Monolithic Electronic-Photonic IC for Data Transmission

Concept and Design

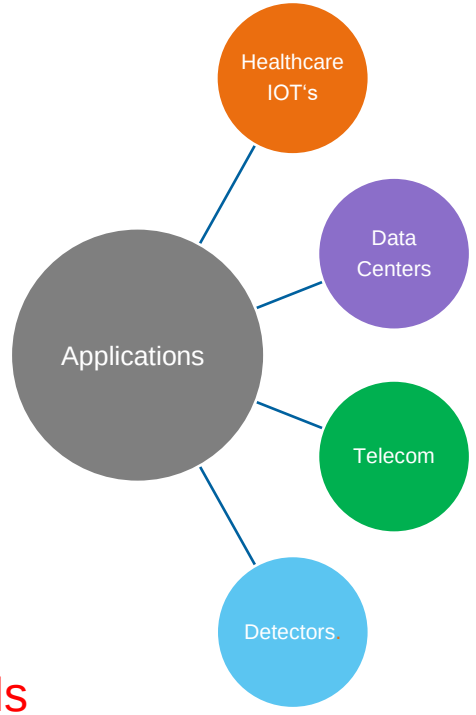
Pradeep Kalavakuru
Hamburg, 12.03.2024

Contents

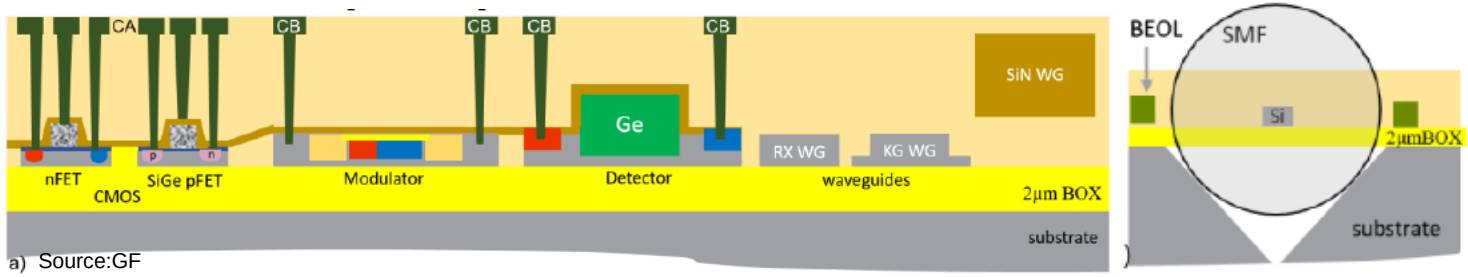
Monolithic Electronic-Photonic IC for Data Transmission

Technology – GlobalFoundries (90nm → 45nm)

	CMS90WG	45SPCLO
NMOS, PMOS f_T (Hz)	150G / 80G	280G / 230G
Supply Voltage (V)	1.2 / 3.3	1 / 1.8
Data Rates	≤ 50Gbps	≤ 100 Gbps
Electronics	RVT, LVT, DG, Coils	RVT, LVT, UVT, DG, Coils
Photonics (O-band)	MZM, WG, PD, IOSMF	MZM, Rings, WG, IOSMF
Packaging	C4 Bumps	C4, 2.5 / 3D stacking, TSV's



✓ state-of-the-art electro-optical Co-Design environment including photonic models

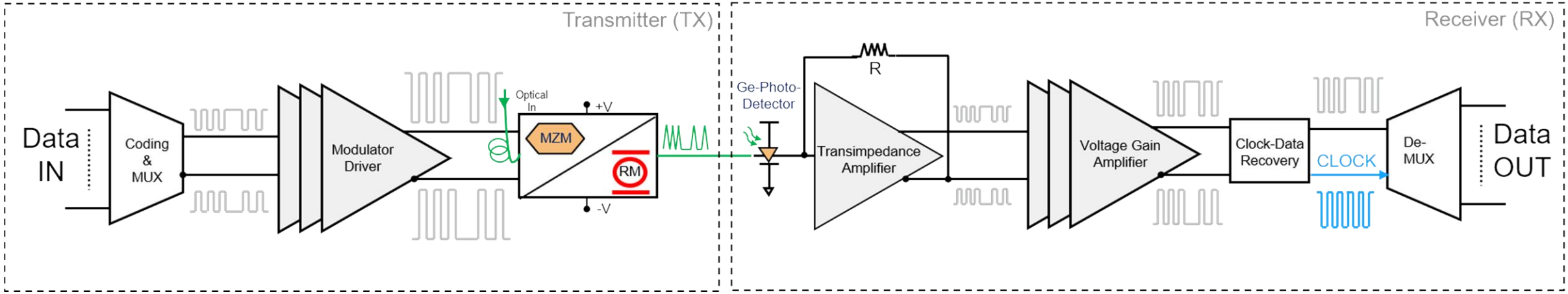


a) Source:GF

- V-Groove fiber attachment

Monolithic Electronic-Photonic IC for Data Transmission

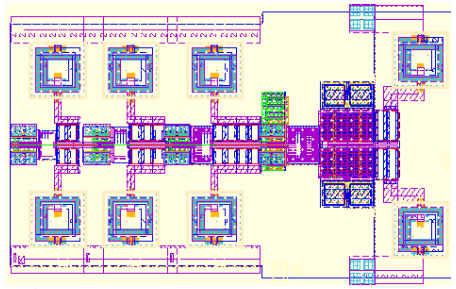
Concept & Design



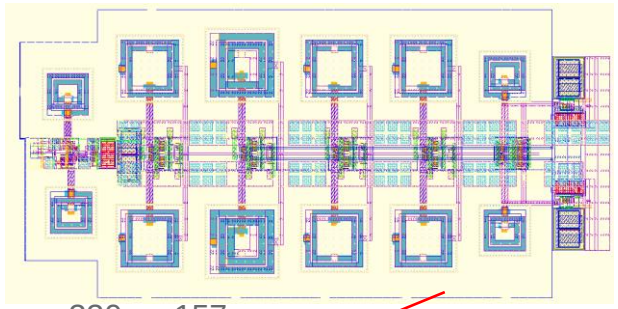
- In any process, channel bandwidth is limited by electronics (50Gbps @ 1bit / UI for 45SPCLO)
- One can increase the data rates by advanced modulation scheme - PAM-4 (2bits / UI)
  - **MZM** – Concept 1
- An alternative approach to enable high transceiver bandwidth is Wavelength Division Multiplexing without increasing optical fibers
  - **Ring Modulators** – Concept 2

Monolithic Electronic-Photonic IC for Data Transmission

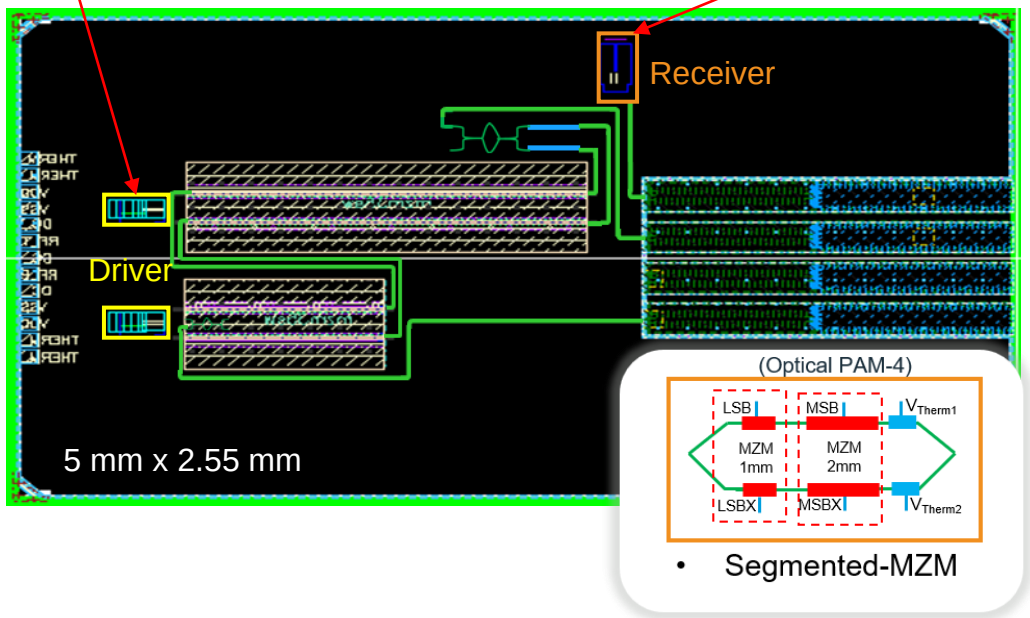
Concept 1 - (Global foundries – 90nm SOI CMOS)



235µ x 138 µm

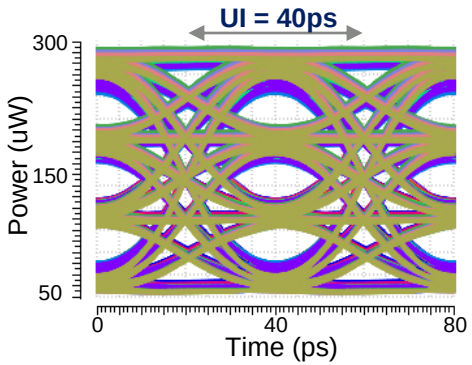


330µ x 157 µm



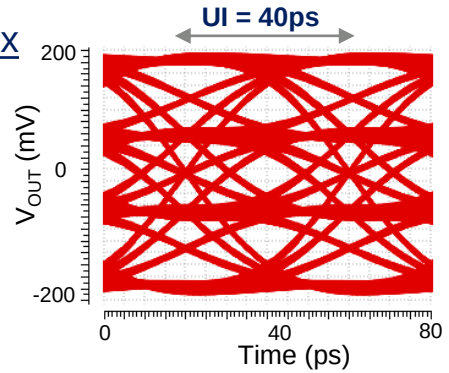
- Segmented-MZM

Tx



- 25 Gbaud PAM-4
- 7 pJ / bit

Rx

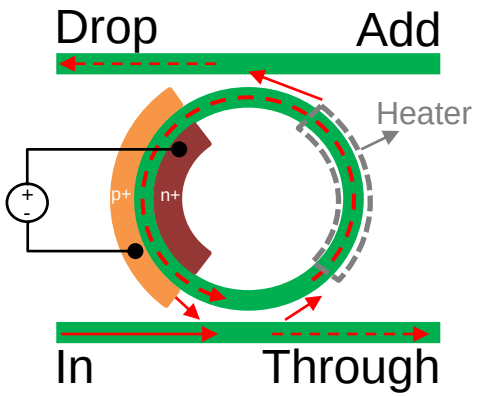


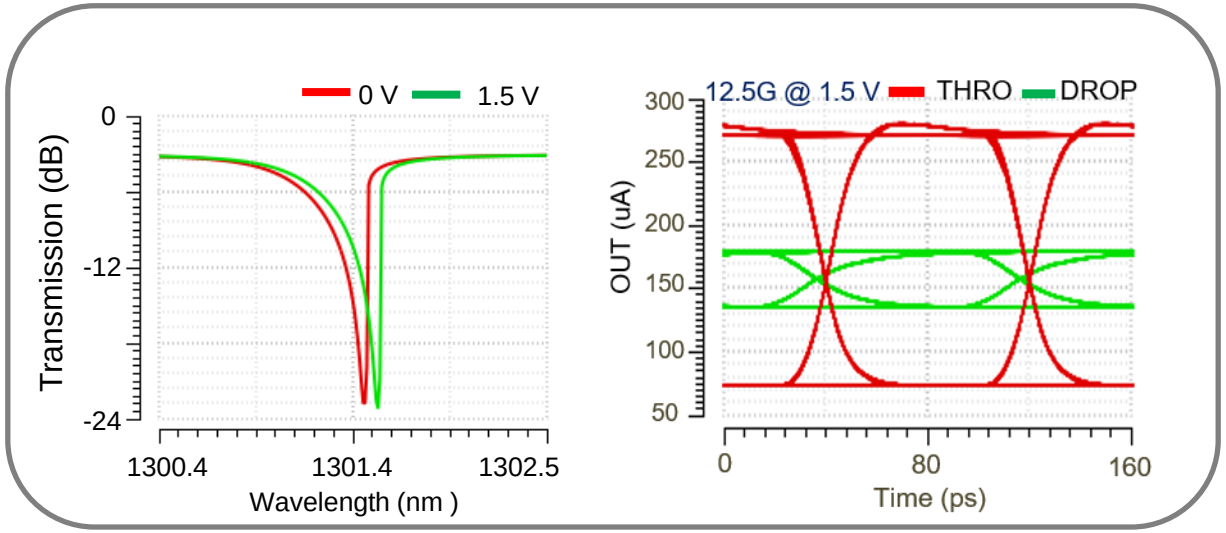
- 25 Gbaud PAM-4
- 0.8 pJ / bit

- PAM-4 can be realized either electrically or optically
- Optical is chosen to keep the design complexity to low
- Large voltage swings, High power consumption
- Large footprints, Large device capacitance,

Monolithic Electronic-Photonic IC for Data Transmission

Concept & Design – Micro Ring Modulator (MRM)

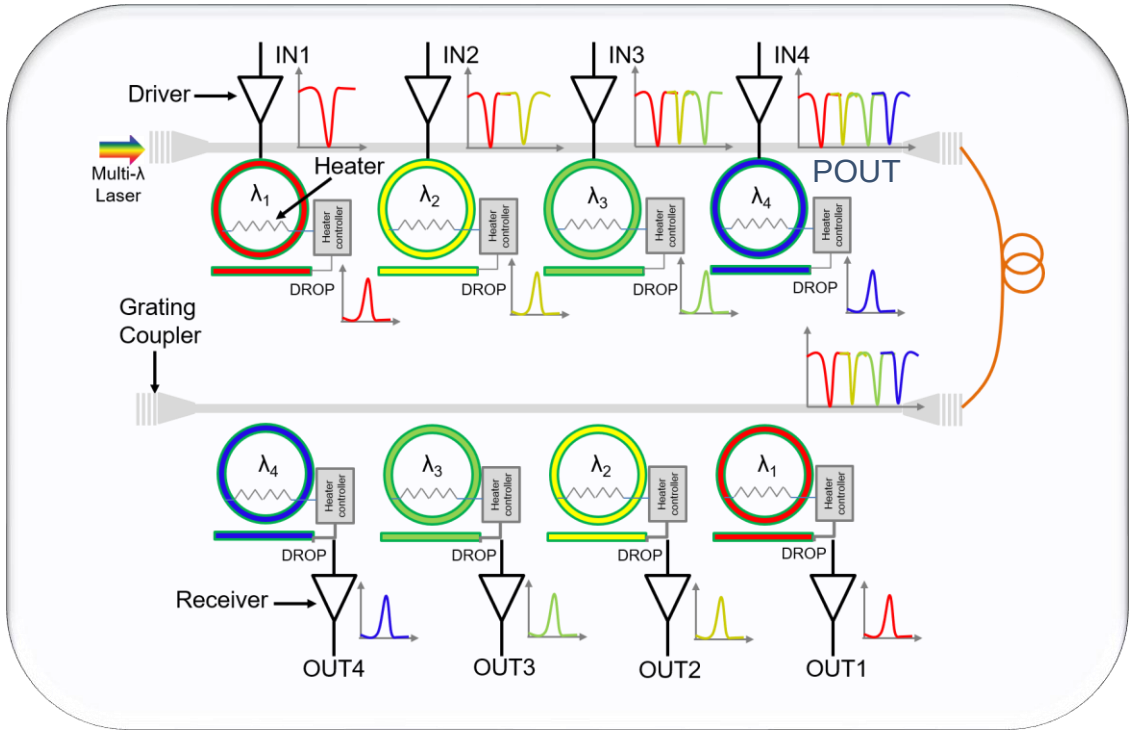


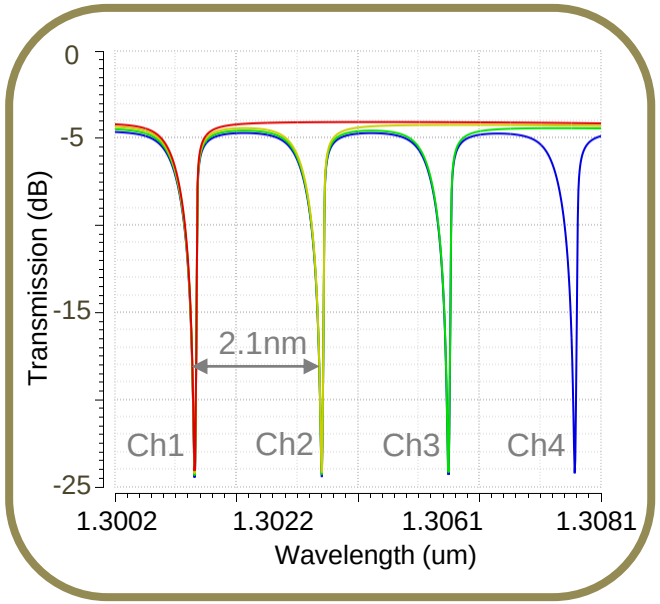


- Because only a selected wavelengths will be at resonance within the loop, RM functions as a filter.
- Small footprint (7.5u x 40u), low device capacitance and low power consumption
- Very sensitive to temperature variations, thermal tuning is needed

Monolithic Electronic-Photonic IC for Data Transmission

Concept & Design – Concept 2 - Dense Wavelength-Division-Multiplexing (DWDM)

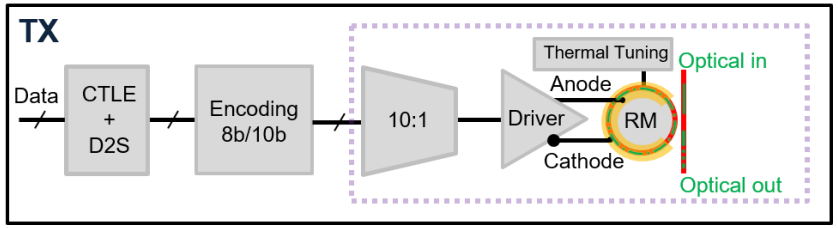




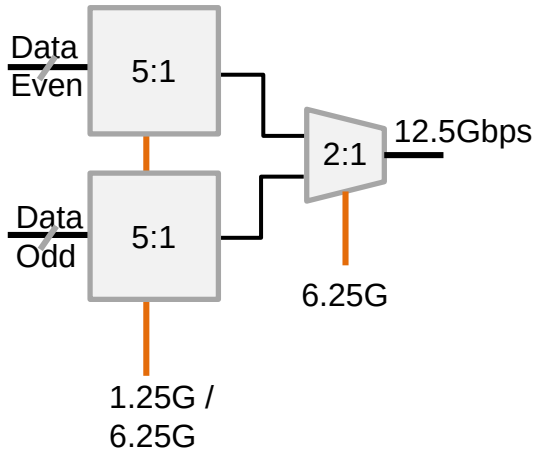
- Attractive approach to realize high data rates up to 50 Gbps per single fiber
- Spacing between the channels → 2.1nm
- highly efficient integrated heating elements to tune their resonant wavelengths to the desired WDM channels

Monolithic Electronic-Photonic IC for Data Transmission

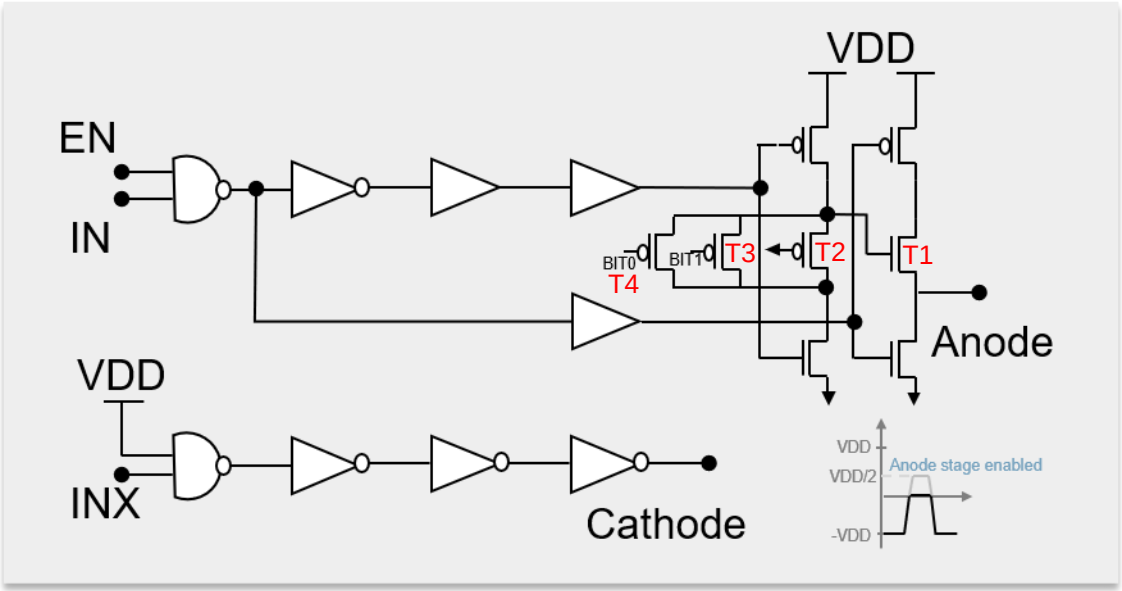
Concept & Design – Serializer, Driver



- 10:1 Serializer
  - Flipflops, Latches are custom made
  - Data rates up to 12.5 Gbps

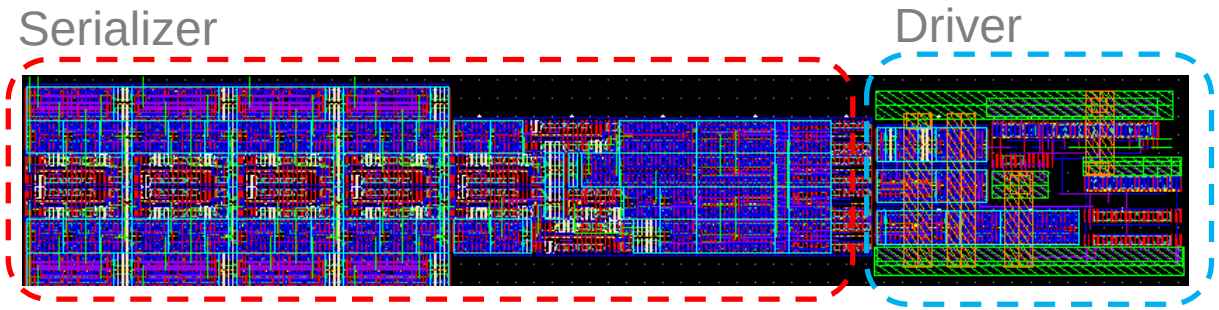


- Asymmetric differential driver
  - Signal 1.5 V_{pk-pk} @ 12.5 Gbps



Monolithic Electronic-Photonic IC for Data Transmission

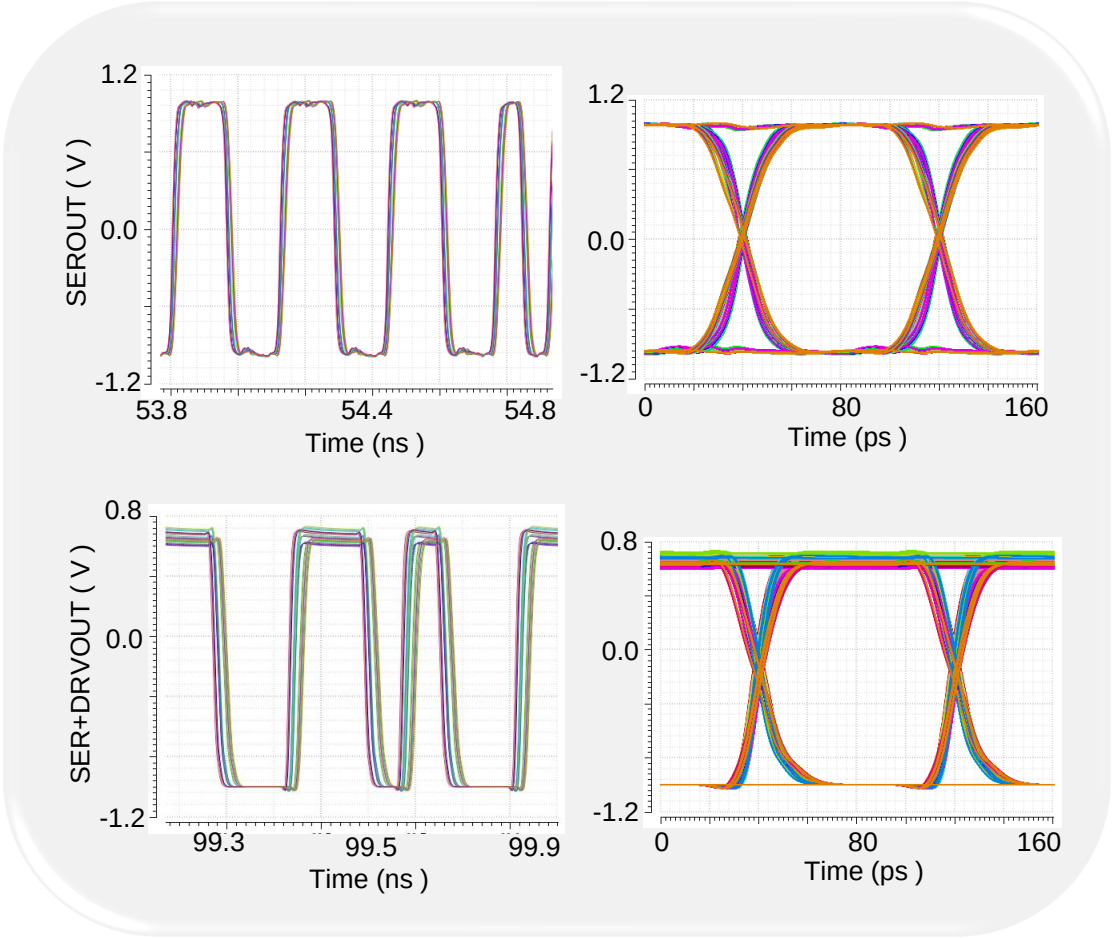
Concept & Design – Serializer, Driver, Layout



- Serializer + Driver: 62u x 11u
- Serializer + Driver: 240 fJ / bit
- Heater power: ~ 400 fJ / bit
- Control circuit: ~ 140 fJ / bit

@ 50Gbps

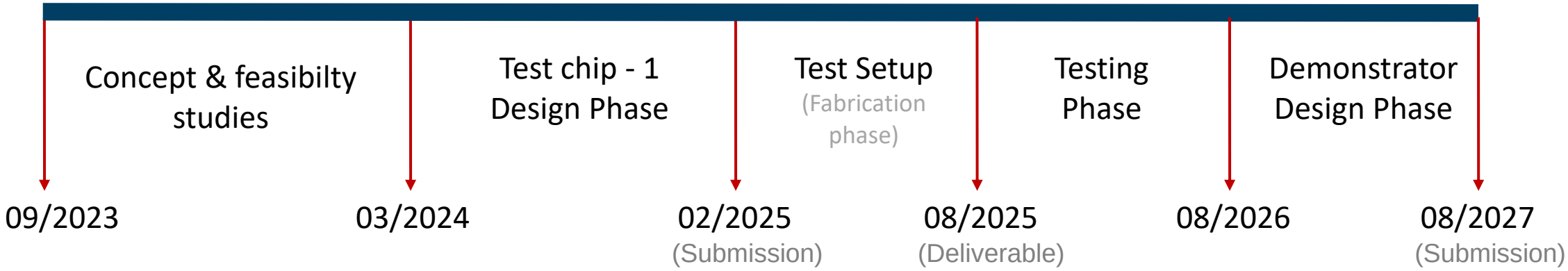
Power (pJ / Bit)	Concept 1	Concept 2
Driver	7	3.12



Monolithic Electronic-Photonic IC for Data Transmission

Concept & Design - Submission

- Test chip would be an optical transceiver (concept 2) targeting data rates up to 50 Gbps



- Design work is in progress - Desy
- Process (Photonics devices) is still in development (6 PDK's) – GF
- Planned to submit in 02/2025