Directional effects in the scattering produced by nanosystems with double negative optical properties

Braulio García-Cámara, José María Saiz, Francisco González, Fernando Moreno
Grupo de Óptica. Departamento de Física Aplicada. Universidad de Cantabria.
Avda de los Castros s/n 39005, Santander (SPAIN)
garciacb@unican.es

This research analyzes the directional scattering behaviour of systems formed by two or three nanoparticles with given optical properties (including non-conventional ones) as a function of the geometrical properties (distance and alignment of the particles on the system). This could be a first step to the design of systems with capabilities for guiding the light at the nanoscale.

Introduction

One of the important challenges in photonics is the possibility to govern the directionality of the light at nanoscales. The efficiency of some applications based on nanoparticles or nanostructures [1, 2] can be improved significantly if we are able to control the scattered light by them. We are talking, for example, about solar cells with very high efficiency or biomedical treatments that will be able to reach a certain area, more accurately, without danger in the surroundings.

This kind of features is closer with the recent studies on nanostructured metamaterials [3]. These researches are focused on producing nanomaterials with effective optical properties that can be chosen previously, including negative-negative values (left-handed materials). The election of the optical constants of the materials allows us to manipulate the scattering behaviour of those materials, and in particular the directionality of the scattered light. In this sense, Engheta [4] proposed a first design of light nanocircuits based on these nanostructured metamaterials.

Kerker et al [5] were pioneers in the study of the scattering behaviour of small spherical particles with whatever values of the optical properties. They demonstrated that, under certain conditions for the optical constants, dipole-like particles don't scatter light in the forward or backward direction. Recently, we have shown that those conditions can be generalized to finite-size particles (nanoparticles in the visible range) and to every scattering direction [5]. In this work we study systems of two or three particles with given optical properties in order to analyze the global scattering behaviour, searching this possibility to govern the directionality of the scattered light by the system.

Description of the system

We consider systems that are formed by two or three spherical particles with different orientations and distances between them. The size of the particles is in the range of 0.01 to 0.05 times the incident wavelength, that is, nanoparticles in the visible range. The optical properties (ε,μ) are in such a way that each particle either scatters mainly in one direction or doesn't scatters in other one. The efficiency of the system may be increased by introducing resonant conditions in the nanoparticles.

The scattering polar diagrams of these systems can be analyzed as a function of the optical or geometrical properties in search overall directional effects.

Results

As an example, in Fig. 1 we show the scattering diagram of two nanoparticles (*R=0.01λ*) at a distance equal to a half of the incident wavelength (λ/2) and with optical constants such as the left one doesn't scatter in the forward direction (ε=μ=–4.55) and the right one doesn't scatter in the backward direction (ε=–1.06, μ=–4.55). So, both particles scatter in the direction of the gap between them. The incident light is polarized perpendicular to the scattering plane and the particles are parallel to the incident direction.

References

[1] J.N. Anker, W.P. Hall, O. Lyandres, N.C. Shah J. Zhao and R.P. Van Duyne, Nat. Materials **7**, 442-453 (2008).
[2] K.R. Catchpole and A.Polman, Opt. Express **16**, 21793-21800 (2008)
[3] V. Shalaev, Nature Phot. **1**, 41-48 (2007)
[3] M. Kerker, D.-S. Wang and C.L. Giles, J. Opt. Soc. A. **73**, 765-767 (1983)
[4] B. García-Cámara, F. Moreno, F. González and J.M. Saiz, J. Quant. Spec. Rad. Trans. (submitted)
[5] N. Engheta, Science **317**, 1698-1702 (2007)

Figures:

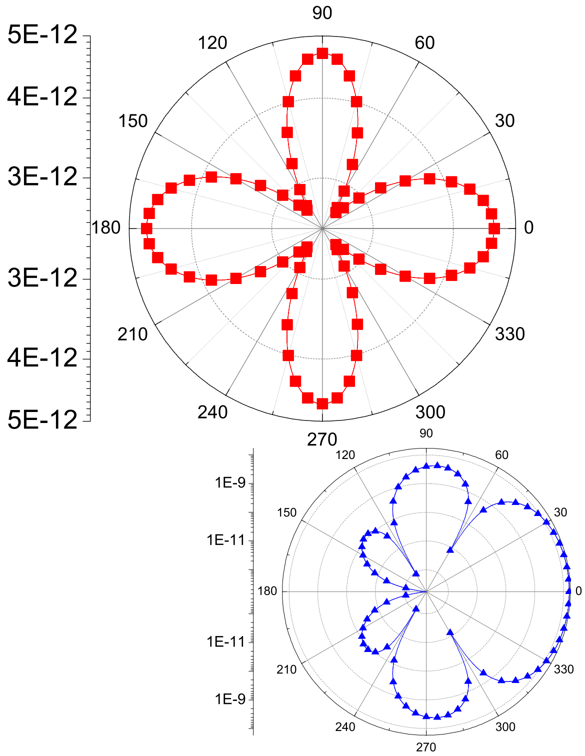

Fig.1. Scattering diagram of a system of two nanoparticles (R=0.01λ) parallel to the incident direction and separate a distance λ/2.The with chosen optical properties such as both scatter to the gap between them. A TE incident polarization is considered.