Dynamic Dispersion Compensator Using MEMS-Actuated Microdisk Resonators

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Abstract: A novel dynamic dispersion compensator has been realized using MEMS microdisks with variable power-coupling ratio. The coupling is controlled by varying waveguide-disk spacing. A group velocity dispersion tuning range of 400ps/nm has been achieved experimentally.

OCIS codes: (000.0000) General

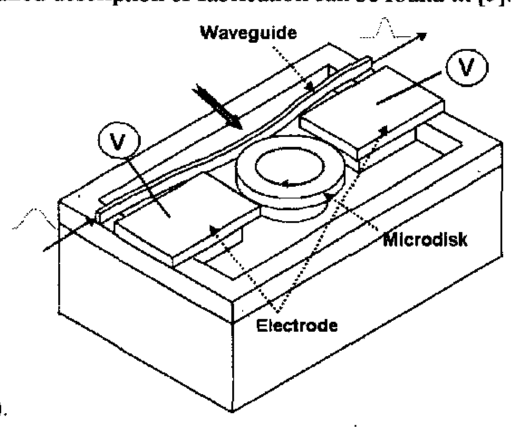
Introduction

Dynamic dispersion compensation is very important for high bit rate fiber optic communication networks. Tunable dispersion compensators using mechanical antireflection switch (MARS) [1], micro-electro-mechanical-systems (MEMS) Gires-Tournois interferometers [2], cascaded Mach-Zehnder interferometers [3], and planar waveguide-based all-pass filters [4] have been demonstrated. Devices based on microdisk resonators are particularly interesting because of their compact size. Previous microring/microdisk all-pass filters have fixed power coupling ratio. Tuning is achieved by thermal-optic phase shifters, which has slow response and high power consumption [4].

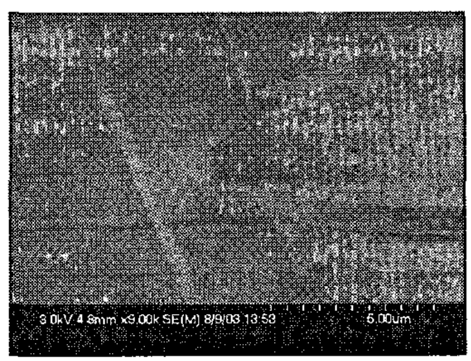
Recently, we demonstrated the first MEMS-actuated microdisk with variable power coupling ratio [5]. In this paper, we report on the first tunable dispersion compensator using such dynamic microdisks. Group velocity dispersion tuning range of 400ps/nm is achieved. The device is very compact ($100 \times 50 \mu m^2$), and multiple microdisks can be easily integrated to increase the bandwidth and dispersion range.

Device Design, Simulation, and Fabrication

Figure 1 shows a schematic and an SEM micrograph of the dynamic dispersion compensator. It comprises a fixed microdisk (10μm diameter) and a suspended optical waveguide (0.3μm wide). The waveguide can be pulled towards the disk by a set of electrostatic microactuators. The actuator spacing is designed to be three times larger than the waveguide-disk spacing to avoid pull-in effect. The waveguide-disk spacing can be continuously varied from 2μm (0V) to almost touching (79V). The device is made on a silicon-on-insulator (SOI) wafer with a single etching step. More detailed description of fabrication can be found in [5].



(a).



(b).

Fig. 1(a) A schematic drawing of the tunable dispersion compensator comprising a MEMS microdisk. (b) A SEM micrograph of fabricated device. A suspended waveguide is shown on the left of the microdisk.

The group delay, τ, can be expressed as

$$\text{Group delay } \tau(\omega) = \gamma T\left[\frac{\gamma - t\cos(\omega T)}{\gamma^2 - 2\gamma t\cos(\omega T) + t^2} - \frac{\gamma t^2 - t\cos(\omega T)}{\gamma^2 t^2 - 2\gamma t\cos(\omega T) + 1}\right] \quad (1)$$

where T is the round-trip delay time;

$\gamma = \exp(2\pi R\alpha)$, R is the radius of disk and α is the propagation loss;

ω is the detuned frequency;

$t=\sqrt{1-\kappa}$ and κ is the power coupling ratio.

In Fact, if the propagation loss is not included, this equation will be reduced to an expression for an ideal all-pass filter. κ is an exponential function of the gap spacing [6]. Figure 2(a) shows the calculated power coupling ratio versus the waveguide-disk spacing for our device. A large change in coupling ratio can be obtained by simply moving the waveguide over a fraction of a micron. For the disk with propagation loss 6dB/cm, the group delays versus detuning frequency for three different gap spacing are shown in Fig. 2(b). Group delay of -60ps is obtained at 0.15μm spacing near resonance.

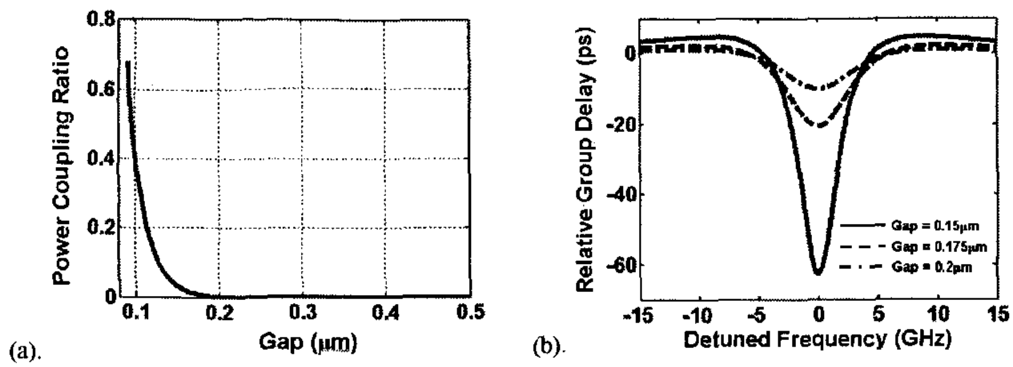


Fig. 2(a) Power coupling ratio versus coupling gap for a silicon waveguide and a microdisk with 10um radius. (b) Calculated group delay versus detuning frequency for three different gap spacing.

Experimental Results

The group delay as a function of wavelength is measured by microwave modulation technique. Optical signal from a tunable laser with 0.01nm wavelength resolution is modulated by a 1GHz microwave signal. The phase shift through the device is compared with that of a reference arm. Figure 3 shows the measured group delay at three different voltages. At 0V, the group delay is essentially zero for all wavelengths. At 79V, a peak delay of -35ps is measured. By fitting the experimental data with the theoretical curve in Eq. (1), the power coupling ratio is found to be 0.014 (at 77.5V) and 0.021 (at 79V). The group velocity dispersion is tunable from 0 to 400ps/nm on positive slope. The passband width is 10GHz. The loss variation across the passband is 2.6dB, and the maximum optical insertion loss (not including the fiber coupling loss) is 3.7dB. Reducing the resonator loss can further reduce the insertion loss. Wider passband can be obtained by cascading multiple microdisks.

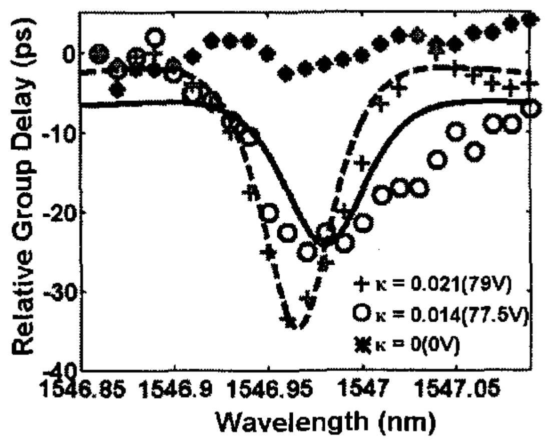


Fig. 3 Measured group delay versus wavelength. The crosses and circles are experimental data, and the lines are the fitted curves..

Conclusion

Dynamic dispersion compensators using MEMS-actuated microdisks are demonstrated with a dispersion tuning range of 400ps/nm and a peak group delay of -35ps. The device area is very small (100x50 μm^2). Wider passband and larger dispersion range can be obtained by cascading multiple MEMS microdisks.

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