

# Feedback Control of an Integrated MEMS-Tunable Silicon Photonic Ring-Resonator

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**Abstract**—We demonstrate a dither-locking scheme that stabilizes an integrated silicon photonic ring-resonator add-drop filter to an external laser wavelength using an electrostatic MEMS phase tuner. We achieve a millisecond-scale step response, high-lighting MEMS actuation as a route to low-power stabilization.

**Index Terms**—photonic MEMS, MEMS tuning, silicon photonics, feedback, dither lock, add-drop filter

## I. INTRODUCTION

Tunable silicon microring resonators enable footprint-efficient implementation of add-drop filters for wavelength-division multiplexing systems. However, the narrow bandwidths involved and the large thermo-optic coefficient of silicon make maintaining the filters in their assigned bands a significant challenge. Thermal tuning of integrated silicon microrings has been employed to this end [1], but the response time is on the order of a 100 ms. Furthermore, thermally tuned rings require static power on the order of 1 mW, and since the tuning efficiency depends on the temperature difference between the ring and its environment, it drops under heavy thermal loads, such as in multiplexers for AI datacenter interconnects. Here, we demonstrate a closed-loop feedback control system implementing dither-locking that leverages an integrated electrostatic MEMS phase tuner to lock the resonance wavelength of an add-drop silicon microring to an external laser operating at 1540 nm (in the C-band).

## II. EXPERIMENTS

The add-drop ring resonator is implemented on the IMEC iSiPP50G silicon photonics platform, with a few post-processing steps to release the MEMS [2], [3]. As seen in Fig. 1, the ring has a radius of 20  $\mu\text{m}$  and the side-anchored rib waveguide at its periphery is suspended on an oxide pedestal at its center. Surrounding the ring are four MEMS tuners that enable independent tuning of the coupling between the ring and each bus waveguide, as well as tuning of the round-trip phase. This phase-tuning allows us to shift the ring's resonance wavelength. Fig. 2 shows the block diagram of the

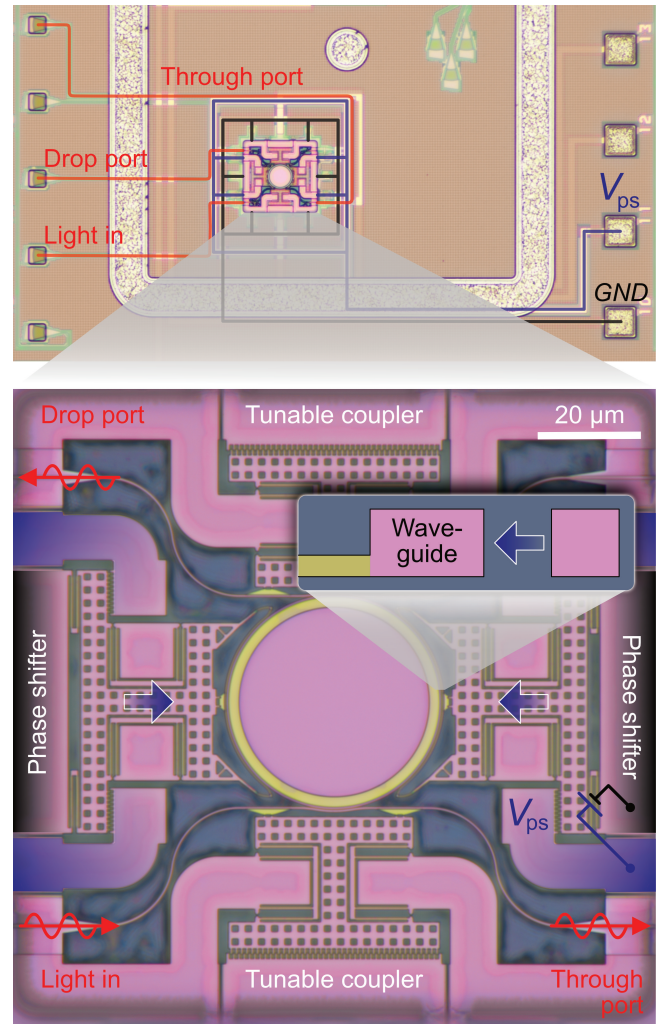


Fig. 1. Optical microscope top views of the fabricated device at low magnification (top) and high magnification (bottom), including comb-drive MEMS actuators to independently tune coupling (top and bottom) and round-trip phase (left and right). The inset shows the phase shifter actuation movement.

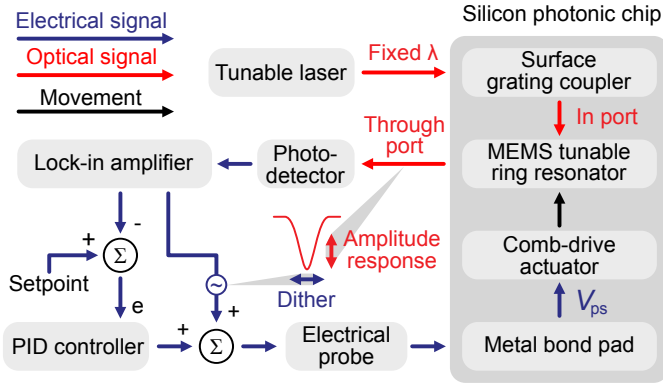


Fig. 2. MEMS-actuated dither-locking feedback scheme. A small sinusoidal drive on the integrated MEMS phase tuner modulates the ring resonance, producing the signed lock-in error used by the PID controller.

feedback control system, implemented using the PID module of a Zurich Instruments HF2LI lock-in amplifier, directly driving the photonic MEMS without further amplification. Light from an external tunable laser is coupled into the In port, and the transmission is monitored at the Through port with an external photodetector. To implement the dither lock, the ring resonance dip is first roughly aligned with the laser, and a small sinusoidal perturbation is added on top. The dither modulates the output at the through port, which is then demodulated by the lock-in to produce an error signal that is positive when the ring is on the blue side, and negative when it is on the red side, of the laser.

We use the in-ring phase shifter as the tuning element in our feedback scheme. To evaluate the available locking bandwidth, we measured the MEMS actuator's electro-mechanical frequency response up to 1 MHz. As seen in Fig. 3, the actuator has its fundamental mechanical resonance at 433 kHz. Thus, we choose a dither frequency of 300 kHz, well below the peak.

As seen in Fig. 4, the feedback loop suppresses the noise amplitude from  $1.1 \mu\text{V}$  to  $0.4 \mu\text{V}$  ( $1\sigma$ ). Finally, we evaluate the step response of the feedback loop by stepping the wavelength of the external laser  $0.1 \text{ nm}$  in each direction, as shown in Fig. 5. The loop exhibits a fall time of  $16 \text{ ms}$  ( $90 - 10 \%$ ) and a rise time ( $10 - 90 \%$ ) of only  $3 \text{ ms}$  when tracking the laser.

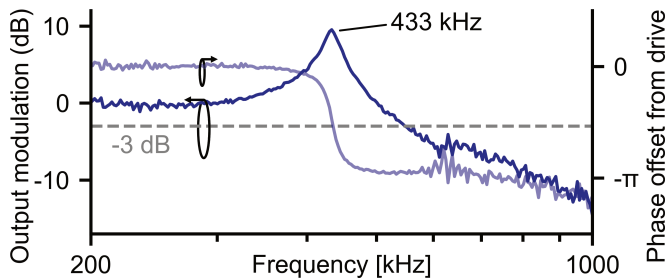


Fig. 3. Measured electro-mechanical frequency response of the two MEMS phase shifters visualized as the output amplitude modulation at the Through port and the phase offset from the drive. The device was driven with a  $0.1 \text{ V}$  amplitude and  $4 \text{ V}$  offset.

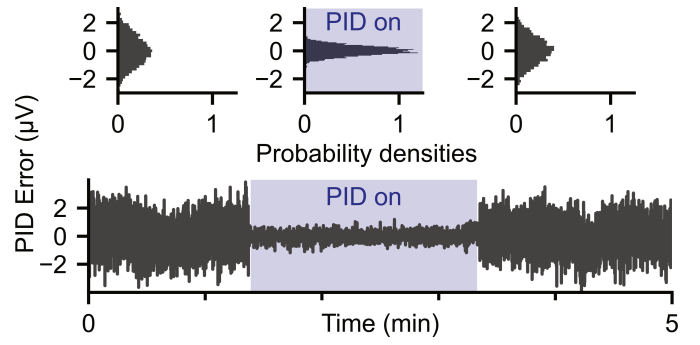


Fig. 4. Measured PID error over time with the PID off, on, and off again. The laser wavelength was preset on resonance to isolate the noise reduction.

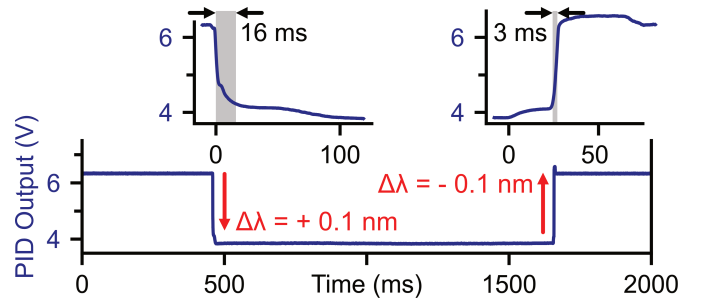


Fig. 5. Measured response to a  $0.1 \text{ nm}$  step change of input laser wavelength. The two insets are magnifications of the steps and show the  $10 - 90 \%$  rise times.

### III. CONCLUSIONS

We demonstrate the implementation of a dither-lock scheme to lock an integrated silicon photonic ring resonator to an external laser. The lock leverages an integrated low-power silicon photonic MEMS phase tuner with over  $400 \text{ kHz}$  mechanical bandwidth and achieves a  $\text{ms}$ -level step response. To our knowledge, this is the first demonstration of microring resonator locking using an integrated photonic MEMS tuner.

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