An Integrated, Silica-Based, MEMS-Actuated, Tunable-Bandwidth Optical Filter with Low Minimum Bandwidth

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Abstract: We present a MEMS-actuated tunable-bandwidth filter implemented in phosphosilicate glass (PSG). Tuning range is 0.8 to 8.5GHz. Based on performance of our stand-alone PSG resonator, minimum bandwidth in PSG can be as low as 30MHz.
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1. Introduction

Tunable-bandwidth filters are a key component in optical access networks, enabling functionality such as dynamic allocation of bandwidth [1]. In the past, these devices have been implemented on-chip using MEMS- or thermally-tuned silicon microdisk or microring resonators [2-5]. The device with the lowest minimum bandwidth demonstrated a tuning range of 2.8 to 78.4GHz [5]. The lower end of this range is limited by the intrinsic absorption of silicon in the C-band. To achieve a lower minimum bandwidth, we have fabricated a tunable-bandwidth filter that integrates Si MEMS actuators with reflowed phosphosilicate glass (PSG) microresonators. Due to the lower optical absorption of silica, we are able to achieve a tuning range of 0.8 to 8.5GHz.

2. Device Design and Fabrication

Our device is a two-port notch filter (Fig. 1a). The bandwidth of the stop band is determined by the loaded Q (quality factor) of the resonator. Here, we use an integrated MEMS actuator to vary the spacing between the coupling waveguide and the resonator. As the coupling distance changes, the coupling coefficients can vary over several orders of magnitude, significantly changing the loaded Q.

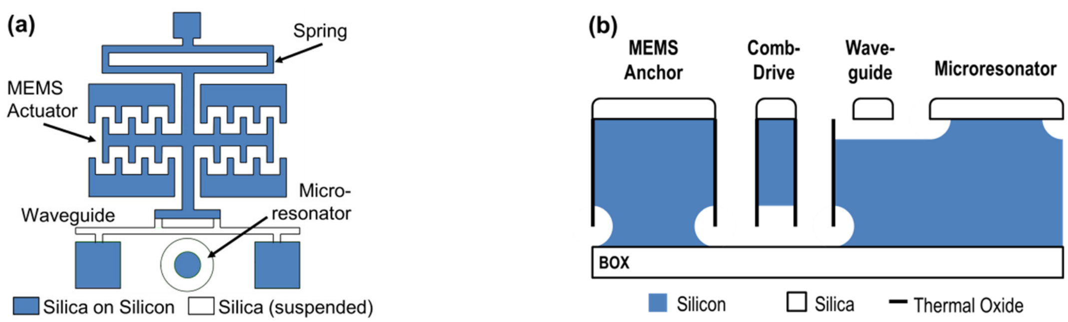

Figure 1: (a) Schematic of the MEMS-tuned filter, (b) Final cross-section of the tunable filter

To increase the MEMS actuation force, the comb-drive actuator is made on a 25µm-thick silicon-on-insulator (SOI) device layer using the SCREAM process [6], modified as described in [7]. The final cross-section of the device is shown in Fig. 1b.

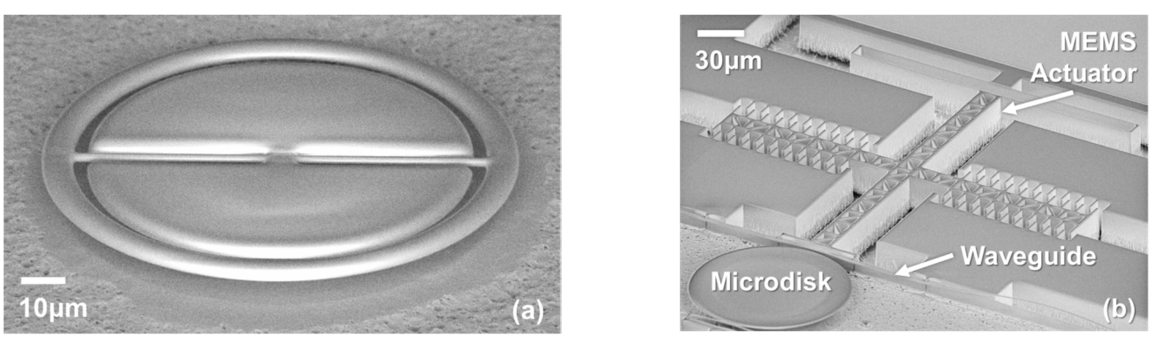

Figure 2: (a) Stand-alone PSG ring resonator, (b) Fabricated tunable filter

The crucial step in the fabrication process is the reflow of the PSG, which reduces the sidewall roughness by bringing the PSG above the glass transition temperature, as demonstrated in [8]. Smoother sidewalls reduce scattering, thereby enabling a higher optical *Q* and a narrower filter bandwidth. The waveguides, the edges of the microdisk, and the MEMS actuator are suspended by release etch in XeF_2. The dimensions of the PSG waveguides are approximately 1μm thick and 1μm wide. The microresonator is 1μm thick and has a 50μm radius, corresponding to a free spectral range of about 5nm. A stand-alone, annealed PSG ring resonator is shown in Fig. 2a, and the full tunable filter is shown in Fig. 2b.

3. Measurement and Results

We first measure the optical *Q* of the stand-alone resonator using a tapered optical fiber on a bulk micropositioning stage, a technique similar to [9]. We measure optical *Q*s up to 6.5 million (corresponding to a bandwidth of 0.24pm/30MHz). This confirms that the PSG anneal process results in high-*Q* optical resonators.

We then characterize the tunable filter using edge-coupled lensed fibers at the in and through ports of the device while varying the bias on the MEMS actuator from 84 to 38V (Fig. 3a). The fiber-to-fiber insertion loss is about 15dB.

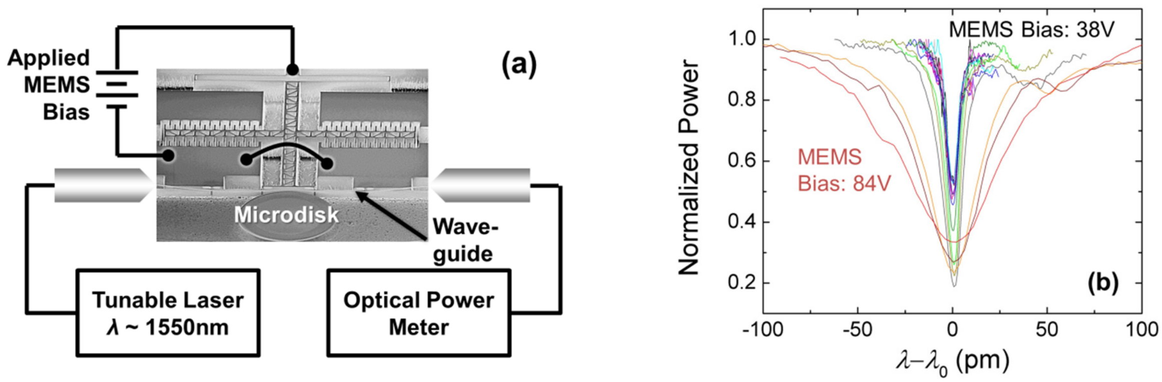

Figure 3: (a) Schematic of optical test setup. Light from a tunable laser is coupled into and out of the integrated waveguide via lensed fibers while varying the bias on the MEMS actuator. (b) Demonstration of bandwidth tuning as MEMS bias is varied from 84 to 38V (a larger MEMS bias results in smaller waveguide-resonator gap)

Using this setup, we measure the intrinsic optical *Q* of the microdisk resonator to be about 810K, and we achieve a tuning range of 7 to 68pm (0.8 to 8.5GHz) (Fig. 3b). Currently, the minimum measurable bandwidth of the device is limited by the actuation range of the MEMS. Although the measured optical *Q* of this device is lower than the optical *Q* measured in the stand-alone resonator, a higher *Q*, and thus a lower minimum bandwidth, can be achieved in the filter by fine-tuning the fabrication process to reproduce the stand-alone device performance.

4. References

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