New sensing scheme in a microresonator-waveguide system using multiple critical coupling

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Abstract

Owing to their large Q factor and tight dielectric confinement, dielectric resonators like micros-spheres and micro-rings have emerged as useful devices to study nonlinear effects, bio-sensing, cavity electrodynamics, quantum optics etc.

The most efficient and practical way to excite the resonances of these resonators is to couple them with a waveguide. The coupling between an external waveguide and a resonator has both been studied theoretically and demonstrated experimentally. In this context, critical coupling refers to the situation where all the optical power injected in the waveguide can be dissipated by the resonator. In such a situation, the transmission of the waveguide coupled to the resonator vanishes when the injected wave is at resonance with the microresonator: $T(\omega) = 0,\ \omega = \omega_R$.

Recently, it was demonstrated that when the waveguide is buried under the microresonator, multiple critical coupling configurations can exist [1,2]. However, until now, it was believed that such an exotic situation can only happen when the resonator and the waveguide lie in different planes.

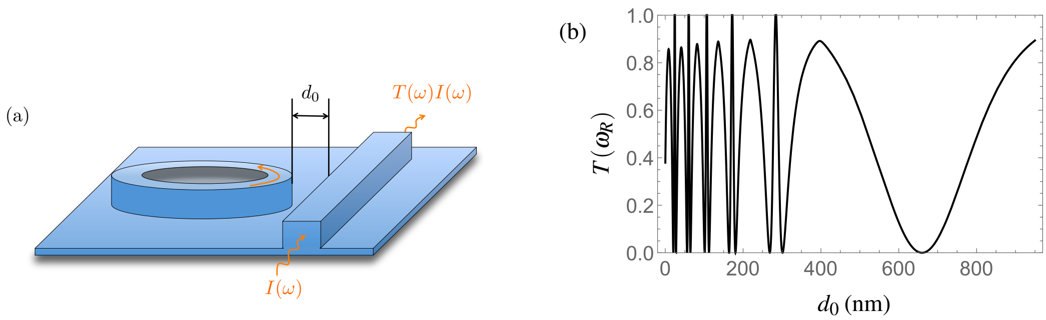

FIG. 1: *(a) Schematic of the waveguide-resonator system. (b) Transmittance at resonance* ($\omega = \omega_R$) *as a function of coupling distance* d_0 *for a 300* μ*m-radius silicon (refractive index=1.65) ring coupled to a ridge waveguide on a* SiO_2 *substrate (refractive index=1.45). Microring and waveguide width:* $w = 300$ *nm. Height: 500 nm. Base height: 100 nm.* $Q = 3.2\times10^5$, $\lambda \approx 1.0\mu m$, $|\tilde{\alpha}| = 0.97$.

Here, we demonstrate that multiple critical coupling configurations can exist even when the microresonator is side-coupled to a waveguide (as shown in Fig.1). The only requirement for multiple criticality is that the radius of the resonator is bigger than a minimum value R_{min}. *The value of the* R_{min} *depends on the resonance wavelength and the geometric parameters. Once* $R > R_{min}$, *multiple critical coupling configurations, parameterised by the separation* d_0, *exist. Such a situation is depicted in Fig. 1, where the usual critical coupling distance* $d_0 \approx 700nm$ *is complemented with a number of new critical coupling configurations in the range* $0 \le d_0 \le 300nm$. *Note that the new critical coupling configurations come in pairs and* $T(\omega_R)$ *varies more and more rapidly with* d_0 *as* $d_0 \to 0$.

These sharp features in the vicinity of secondary or higher-order critical coupling can be exploited as the basis of a new detection principle: any change in the environment (cladding refractive index) leads to a change in effective d_0 *and consequently, yields a large change in* $T(\omega_R)$. *Instead of monitoring the spectral shift of the resonances (as in the conventional sensing scheme), here, we monitor the change in the transmittance dip* $T(\omega_R)$ *as the refractive index is changed and evaluate the limit of detection (LOD). We find that the LOD improves with the order of critical coupling, i.e. for smaller* d_0.

References

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