Numerical Approaches to Modeling of WGM Resonator and Waveguide Coupling

N. M. Kondratiev[1]

[1]Russian Quantum Center (RQC), Skolkovo, Moscow, Russia

Abstract

Whispering-gallery mode resonators (WGR) are promising elements for future photonic devices, as they combine ultra-high quality factor with small size and mode volume. Many practical applications of such microresonators, such as ultra-sensitive chemical and biological sensors [1] electro-optical modulators [2], [3] and receivers [4], optoelectronic oscillators [5], and optical Kerr comb generators [6] attract growing attention. They are also widely used in fundamental high-precision experiments like in quantum optomechanics [7], [8].

The crucial point in experimental usage of the WGM resonators is coupling to the rest optical cirquit. The mos common prism coupler is very robust, but uses free space optics, which is rather bulky. The more promissing method, employing waveguides [9], however, may require careful shape design, requiring numerical modeling. Furthermore, while for big crystalline WGR the coupling can be usually adjusted during experiment, the integral chip resonators are usually fabricated rigidly together with the coupler.

In this work several modelling methods are implemented and tested in COMSOL Multiphysics® software for both discs and microrings:
1) Direct computation of system transmittance (in 2D) to extract the coupling from the resonance curves.
2) Partial computation of system transmittance (in 2D) with 4 ports
3) Modal analysis of the cross-section for quasi-analytical approach, similar to [9]
4) Analytical approach with overlap integral calculation [10]

The results of first three methods are found to be in good agreement with each other, while the last method was found to be unable to reproduce the beating effect [9]. It should be noted though, that the third method has an interaction length parameter, that is not well-defined. It is shown that the exact effective refractive index matching is not necessary for good coupling for heigh enough internal quality factor of the WGR.

References

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Figures used in the abstract

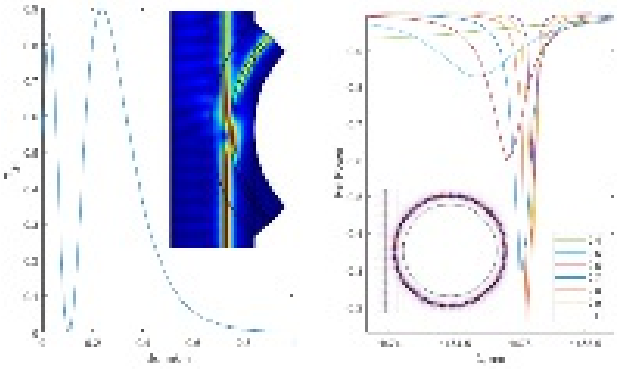

Figure 1: Left: Coupling coefficient and 4-port scheme. Right: full model and resonance curves.