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Photonic biosensor for label-free detection based on photonic nanostructures on Si-waveguide ring resonator

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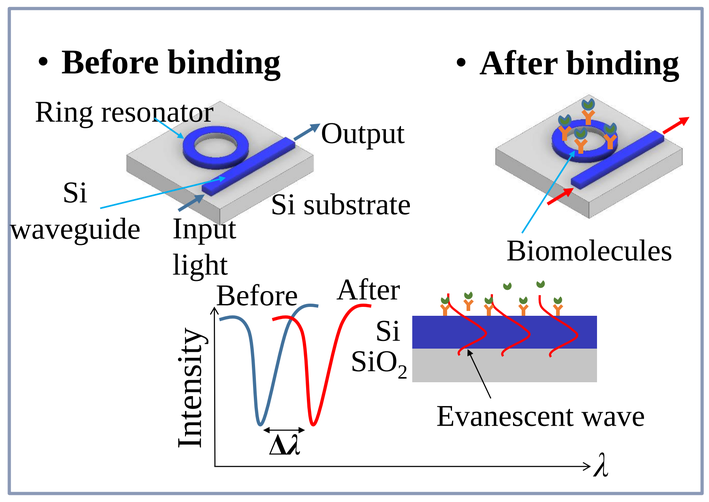
INTRODUCTION

- Silicon based micro-ring resonator biosensor is a high potential label-free biosensing device with advantages of a possibility of all-in-one-chip detection and low-cost fabrication.
- The sensitivity of sensing biomolecule is proportional to the change of effective refractive index as the light-matter interaction occurs on the surface of the waveguide.

$$\Delta\lambda = \frac{\Delta n_{eff}\lambda_0}{n_g}$$

n_{eff}: effective refractive index
λ_0: resonance wavelength
Δn_{eff}: the change of the effective index, by the interaction of field and analyte

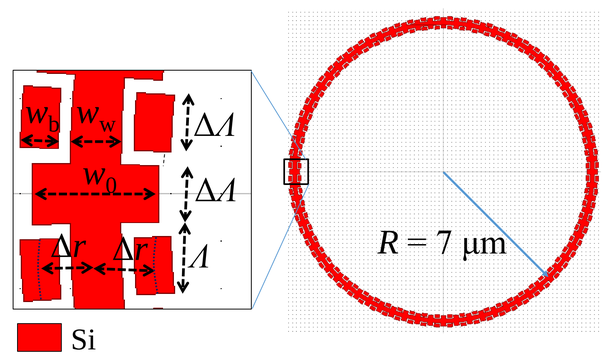


- The sensitivity depends on the light-matter interaction on the surface or the sidewall of the waveguide.

OBJECTIVE

Analyzing the effect of enhanced sensing surface based on photonic nanostructures of the micro-ring resonator on the sensitivity and quality factor.

PROPOSED STRUCTURE OF RING RESONATOR



Periodical combination of
- Sidewall-grating waveguide
- Side-blocks

Number of blocks: 72
R: 7 μm, Δ*r:* 0.15 μm
w_b: 0.15 μm, w_w: 0.2 μm, w_0: 0.5 μm
Λ: 5 ° , ΔΛ: 2°

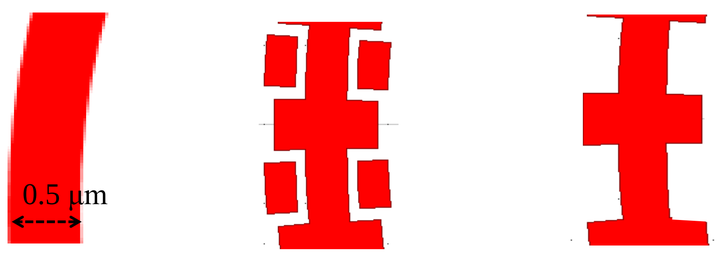
The proposed structure enhances the sensing surface of the ring resonator

CHARACTERISTICES OF RING RESONATOR

- Spectral response calculation method: 3D Finite Difference Time-Domain by Rsoft Photonic CAD Suit
- Electric field calculation method: Finite Element Method by Rsoft Photonic CAD Suit

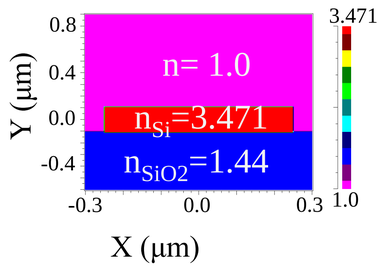
Ring resonator structures

Conventional | **Proposed structure Bragg grating I** | **Bragg grating II**



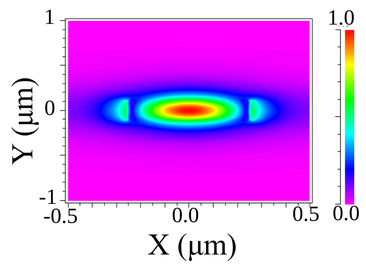
Ring radius: 7 μm

Cross section of refractive index distribution

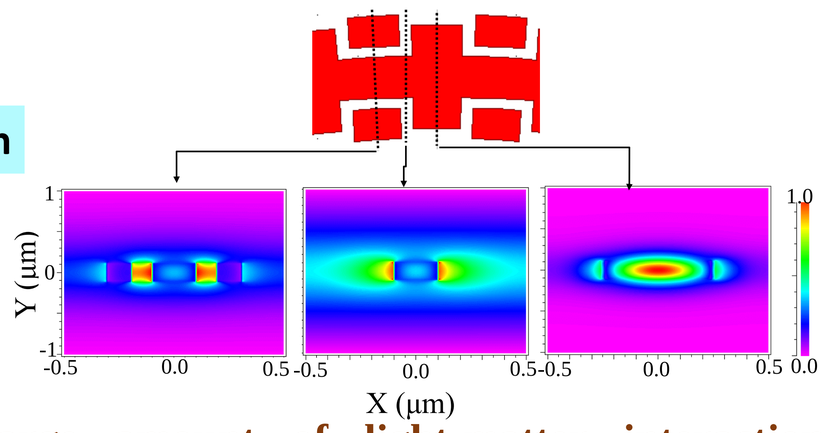


Electric field intensity distribution

- Conventional structure



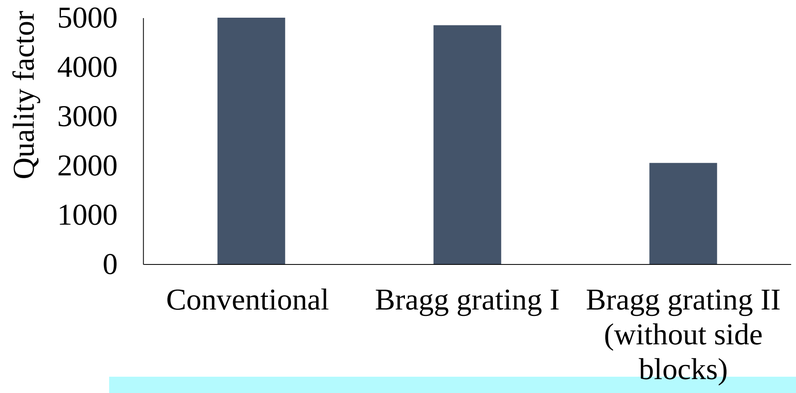
- Proposed structure



A large amount of light-matter interaction results in the increase sensitivity.

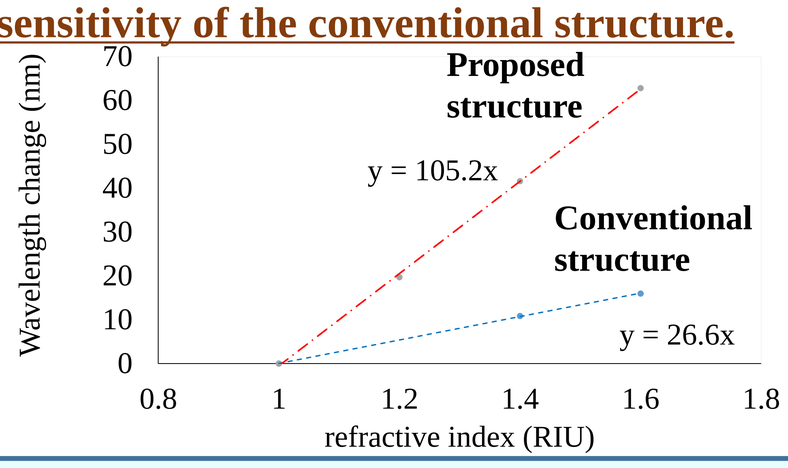
Quality factor

There is no significant reduction in quality factor of the proposed structure.



Sensitivity

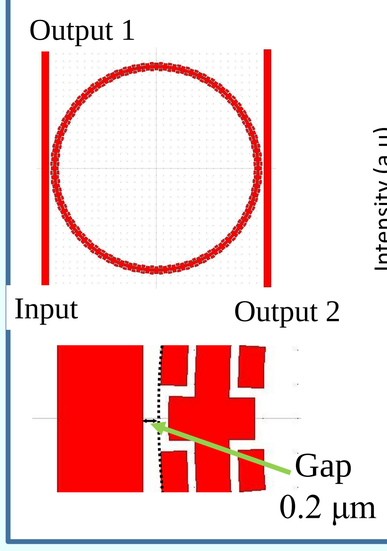
The proposed structure obtained four-fold sensitivity of the conventional structure.



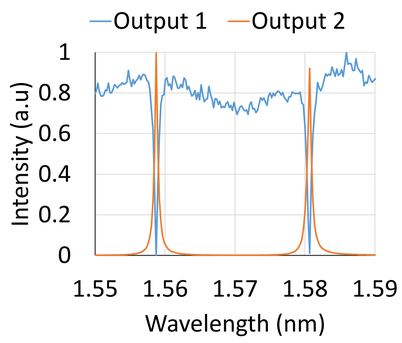
RING RESONATOR WITH BUS WAVEGUIDE

- Calculation method: 2D Finite Difference Time-Domain by Rsoft Photonic

Structure design

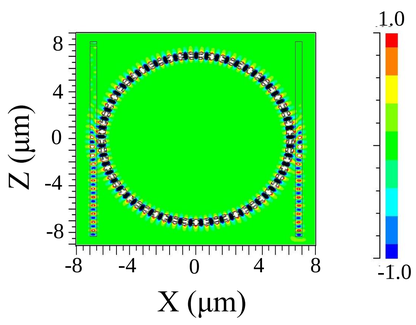


Spectral response



Quality factor 3072

Electrical amplitude distribution



Almost the entire field is propagating in the output waveguide.

CONCLUSIONS

We proposed a Bragg grating ring structure for photonic ring resonator biosensor.

- The simulated results of the ring resonator with photonic nanostructures show four-fold improvement of the sensitivity compared with the conventional structure of the waveguide while the quality factor does not change.
- The improved sensitivity is promising for detection of nanoparticles in the application of environmental field and clinical diagnostics.

FUTURE WORK

- Improving Q factor for the micro ring biosensor when combining with the bus WG. For example, changing the gap and width of structures.
- Device fabrication and experimental demonstration.