Numerical Approaches to Modeling of WGM Resonator and Waveguide Coupling

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INTRODUCTION: 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. The crucial point in experimental usage of the WGM resonators is coupling to the rest optical circuit. The most common prism coupler is very robust, but uses free space optics, which is rather bulky. The more promising method, employing waveguides [1], 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.

COMPUTATIONAL METHODS: 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 (fig. 1).

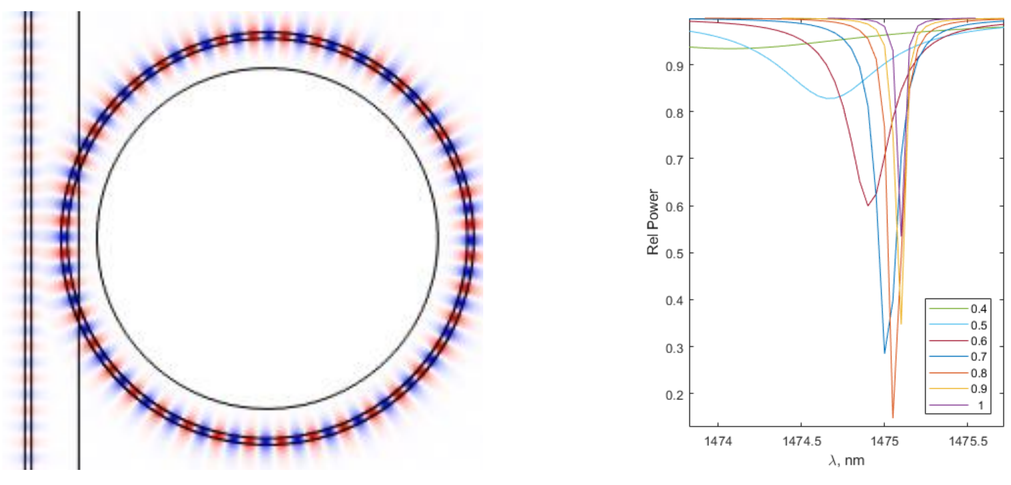

Figure 1. A waveguide-pumped 6 mkm-radius ring cavity and it's transmittance

2) Partial computation of system transmittance (in 2D) with 4 ports (fig. 2)

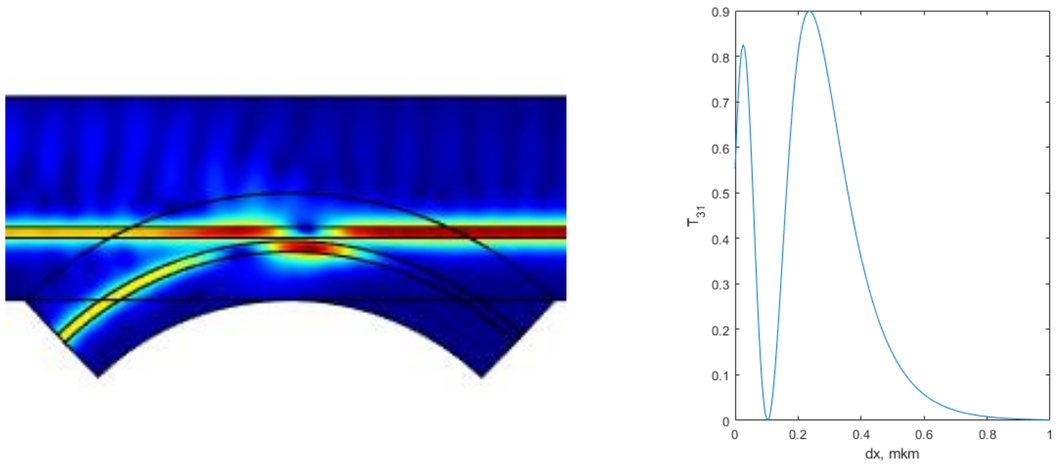

Figure 2. A ring sector pumped with a guide and transmittance at 1475 nm

3) Modal analysis of the cross-section for quasi-analytical approach (fig. 3), similar to [1] (fig. 1).

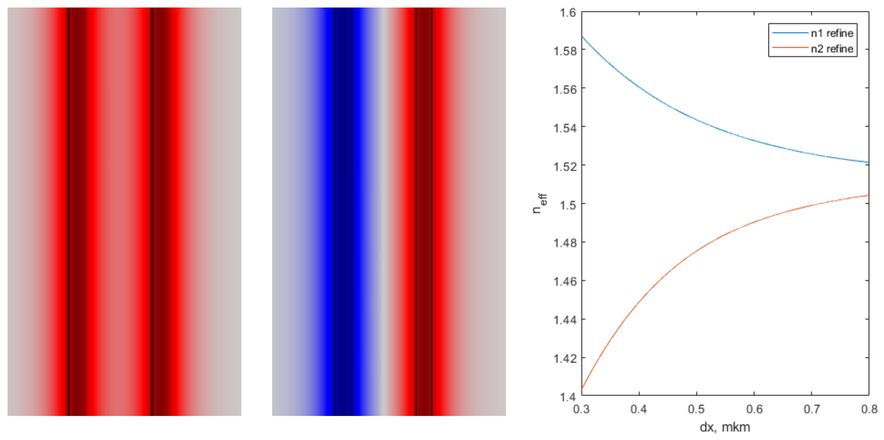

Figure 3. Cross-section of two waveguides (even and odd mode) and effective refraction index

4) Complex eigenmode calculation. Similar to the model 1 (fig.1) but an eigenmode problem is solved. The imaginary part of the frequency determines total loss.

5) Semi-analytical approach with overlap integral calculation [2,3]. Field patterns are calculated separately and exported MATLAB®.

RESULTS: The results of first four 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 [1]. The figure 4 shows comparison of all methods for microring and figure 5 – for the microdisc.

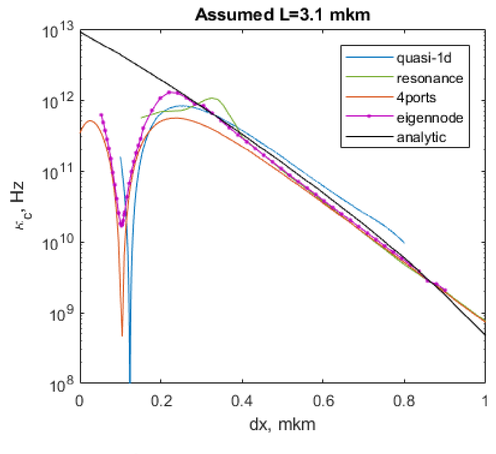

Figure 4. Microring

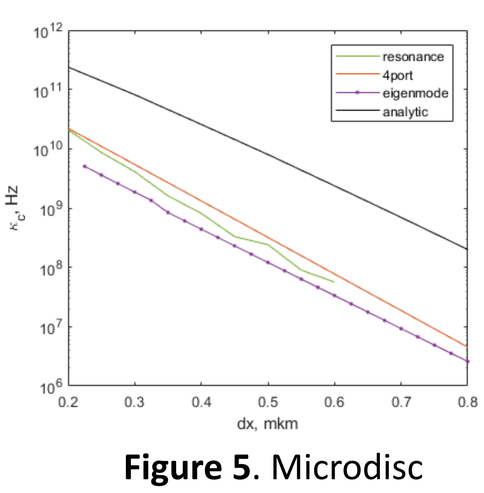

Figure 5. Microdisc

CONCLUSIONS: The second and fourth methods were found to be the most universal. The methods 2, 3 and 5 are suitable for large cavities, but the third method has a free parameter that is not well-defined and 5 gave bad correspondence with others. The method 2 was found difficult to implement for discs.

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