Coupled-Cavity Optofluidic Fabry-Perot Resonators for Enhanced Volume Refractometry

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This paper reports the design, fabrication and preliminary characterization of optofluidic Fabry-Perot micro coupled cavities enabling on-chip refractometry with large dynamic range.

Large dynamic range refractometry is needed in several applications such as in portable food analyzers, where the quality of fruits and beverages are classified based on their Brix number, which indicates the sugar content. The Brix numbers is obtained from the refractive index using standard conversion tables [1-2], where the refractive index varies from 1.333 (0 ^{o}B) to 1.49 (80 ^{o}B). The conventional design of integrated refractometer is based on Fabry-Perot cavity, in which the wavelength of longitudinal modes shifts with the change in the refractive index of the filling medium [3-4]. Their dynamic range is usually in the order of 10^{-3}, limited by the free spectral range (FSR) of the micro cavity. Therefore, the food analyzers are usually based on volume optics components and the change of the refraction angle with the change in the refractive index that allows for the large dynamic range of sensing.

In this work, we report a novel design based on cascading two coupled Fabry-Perot micro cavities allowing for orders of magnitude increase in the FSR besides the decrease in the linewidth which enhances the resolution as well. Fig. 1 shows the schematic diagram of the new design and the idea of operation. The lengths of the two cavities are slightly different and adjusted such that some modes are suppressed after each allowed mode. The use of Si/Air layers to form the Bragg mirror with thickness of 3.8/3.6 μm allowed us to achieve designs with mode separation of 40 nm around a wavelength of 1550 nm.

Fig. 2 shows a SEM photo of part of the fabricated structures. The fabrication was done using standard MEMS technology in which DRIE process is used to make a 150 μm deep etching in Si to form the Bragg mirrors, fiber grooves, and the microfluidic channels and ports. Test structures in the form of single cavities and mirrors were also fabricated on the same chip.

Fig. 3 shows the measured transmittance of one of the fabricated coupled-cavities together with the measured transmittance of the single cavity corresponding to one of them. The single cavity has a length of 128 μm and the coupled-cavities have lengths L_1 = 160 μm and L_2 = 128 μm as referred to Fig. 1. The mirrors are composed of two Si layers in both cases. We can see the increase in the FSR achieved in the coupled cavity which is about 3 times as the single cavity and also the reduction in the line-width by less than half. In fact the technology tolerance, especially the over-etching, had a great effect on the fabricated structures. The fabricated mirrors had a wider bandwidth than expected and we could obtain a much larger FSR in the coupled-cavity. In some designs we obtained only one peak in the whole measured band of 140 nm.

Word count: 489

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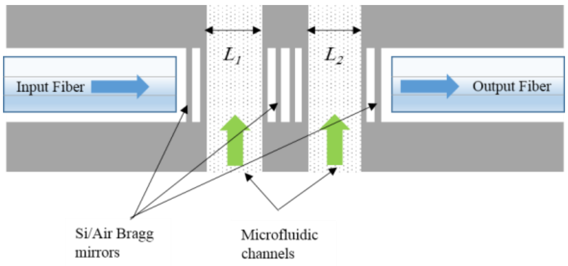

Fig. 1.a: Schematic diagram of the new design.

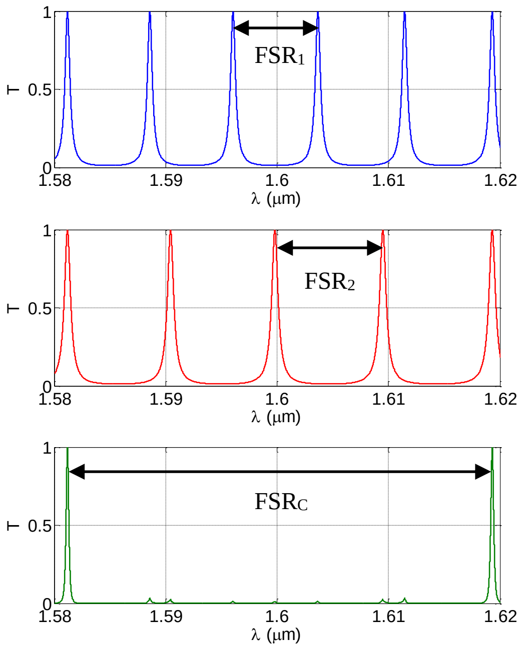

Fig. 1.b: The idea of operation of the new design showing the modes of the first cavity (top), the modes of the second cavity (middle), the modes of the coupled cavity (bottom).

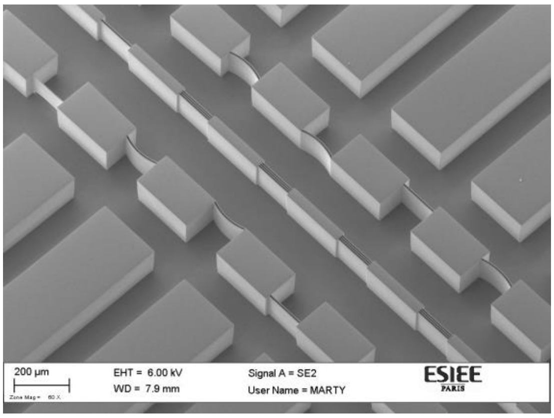

Fig. 2: SEM photo of part of the fabricated micro coupled-cavities.

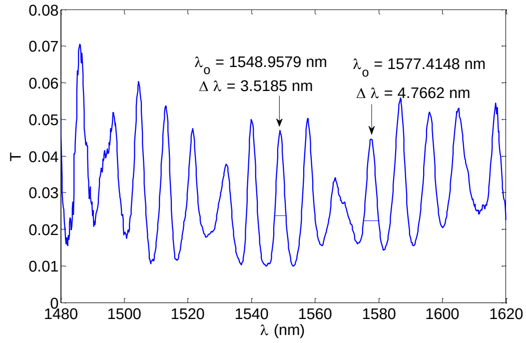

Fig. 3.a: Measured Transmittance of a single cavity corresponding to one of the coupled cavities measured below.

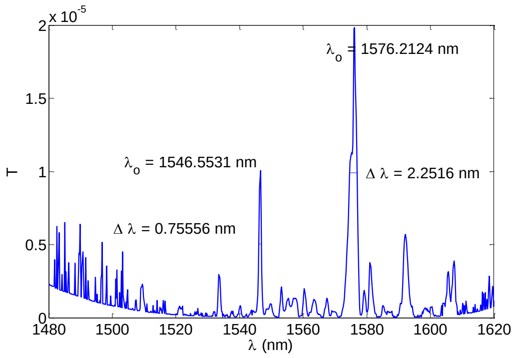

Fig. 3.b: Measured transmittance of the fabricated coupled-cavity showing an increase in the FSR and a reduction in the line-width as compared to the single cavity.