Low-power micro-electro-mechanical ring resonators on IMEC's iSiPP50G platform

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A need for low power tunable ring resonators in silicon photonic circuits

Why?

- Programmable PICs
- Filter circuits, neuromorphic computing, ...

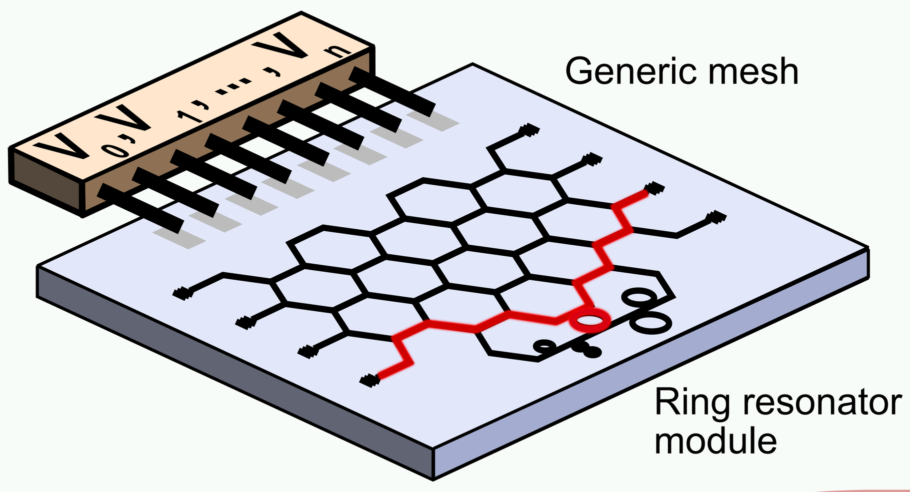
How?

- Generic mesh: only phase shifters, but lossy and long round-trip lengths
- Dedicated rings: compact, high-Q, but low-power tuning missing

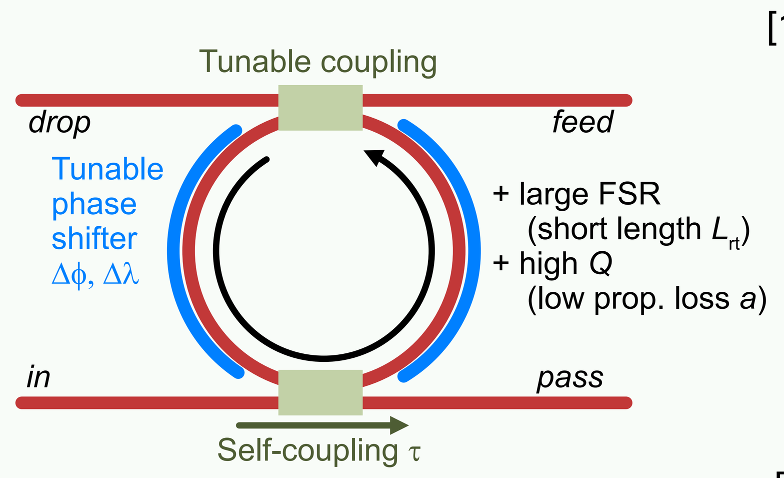
Our proposed solution

- MEMS actuators: <μW/device
- On a silicon photonic foundry

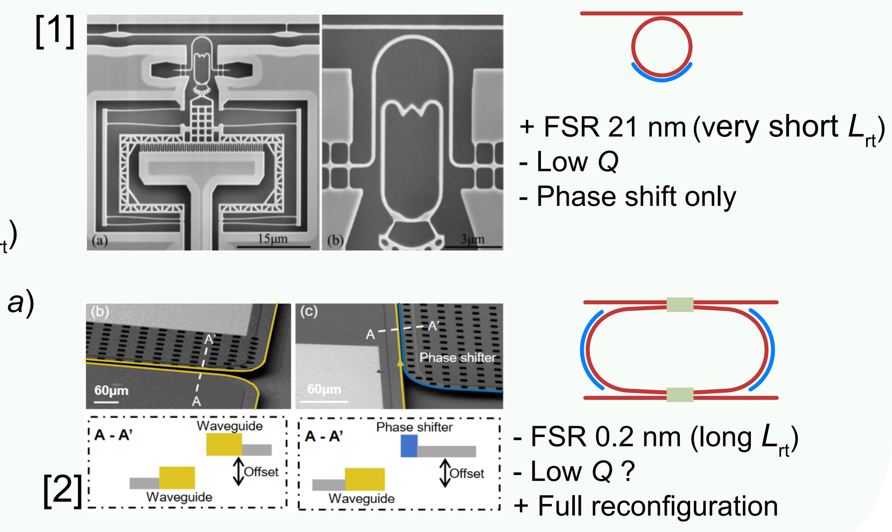
Programmable circuit with compact high-Q rings



Tunable ring resonator



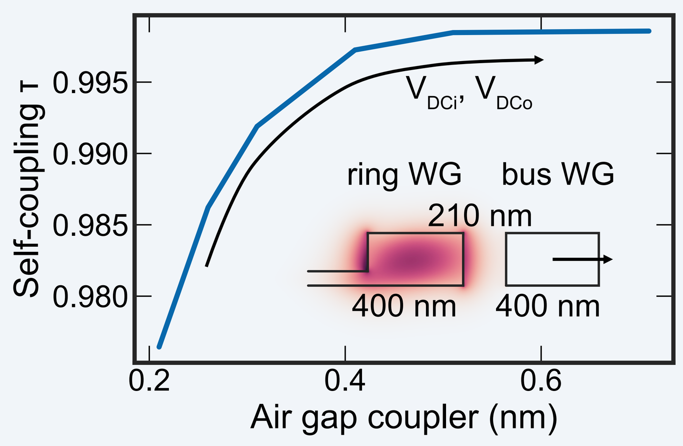
Photonic MEMS ring resonators

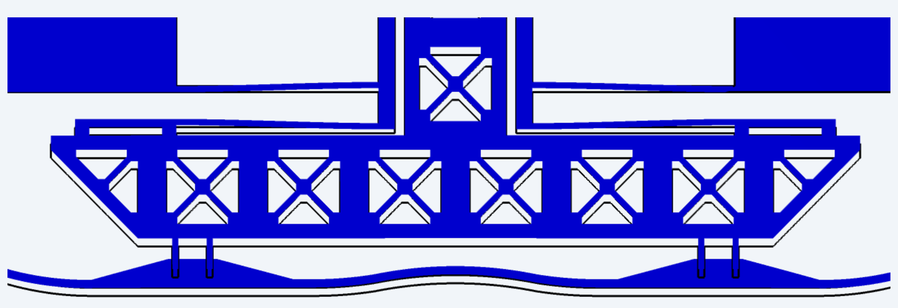


PIC: Photonic Integrated Circuit, MEMS: Micro-Electro-Mechanical-Systems

L_{rt}: round-trip length, Q: Quality Factor, FSR: Free Spectral Range

Tunable coupling

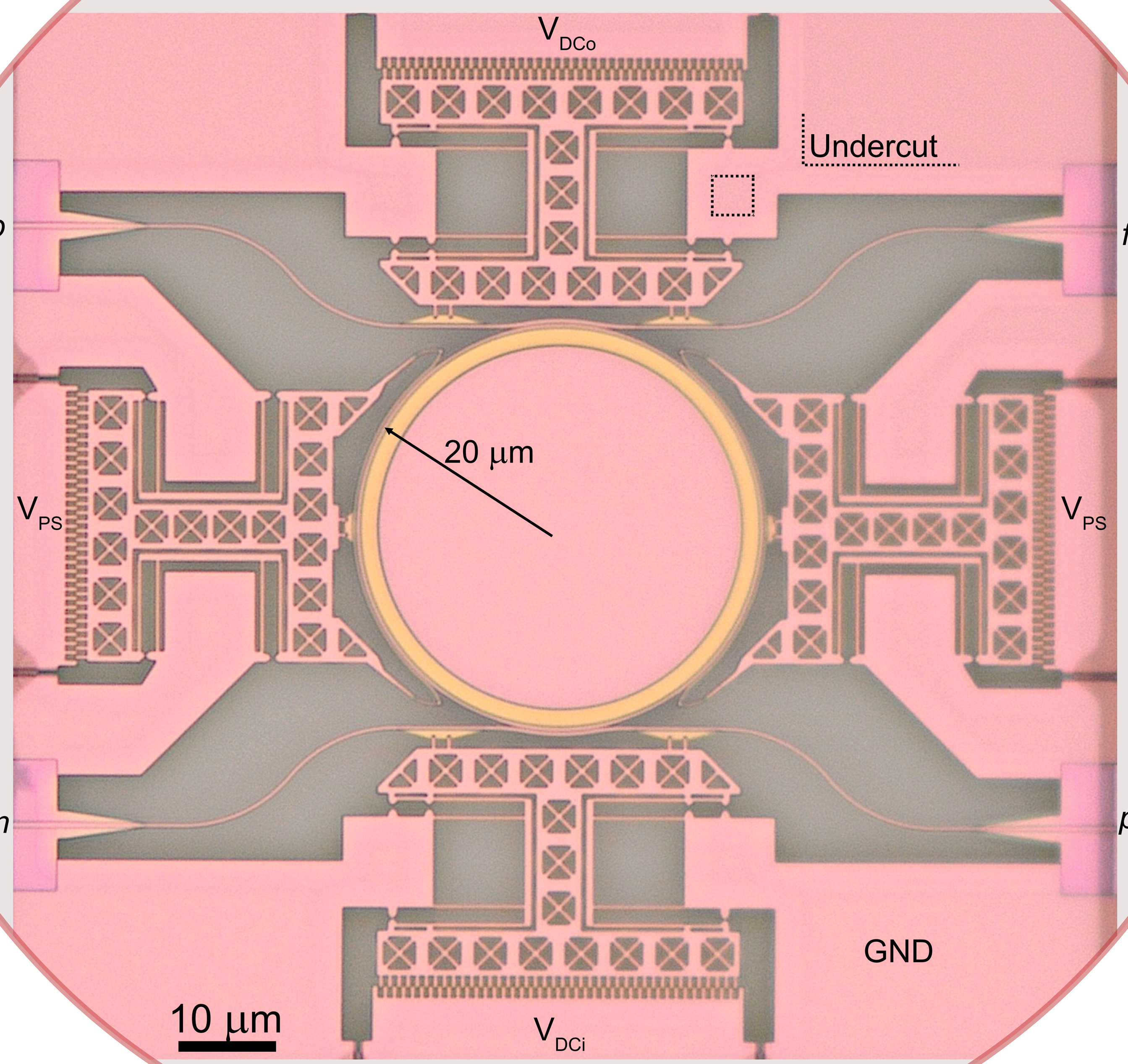




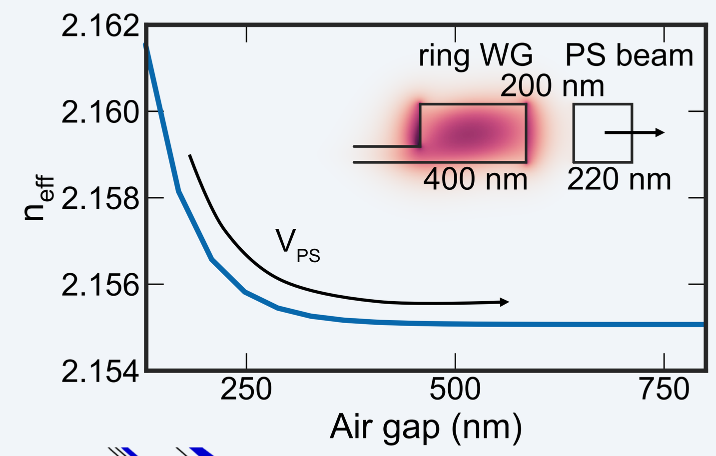
Main design parameters

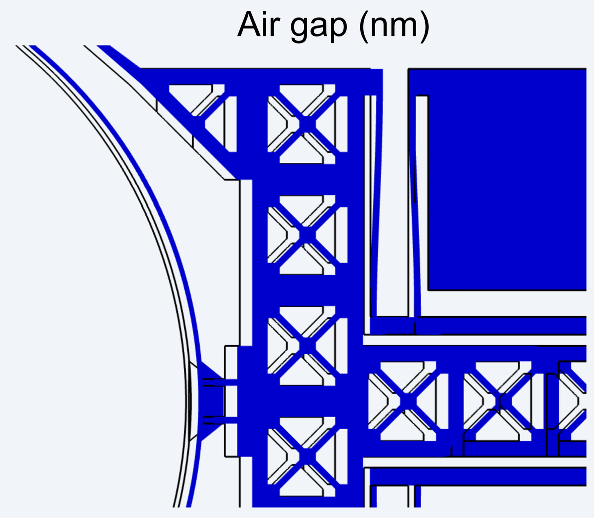
- self-coupling τ > 0.975 (0.11 dB)
- f_{res} = 680 kHz
- voltage range 0-30 V

Our MEMS-tunable add-drop ring resonator



Phase shifting





Main design parameters

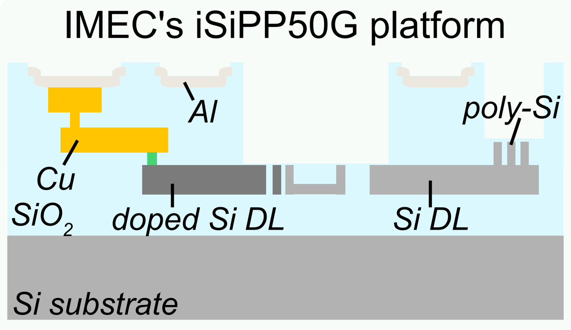
- Δn_{eff} > 0.04
- L_{PS} = 69 μm

} Expected Δλ > 0.5 nm @1550 nm

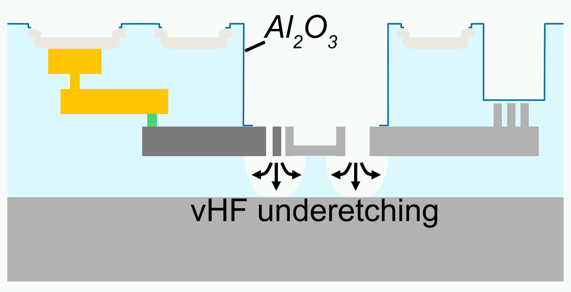
- Based on [3]: f_{res} = 500 kHz, 0-30V, ~1 nW DC

Implementation

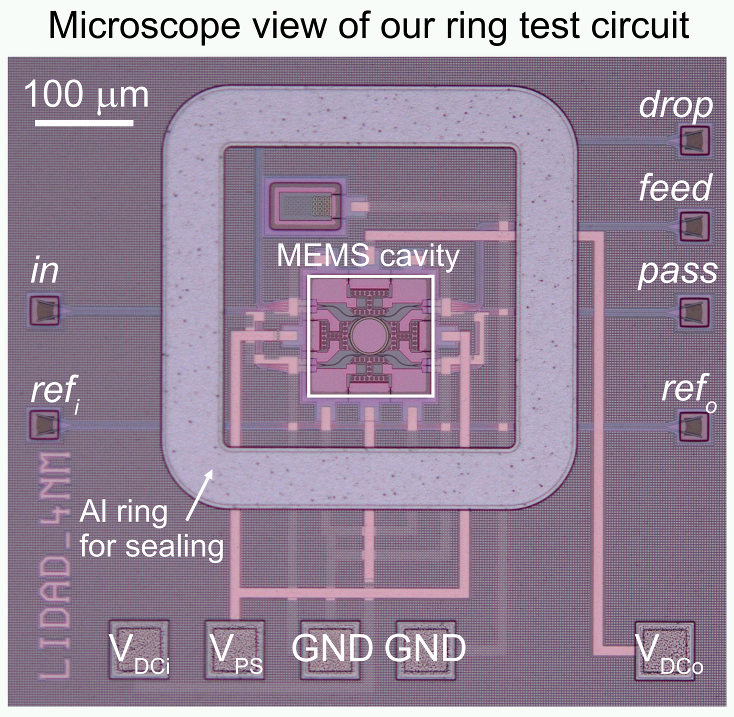
IMEC's iSiPP50G platform



+ MORPHIC post-processing



Microscope view of our ring test circuit



Post-processing

- Few steps only
- No impact on protected BEOL
- Wafer compatible

Design on IMEC's iSiPP50G

- PDK components: bondpads, waveguides, splitters, ...
- Selective doping of Si DL used for MEMS actuators

PDK: Process Design Kit, DL: Device Layer, BEOL: Back-End-Of-Line

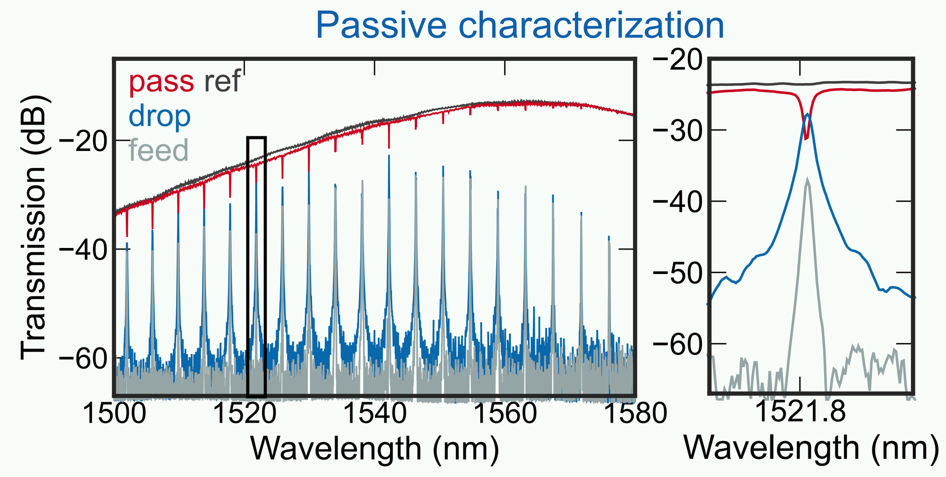
Measurements

Key measurement results

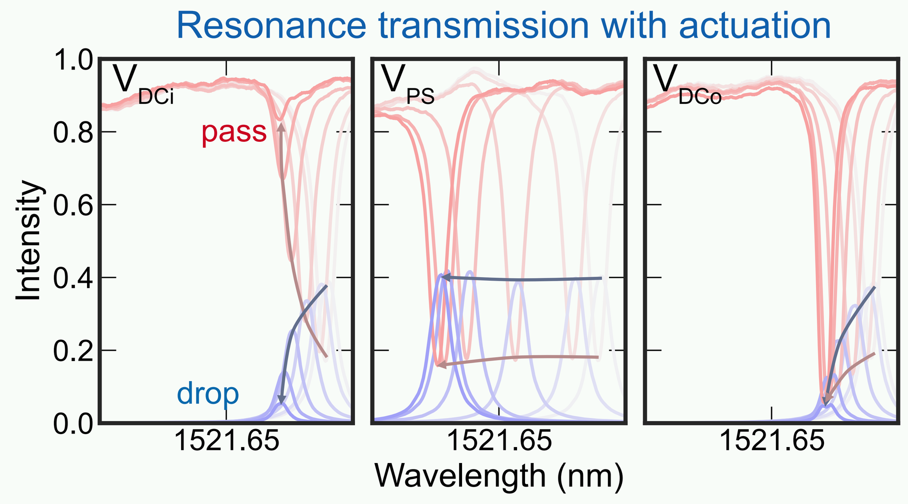
+ FSR of 4 nm
+ Q > 30k
+ V_{PS}, V_{DCi}, V_{DCo} work as intended
+ PS does not change losses

- Peak splitting (at longer λ)
- Low resonance tuning Δλ

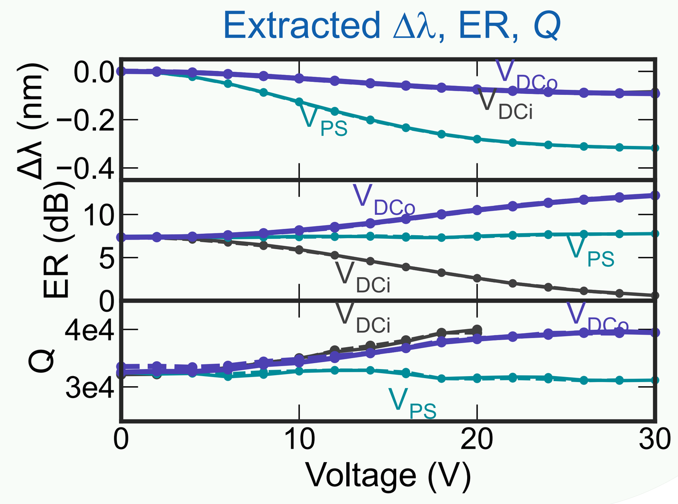
Passive characterization



Resonance transmission with actuation



Extracted Δλ, ER, Q



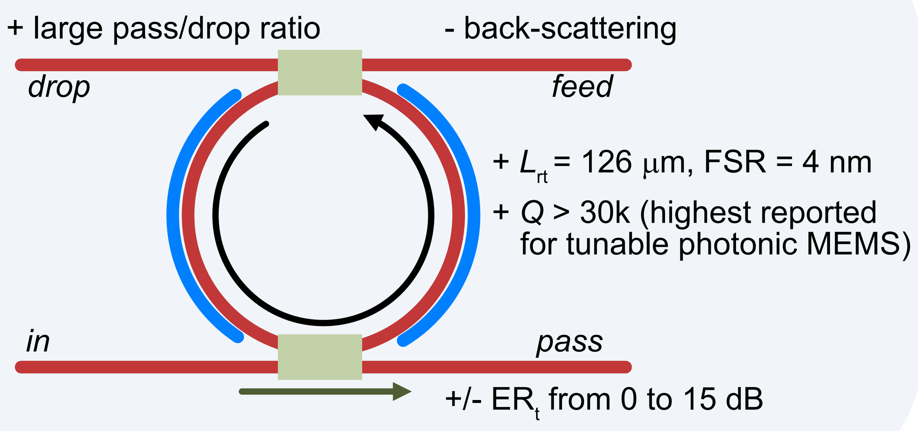
Conclusions

A MEMS-tunable add-drop ring resonator

- with independent tuning of coupling and round-trip phase
- on a silicon photonics foundry platform
- with a short length, and Q>30k

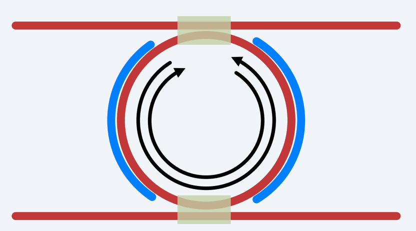
For programmable PICs where low-power, compact, high-Q tunable rings are missing

- microwave photonics
- neuromorphic computing



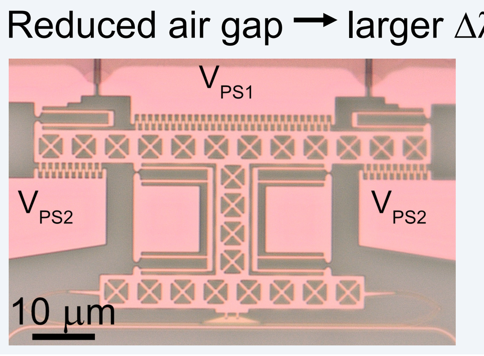
Q: quality factor, BS: Back-Scattering, Lrt: round-trip length, ER_p: resonance extinction at pass port, FSR: Free Spectral Range

Next steps



Larger Δλ tuning

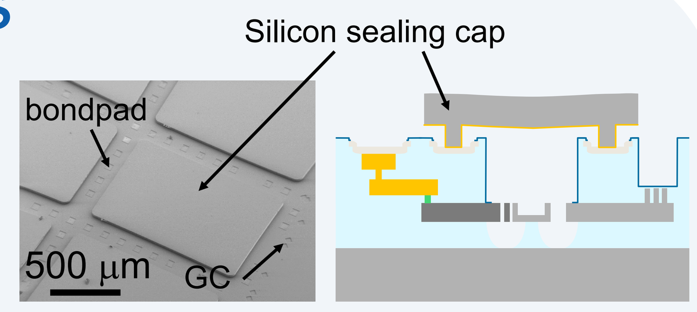
- Gap-reducing actuator shown for 2-level nonvolatility [4]
- Reduced air gap → larger Δλ



Peak-splitting analysis

- Intrinsic Q (no BS) up to 80k
- MEMS-tunable reflection?

BS: Back-Scattering



Vacuum sealing of the ring

+ Demonstrated for phase shifters [5]
+ Compatible with standard interfaces
+ Enhanced mechanical performance

[1] H. M. Chu and K. Hane, "A Wide-Tuning Silicon Ring-Resonator Composed of Coupled Freestanding Waveguides," Photonics Technology Letters, IEEE, vol. 26, no. 14, pp. 1411–1413, Jul. 2014, doi: 10.1109/lpt.2014.2326405.
[2] Y. J. Park et al., "Fully Reconfigurable Coupled-Resonator Optical Waveguides (CROWs) with 10 nW Static Power MEMS," in Conference on Lasers and Electro-Optics (2021), paper STh1Q.5, May 2021, p. STh1Q.5. doi: 10.1364/CLEO_SI.2021.STh1Q.5.
[3] P. Edinger et al., "Silicon photonic microelectromechanical phase shifters for scalable programmable photonics," Opt. Lett., OL, vol. 46, no. 22, pp. 5671–5674, Nov. 2021, doi: 10.1364/OL.436288.
[4] P. Edinger et al., "A Bistable Silicon Photonic Mems Phase Switch For Nonvolatile Photonic Circuits," in 2022 IEEE 35th International Conference on Micro Electro Mechanical Systems Conference (MEMS), Jan. 2022, pp. 995–997. doi: 10.1109/MEMS51670.2022.9699739.
[5] G. Jo et al., "Wafer-level hermetically sealed silicon photonic MEMS," Photon. Res., PRJ, vol. 10, no. 2, pp. A14–A21, Feb. 2022, doi: 10.1364/PRJ.441215.

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