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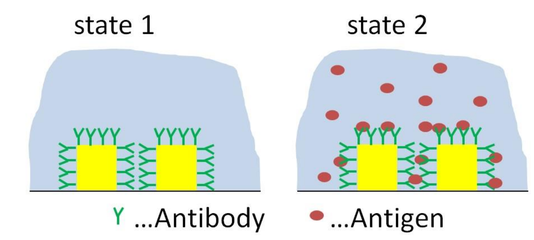
Novel Integrated Ringresonator for Biosensing

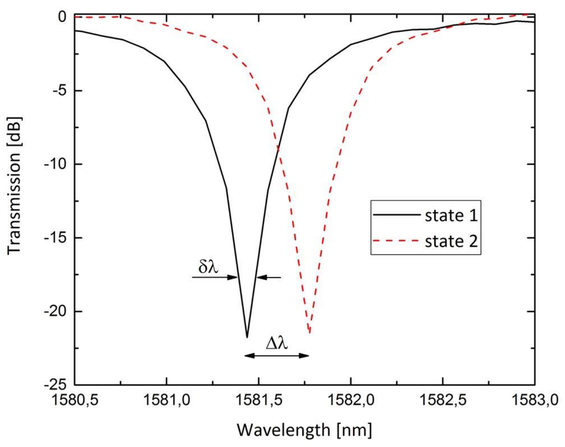
Abstract

A novel silicon photonic sensor based on a partially slotted micro-ringresonator is presented. The proposed concept takes advantage of both, a highly sensitive vertical slot waveguide and of a low loss strip waveguide in a single ringresonator.

Sensor principle and characteristics

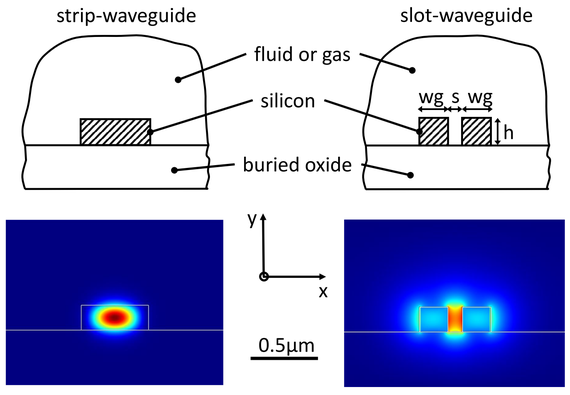
In principle, the resonant wavelength of the ringresonator depends on the effective index of the waveguide which, in turn, is determined by the refractive index of the analyte. Therefore, by measuring changes in the resonant wavelength of the ring, small changes in refractive index of the solution can be detected. The wavelength shift can be calculated with:





$$\Delta\lambda = \frac{\lambda_{res}}{n_g} \cdot \Delta n_{clad} \cdot \Gamma_{clad}$$

Common silicon based ring resonators are based on strip-waveguides, where the light is highly confined in the high-index silicon and exhibit low optical losses. In contrast to that, ring resonators based on slot-waveguides have high optical losses due to enhanced side-wall scattering but enhanced light-analyte interaction. The light-analyte interaction can be described by the waveguide sensitivity S_{wg} and with the field confinement factor Γ_{clad} determined by:



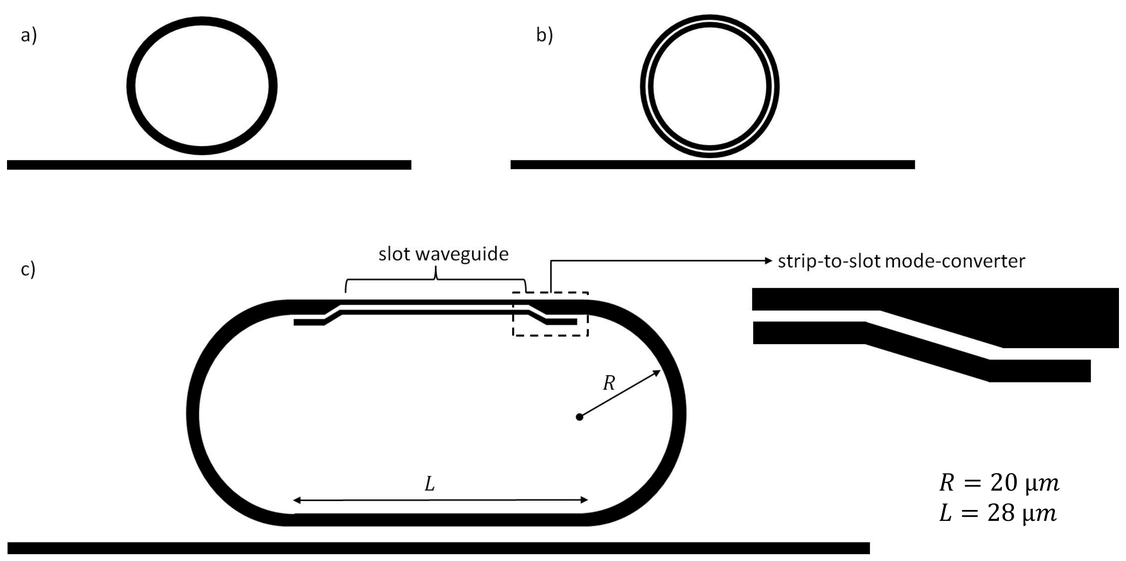
$$S_{wg} = \frac{\delta n_{eff}}{\delta n_{clad}} \quad \text{and} \quad \Gamma_{clad} = \frac{\iint_{clad} Re\{[E \times H^*] \cdot e_z\} dxdy}{\iint_{D_{tot}} Re\{[E \times H^*] \cdot e_z\} dxdy}$$

A Figure Of Merit (FOM) for the overall sensitivity of the ringresonator is given by:

$$FOM = \frac{S_{wg}}{n_g} \cdot Q$$

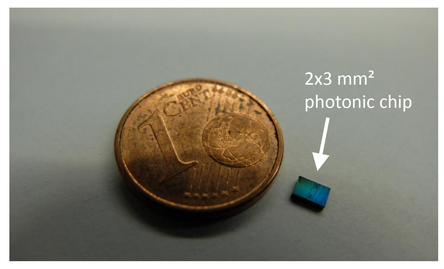
Novel ringresonator concept

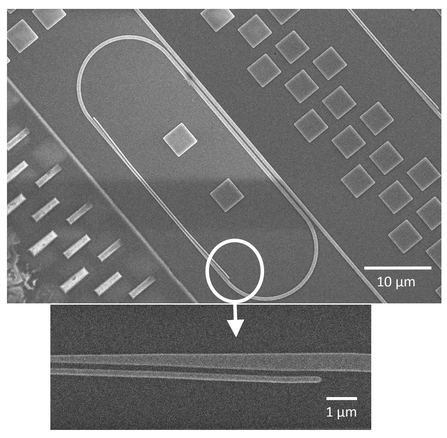
For a high overall sensitivity an integrated ringresonator has to exhibit both, low losses characterized by a high optical quality factor *Q* and a high light-analyte interaction characterized by a high peak wavelength shift *Δλ*. Towards this goal a novel silicon photonic sensor based on a partially slotted micro-ringresonator is presented. The proposed concept takes advantage of both, a highly sensitive vertical slot-waveguide and of a low loss strip waveguide in a single ringresonator.

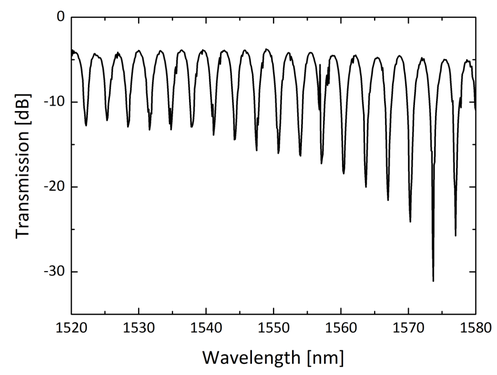


Fabrication and optical characterization

The ringresonator is realized on 200 mm silicon-on-insulator wafers using 248 nm DUV lithography in a SiGe BiCMOS-pilotline at the IHP in Frankfurt(Oder).

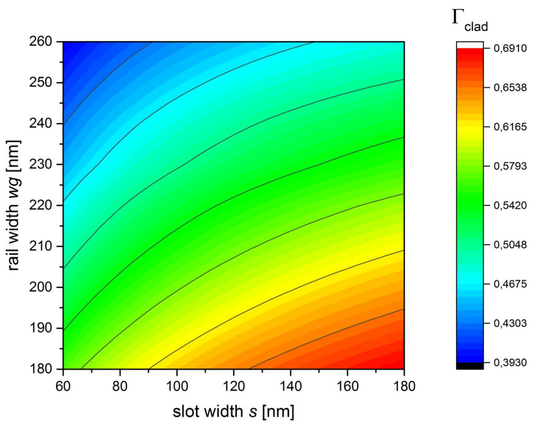






Results and discussion

Using the finite element method we determined the slot waveguide sensitivity and experimentally we obtained the Q-factor of the partially slotted ringresonator. Our results are summarized and compared with state of the art ringresonator in the following table. In order to maximize the wavelength shift Δλ we have determined the field confinement factor Γ_{clad}. In conclusion, we have demonstrate a novel ringresonator with a high overall sensitivity. Further, we have shown optimized slot-waveguide parameters.



Waveguide type	S_{wg}	Q	FOM	Ref.
Slot (TE-Mode)	0.89	5,000	1,481	[1]
Strip (TE-Mode)	0.14	100,000	3,271	[2]
Strip (TM-Mode)	0.5	20,000	2,293	[3]
Partially slotted (TE-Mode)	0.25	69,000	4,314	[4]

Literature:
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