of a single plasmonic nanocylinder with electrical dimension $q = 2\pi\, a/\lambda$ ranging from 0.1, 0.2 to 0.3 for the relative permittivity $\varepsilon_r = -1 + 0.1i$, where a is the radius of the nanocylinder and λ is the incident wavelength. It can be seen that the radar cross section increases with bigger q.

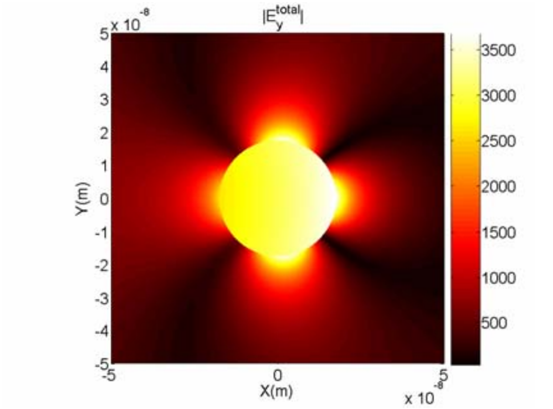
We show the electric and magnetic field distribution of a single plasmonic nanocylinder illuminated by TE plane wave from left hand side in Fig. 2. The incident wavelength is assumed to be 366nm and the radius of the nanocylinder is 17.5nm. As a result, the electrical dimension is $q = 0.3$. The relative permittivity of the nanocylinder is assumed to be $\varepsilon_r = -1.14 + 0.1i$ which is near the plasmon resonance. Silver has a relative permittivity that is close to this assumed value when the incident wavelength is 366nm according to Johnson and Christy [7]. In the four subfigures of Fig. 2, we show $|H_z^{total}|$, $|E_x^{total}|$, $|E_y^{total}|$ and $|E^{total}|$ of the plasmonic nanocylinder, respectively.



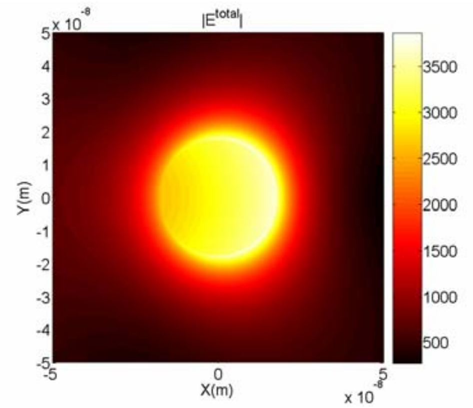
(a) $|H_z^{total}|$



(b) $|E_x^{total}|$



(c) $|E_y^{total}|$



(d) $|E^{total}|$

Fig. 2 Field distribution of a single plasmonic nanocylinder. Field units are normalized to the incident wave ($H_0 = 1$).

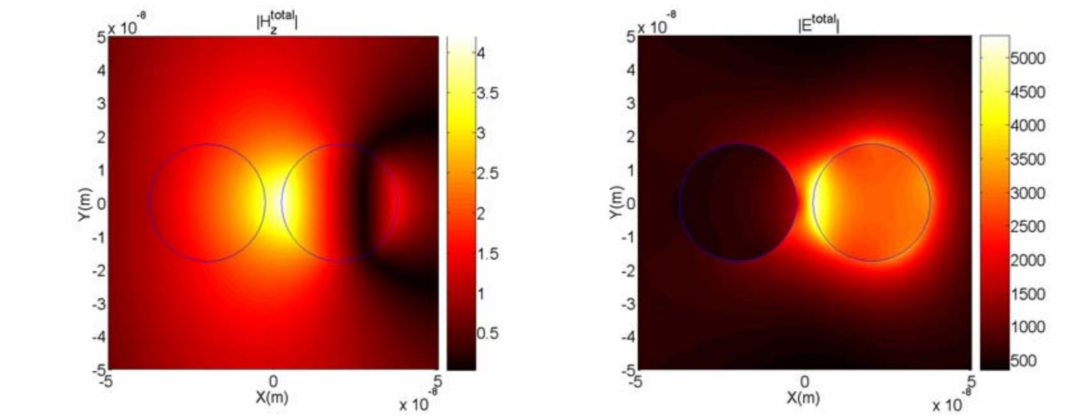
It is apparent that the near-field intensity can be enhanced greatly compared to the incident wave which has amplitude of $H_0 = 1$. This is also known as the surface plasmon resonance, where energy is the strongest.

3. Optical Interaction of Plasmonic Nanocylinders and Other Cylindrical Structures

From Fig. 2(a), we can see that the backscattering of the magnetic field is very strong. So in this section, we discuss the interaction of a normal nanocylinder with a plasmonic array of nanocylinders. In Fig. 3, we show the total magnetic and electric field distribution of a SiO_2 nanocylinder with a plasmonic nanocylinder. The radii of the two cylinders are 17.5nm and they are placed at (-20, 0) nm and (+20, 0) nm, respectively.

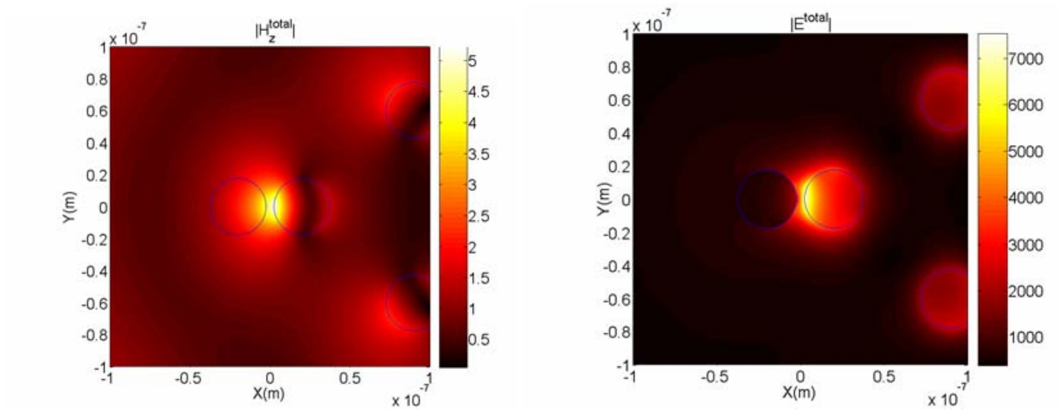
One can see that the interaction of the two nanocylinders is very strong. Using this method, we can increase the field intensity of normal materials. As shown in Fig. 4, we iteratively found that the structure of a normal nanocylinder with an array of plasmonic nanocylinders can strengthen the optical interaction significantly.

Three plasmonic nanocylinders are located at (+90, +60) nm, (+90, -60) nm and (+20, 0) nm. The greatest value of the total field intensity can be increased to more than a factor of 5.



(a) $|H_z^{total}|$ (b) $|E^{total}|$

Fig. 3 Total field distribution of two nanocylinders.



(a) $|H_z^{total}|$ (b) $|E^{total}|$

Fig. 4 Total field distribution of a normal nanocylinder with an array of plasmonic nanocylinders.

4. Conclusion

We have discussed the interaction of a normal (dielectric) nanocylinder with plasmonic nanocylinders. It is found that the near-field energy distribution near the normal nanocylinders can be enhanced greatly. This property can provide us some applications in surface cleaning, nanopatterning, biosensing and chemosensing.

References

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