Resonant states and Q-factors of whispering-gallery-mode dielectric microdisk cavities for lasing applications

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In the present paper we develop a new, computationally effective, and numerically stable approach for calculation of resonant states and Q-factors of a two-dimensional dielectric cavity based on the scattering matrix (S-matrix) technique that is capable to deal with both arbitrary complex geometry and inhomogeneous refraction index inside the cavity [1].

We apply the developed algorithm to the calculation of resonant states and Q-values of nonideal microdisk cavities with (a) side wall imperfections and (b) circular cavities with inhomogeneous refraction index $n = n(r, \varphi)$ [1,2]. We find that the surface roughness Δr and refraction index inhomogeneity Δn that produce similar degradation of low-Q states, cause strikingly different effect on high-Q resonances. In particularly, in the case of inhomogeneous refraction index the variation of Δn causes graduate and rather slow decrease of the high-Q resonances (the same as in the case of low-Q resonances). In contrast, in the presence of surface roughness even small imperfections ($\Delta r \lesssim \lambda/30$) can lead to a drastic degradation of high-Q cavity modes by many orders of magnitude.

In order to understand these features, we combine Poincaré surface of section and Husimi function methods with an analysis of ray reflection at a curved dielectric interface. We argue that the main mechanism responsible for the rapid degradation of high-Q resonances in non-ideal cavities with the surface roughness is the enhanced radiative decay through the curved surface because the effective local radius (given by the surface roughness) is smaller that the disk radius R. In contrast, the degradation of low-Q resonances (as well as high-Q resonances in the case of inhomogeneous refraction index only), is mostly related to the broadening of the phase space caused by the transition to the chaotic dynamics.

[1] A. I. Rahachou and I. V. Zozoulenko, "*Scattering matrix approach to the resonant states and Q-values of microdisk cavities*", arXiv:physics/0307024

[2] A. I. Rahachou and I. V. Zozoulenko, "*Effects of boundary roughness on a Q-factor of whispering-gallery-mode lasing microdisk cavities*", arXiv:physics/0305111