Numerical Analysis of Perforated Microring Resonator Based Refractive Index Sensor

M. Gabalis[1], D. Urbonas[1], R. Petruskevicius[1]

[1]Institute of Physics of Center for Physical Sciences and Technology, Vilnius, Lithuania

Abstract

Label free, refractive index (RI) based biosensors have recently emerged as one of the most promising optical sensing techniques [1]. Microring resonators have several attractive features for sensing applications. It's high quality factor (Q) and multiple pass interaction nature allows to resolve small shifts in resonance wavelength induced by introducing sensing object near the resonator [2, 3]. When a sensing object, having different RI than media that surrounds microring is positioned near the resonator, it induces the change in average refractive index at that location. This in turn changes the resonance condition. This change can be observed as a resonance wavelength shift in the transmission spectra. Monitoring this change allows one to determine the nature of the sensing object. However, ordinary microring resonator does not have high sensitivity (sensitivity can be defined as the ration of resonance wavelength shift with RI change [3]). This is mainly attributed to high confinement of light in the guiding material. Several microring geometries aimed at increasing extension of light into the surrounding media have been reported (slotted microring [4, 5], SNOW microring [6]). In this work we present microring resonator with perforated circular holes (Figure1) and numerically analyze its performance in sensing applications.
For this analysis RF Module in COMSOL Multiphysics® is used. Transmission spectra is obtained by performing parametric sweep for various wavelengths and monitoring output power at the drop port (Figure 1).
2D simulations showed that our microring resonator exhibits higher sensitivity than ordinary microring resonator. In particular high sensitivity is observed when one of the holes have different radius and only this hole is filled with optically denser material (transmission spectra shown in Figure 2). This makes our design of the microring resonator promising in single particle detection applications. Next step is to repeat analysis in 3D and to calculate optical forces acting on a sensing particle in the vicinity of the resonator at various locations. We expect it to be attractive force, so that once the particle is near the resonator it is sucked in to the hole.

Reference

1. M. S. Luchansky, R. C. Bailey, High-Q Optical Sensors for Chemical and Biological Analysis, Analytical Chemistry, 84, 793-821 (2012)
2. C. A. Barrios, Integrated microring resonator sensor arrays for labs-on-chips, Analytical and Bioanalytical Chemistry, 403, 1467-1475 (2012)
3. C. Chao, A. Arbor et al., Design and optimization of microring resonators in biochemical sensing applications, Lightwave Technology, 24, 1395-1402, (2006)
4. K. R. Hiremath, J. Niegemann, K. Busch, Analysis of light propagation in slotted resonator based systems via coupled-mode theory, Optics Express, 8641-8655, 19 (2011)
5. C. A. Barrios, K. B. Gylfason, et al., Slot-waveguide biochemical sensor. Optics Letters, 32, 3080-3082 (2007)
6. M. Khorasaninejad, N. Clarke, et al., Optical bio-chemical sensors on SNOW ring resonators, Optics Express, 19, 17575-17584 (2011)

Figures used in the abstract

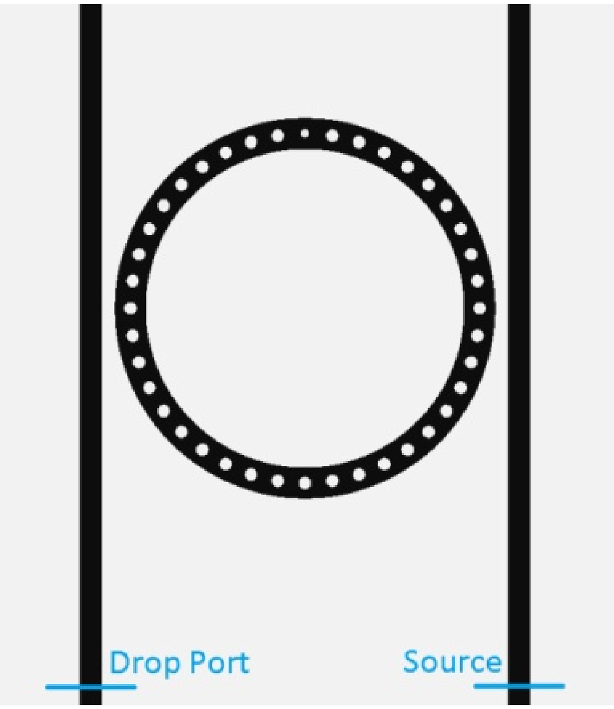

Figure 1: Geometry of the perforated microring resonator. Black color represents Si (refractive index 3.46), and grey - SiO_2 (refractive index 1.46)

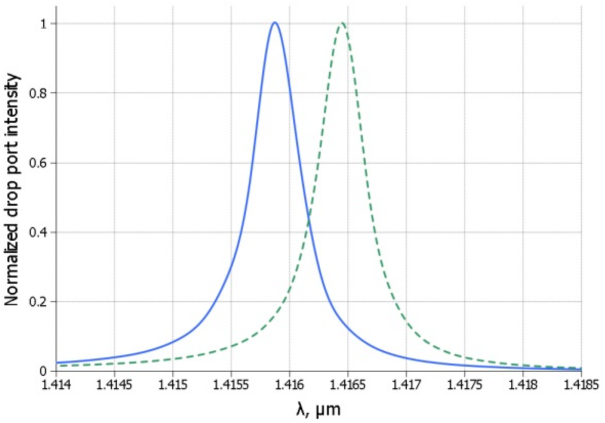

Figure 2: Normalized drop port intensity at normal conditions (solid blue line) and when smaller hole is filled with optically denser material, which refractive index is 1.52 (dashed green line)