Amplifying the zero-th order mode absorption in the ultra-thin film regime

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Abstract

The homogenous slab system plays a central role in the design of opto-electronic devices, like for example solar cells, where the active region is constituted by a single layer. In the case of a slab comprising a non-dispersive material, the reflection and transmission spectra exhibit a series of maxima and minima which can be exactly described by the Fabry-Perot (FP) resonances. If the material presents losses, these are described by a complex refractive index. The absorption spectra result in a series of peaks, where their maxima are coincident with those of the transmission spectra. The exact position of this maxima is well predicted by the real part of the complex frequencies of the quasinormal modes.[1] It is possible to identify a maximum appearing at smaller frequencies than the fundamental FP mode, whose position has no correspondence with the real part of any quasinormal mode frequency, but with the imaginary part of the zero-frequency one (see Fig. 1). This is a consequence of its over-damped character, given that the real part is very close to the absolute zero frequency. The small frequency regime is equivalent to the ultra-thin film one, i.e. the wavelength is much larger than the thickness of the slab. Even at thicknesses of just a few nanometers, it is possible to observe an absorption peak at visible frequencies. If the surrounding refractive index is non-absorbing, the absorption of the zero-th FP mode amounts a 5% of the incoming light. However, if the layer sits on top of an absorbing substrate, the zero-th order mode red-shifts, increase its absorption and becomes a regular weakly damped resonance. This interpretation is compatible with the experimental observation of a peak in a 25 nm GaAs layer over a gold substrate [2] and in nanometer films of germanium also over a gold substrate [3].

References

[1] J. M. Llorens, J. Buencuerpo, and P. A. Postigo, “Absorption features of the zero frequency mode in an ultra-thin slab,” Appl. Phys. Lett. **105**, 231115 (2014).

[2] I. Massiot, N. Vandamme, N. Bardou, C. Dupuis, A. Lemaitre, J.-F. Guillemoles, and S. Collin, “Metal Nanogrid for Broadband Multiresonant Light-Harvesting in Ultrathin GaAs Layers,” ACS Photonics **1**, 878 (2014)

[3] M. A. Kats, R. Blanchard, P. Genevet, and F. Capasso, “Nanometre optical coatings based on strong interference effects in highly absorbing media,” Nat. Mater. **12**, 20 (2013)

Figures

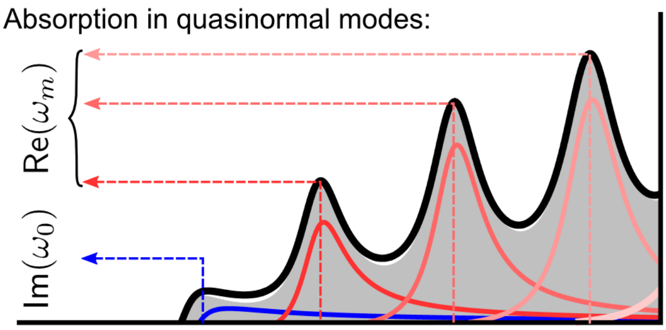

Fig. 1 Modal decomposition of the absorption spectrum of a non-dispersive homogeneous slab