OIF 448G AI WORKSHOP

OIF 448Gbps Signaling for AI Workshop
April 15-16, 2025

448G Technology:

Powering next-gen scale-up and scale-out connectivity

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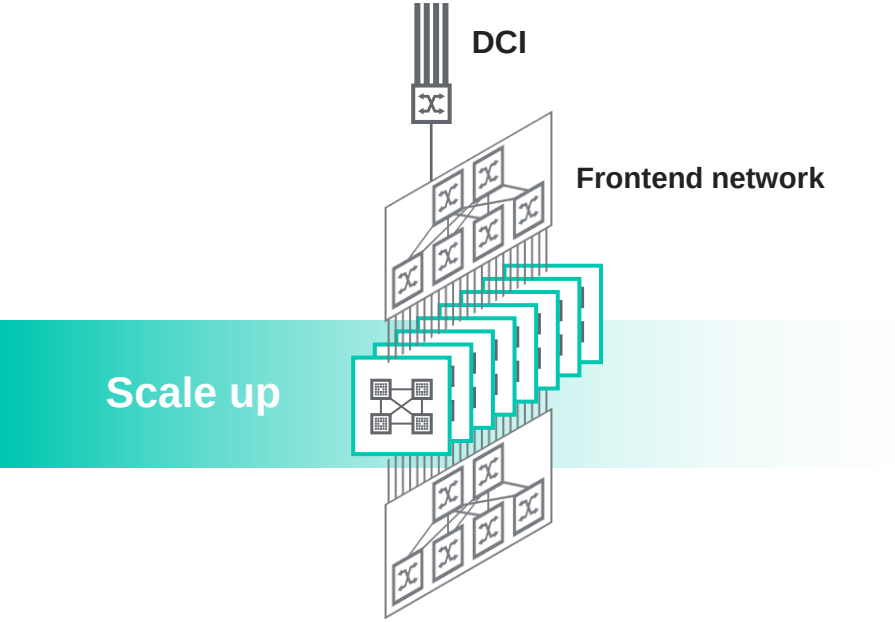
Scale-up interconnect



- Multiple XPUs appearing as one
- Extremely low latency and high bandwidth
- Full capacity available to a single task
- Powered by copper connectivity today
- Speed/lane: 224G → Next-gen 448G

Today's scale up is typically: < 500 XPUs

Scale-up interconnect **Evolution**

PCB trace

Tray

Lowest power | Lowest cost

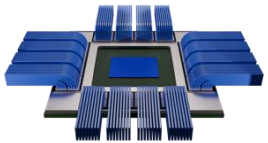
Copper cable

Rack

Lower power | Lower cost

Co-packaged copper (CPC)

CPC



Cabled backplane

In tray / In rack

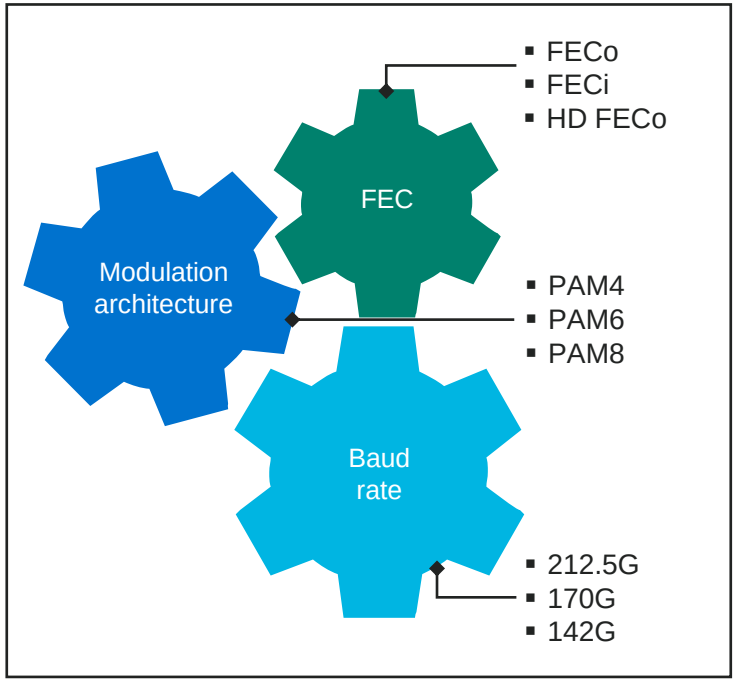
Low power | Low cost

CPC: paving the way to extend copper reach for 448G

Path towards 448G Copper : PAM-n Modulation

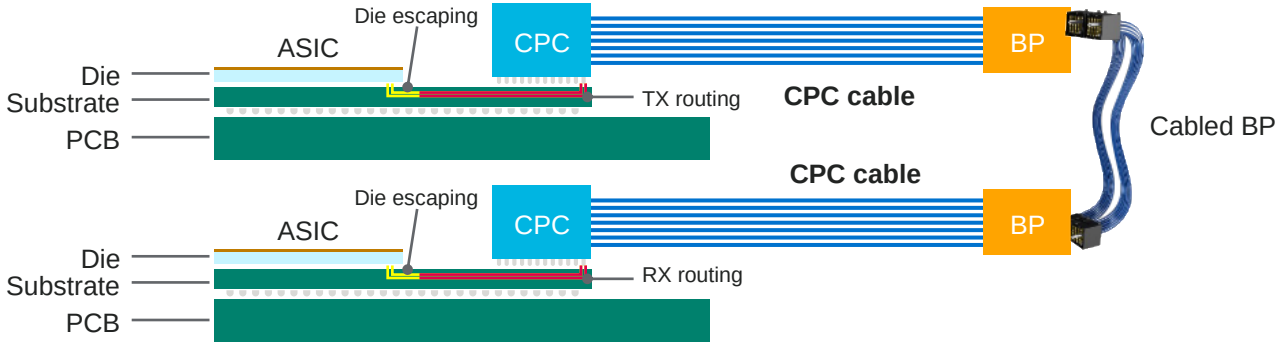
Modulation Format	Baud Rate: FECo	Required SNR for FECo	
PAM4	212.5G	17.65 dB	3.6dB
PAM6	170G	21.2 dB	
PAM8	141.6G	23.7 dB	2.5dB

**Pre-FEC BER: <2.4e-4*



Advanced Equalizer, Higher order Modulation with FEC are the tools to enable 448G

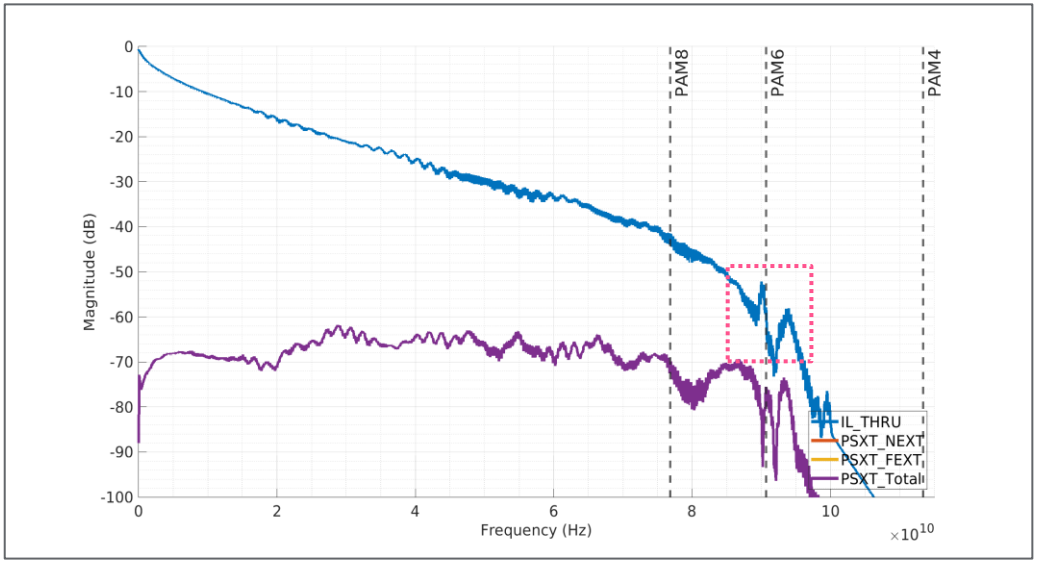
CPC (copper channel) for 448G scale-up connectivity



Modulation	Baud rate	Required SNR	Target reach	Insertion loss	Additional note
PAM4	212.5G	17.65 dB	>1m cabled backplane	>80 dB	Not feasible
PAM6	170G	21.2 dB	>1m cabled backplane	>50 dB	Optional FECi may be needed
PAM8	141.6G	23.7 dB	>1m cabled backplane	>40 dB	

448G copper interconnect: PAM4 is a non-starter

Example of 400G Copper Channel with 1m Copper Cable



*Courtesy – Meta

@ KP Rate

Modulation	Baud rate	IL @Nyquist	Xtalk @ Nyquist	ICR
PAM4	212.5G	Too lossy	NA	NA
PAM6	170G	**52 dB**	70dB	18 dB
PAM8	141.6G	**40 dB**	68 dB	28 dB

- *PAM4 – Loss is too high*
- *PAM6 – loss looks high as well & it is right on the cliff*
- *PAM6/PAM8 – ICR looks healthy but may be a bit optimistic*

SNR Margin Analysis @ FECo rate

Simulation Criteria:

- **Baud rate**: FECo rate (KP rate) only
- **SerDes Spec**: FFE + RC + DFE + a*MLSD mode
- **Case-1:** Run at FECo rate with PAM6
- **Case-2:** Run at FECo rate with PAM8

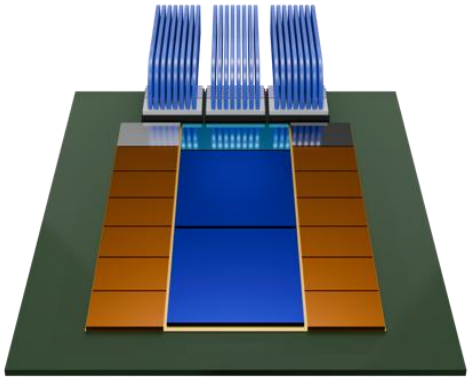
PAM-n	SNR margin @ FECo rate	Simulated BER
PAM4	Not Applicable	NA
PAM6	~ 1dB	<5e-5
PAM8	~ 2.4 dB	<3e-6

Summary:

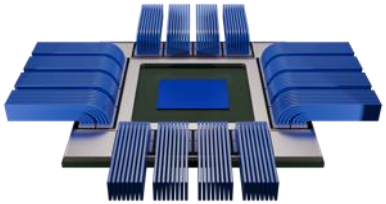
- For this particular channel : Both PAM6 & PAM8 can work but slight advantage to PAM8.
- Both the modulation scheme needs extra boost from additional coding gain from FEC

448G electrical I/O for scale-up interconnect

I/O	Modulation	Channel	Power efficiency
Electrical I/O	**PAM8** or **PAM6** with **optional** FECi for Cu	CPC + 1.5m cabled backplane	< 4.25 pJ/bit



System core technology innovation

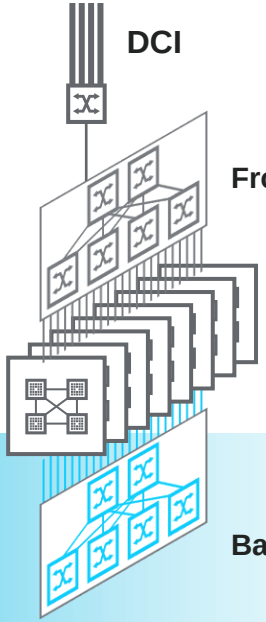


- Co-packaged copper I/O
- Reduces loss from package; extends reach
- Supports 448G

Application: Cabled backplane

- E2E channels spanning entire rack
- Pushes boundaries of SerDes reach

Scale-Out interconnect



Scale out
Connects XPUs via NIC ports and backend network

- Connects multiple AI clusters together
- Multi-row-scale interconnects
- Powered by optical connectivity
- Reliability and serviceability is a must
- 1.6T today → next-gen 3.2T

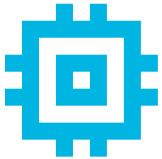
Scale out enables > 100K XPU clusters today

Scale-out interconnect **evolution**

	Modulation	Optical reach	Power efficiency
3.2T	PAM4	~500m	<12 pJ/bit
1.6T	PAM4	~3km	<14 pJ/bit
800G	PAM4	~10km	<16 pJ/bit

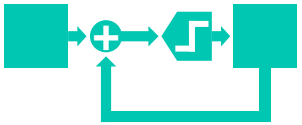
2x Bandwidth every 2 years

Path towards 448G/Lambda and beyond



Analog
bandwidth

Faster components



Signal
compensation

Stronger DSP engine to compensate for optical impairments

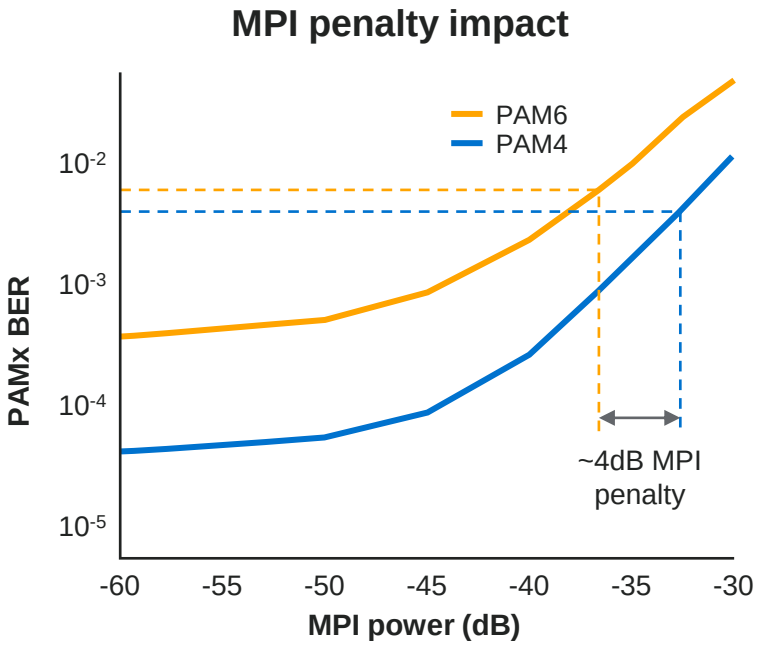
Error
correction

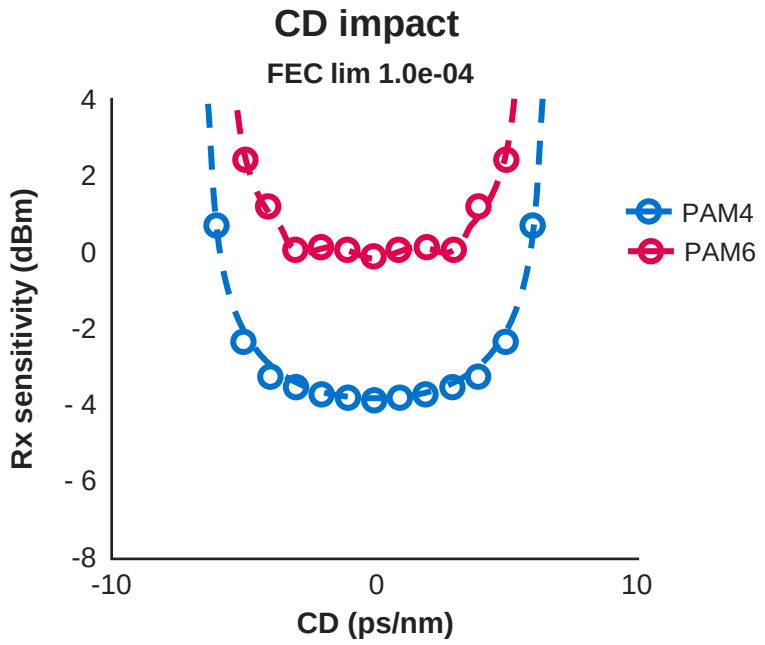
Low-latency FECi for 448G

Photonic
integration

Tighter integration with optical engine

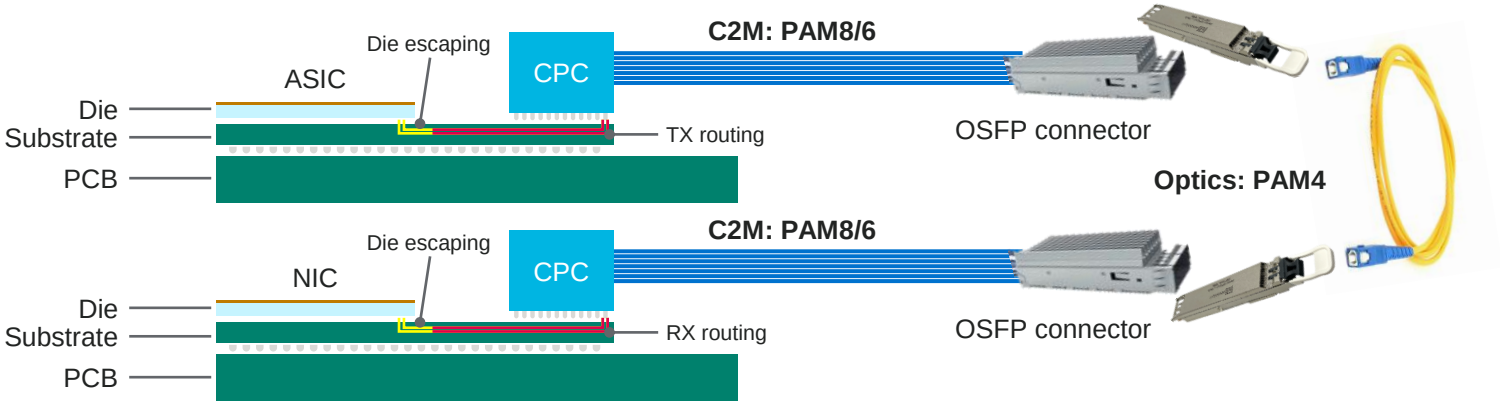
Optical Impairments: PAM4 Vs PAM6





PAM4 offers more resiliency to optical impairments vs. PAM6

3.2T scale-out connectivity powered by DSP



DSP enables the PAM-n gearbox

448G	C2M	Optical	Notes
DSP	PAM8/6	PAM4	✓
LRO	PAM8/6	PAM4	✗
LPO	PAM8/6	PAM4	✗

NextGen 448G PAM4 **Optical** is already here

Real **Silicon** Data – Marvell's 448G Optical TX Eye in OFC 2025

Key takeaways

1. 448G Optical Connectivity continues to lead the scale out Connectivity
2. CPC Technology - key enabler to extend the Copper for scale up connectivity
3. Higher-Order PAM-n modulation - need of the hour to enable the Copper reach
4. Augmenting the FECo with additional coding gain will boost the Link margin

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Q&A

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Thank You

Essential technology, done right™