Flat optics and generalized reflection and refraction laws

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We have recently proposed a structure that generalizes classical Snell and Fresnel laws, based on "phase discontinuities" [1]. The discontinuities in the wave propagation allow for the introduction of the idea of “flat optics”, a way to squeeze the thickness of optical devices by four orders of magnitude or more, with dramatic implications for mobile optical applications and for novel medical devices. I provide a newer outlook on this concept, from four basic, different, and complementary points of view, referred to classical Huygens, Fermat, Bragg, and Fresnel laws.
Generalized Fresnel coefficients can be formulated as the solution of a 1D equivalent circuit of a 3D flat optic device (Fig. 1). The tangential components of electromagnetic fields are not conserved across interfaces loaded with our structures.
The Bragg's approach [2] shows a generalization of the concept of “systematic absence”, a known effect of natural crystals. Here, a novel concept of "metacrystal" can be introduced, where systematic absences can be originated from form factors of meta-atoms (Fig. 2), in contrast with natural absences, which are based on geometrical structure factors only. Strategies for broadband operation will be presented. Implications in optomechanics will be discussed.
An update on applications, including vortex generators, polarizers and flat lenses, will be also presented [3].

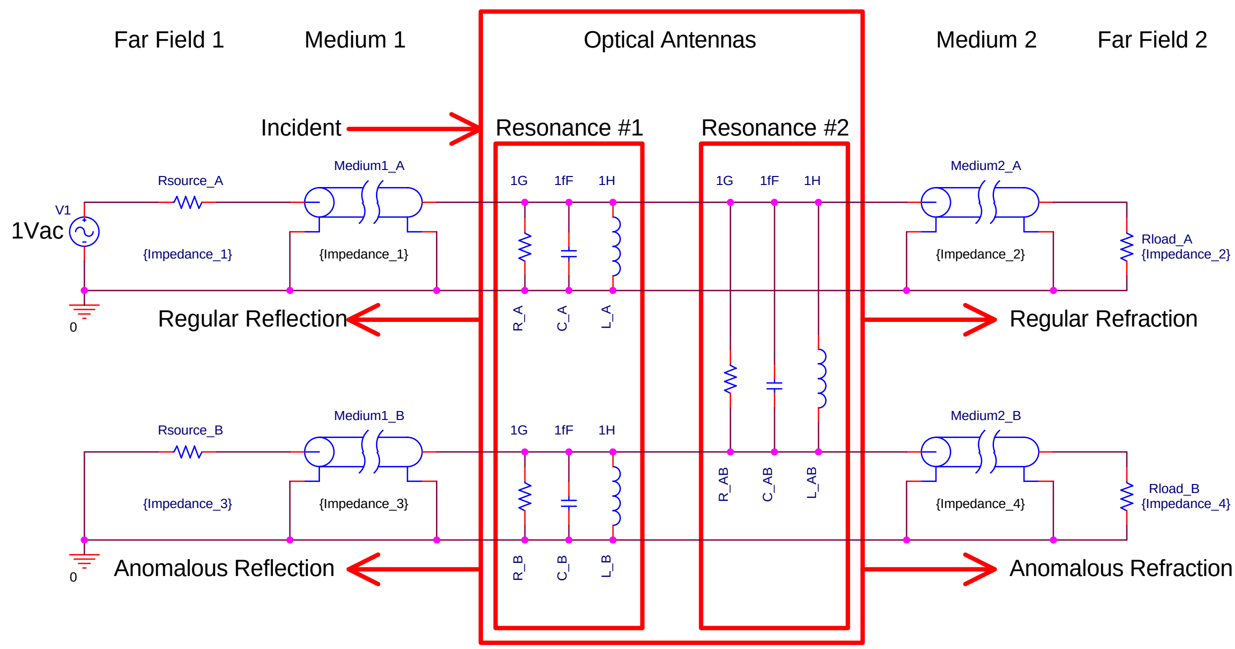

Fig. 1: Equivalent circuit, with coexisting lumped and distributed impedances, of the metainterface that generalizes reflection and Snell’s laws [1]. The figure is a snapshot from Spice, the well-known electronic simulator, which has been used to simulate the Fresnel coefficients (results are not shown here, but will be discussed in the presentation).

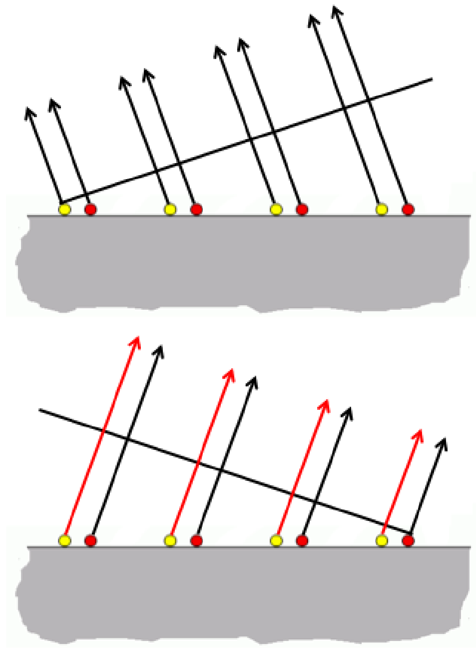

Fig. 2: Example of systematic absence due to form factor. Yellow and red dots represent simultaneously excited meta-atoms of a 1D crystal. Meta-atoms are designed in such a way that amplitude of scattered waves is the same for all meta-atoms, whereas phase response of red dots is ahead ¼ of time period from yellow dots. Red dots are displaced by ¼ of space period from yellow dots. Resulting interference of first Bragg order is fully constructive to the left (top panel) and fully destructive to the right (bottom panel). Hence, this structure provides a net photonic momentum as a collective interference effect.

References:

[1] N. Yu *et al.*, *Science* **334**, 333 (2011).
[2] S. Larouche and D. R. Smith, *Optics Letters* **37**, 2391 (2012).
[3] P. Genevet *et al.*, *Appl. Phys. Lett.* **100**, 13101 (2012); F. Aieta *et al.*, *NanoLetters* **12**, 1702 (2012); N. Yu *et al.*, *Nanoletters* **12**, 6328 (2012).