Enhanced transmission through nano-structured gratings: Compositional and geometrical effects

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Abstract

Since the pioneering works of Ebbesen [1], many studies have been dedicated to the enhanced transmission through subwavelength nano-structured gratings [2,3] (for a review, see [4]). This extraordinary transmission was primary based on the resonance of surface wave (plasmon) and Fabry-Perot resonance, phenomena inherently limited in terms of frequency. More recently, enhanced transmission has been reported over broadband frequency range at an optimal angle corresponding to the impedance matching between the host medium and the metallic grating [5-6], and this optimal angle is often called Brewster angle in this context. Although some studies have revealed the influence of the grating geometry [7,8], structural effects are in general disregarded. More generally, the grating are made of periodic metallic layers for which the controlling parameter is the filling fraction of the layers and the attempts to propose simple analytical results were limited to that case [6,9]. We show that the homogenization theory of layered media allows to describe acurately the observed transmission accounting for the compositional effects. This means that we consider finite values of the permittivity and magnetic materials (the metallic case being a limiting case), see Fig 1 and 2. Besides, applying a two step homogenization, inspired by [10], geometrical effects can be taken into account, beyond the simple influence of the filling fraction (Fig. 3 and 4). The versatility of our analytical prediction is exemplified and compared to direct numerical calculations. Our approach should allow to design nano-structured gratings with controlled transmission properties.

References

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Figures

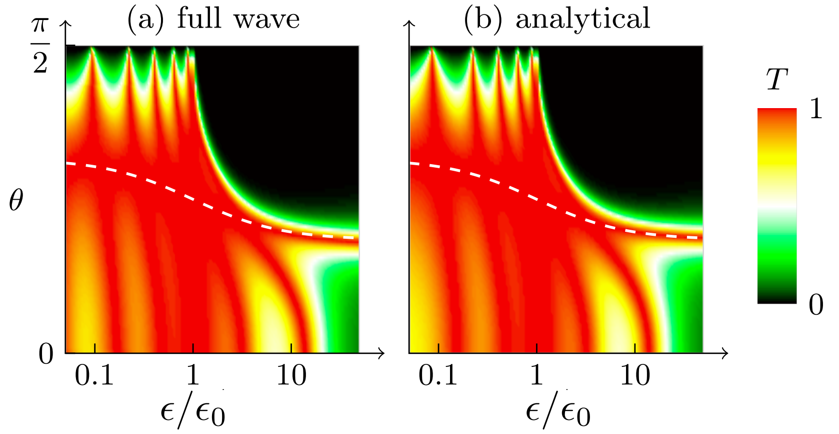

Fig. 1: Transmission spectrum function of the permittivity contrast and the incidence angle, θ. The grating thickness is shown on Fig. 2 and the frequency is kd = 0.5. (a) Full wave calculation, and (b) analytical result. The dashed line indicates the optimal angle.

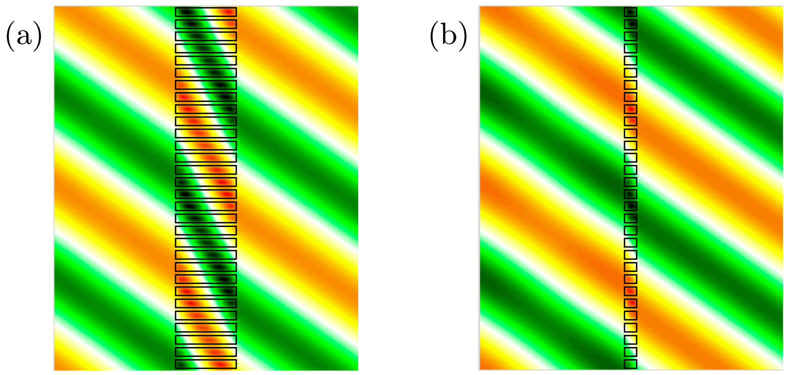

Fig. 2: Spatial distribution of the wave field (real part) at frequency kd = 1 in a SLG grating with filling fraction b = 0.7 and a contrast 50 (non magnetic material), at the optimal transmission angle, $\theta_{opt} \simeq 0.58$. The length of the grating is (a) l = 5d and (b) l = d, d being the grating period.

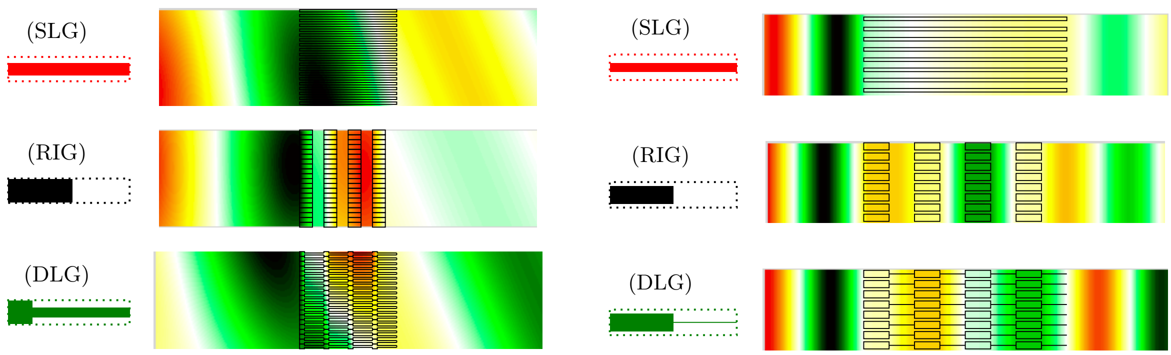

Fig. 3: Examples of the spatial distributions of the wave field (real part)

Left: Gratings are made of a sound hard material with the same filling fraction φ = 0.5 (the geometries of the unit cell are indicated on the left of the field pattern) at frequency kd = 1 and θ= 0.4.

Right: Gratings are made of a non magnetic material with the same filling fraction φ = 0.35 at f requency kd = 0.5 and θ= 0.

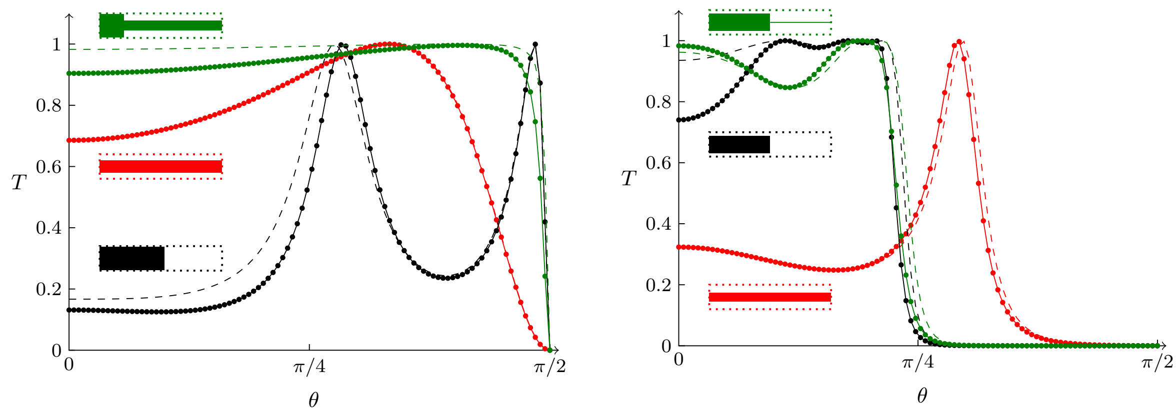

Fig. 4: Transmission as a function of the incidence angle θ (same grating as considered on Fig. 3). Plain line, full wave calculations and dashed lines, analytical predictions from the two step homogenization.