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A High-resolution Fourier-transform Spectrometer based on cascaded a ring resonator and an MZI array

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Abstract: A high-resolution FT spectrometer consists of a cascaded microring resonator and an MZI array is demonstrated and achieved a high resolution of 0.74 nm and bandwidth of 20 nm. It has high potential in biochemical sensing applications.

OCIS codes: (300.6190) Spectrometers; (130.3120) Integrated optics devices; (130.6010) Sensors.

Introduction

One of the most significant current researches in spectrometer is about spectrometers based on planar integrated optical waveguide technology with various structures, such as arrayed waveguide gratings (AWGs) [1], echelle gratings [2], microring resonators (MRR) [3] and waveguide Fourier-transform (FT) spectrometers [4-5]. Among them, the on-chip interferometric spectrometer raises much research attention, which is different kind of spectrometer compared with spectrometers with splitting light and it is also called FT spectrometers. In our previous work, we proposed and demonstrated a FT spectrometer with high resolution and wide bandwidth based on the cascaded heat-tuning MRR and heat-tuning MZI [4]. However, two-dimensional scanning with two thermal tuning electrodes is time-consuming. In this paper, we proposed a structure of cascading a heat-tuning MRR with a static MZI array to produce a high-resolution FT spectrometer, which reduces time spent caused by two-dimensional scanning.

Design and theoretical analysis

The image of the chip packaged to a control PCB and an optical microscopic picture of the tunable MRR is presented in Fig. 1. The spectrometer comprised of two main components: a MRR and a 16 MZI array. The chip was fabricated on a silicon on insulator (SOI) platform with a 220 nm silicon layer on a 2 μm silica insulator layer. For the MRR, the widths of all the straight waveguides are 0.45 μm with a ridge height of 0.22 μm and the ring diameter of 5 μm . For the MZI arrays, it consists of 16 MZIs with arm length differences varied linearly from 0 to 81.8 μm . To measure the spectral response of the spectrometer, a tunable laser source (Santec TSL-510) was used as the light source. A polarization controller was used to rotate the polarization of the input light for maximum coupling to the TE mode. The light is coupled into the input port of MRR by edge coupling and transmitted into the MZI array. The output signals from another part of the MZI array are finally received by the power detector (Santec MPM-210).

Fig. 1: (a): Image of the chip packaged to a control PCB; (b): Optical microscopic picture of the tunable MRR.

Results and Discussions

In Fig. 2 (a), different colors denote different modulated states of the MRR. The output from drop port of the MRR transmit to the MZI array. With the power values from the power detector, the spectrum from MRR drop port can be retrieved by Fourier transform, as shown in Fig.2 (b). from the retrieved spectrum, we can see that the retrieved spectrum deviates from the original input spectrum. Because the sampling of the interferometric optical path difference is deviated from the ideal state of continuous change of optical path difference from zero to infinity. However, if we use this spectrometer in sensing applications, the peak position can be read accurately.

Fig. 2: (a): MRR transmission from drop port when input spectrum is Gaussian distribution; (b): Retrieved spectrum.

Fig.3 (a)-(d) depict measured output spectrum from the MZI array No.1, No.6, No.10 and No.16 when we set the input signal as three single laser sources, whose wavelengths are on the resonance wavelengths of the MRR. We can see that the output spectrum is tuned by the MZI array and based on the relation between the input spectral distribution and the interferogram, we can retrieve the input spectrum after we obtain the output power from the 16 MZI array, as shown in Fig.4 (e). As we can see, the spectrum of three single laser sources can be retrieved and the central wavelengths of the signals fit the original ones well. The adjacent wavelengths difference with 1.3 nm can be clearly distinguished.

Fig. 3 (a)-(d). Measured spectrum from the output of MZI arrays No.1, No.6, No.12 and No.16; (e). Normalized three original input signals and normalized experimentally retrieved spectra of these three input signals. The normalization is based on the 1555.2 nm wavelength signal, and the relative intensity between signals is preserved.

Conclusions

In conclusion, we have proposed a novel on-chip FT spectrometer structure with small footprint, which is composed of cascading a MRR and a MZI array. The high resolution of the spectrometer has been demonstrated experimentally. The measured resolution is as high as 0.74 nm and the bandwidth are 20 nm. It has further applications in the biochemical sensing field.

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References

- [1] Nguyen, V. Duc, et al. "Spectral domain optical coherence tomography imaging with an integrated optics spectrometer." *Optics letters* 36.7 (2011): 1293-1295.
- [2] Ma, Xiao, Mingyu Li, and Jian-Jun He. "CMOS-compatible integrated spectrometer based on echelle diffraction grating and MSM photodetector array." *IEEE Photonics Journal* 5.2 (2013): 6600807-6600807.
- [3] Redding, Brandon, et al. "Compact spectrometer based on a disordered photonic chip." *Nature Photonics* 7.9 (2013): 746.
- [4] Zheng, Shao Nan, et al. "Microring resonator-assisted Fourier transform spectrometer with enhanced resolution and large bandwidth in single chip solution." *Nature communications* 10.1 (2019): 2349.
- [5] Yang, Minyue, Mingyu Li, and Jian-Jun He. "Static FT imaging spectrometer based on a modified waveguide MZI array." *Optics letters* 42.14 (2017): 2675-2678.