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Parametric Optimization of Optical Ring Resonators for Biomedical Biosensing Applications

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Introduction

Biosensors, which emerged in the 1960s, convert biological interactions into measurable signals through a system comprising recognition, transduction, and signal processing elements. Among them, optical biosensors—particularly those based on resonators such as ring resonators—stand out for their high sensitivity and ability to detect small changes in the refractive index. In this work, we designed the structure of the resonator ring, this structure was selected as the most suitable due to its advantageous operational principles, illustrated in Figure 1.

Materials and Methods

Ring resonator-based optical biosensors were designed and simulated using the software COMSOL to optimize sensitivity, quality factor, and detection limits. Using Silicon and Silicon Dioxide as materials of Cladding and Core, respectively. Key geometric parameters are Radius of curvature (R): $62 \mu\text{m}$
Cladding width (W_i): $2 \mu\text{m}$
Core width (W_r): $0.2 \mu\text{m}$
Gap (dx): $0.7 \mu\text{m}$, with the modeled structure shown in Figure 2.

Results

The electric field distribution reveals the resonant modes.

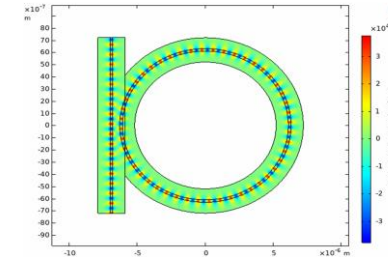


Fig. 3: Resonant Mode Distribution in the Optical Ring Resonator Structure

The figure 4 show the optimization of the transmission spectrum of a ring resonator. Obtained values of FWHM: 0.3 nm represents the full width at half maximum of the resonance dip. A FSR of 2.7 nm indicated the free spectral range between consecutive resonances. A High Q-factor of 1.5×10^6

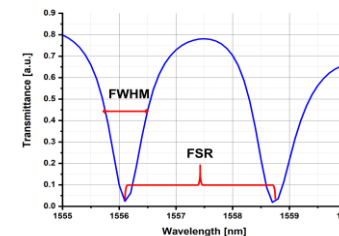


Fig. 4: Optimization of Resonance Wavelength and Expression of Quality Parameters.

Conclusions

The optimized ring resonator biosensor, built with silicon and silicon dioxide, achieved high Q-factors ($\sim 10^6$), demonstrating strong sensitivity and compact design. Its performance is comparable to advanced structures like microdisks and photonic crystals. This makes it a promising candidate for lab-on-chip and clinical sensing applications.

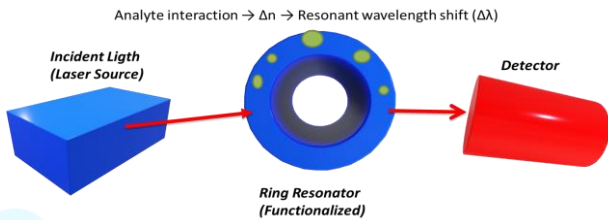


Fig. 1: Schematic Diagram of Principle of Operation of Optical Ring Resonator.

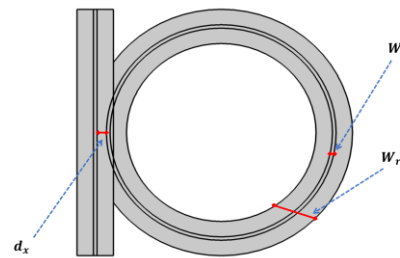


Fig. 2: Optical Ring Structure.

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Conflicto de interés: ninguno



Investigación



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