STUDY OF AN INTEGRATED-OPTICAL SLOW-LIGHT RING-RESONATOR FOR SENSING APPLICATIONS

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Integrated-optical (IO) micro-ring, -disk, and -sphere resonators have been long considered as a good candidate to enhance optical sensor performance. To the best of our knowledge, none of previous reported works [1]-[3] has explicitly attributed such (expected) enhancement to slow-light [4] phenomenon, i.e. a phenomenon where the group velocity of light is much lower than the light velocity in vacuum (c); a phenomenon which obviously can be expected also for a properly-designed ring-resonator circuit [5]. Consequently, none of those works has explicitly made use of this phenomenon for optimizing the sensor performance. Hence, so far, the reported detection limit of ring-resonator based sensor (best reported value around 1E-7 RIU) is in general poorer than IO Mach-Zehnder interferometer (MZI) sensor (best reported value around 1E-8 RIU) [6].

In this work, we present a theoretically study on slow-light in ring-resonator circuits and discuss quantitatively its role in enhancing the sensor performance. The model is based on the transfer matrix method and the complex transmission coefficient approach [5], by assuming a homogeneous refractometric IO sensor with MZI read-out scheme. The modeling results show that using realistic structure parameters and a typical read-out capability, a refractive index detection limit of one order better than the present state of the art IO MZI sensing structure [6] can be expected by the inclusion of such a slow-light structure.

The realization of such device is under progress at the moment of the preparation of this abstract. The device will be based on Si_3N_4 IO technologies with a serrodyne phase read-out scheme employing a ZnO electro-optical modulator. The latest results of the realization and experimental progress will be reported in the conference as well.

References

[1]. R. W. Boyd and J. E. Heebner, “Sensitive disk resonator photonic biosensor,” Appl. Opt., Vol. 40, No. 31, pp. 5742-5747, 2001.

[2]. C. Y. Chao and L. Y. Guo, “Design and optimization of microring resonators in biochemical sensing applications,” J. Lightwave Technol., Vol. 24, No. 3, pp. 1395-1402, 2006.

[3]. K. de Vos, I. Bartolozzi, E. Schacht, P. Bienstman, and R. Baets, “Silicon-on-Insulator microring resonator for sensitive and label-free biosensing,” Opt. Express, Vol. 15, No. 12, pp. 7610-7615, 2007.

[4]. R. W. Boyd and D. J. Gauthier, “’Slow’ and ‘fast’ light,” in Prog. in Optics, ed. E. Wolf, Vol. 43, pp. 497-530, 2002.

[5]. H. P. Uranus and H. J. W. M. Hoekstra, “Modeling of Loss-Induced Superluminal and Negative Group Velocity in Two-Port Ring-Resonator Circuits,” J. Lightwave Technol., Vol. 25, No. 9, pp. 2376-2384, 2007.

[6]. R. G. Heideman and P. V. Lambeck, “Remote opto-chemical sensing with extreme sensitivity: design, fabrication and performance of pigtailed integrated optical phase-modulated Mach-Zehnder interferometer system,” Sensors and Actuators B, Vol. 61, pp. 100-127, 1999.