EUROPEAN CONFERENCE ON INTEGRATED OPTICS

# Double $Al_2O_3$ Microring Resonator for Self-Referenced Sensing Applications

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Microring resonators (MRRs) find many applications for on-chip integrated optical sensors. Their operation is based on the spectral shift of resonance notches due to the probing of the evanescent modal field of local dielectric variations. MRR sensors are sensitive to any environmental perturbations, including temperature fluctuations and bulk refractive index variations, making it difficult to de-embed these from the actual analyte signal. By using a double MRR and by recording the differential spectral shift of the resonance notches of both a signal and a reference MRR the effect of the environment can be minimized [1]. Here, an $Al_2O_3$ double MRR with high quality factor $Q$=1.5e5 is demonstrated that is insensitive to both temperature and bulk refractive index changes. This system can be used for self-referenced and stable biosensing applications by functionalizing one of the two MRRs. Then, a change in differential resonance wavelength shift arises only due to the attachment of analytes to the sensing MRR surface, eliminating the environmental variations.

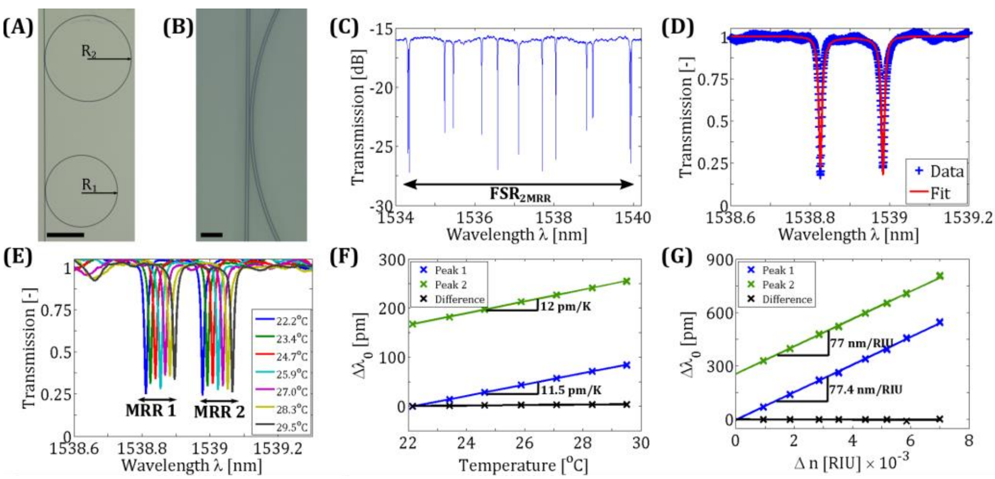

**Fig. 1. (A), Optical microscope image of the double MRR indicating the MRR radii. Scale bar is 100 µm. (B), Close up of a MRR. Scale bar is 20 µm. (C), Transmission spectrum of the**

**double MRR. (D), Double resonance with fit. (E), Spectral shift of the double resonance due to stage temperature. (F), Slope sensitivity of double resonance for temperature variations. (G), Slope sensitivity of double resonance for refractive index sensing.**

To measure the differential wavelength shift of the resonances of two MRRs in series two MRRs with radii of 200 µm and 240 µm were connected to the same bus waveguide. The ration between their radii was chosen to ensure that the free spectral range of the double MRR device ($FSR_{2MRR}$) is smaller than the spectral length of the C-band and that multiple closely spaced resonances will be present. Optimized geometrical parameters of the device are a waveguide width and height of 2.4 µm and 0.7 µm respectively, together with a coupling gap of 0.8 µm. Fabrication was done by the method described by [2] and the resulting device is shown in Figures 1 A and B.

The double MRR device was characterized by transmission measurements with a tunable laser for TE-polarized light in the C-band, as shown in Figure 1 C. By fitting a double resonance with a double Lorentzian function the location of the resonance wavelengths $\lambda_0$ and the corresponding $Q$ factor can be determined, as shown in Figure 1 D. For an air cladding both the MRRs have a $Q$=1.5e5, corresponding with a finesse $F$=100 and propagation loss $\alpha$=1.4 dB/cm. Using $H_2O$ as cladding gives extra water absorption losses and results in $Q$=40e3, $F$=26 and $\alpha$=6 dB/cm.

Self-referenced sensor operation is demonstrated by varying an external parameter while monitoring the difference of the $\lambda_0$'s of two closely spaced resonances of the double MRR device. By varying the temperature of the stage the location of both resonances shifts, as shown in Figure 1 E. Figure 1 F shows the positions $\lambda_0$ of both MRRs together with their difference. It was found that the two MRRs have a slope sensitivity of 12 pm/K and 11.5 pm/K respectively, yielding in a slope of the differential spectral shift of 0.5 pm/K. A similar self-referenced experiment was repeated by keeping the temperature fixed with a precision of 0.05 K and by adding $H_2O$ droplets of varying NaCl concentration, and thus bulk cladding refractive index, on top of the double MRR device. The shifts in $\lambda_0$ of both MRRs are shown in Figure 1 G. Slope sensitivities of respectively 77.4 nm/RIU and 77.0 nm/RIU were found for the two MRRs. Again, the small difference between these two slopes effectively cancels the response of the differential resonance wavelength of the double MRR device within 0.4 nm/RIU.

In conclusion, a double MRR was reported that operates self-referenced and stable under environmental perturbations, namely, temperature and bulk refractive index. Temperature and refractive index variations were effectively eliminated. Using this result, next steps involve the functionalization of one of the two MRRs such that analytes can only attach to a single MRR. Then, the self-referenced sensor operation can be used to demonstrate ultra-stable surface sensing for the detection of biomarkers.

References

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[2] J. Bradley et al, *Fabrication of low-loss channel waveguides in Al2O3 and Y2O3 layers by inductively coupled plasma reactive ion etching*, Applied Physics B, vol. 89, no. 2, pp 311-318, 2007