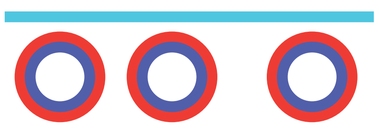
1.9-pJ/bit 0.5-mm² High-Speed Optical Transmitter including Silicon Slow-Light Modulator and Current-Mode BiCMOS Driver

K. Kawahara[1], T. Tsuchizawa[2], N. Yamamoto[2], Y. Maegami[2], K. Yamada[2], S. Hara[3], and T. Baba[1]
[1]Yokohama National University, [2]AIST, [3]NICT

Background

Si Photonics Transmitter for Optical Interconnects

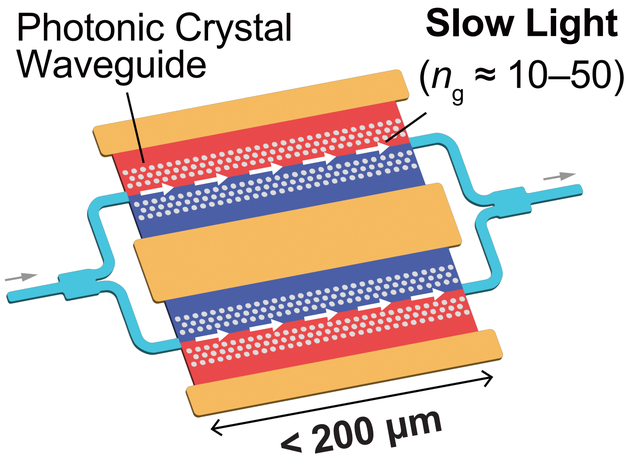
	MRM-based Tx	MZM-based Tx
		
😀 > 50 Gbps	Speed	😀 > 50 Gbps
😀 < 2 pJ/bit	Power	😭 > 5 pJ/bit
😀 < 1 mm²/Ch.	Footprint	😭 > 5 mm²/Ch.
😭 Required	TEC	😀 Free

Challenges: **High Speed** (> 50Gbaud), **Low Power** (< 2 pJ/bit), **Compact** (< 1 mm²/Ch.), and **TEC Free** (MZM)

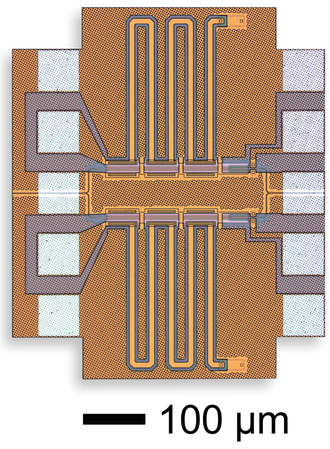
Si Photonic Crystal Modulator

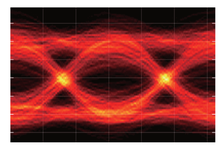
😀 **Compact & Small Capacitance**

Modulation Efficiency ∝ n_g



Optica, vol.11, no.9, Sep. 2024.





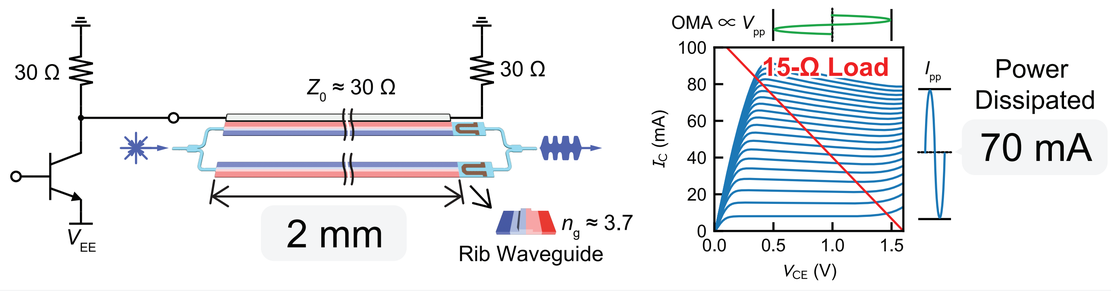
64 Gbps

V_{pp} = 0.87 V

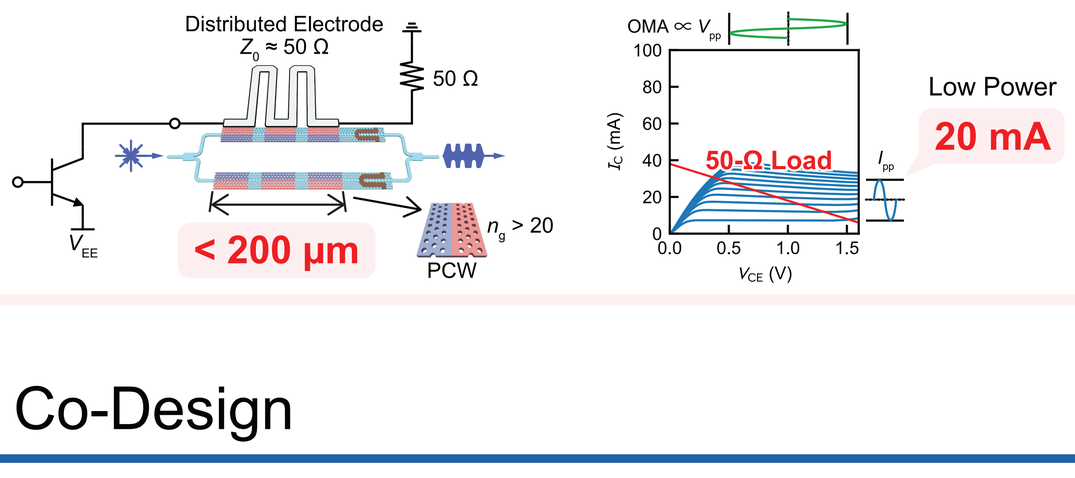
59 fJ/bit

Concept

😥 Conventional: Rib Waveguide Modulator + Terminated Driver

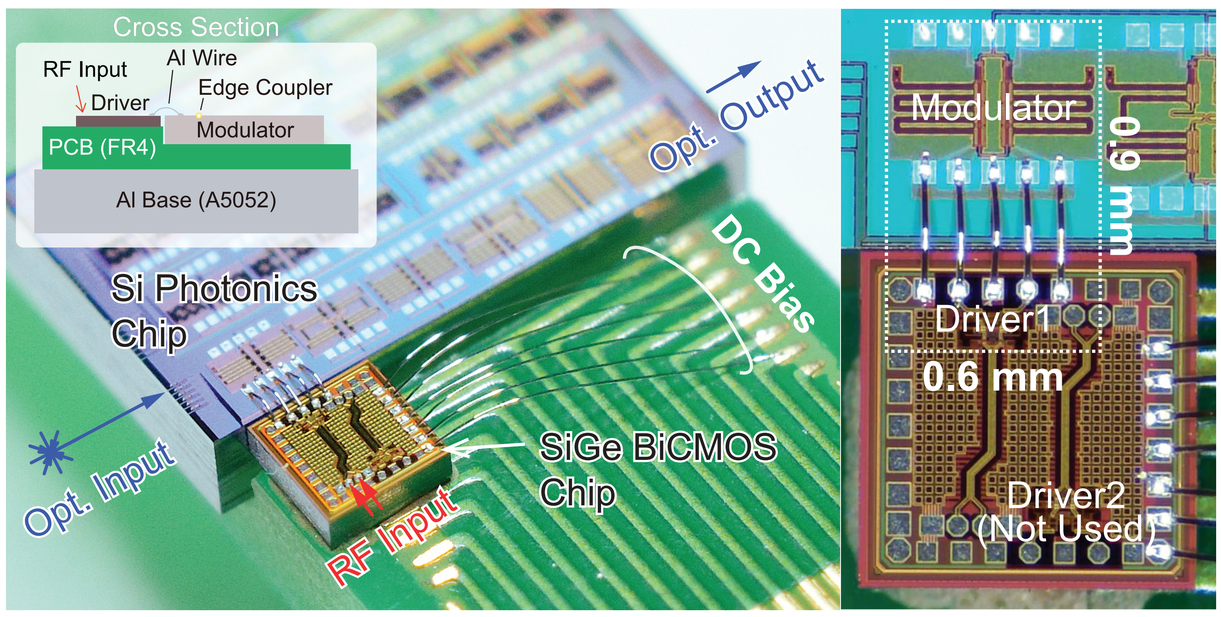


😀 **This Work: PCW Modulator + Open-Collector Driver**



Fabricated Transmitter

0.5 mm²/Ch. Small Footprint

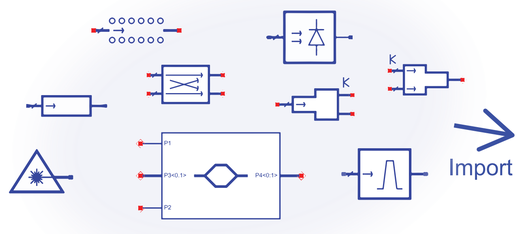


Modulator: AIST Si Photonics Driver: IHP SG13G2 130-nm BiCMOS

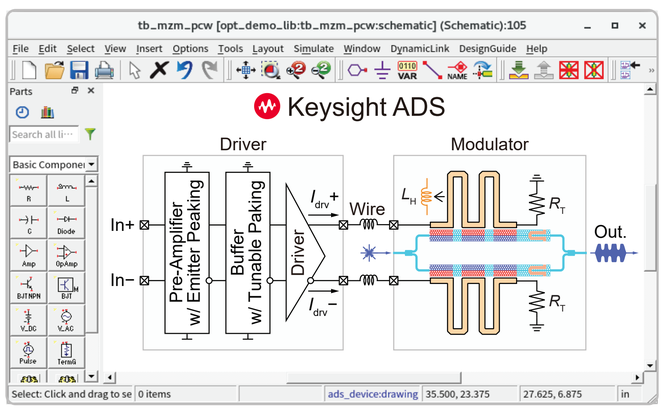
EO Co-Design

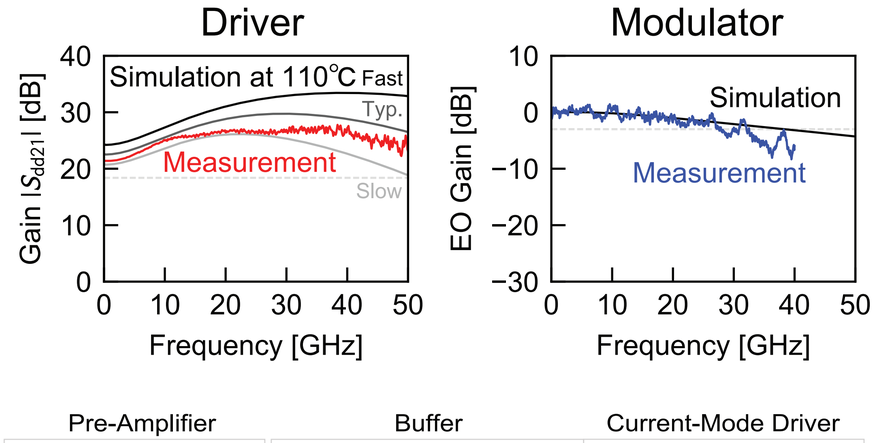
Using de-fact standard electronic circuit simulators

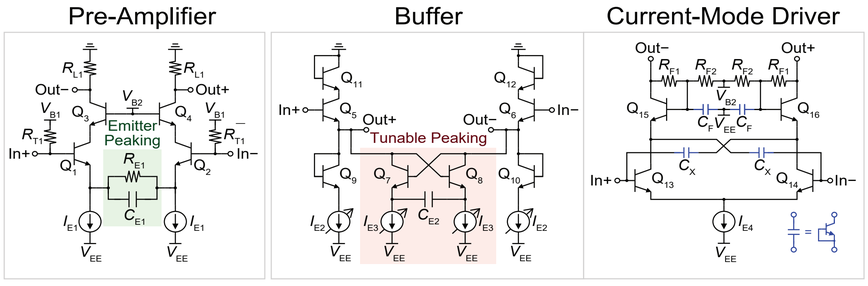
In-house Photonic Models



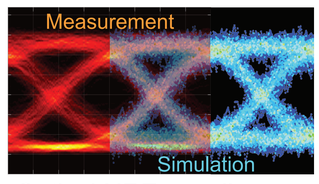
Interoperable in Synopsys, Cadence, Keysight etc...







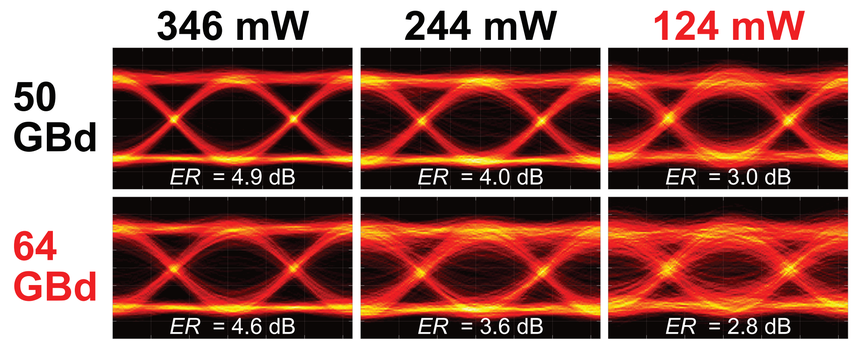
EO Co-Simulaiton

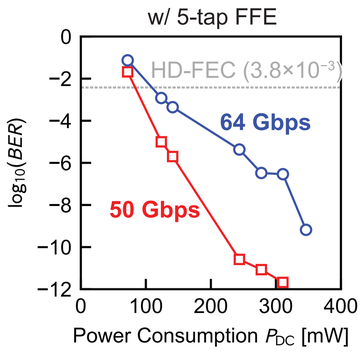


Optical NRZ eye diagram at 50 Gbaud w/o DSP

Results

1.9 pJ/bit Including the Driver





Ref.	Device	EO Integration	Symbol rate [Gbaud]	Rx DSP	DC Power [mW]	Efficiency [pJ/bit]	ER [dB]	Footprint [mm²/Ch.]
This Work	Si PCW MZM + 130-nm BiCMOS	Hybrid	64 (NRZ)	5-tap Eq.	124	1.9	2.8	0.5
[1]	Si MZM + 28-nm CMOS	Hybrid	112 (NRZ)	6-tap Eq.	78	0.7	1.1	2.0
[2]	Si MZM + 250-nm BiCMOS	Monolithic	44 (NRZ)	None	500	11.4	3	7.8
[3]	Si MZM + 55-nm BiCMOS	Hybrid	26.5 (PAM4)	5-tap Eq.	290	5.5	6.9	11
[4]	SiGe EAM + 55-nm BiCMOS	Hybrid	53 (PAM4)	None	159	1.5	4.5	0.8

[1] K. Li et al., Nat. Elec., 6(11), pp. 910–921, 2023.
[2] F. Iseini et al., IEEE SiRF, 2023.
[3] E. Sentieri et al. IEEE ISSCC, 2020.
[4] J. Lambrecht et al., JLT, 38(2), pp. 432–438, 2020.

EO co-designed and integrated Tx including a Si photonic crystal modulator and driver

➡ High seed, low power, and small footprint