

Silicon photonic MEMS Switches

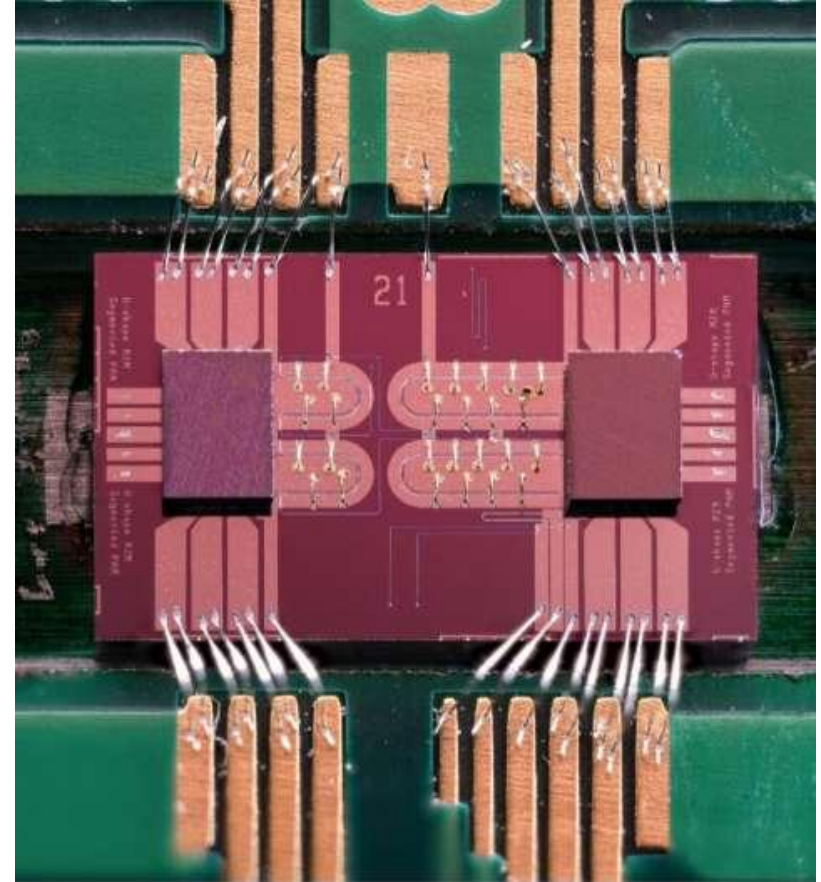
Mathieu Dubois

EPFL

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History and actual status

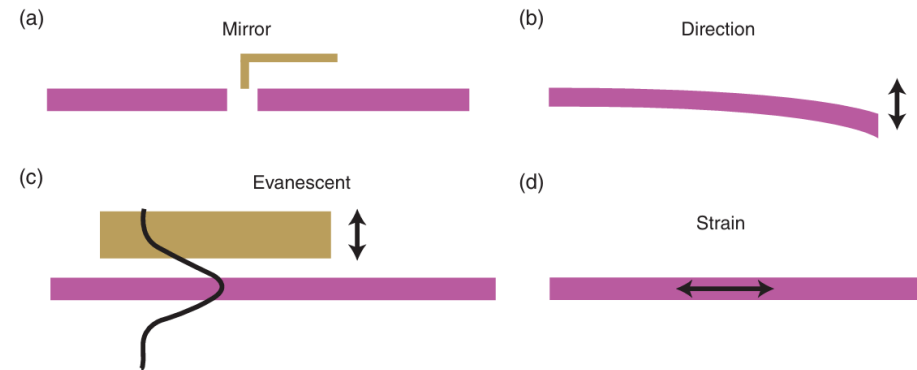
- First Si photonic switch in the 1980s
- Use of cascaded MZZs and MRRs
- MEMS based Si photonic switches (around 2015)



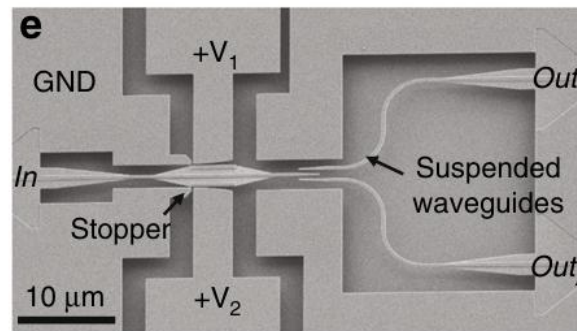
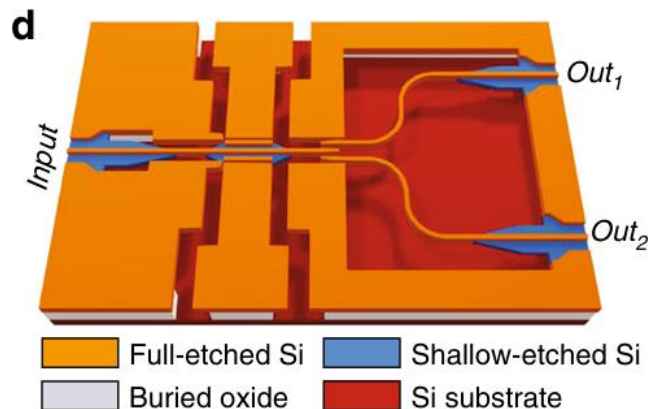
[An energy efficient transmitter based on a CMOS chip and silicon photonics](#)

MEMS operation principle

- 4 different basic operation principle
- Sequential directional couplers with movable branches attached to the MEMS
- Capacitor plate MEMS actuator
- Voltage activation required
- Change in the optical path



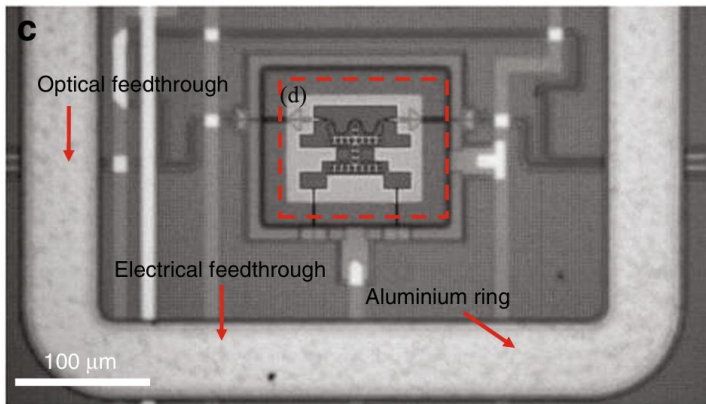
[Silicon Photonic Switches - Optical Switching - Wiley Online Library](#)



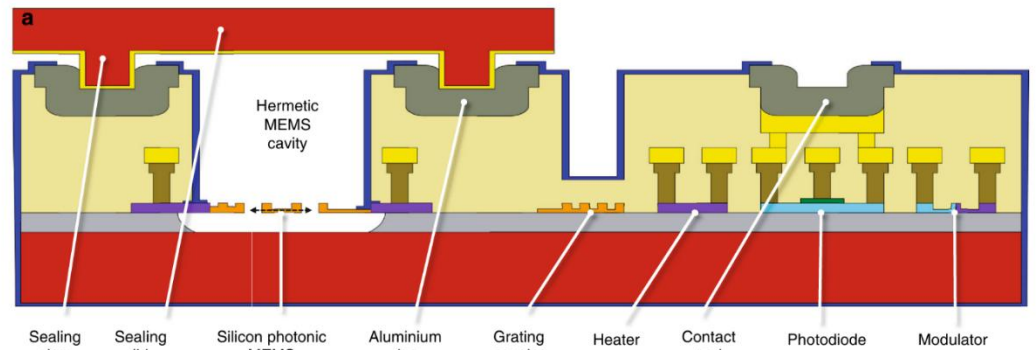
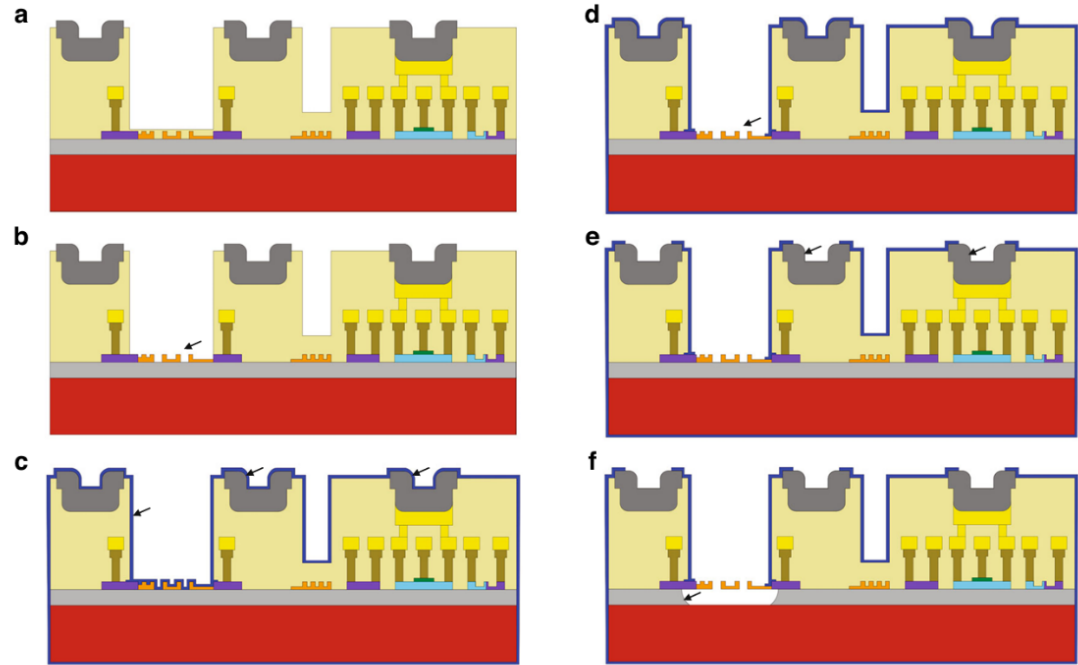
[Integrated silicon photonic MEMS | Microsystems & Nanoengineering](#)

MEMS implementation

- Foundry process (IMEC's iSiPP50G) on SOI wafer
- Oxide etching
- ALD deposition of Alumina
- Liquid BHF etch
- vHF etching
- Wafer-sealing by Al-Au thermocompression



Integrated silicon photonic MEMS |
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Characteristics

Low power consumption (Picojoules)

Large Bandwidth (Tb/s)

High level integration

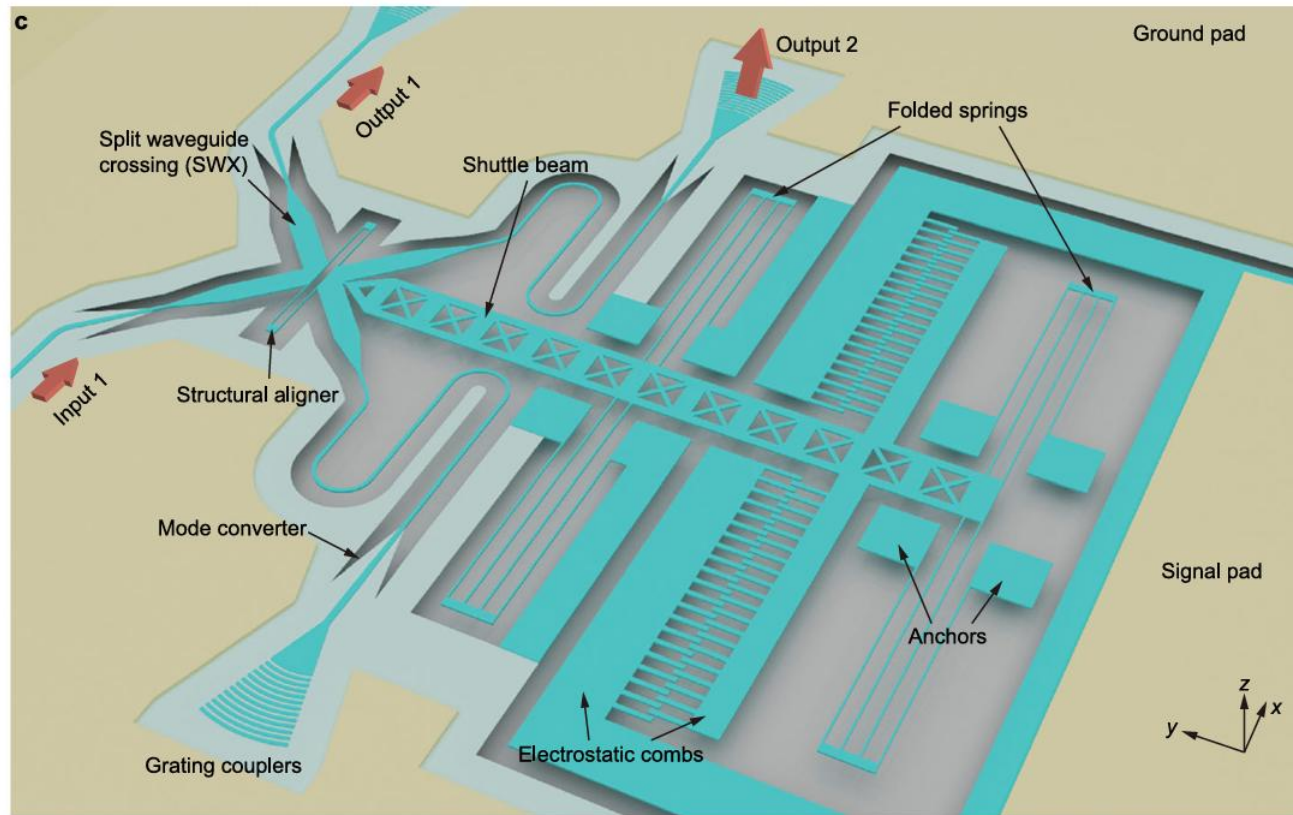
Fast switching speed

Ref.	Institution	Switch Engines	Scalability & Topology	On-chip Insertion Loss (dB)	Coupling Loss (dB)	Crosstalk (dB)	Switch Time	Power (W)	Size (mm ²)
[68]	NEC	T-O MZI	8 × 8 PILOSS	-	-	-25	-	-	12 × 3
[69]			8 × 8 Switch & select	4	1	-35	150 μs	-	12 × 14
[28]	Bell Labs		8 × 8 Switch & select	4	3.5	-30	250 μs	0.07	8 × 8
[70,71]	AIST		32 × 32 PILOSS	8.4	1.4	-35	30 μs	1.9	25 × 11
[72]	IBM	E-O MZI	4 × 4	3.7	-	-15	5 ns	0.05	0.165
[73]			8 × 8 Double Layer	-	-	-	-	-	0.675
[41]	SJTU		16 × 16 Benes	14	5	-10	3.2 ns	1.2	10.7 × 4.4
[74]	CAS	T-O MZI	32 × 32	18.5	5	-15	1.2 ns	0.54	12.1 × 5.2
[75]		E-O MZI	64 × 64 Benes	12	-	-30	-	-	21.7 × 9.6
[76]	Huawei	T-O MZI	32 × 32	13	3.2	-20	1.4 ms 70 μs	1 20	12 × 12
[77]			16 × 16 Hybrid Dilated Benes	22	4.5	-	-	-	12.5 × 12.5
[44]	HKUST	E-O MRR	5 × 5 Cross-bar	-	-	-11	1.3 ns	-	0.1 × 0.1
[78]	TU/e	T-O MRR	8 × 7 Cross-bar	22	6	-20	17 μs	-	-
[79]	CAS		4 × 4	-	-	-13	25 μs	-	-
[80]	Ericsson		48 × 8 Cross-bar	~3	3.2	-23	4 μs	-	8.4 × 7.8
[81]	Columbia University	T-O MRR	8 × 8 Switch & select	10	-	-39	20 μs	-	-
[63]	UC	MEMS	64 × 64	3.7	6.5	-60	<1 μs	40V	8.6 × 8.6
[82]	Berkeley		128 × 128 Cross-bar	22.7	-	-	-	25V	16 × 17

[State of the Art and Perspectives on Silicon Photonic Switches - PubMed](#)

Packaging and systems integration

- MEMS placed in hermetically sealed cavities
- High-density control
 - Optical package
 - Electrical package
 - Cooling package



[Silicon photonic MEMS switches based on split waveguide crossings | Nature Communications](#)

- Telecom networks
- Data center
- High-throughput computing
- Quantum computing



[SM OSW Module 4 \(2≤N≤128\) - ETSCマイクロデバイス株式会社](#)

References

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- **ETSC Micro Devices Co.**