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Minimum Forward Light Scattering by Silicon nanopillars

J. F. Algorri[1*], R. Vergaz[1], A. Cuadrado[2], J. M. Sánchez-Pena[1], and B. García-Cámara[1]
[1] Group of Displays and Photonic Applications (GDAF-UC3M), Carlos III University of Madrid, Spain.
[2] Laser Processing Group, Instituto de Óptica, CSIC, C/Serrano 121, 28006 Madrid, Spain
[*]corresponding author: jalgorri@ing.uc3m.es

Abstract- In this paper, we demonstrate that for silicon nanopillars an optimum aspect ratio can be found, at which the overlapped electric and magnetic dipole resonances provide an optimized minimum forward scattering. This optimum shape depends on the aspect ratio, wavelength and refractive index of the surrounding medium. We work in the frame of numerical simulations based on Maxwell equations solved by finite element method. These results are promising for design and create novel flat optical devices.

Kerker's conditions were theoretically proposed for spherical particles in 1983 [1]. Two possible conditions were predicted, in this work the second condition (minimum forward) is sought. This condition appears when a constructive interference in the backscattering direction is produced while almost cancel each other in the forward direction. This theoretical work was experimentally demonstrated at micrometric wavelengths in 2012 [2] and at nanometric wavelengths in 2013 [3]. In addition, a significant greater overlap of the electric and magnetic-dipole resonances, and in consequence a higher forward scattering, can be realized if spheroidal [4] and disks [5] are considered. In this paper, we demonstrate that for silicon nanopillars also an optimum aspect ratio can be found for an enhanced forward scattering condition.

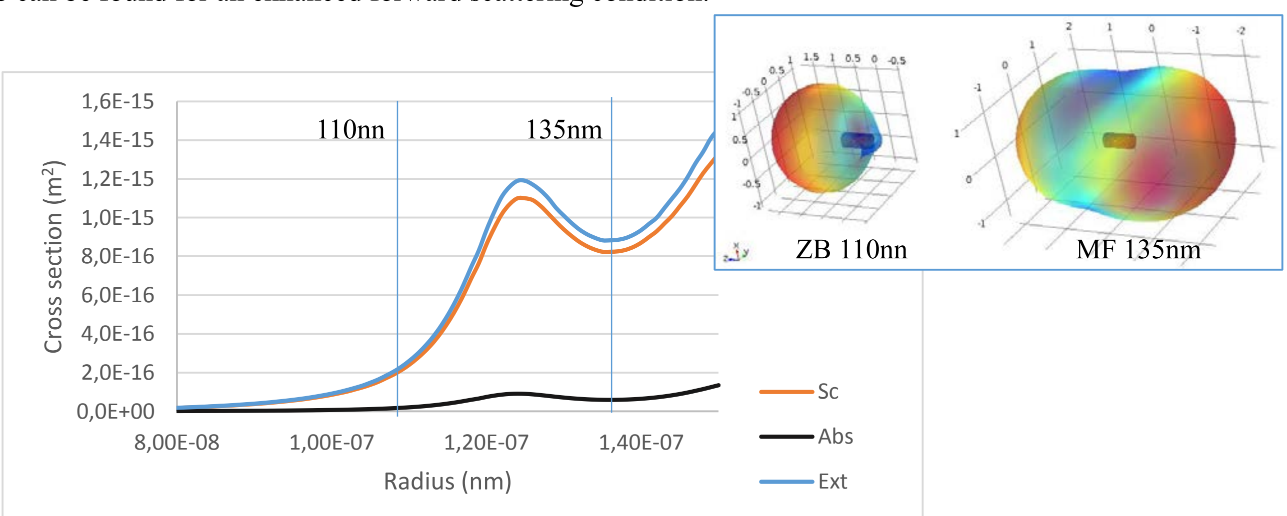

Figure 1. Extinction, scattering and absorption cross sections for a nanopillar with height of 480nm. The inset shows the far field scattering for two radius satisfying Kerker's conditions.

From this study, the forward condition can be easily extracted because it is produced when both dipolar contributions, electric and magnetic, intersect. Although there are several intersections, the minimum forward condition can be found at the minimum value between peaks (Fig. 1, R=135nm). For example, for a determined wavelength of 1250 nm the results are shown in Fig.1 (a). As can be observed, by studying the far field [Fig. 1 (b)] the intersection of both contributions produce a minimum forward scattering. By studying all of the scattering profiles for each height, radius and wavelengths, the minimum forward condition is extracted. The result is a graph at which all the relations can be observed (Fig. 2). A linear behavior is observed when the aspect ratio is of a nanopillar (height higher than diameter). Also, for this aspect ratio the minimum forward has a higher value.

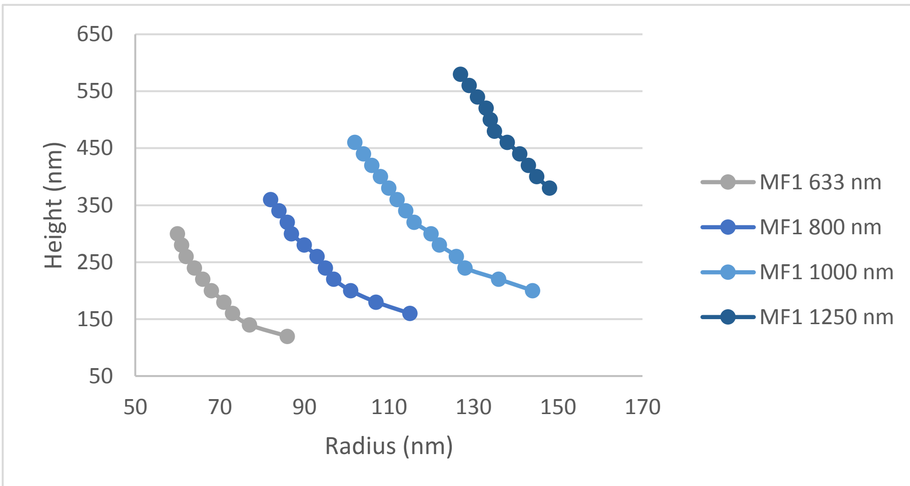

Figure 2. Parameters at which minimum zero forward condition is satisfied.

We have demonstrated that the use of Si nanopillars are easy to design due to a linear relation between the aspect ratio and the minimum forward condition. Moreover, a higher forward scattering than usual spherical nanoparticles can be obtained. These results are of great value in order to design very efficient, low-loss flat-optical devices.

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