Localized Extraordinary Optical Transmission of THz radiation through subwavelength apertures

S. Carretero-Palacios[1], Sergio G. Rodrigo[2], L. Martín-Moreno[1], F.J. García-Vidal[3]

[1]Instituto de Ciencia de Materiales de Aragón and Departamento de Física de la Materia Condensada, CSIC-Universidad de Zaragoza, E-50009 Zaragoza, Spain

[2]Institute of Optics, University of Rochester, Rochester, New York 14627, USA

[3]Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Madrid 28049, Spain
sol@unizar.es

Sub-wavelength apertures periodically arranged may transmit electromagnetic waves beyond the cut-off wavelength with a much higher intensity than if they were isolated. It has been established that resonant excitation of surface plasmons creates huge electric fields at the surface that force light through the holes, giving very high transmission coefficients. This is the so-called Extraordinary Optical Transmission [1].

We analyze theoretically resonances appearing at wavelengths beyond the cut-off of the holes [2], [3]. We name this phenomenon Localized Extraordinary Optical Transmission (LEOT). Interestingly, no surface modes are involved; therefore, the physical mechanism is valid for both single holes (SH) and hole arrays (2DHA).

In particular, we will give analytical expressions for the LEOT peak position as a function of the film thickness (h), and the dielectric constants of the environment (the cover, the substrate, and inside the holes, ε_1, ε_3, ε_2, respectively) for both symmetric ($\varepsilon_1 = \varepsilon_3$) and asymmetric ($\varepsilon_1 \neq \varepsilon_3$) configurations, for any hole shape of high aspect ratio (See Fig.1). Furthermore, the peak position is not the only spectral property affected by the dielectric environment, but also LEOT peak intensities are drastically modified.

These results explain the unexpected fact reported by some experiments in the THz regime about enhanced transmission [4] through isolated holes at wavelengths red-shifted from the cutoff wavelength.

References

[1] T. W. Ebbesen et al. Nature (London) 391, 667 (1998)

[2] A. Degiron et al., Opt. Commun 239 (2004)

[3] K. J. Klein Koerkamp et al., Physs. Rev. Lett. 92, 1839901 (2004)

[4] M. A. Seo et al., Opt. Express, 16, 20484, (2008)

Figures

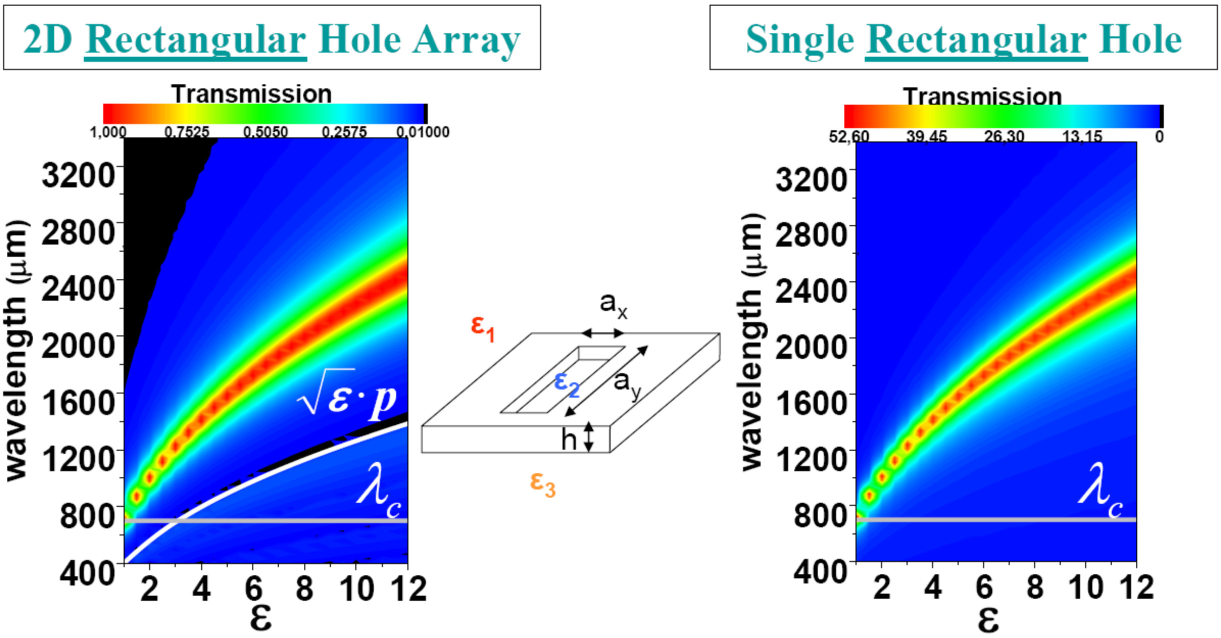

Fig.1. Transmission of light as a function of the wavelength and the dielectric constant ε, through a 2DHA with rectangular holes on it (left panel, P=400μm) and through an isolated rectangular hole (right panel) placed in a symmetric environment ($\varepsilon=\varepsilon_1=\varepsilon_3$). The film thickness is chosen to be h = 1μm, for the rectangular holes a_x = 10μm, a_y = 350μm, and ε_2 = 1.0. The horizontal grey line in both graphs depicts the cut-off wavelength of the holes, and the white line in the array corresponds to the Rayleigh condition.