HIGH SENSITIVITY AND LARGE MEASUREMENT RANGE REFRACTOMETRY SENSING BASED ON MACH-ZEHNDER INTERFEROMETER

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Refractometer is an important device to measure the concentration of biochemical such as biotoxins in drinking water based on refractive index change [1, 2]. Silicon photonics device is a promising platform for refractometer development with the advantages of high sensitivity, fast response, capable of real-time measurement. Moreover, silicon photonics device fabrication is CMOS compactable, which can significantly reduce device footprint and manufacturing cost. In this paper, a Mach-Zehnder interferometer based refractometer is proposed to achieve high sensitivity and wide measurement range.

A Mach-Zehnder interferometer is used for refractive index measurement. The schematic of the device is shown in Figure 1. Light is coupled into the waveguide from the left terminal and then split in the Y-branch into the upper sensing arm and the bottom reference arm. The waveguide used has thickness of 340 nm and width of 500 nm. The sensing and reference arms have a total length of 5 mm and 4.9 mm, respectively. The ultra-low loss Y-branch has a loss less than 0.28 dB. The top cladding layer of the sensing arm is removed to expose the silicon waveguide. When the sensing arm is immersed into different media (refractive index), the refractive index change in the sensing area will cause the change in the optical path difference of the two arm. Thus, the interference pattern measured on the right terminal will change and such change can be quantified to measure the concentration of chemical and biochemical molecules in drinking water.

In our sensor design, the 340-nm thickness and 500-nm width waveguide will support both TE- and TM- mode. Since TE- and TM- mode has different group index, there present two different periods corresponded to TE- and TM- in the device spectrum. And it can be distinguished by doing fast Fourier transform to the spectrum. Additionally, the two modes have different sensitivities, which can be used to complement each other.

The refractometry response is measured by adding ethanol (with refractive index of 1.36) on top of chip surface. The refractive index change will be 0.36 in this case. Figure 2 (a) shows the spectrum measured when cladding is ethanol and Figure 2 (b) shows the spectrum measured in air. And after using fast Fourier transform to those spectrums and using chirp Z-transform to refine the result, the power changing frequency of each condition is shown in Figure 3. There are mainly 2 peak represented the TE and TM mode. Further improvement can be made to add polarization controller to filter out only one mode and detect the two modes separately.

As calculated from Figure 3, the period sensitivity S_T is 2.9 nm/RIU for TE mode and 4.21 nm/RIU for TM mode. This period sensitivity can be used to determine the large shift of cladding refractive index. And the very high wavelength sensitivity of 600 nm/RIU can be used to calculate the small change of cladding refractive index. By combine both the TE and TM mode result, and both the period shift and wavelength data, high sensitivity and large measurement range can be achieved.

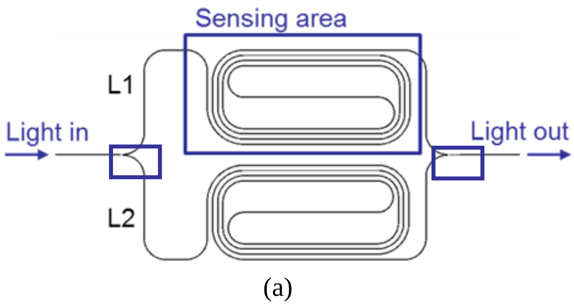

Fig.1 (a) Schematic for Mach-Zehnder Interferometer structure. Light input from the left waveguide and split into two arms. Then combine and form interference pattern in the right terminal. Arm 1 has a sensing window opened on top.

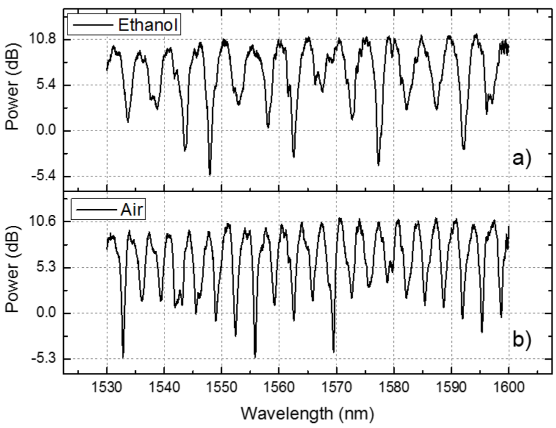

Fig.2 The transmission spectrum of the Mach-Zehnder Interferometer structure when expose to air and ethanol.

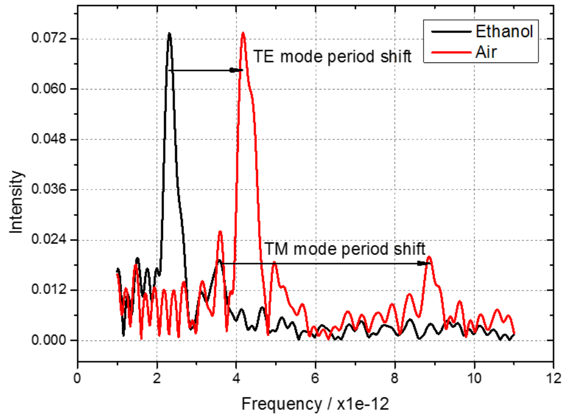

Fig. 3 Fast Fourier transform with frequency result for the corresponding spectrum