FINITE SIZE EFFECTS ON THE OPTICAL RESONANCES OF NANOCYLINDER ARRAYS

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The study of light scattering from periodic structures has been a topic of interest during the last century. Already in 1902, Wood [1, 2] reported remarkable effects (known as Wood's anomalies) in the reflectance of one-dimensional (1D) metallic gratings. Two different types of anomalies were definitely identified by Fano [3]. One is associated to the discontinuous change of intensity along the spectrum at sharply defined frequencies and was already discussed by Rayleigh [4]. The other is related to a resonance effect. It occurs when the incoming wave couples with quasi-stationary waves confined in the grating. The nature of the confined waves depends on the details of the periodic structure [5] and is usually associated to surface Plasmon polaritons in shallow metallic gratings, standing waves in deep grating grooves [5] or guided modes in dielectric coated metallic gratings [6].

In an infinite array of sub-wavelenght cylinders, the coupling of the scattered dipolar field with diffraction modes may induce dramatic resonant effects close to the onset of new propagating modes even in absence of particle resonant modes, i.e. when the cross-section of a single non-resonant nanocylinder is extremely small [7].

As we can see in Fig. 1, at the lowest resonance frequency, and in the absence of absorption, the wave is perfectly reflected even for vanishingly small cylinder radii. These sharp resonances, so-called geometrical resonances, with typical Fano line shapes, present a strong dependence with the angle of incidence and could play an important role in the design of chemical and biological sensors. However, for practical applications, finite size effects must be considered.

Here we present a multiple scattering analysis of the reflectance of a finite array of sub-wavelength cylinders. The finite array, made of N parallel infinite cylinders separated by a distance d, is illuminated by a Gaussian beam of width W_0 ($W_0<N_d$). As we will show, the shape and strength of the resonance depend mainly on the width of the Gaussian beam (i.e. on the number of cylinders under illumination).

References

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Figures:

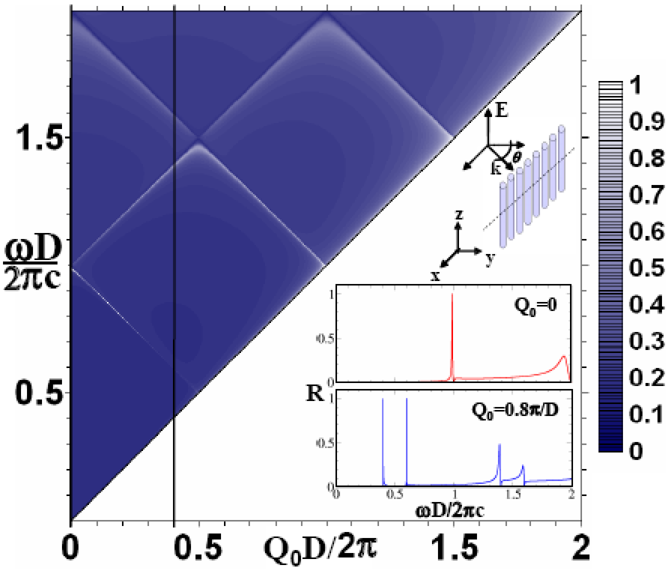

Fig. 1: (s-polarization) Reflectance of a infinite array of sub-wavelength cylinders in a frequency ω versus in-plane wave number Q_0 = (ω/c) sin(θ). The reflectance along the vertical lines is shown in the inset.

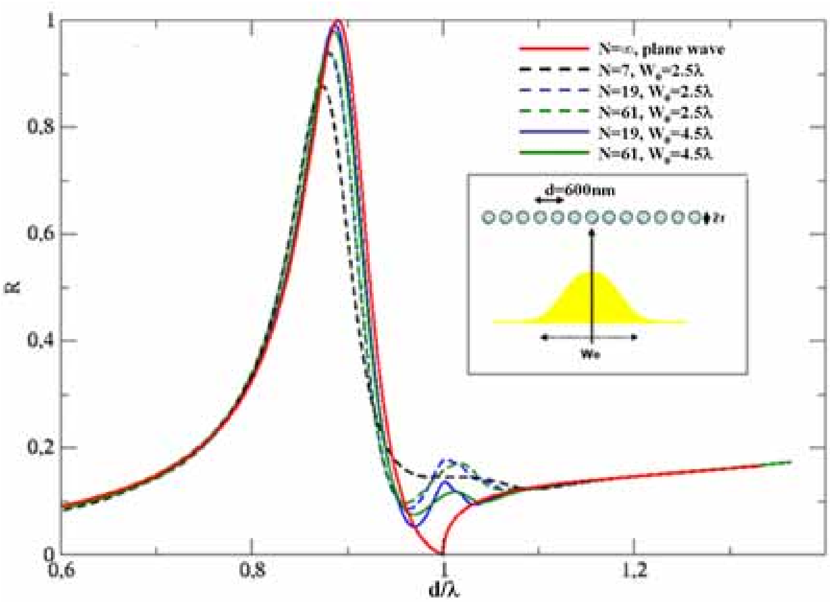

Fig. 2: Reflection coefficient for a set of parallel Si cylinders (ε=11.9, r=45nm) versus d/λ for different beam widths and cylinder numbers.