On-chip Cavity-enhanced Fourier-transform Spectrometer

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Abstract: A microring resonator (MRR) cavity-enhanced on-chip Fourier-transform spectrometer (FTS) is demonstrated. High resolution (1.7 nm) and large bandwidth (at least 100 nm) are achieved with the help of high-Q cavity. The on-chip spectrometer is very robust, cheap and compatible with other integrated photonic devices. It is promising to be applied in integrated photonic sensing and on-chip spectroscopy system.

1. Introduction

On-chip spectrometer is important for on-chip spectral analysis in applications such as chemical and biological sensors, etc. Different on-chip spectrometers are demonstrated by using arrayed waveguide gratings [1], planar concave gratings [2], photonic crystal [3] and ring resonator array [4] and on-chip FTIR spectrometer [5]. However, they sacrifice and suffer with very limited bandwidth in order to achieve high spectral resolution. On the other hand, Fourier transform spectrometer (FTS) with a tunable Mach-Zehnder interferometer (MZI) has the advantage of wide bandwidth, but the resolution is compromised. In this paper, a microring resonator (MRR) is exploited to boost the resolution of a FTS by taking advantage of its high quality factor, developing a spectrometer with both high-resolution and large bandwidth. It is potential for applications such as on-chip chemical and biosensors in environmental and water quality monitoring.

2. Design and working principles

Figure 1 shows the schematic of the MRR cavity-enhanced FTS. The input light is firstly filtered with a MRR to the input of the MZI. The MZI is then tuned by heater 2 based on thermo-optic effect, generating a time-varying light intensity in the output from which the input of the MZI can be retrieved with Fourier transform. Heater 1 is used to finely tune the MRR based on the same effect, switching the filtered light to other spectrum channels. As a result, the FTS can retrieve the full spectrum with a high resolution. In this design, the resolution is enhanced substantially due to the high finesse of the filtered light from the MRR.

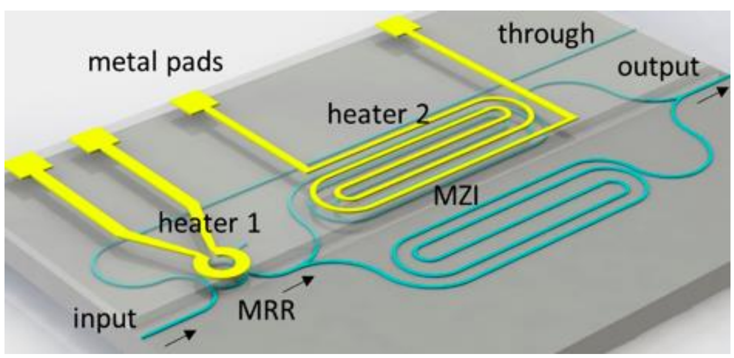

Fig. 1. Schematic of the MRR cavity-enhanced FTS.

3. Results and discussions

Figure 2(a) shows the optical microscopic image of the cavity-enhanced FTS. Light output from the MZI is detected by the photodetector for signal processing. Figure 2(b) is the magnified optical microscopic image of the tunable MRR. Trenches in the vicinity of the MRR and MZI are aimed to reduce heat dissipation, increasing heating efficiency and reducing heat interruption.

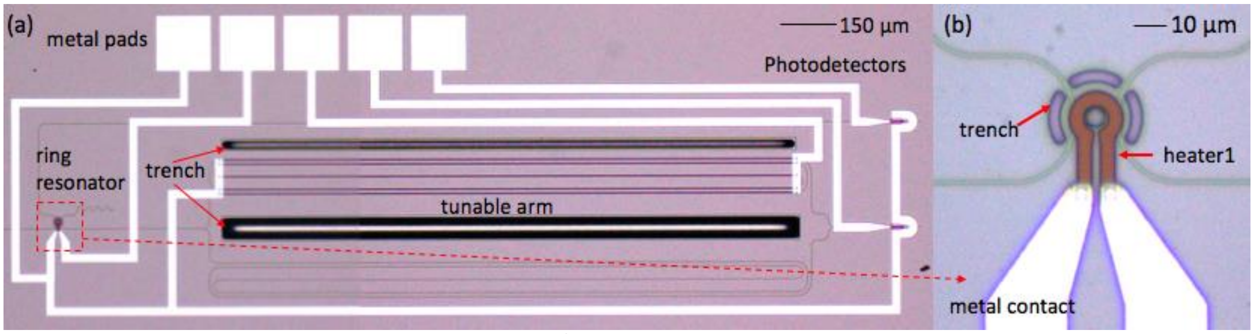

Fig. 2. Optical microscopic picture of (a) the on-chip spectrometer and (b) tunable MRR.

Figure 3(a) shows the fast Fourier transform (FFT) results of the detected signals with 1,565 nm (on resonance) and 1,567 nm (off resonance) laser inputs, respectively. When the MRR is switched to a specific resonance condition, a signal peak appears when the input light coincides with the resonance wavelength and there is no obvious signal peak when the input wavelength is off resonance. This shows that the light at off resonance is effectively blocked by the MRR. The MRR has a free spectral range is 19 nm and quality factor of ~40,000. Figure 3(b) shows the retrieved spectra with single laser sources (on resonance) input. Figure 3(c) shows retrieved spectrum with two laser sources input. It shows that two laser sources with the separation of a value equal to FSR can be differentiated. The MRR can be finely tuned by the value of the linewidth of the resonance peak which is about 0.2 nm. As a result, tuning the MRR and FTS collaboratively, high resolution as well as large bandwidth can be realized.

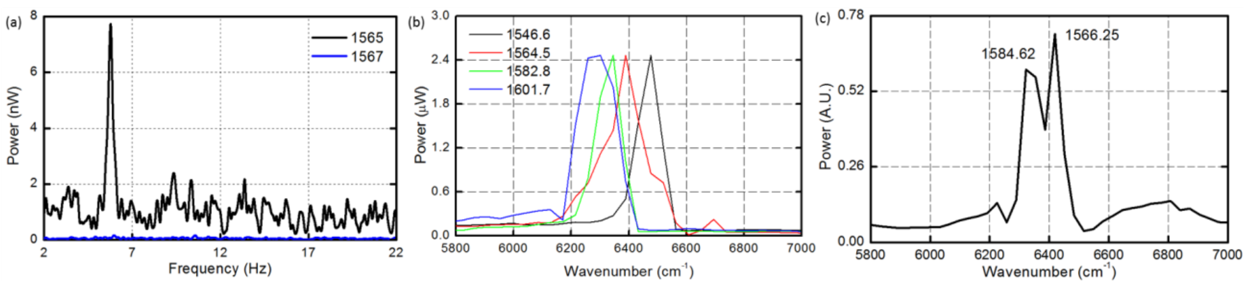

Fig. 3. (a) FFT results of detected signals. (b) Retrieved spectra with single wavelength (on resonance) input. (c) Retrieved spectrum with two wavelength input.

3. Conclusions

A microring resonator cavity-enhanced Fourier transform spectrometer is demonstrated to realize high resolution and large bandwidth. The MZI can transmit a wide spectrum range up to 100 nm, and the MRR can be finely tuned due to its high quality factor (~40,000). Currently, a resolution of 1.7 nm has been achieved. The on-chip spectrometer is promising for applications in chemical and biological sensing in environmental and water quality monitoring.