A MEMS-Actuated Tunable Microdisk Resonator

Ming-Chang M. Lee and Ming C. Wu
Electrical Engineering Department, University of California, Los Angeles
Phone:+1-310-825-7338, Fax:+1-310-794-5513, E-mail:marklee@icsl.ucla.edu

Abstract— A novel tunable microdisk resonator with integrated MEMS actuator to alter coupling gap is proposed and experimentally demonstrated for the first time. The fabricated device shows a transmittance change about 8dB and a quality factor of 6200.

I. Introduction

Microdisk or microring resonators are key enabling elements for wavelength-selective devices such as channel add-drop filters[1] and optical delay lines[2]. They are also the basic building blocks for compact wavelength-division-multiplexing (WDM) photonic integrated circuits (PIC), including WDM demultiplexers[4], wavelength-selective switches, crossconnects, and group velocity dispersion compensators[3].

An important condition for microdisk PIC is critical coupling, i.e., the waveguide-disk coupling is equal to the cavity loss. In all previous microdisk resonators, the coupling is fixed by microfabrication. Due to process variation (lateral undercut or misalignment), the coupling coefficients vary from device to device and run to run. To achieve critical coupling, the intrinsic quality factor (Q) is tuned to match the coupling loss by introducing loss or gain in the microdisks. This is not ideal since loss lowers the Q while gain introduces excessive noises in the signal band.

In this paper, we propose and demonstrate MEMS-based tunable microdisk resonator. In high-Q resonators, varying the gap spacing between the waveguide and the microdisks by simply a fraction of a micron could lead to more than ten orders of magnitudes change in the output transmission, as shown by the theoretical calculation in Fig. 1. The ability to vary the gap spacing not only relieves tight fabrication tolerance but also enables many new tunable WDM components such as wavelength-selective switches and dynamically add-drop filters. To our knowledge, this is the first experimental demonstration of MEMS actuated microresonator circuits.

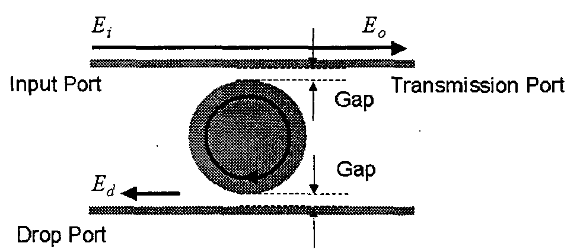

Figure 1(a). A channel drop filter with microdisk resonator.

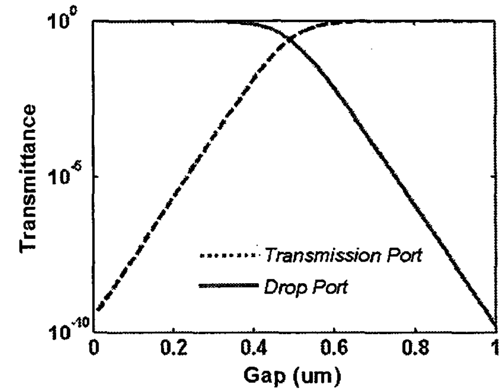

Figure 1(b). The calculated transmittance at resonance versus the gap spacing between waveguide and microdisk.

II. Device Design and Fabrication

The schematic of our device is shown in Fig. 2. It is fabricated on a silicon-on-insulator (SOI) wafer. Two suspended waveguides are placed in close proximity to the microdisk. The initial gap (0.9 μm wide) is large so there is no coupling between the waveguide and the microdisk. The suspended waveguides can be pulled towards the microdisk by four electrostatic gap-closing actuators. Therefore, the coupling coefficient can be varied by voltage. The radius of microdisk is 10 μm and the width of waveguides is 0.7 μm.

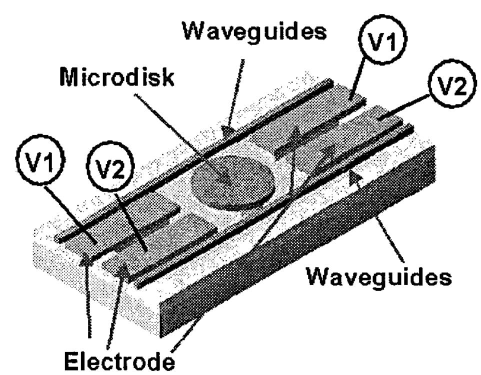

Figure 2. Schematic diagram of the variable-gap microdisk resonator. The waveguides near the disk are suspended.

The fabrication process is described in the following. First we grow thermal oxide on the top of SOI wafer. The waveguides, microdisks, and electrodes are patterned simultaneously using a single photomask. The patterns are transferred to the silicon layer by HBr-based reactive ion etching using the thermal oxide as hard mask. The etching process has been optimized for smooth vertical sidewalls. Thermal oxidation[5] is employed to further reduce the surface roughness of the sidewalls. The waveguides around the microdisks are released in BOE through lithographically patterned photoresist windows. After releasing, the devices are cleaved into chips and anti-reflection coatings are applied on both facets. The SEM of the fabricated device is shown in Fig. 3.

Unlike other laterally coupled microdisks that usually require electron-beam lithography to pattern the small gaps (0.1 ~ 0.2 μm), our device has a large initial gap spacing (0.9 μm) and can be fabricated using optical lithography only. More significantly, any process variation that results in change of disk-waveguide spacing can be compensated by the MEMS actuators, which greatly increase the yield of microdisk PICs..

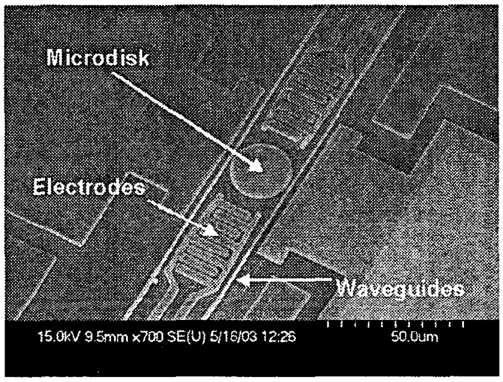

Figure 3. The SEM picture of fabricated device.

III. Measurements

Full displacement of the waveguide from 0 to 0.9 μm is achieved by the gap-closing actuator without pull-in. The voltage at maximum displacement is 120V. The suspended part of the waveguide is 100 μm long.

Optical characterization is performed by using two lensed fibers to couple to the waveguides. The spectral response of the microdisk is measured using erbium-doped fiber amplified spontaneous emission (ASE) source. The spectra at the output port are shown in Fig. 4. At zero bias (green curve), the microdisk is not coupled to the waveguide, and no output was observed. When both waveguides are moved until they touch the microdisk, clear resonance peaks are observed (blue curves). The highest peak is 8 dB above the noise floor. The loaded Q at contact is estimated to be 6200.

IV. Summary

We have successfully demonstrated the first tunable microdisk resonator with integrated MEMS actuators. The waveguides around a microdisk are suspended over a length of 100 μm. The spacing between waveguides and microdisks can be continuously varied from 0.9 μm to contact by gap-closing actuators (120 V). Switching of resonance peaks with 8 dB contrast ratio is clearly observed. The loaded Q of the microdisk is estimated to be 6200. The tunable/switchable microdisks are important building blocks for compact photonic integrated circuits.

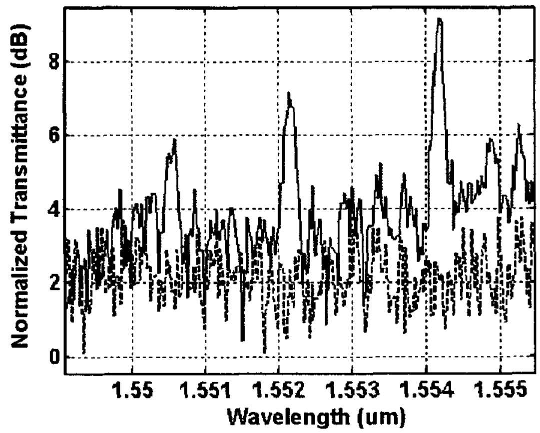

Figure 4. Optical spectra at the drop port. The solid line is the transmittance when the waveguide is in contact with the microdisk. The dashed line is the transmittance when the waveguide is far from the microdisk (zero bias).

Acknowledgment

This project is supported by DARPA Optoelectronics Center (CHIPs) and the CS-WDM programs.

References

[1] B. E. Little, S. T. Chu, H. A. Haus, J. Foresi, and J. –P. Laine, "Microring Resonator Channel Drop Filter", Journal of Lightwave Technology, Vol. 15, No. 6, Jun. 1997, pp. 998~1005

[2] G. Lenz, B. J. Eggleton, C. K. Madsen, and R. E. Slusher, "Optical Delay Line on Optical Filter", IEEE Journal of Quantum Electronics", Vol. 37, No. 4, Apr. 2001, pp.525~532

[3] C. K. Madsen, G. Lenz, A. J. Bruce, M. A. Cappuzzo, L. T. Gomez, T. N. Nielsen, L. E. Adams, and I. Brenner, "An All-Pass Filter Dispersion Compensator Using Planar Waveguide Ring Resonators", OFC/IOOC'99. Optical Fiber Communication Conference and the International Conference on Integrated Optics and Optical Fiber Communications (Cat. No.99CH36322). IEEE. Part vol.4, 1999, pp.99-101 vol.4. Piscataway, NJ, USA.

[4] B. E. Little, S. T. Chu, W. Pan, and Y. Kokubun, "Microring Resonator Arrays for VLSI Photonics", IEEE Photonics Technology Letters, Vol. 12, No. 3, Mar. 2000, pp.323~325.

[5] Kevin K. Lee, Desmond R. Lim, Lionel C. Kimerling, "Fabrication of Ultralow-loss Si/SiO2 Waveguides by Roughness Reduction", Optics Letters, Vol. 23, No. 23, Dec. 1, 2001, pp. 1888~1890.