An open rectangular dielectric optical cavity with unlimited Q

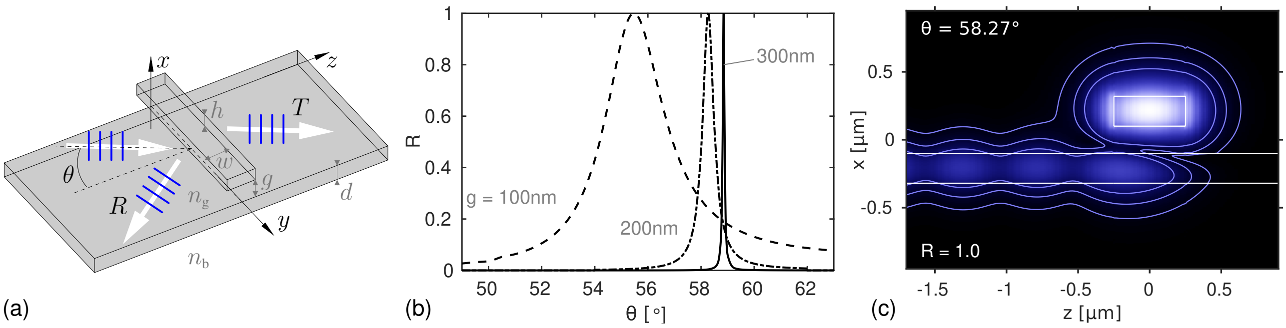
Manfred Hammer *, Lena Ebers, Jens Förstner

Theoretical Electrical Engineering, Paderborn University, Paderborn, Germany
* *manfred.hammer@uni-paderborn.de*

Transmission resonances of unlimited quality can be observed in a 2.5-D system where a dielectric strip is excited by semi-guided optical waves at oblique angles of incidence. In a limit of small interaction strength at large gaps between strip and slab, angular and wavelength spectra show fully formed resonances of zero width.

Oblique evanescent excitation of a dielectric strip

Open dielectric optical cavities are always deemed to be inherently lossy. Even in a limit of weak excitation, these inherent losses establish an upper bound to their quality factors (Q-factors). Specifically we look at a dielectric cavity of rectangular shape, such as the resonator device outlined in part (a) of the figure. If considered in a standard 2-D setting, i.e. for normal excitation at angle $\theta = 0$, specific dimensioning of the cavity is required to obtain resonators of tolerable quality. We shall reason in this contribution [1] that the cavity with our — rather arbitrary — parameters supports resonant states of in fact *infinite* Q, in the form of the guided modes of the dielectric strip. Merely a change in excitation conditions is required: We reconsider the resonator device in a "2.5-D" setting, with excitation of the strip by vertically (x-) guided, laterally (y, z-) nonlocalized waves at oblique angles of incidence θ. Radiation losses are suppressed for incidence above a certain critical angle, such that transmittance T and reflectance R total to 100%. Scans (b) over θ then reveal fully formed resonant states (c) with unit reflectance. For growing gap g, the angular width of these resonances decreases, accompanied by an increasing relative intensity in the strip region, while the resonance position approaches the angle associated with the guided mode of the isolated strip. Analogous features can be observed if, for fixed angle of incidence, one varies the frequency of the incoming wave.



Evanescent excitation (a) of a dielectric strip at incidence angle θ. Parameters: $n_g = 3.45$, $n_b = 1.45$, $d = h = 0.22\,\mu$m, $w = 0.5\,\mu$m; incoming TE waves at wavelength $\lambda = 1.55\,\mu$m. (b): Reflectance R versus angle of incidence θ, for varying gaps g; $R + T = 1$ for $\theta > 46.3°$. (c): Resonance for $g = 200$ nm, absolute electric field $|\boldsymbol{E}|$ on the x-z-plane.

Bound state coupled to the continuum

In a setting with fixed angle θ and variable frequency, at *large* g, this would be a system with a nonradiating bound state (the rib mode) and a wave continuum (the waves in the slab) in a range of frequencies that cover the eigenfrequency of the bound state. Hence one might argue that this is an explicitly simple way to approach what has been termed a "bound state in the continuum" (BIC).

References

[1] M. Hammer, L. Ebers, and J. Förstner. Oblique evanescent excitation of a dielectric strip: A model resonator with an open optical cavity of unlimited Q. *Optics Express*, accepted for publication, 2019.