# Add-drop silicon ring resonator with low-power MEMS tuning of phase and coupling

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**Abstract:** Applications of silicon photonics range from sensing to microwave processing. However, low-power active filters with long FSRs are lacking. We demonstrate an add-drop ring filter with 4 nm FSR and nW-level MEMS tuning of phase and coupling. 

## 1. Introduction

Silicon photonics are rapidly expanding into new applications, such as sensing and microwave photonics [1]. For such applications, tunable filters are needed, which can be efficiently built using waveguide ring resonators (RRs). Such infinite impulse response (IIR) filters can also be flexibly implemented by configurable recirculating waveguide meshes, but those display lower quality factors ($Q$) and free spectral ranges (FSR), due to long optical lengths and multiple discrete components. Moreover, active components available in current foundry platforms consume power in the mW-range, due to the thermo-optic actuation employed.

MEMS-based components are attractive for programmable circuits, as they can efficiently tune phase or power within short optical lengths and with sub-µW power consumption [2]. MEMS actuators have been used for tunable RRs [3–5], but no compact add-drop ring with control over phase and both couplers has been shown. Chu and Hane demonstrated a RR with very short optical length and large resonance tuning, but the $Q$ was limited to $1.6\times10^3$ [3]. Park et al. reported on fully reconfigurable rings, but with an FSR lower than 0.2 nm [5]. Here, we show an add-drop ring resonator with 4 nm FSR and analog control over both the phase (detuning) and the two directional couplers. The device was implemented on IMEC's iSiPP50G foundry platform, with a few post-processing steps.

## 2. Device

The device was designed on IMEC's iSiPP50G platform, and its performance benefits from selective doping and low-resistance metal routing, while its characterization is eased by high performance PDK components such as grating couplers (Fig. 1 (a)). The MEMS actuators and ring waveguide were released using vapour HF after alumina protection of the back-end-of-line dielectric stack. The device (Fig. 1 (b)) is composed of a 20 µm-radius ring, with a 400 nm × 214 nm waveguide core supported by a 70 nm thin disk membrane; two comb-drive actuators

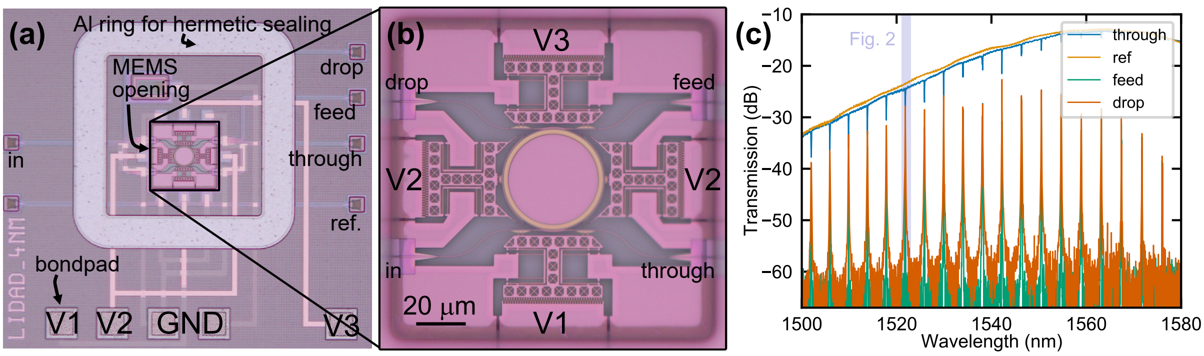


Fig. 1. Our compact add-drop ring-resonator, (a) implemented on IMEC's iSiPP50G, (b) composed of independent MEMS actuators to tune both the round-trip phase, and the input/output coupling. (c) Measured passive transmission at the through, drop, and feed ports, and a reference waveguide.

with independent voltage control for in- and out-coupling that can move the bus waveguides away from the ring (V1, V3); and two comb-drive actuators with common voltage control to tune the effective index of the ring waveguide by moving a 220 nm wide Si ribbon within the evanescent field of the ring waveguide mode (V2). All four MEMS comb-drive actuators and restoring springs are based on our previously published phase shifter, featuring a sub-nW static power consumption and a time response of 2 µs [2].

## 3. Device characterization

We used a tunable laser to measure the device transmission from 1500 to 1580 nm for all three output gratings, and a reference (Fig. 1 (c)). Resonances are visible across the spectrum with an FSR of 4 nm, although with some peak-splitting, particularly at longer wavelengths. We actuated each MEMS tuning block using a custom printed circuit board controlled by a single board computer. We tracked the transmission at the through and drop ports for a resonance at 1522 nm, see Fig. 2 (a). We measured the transmission both with increasing and decreasing biases, and did not observe any hysteresis. We fitted the through transmission to obtain resonance shift, extinction ratio (ER) and quality factor with respect to V1, V2, and V3, see Fig. 2 (b). The different MEMS actuators behave as intended: V1 mainly reduces the coupling from the input waveguide to the ring, V2 shifts the resonance by tuning the round-trip phase, and V3 reduces the coupling from the ring to the output waveguide.

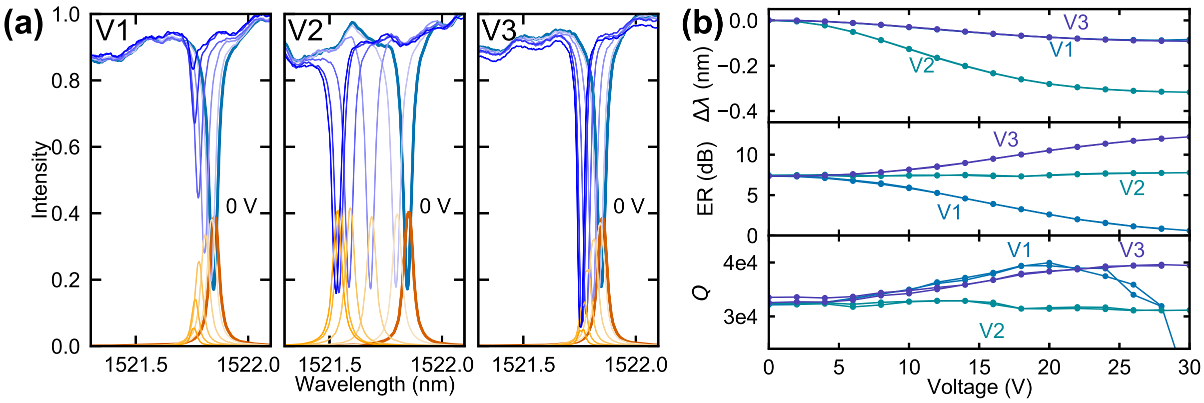


Fig. 2. Device actuation. (a) Close-up view of a single resonance, with MEMS tuning of the input coupler (V1), the phase shifters (V2), and the drop coupler (V3). (b) Corresponding resonance shift, extinction ratio, and $Q$ versus V1, V2, V3, obtained by fitting the resonance at the through port.

## 4. Conclusions

We have presented a ring resonator based add-drop filter implemented on a silicon photonics foundry platform with a few post-processing steps. The ring has a much longer FSR (4 nm) than rings composed of discrete active elements, while still providing low-power tuning over the round-trip phase and both couplers, and a $Q$ up to $4 \times 10^4$. We believe that our MEMS-tunable add-drop ring with nW leakage power and implemented on a foundry platform can become a key building block for large filter circuits needed in microwave photonics and sensing.

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