A.I. CONNECTIVITY

DIRECT DETECTION AND COHERENT DETECTION

IX FORUM 17

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VP Sales

COHERENT

AI CONNECTIVITY

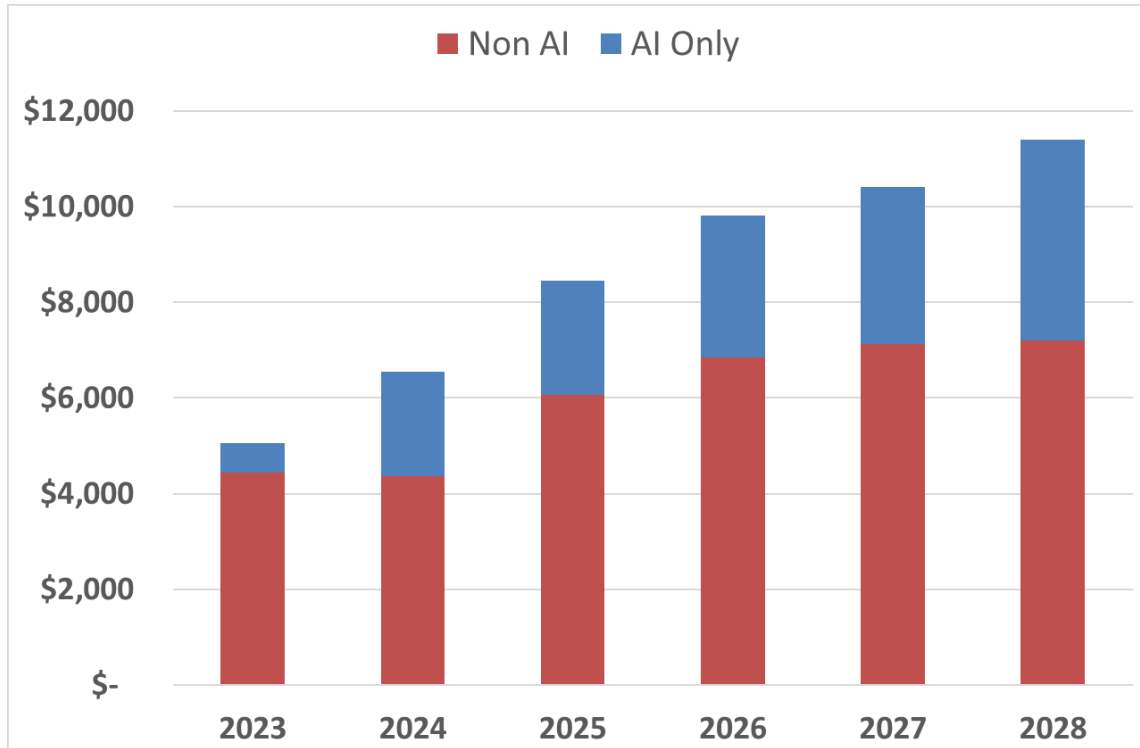| Time to reach **one million** users	
ChatGPT	**5 days**
Instagram	2.5 months
facebook	10 months
Twitter	2 years
NETFLIX	3.5 years

- Mainstream networking topology is giving way to a new topology to accommodate AI systems

- AI/ML networks add to compute and storage networks

- Both Level 0 and Level 1 connectivity will drive significant optics growth

AI systems integrated into data centers

Spine Switches

Level 1:
Optical Interconnects, up to 500 m

Leaf/ToR Switches

Legacy Compute

Storage

Accelerated Compute

AI/ML SERVER

Level 0:
Back end. GPU Fabric. Up to 50 meters.

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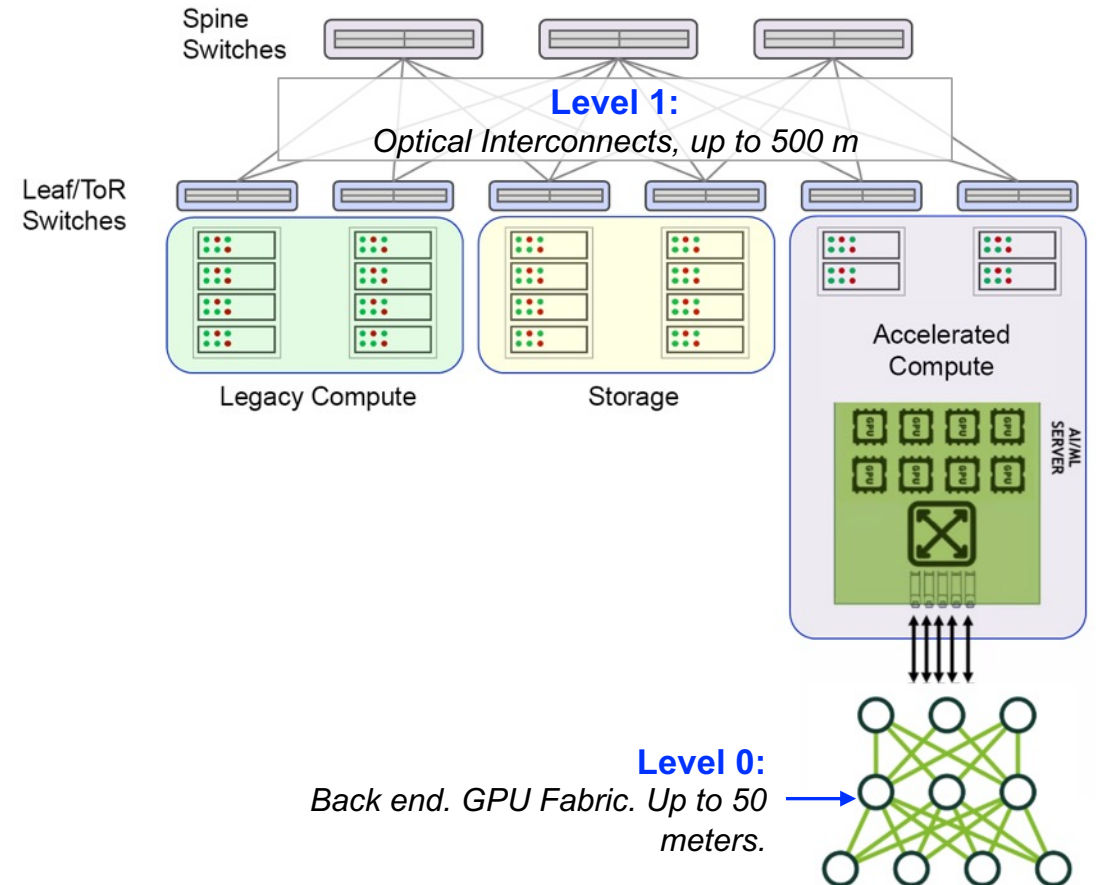
AI HAS RAPIDLY EMERGED AS A KEY CATALYST FOR LONG TERM GROWTH

Datacom Transceivers

Legend: Non AI (red), AI Only (blue)

Chart axis: $12,000, $10,000, $8,000, $6,000, $4,000, $2,000, $-

Years: 2023, 2024, 2025, 2026, 2027, 2028

- Generative AI trend

- Datacom Transceivers for **AI Only: 47% CAGR ('23 - '28)**

- All Datacom Transceivers: 18% CAGR

- Driven primarily by 800G, 1.6T and 3.2T

Source: LightCounting July '23 and internal estimates

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DATACOM REQUIRES A DIVERSE SET OF OPTICAL TECHNOLOGIES
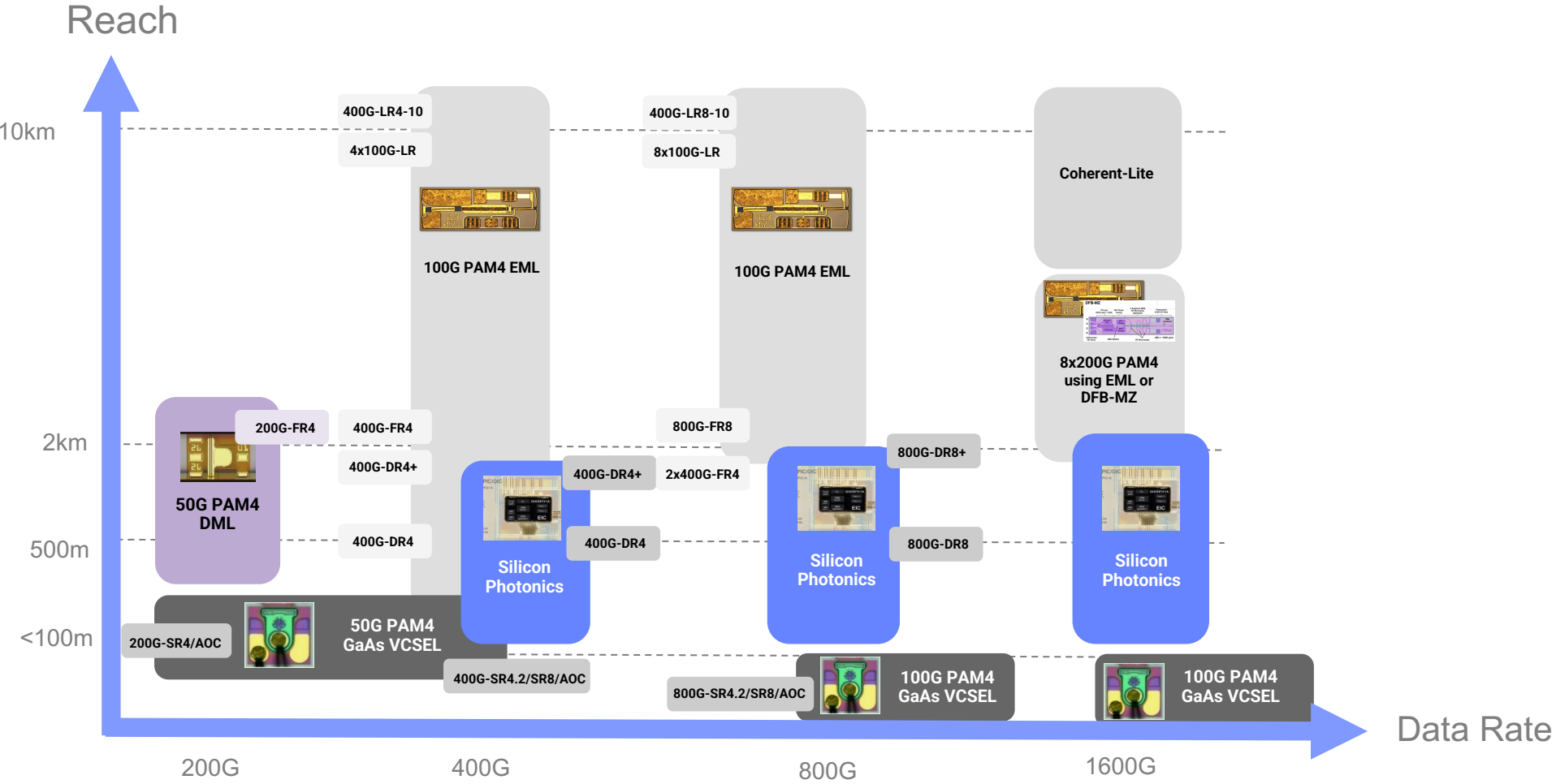
MAJOR HPC AND AI PRODUCTS: LEGACY, CURRENT, AND NPI

	Data Rate	Form Factor	Ethernet PMD(s)	InfiniBand Generation	Optical Interface	Electrical Interface
Legacy Products	40G	QSFP AOC	40G Ethernet	QDR	4x10G	4x10G
	56G	QSFP AOC	n/a	FDR	4x14G	4x14G
	100G	QSFP28 AOC	100G Ethernet	EDR	4x50G	4x50G
	200G	QSFP56 AOC QSFP56	200G AOC 200G FR4	HDR	4x50G	4x50G
	400G	QSFP-DD	400G SR8 400G FR4	n/a	4x100G 4x100G	8x50G 8x50G
Ramping now	800G	OSFP QSFP-DD	2x400G FR4 800G DR8 800G SR8	NDR	8x100G 8x100G 8x100G	8x100G 8x100G 8x100G
NPI	1.6T	OSFP	8x200G DR8 8x200G FR8	XDR	8x200G 8x200G	8x200G 8x200G

- **This is only a sampling of the most prominent transceiver optics for AI. There are many others.**

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MULTI-TERABIT COHERENT TRANSCEIVERS FOR PETABIT PER SECOND SWITCHES

- System face plate space will not increase but switches will scale from 10T to >100T
- 1 Pbps requires 40000 optical connectors with transceivers at 100 Gbps and only 2500 connectors with transceivers at 1.6 Tbps
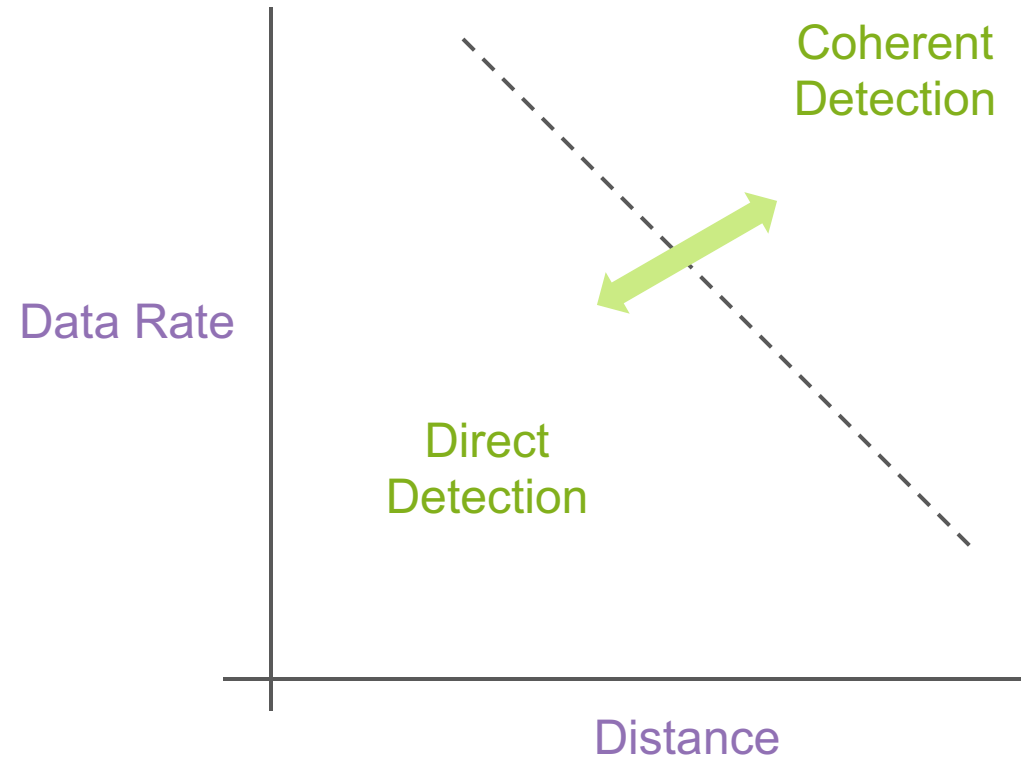
1 Pbps

| 100 Gbps X 40,000 | 1.6 Tbps X 2,500 |
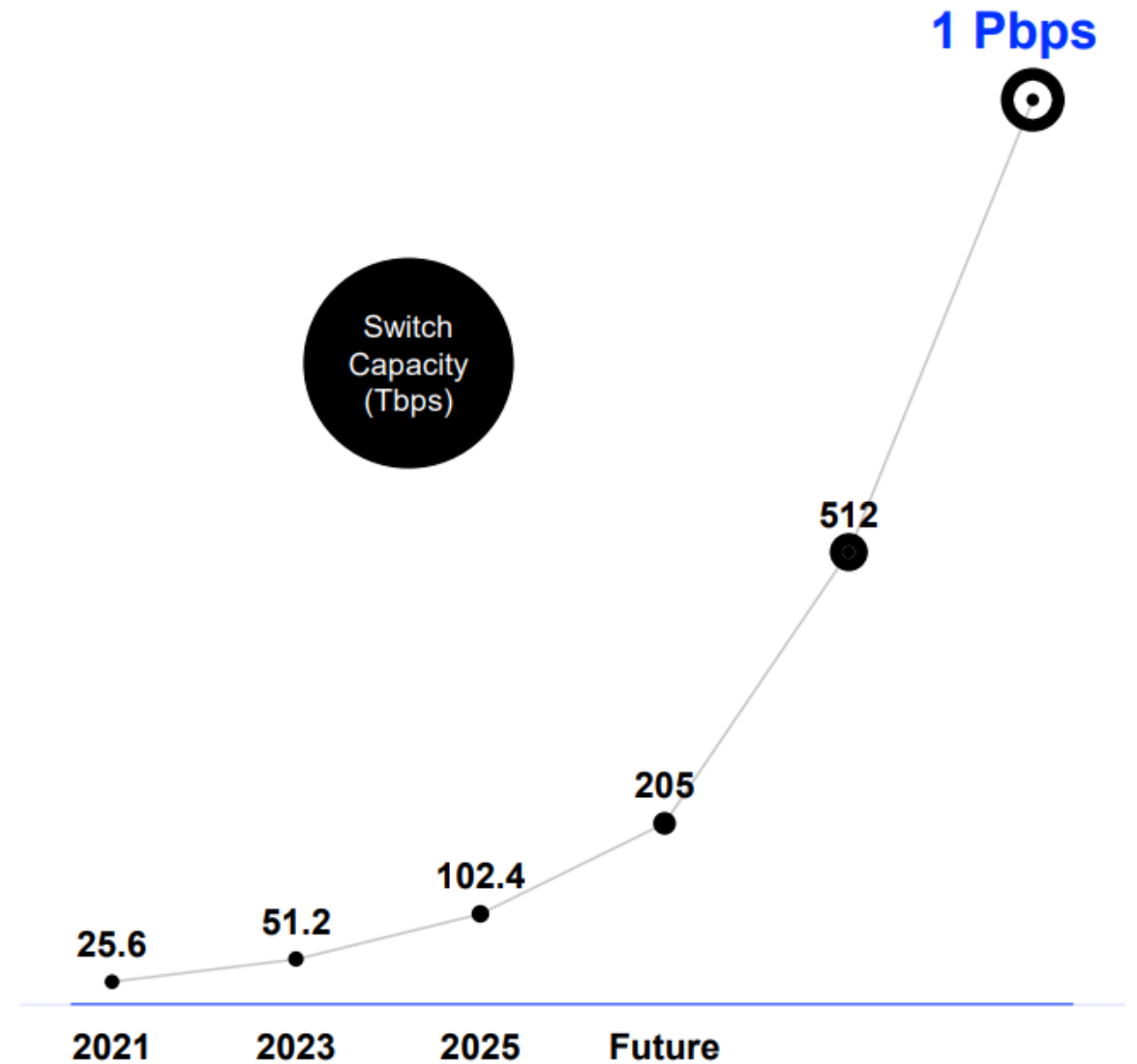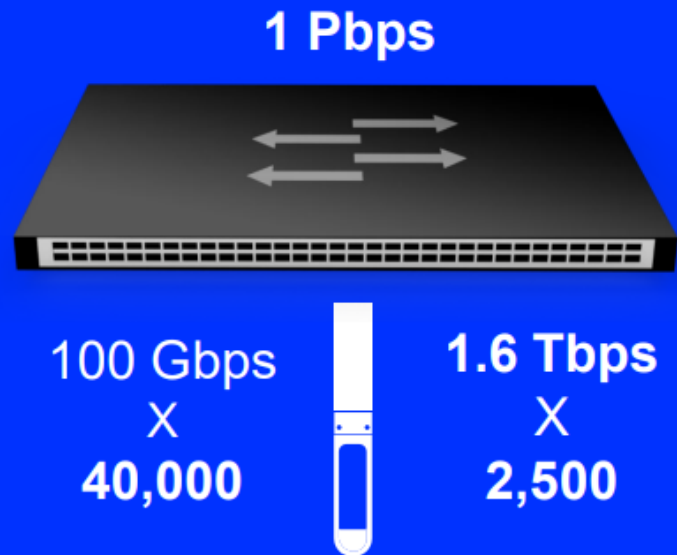
COHERENT DETECTION VS. DIRECT DETECTION IN DATA CENTER LINKS?

- ▪ **Not Soon**
  - Direct-detect links are taking advantage of multi-lane link architecture
  - Component bandwidth for direct-detection now supports 200G per lane

- ▪ **Not Much**
  - Direct-detect links are benefiting from volumes, keeping them competitive
  - New short-reach applications will add further volumes

Coherent Detection

Data Rate
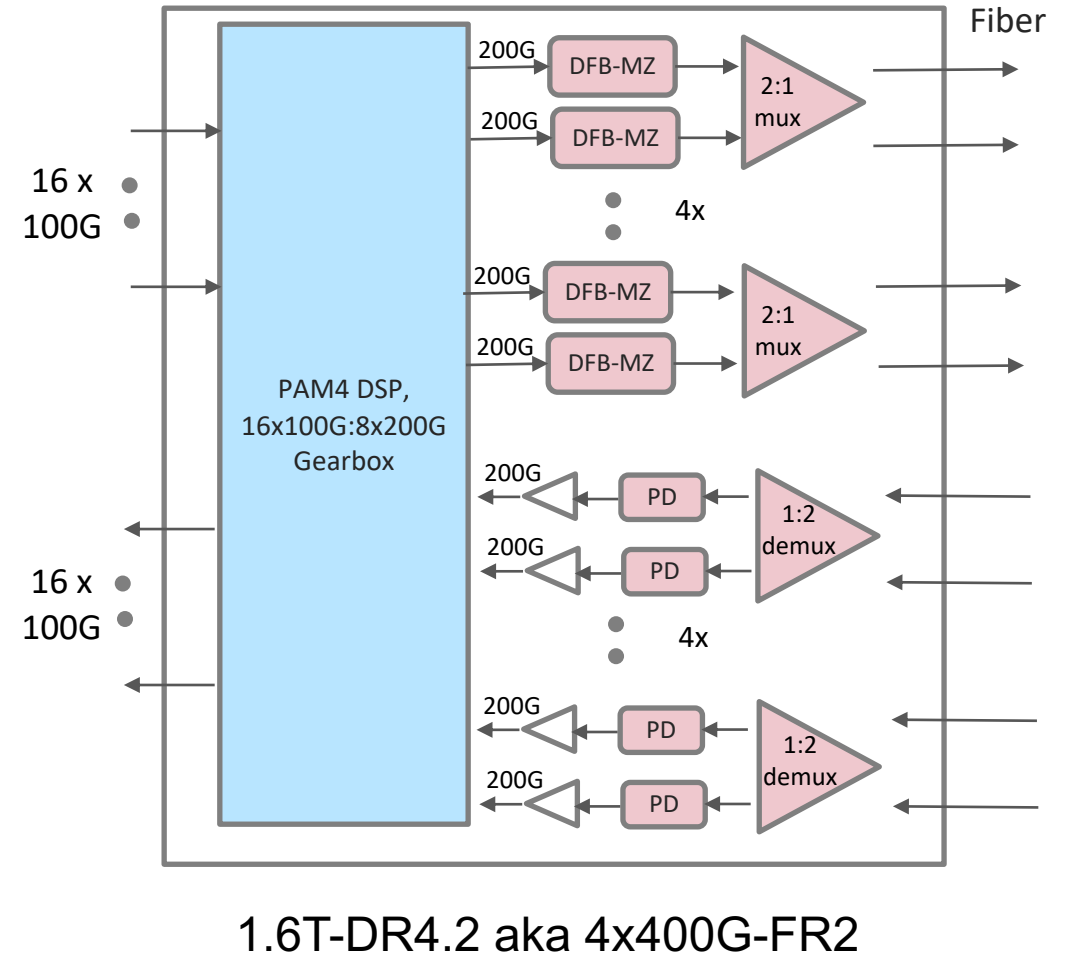
Direct Detection

Distance

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NOT SOON

Short reach makes the use of multi-lane link architecture feasible for 800G and 1.6T

- Example: 4 fibers and 2 wavelengths combine to achieve a low-cost, low-power solution for 2 km reach.

- Spectral efficiency is irrelevant when a data center is fiber-rich

- 200G-capable components keep lane count small
  - Examples: 200G EML, 200G InP DFB-MZ

Future successful links may include

- 2 km:1.6T-DR4.2

- 6 km: 800G-LR4-6, 2x800G-LR4-6 (CWDM)

- 10 km: 800G-LR4-10, 1.6T-LR8-10

1.6T-DR4.2 aka 4x400G-FR2

COHERENT DETECTION VS. DIRECT DETECTION IN DATA CENTER LINKS?
## NOT MUCH

Direct-detection links have high volumes

That is a self-perpetuating advantage

- Suppliers ride the experience curve, pushing cost and power further down
- Larger ecosystem ensures continuous improvement in cost and power

New applications of direct-detection links will add to volumes

- Elimination of ToR (Top-of-Rack) switch
- Machine learning systems where switches connect to accelerators and memory
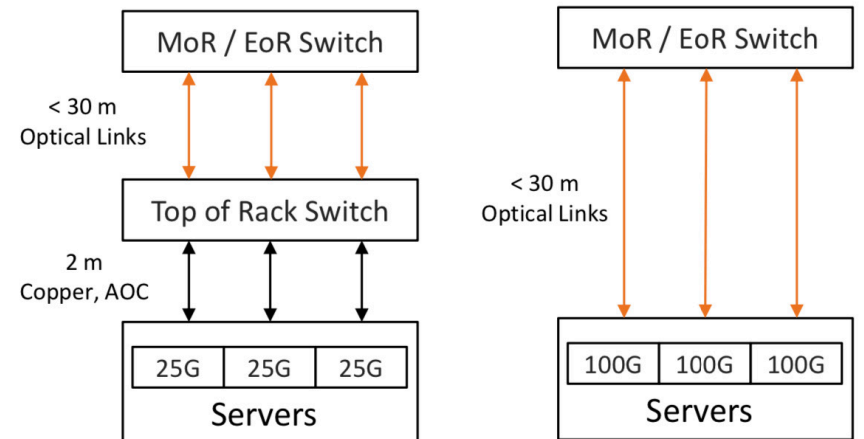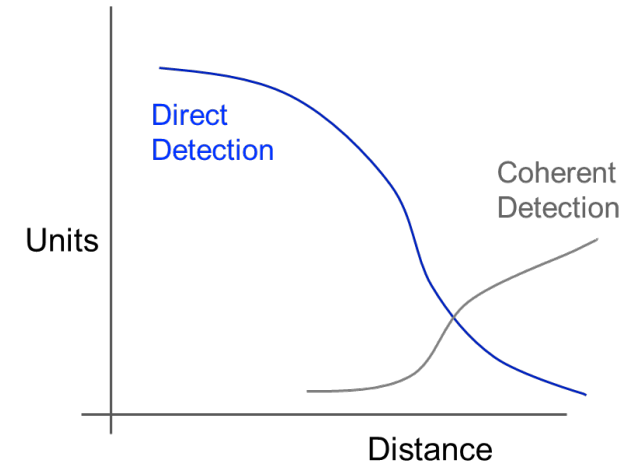
DIRECT VS. COHERENT DETECTION

- Shorter reaches and fiber-rich environments of data centers permit the use of multi-lane link architectures

- This creates a natural fit for direct-detection links to serve that market

- This leads to volumes, and volumes keep perpetuating that advantage

- The next two data center upgrade cycles – 800G and 1.6T – will be predominantly served by direct-detection products

- **BUT**, Coherent Detection transceiver demand is on the rise

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TRANSFORMATIONS IN THE OPTICAL NETWORK
NOW, NEXT, AND BEYOND

Coherent R&D lab in Fremont, CA

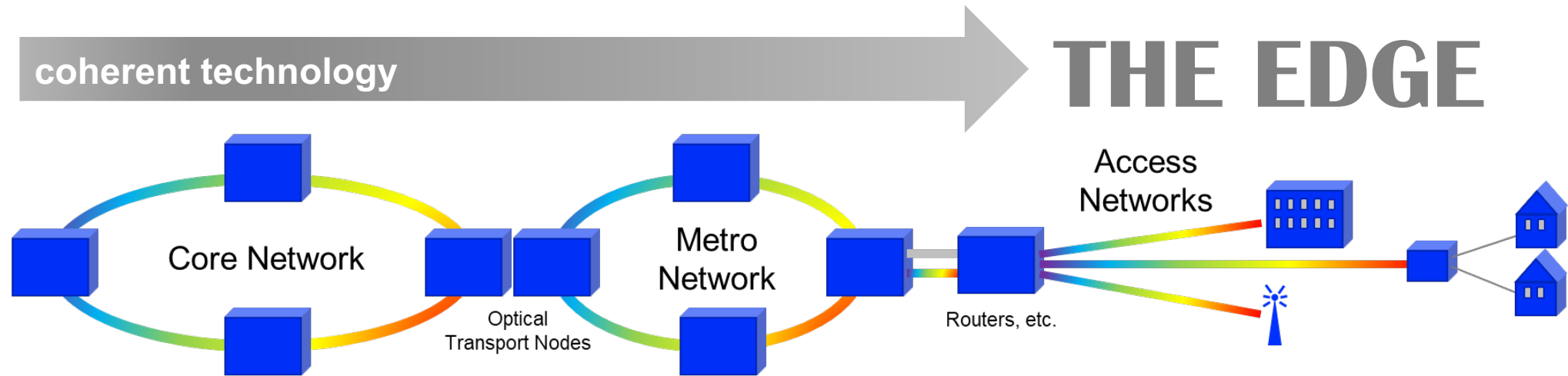| Now	Next	Beyond
Disaggregation of the transport network driven by the growing influence of hyperscalers	Low power, low cost coherent interfaces move to the **edge of optical networks**	Optical transport data rates **exceed 1Tbit/s**
High level of photonic integration and low power DSPs **enable WDM line interfaces in pluggable modules** **IP** over **DWDM**	**Communication in space** moves from radio to optics Wireless Access network upgrade 10G to **100G ZR QSFP-28 DCO**	With continued increase in data rate, physics drives **coherent technologies into datacom** space

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WHAT IS IP-OVER-DWDM?

- **Coherent "colored" pluggable transceivers plug directly into routers**

- **Enabler: coherent technology has shrunk in size and power dissipation to fit into small form-factor pluggable modules**

- **Two network applications:**
  - Metro networks with ROADMs
    - Ring/mesh architectures that require ZR+ modes and high transmitter optical power
  - Data Center Interconnects
    - Point-to-point architecture which only requires ZR mode and low transmitter optical power (-10 dBm)
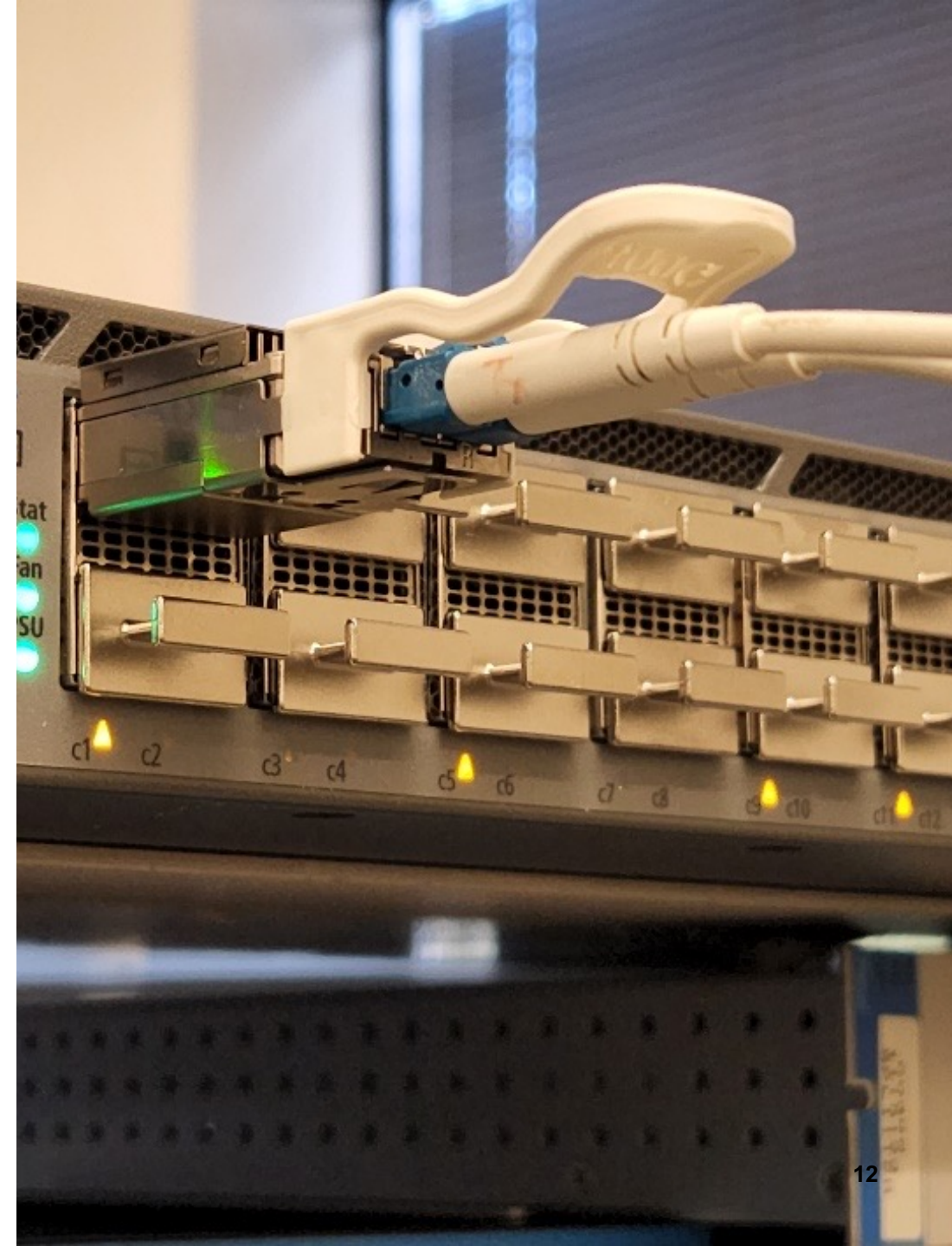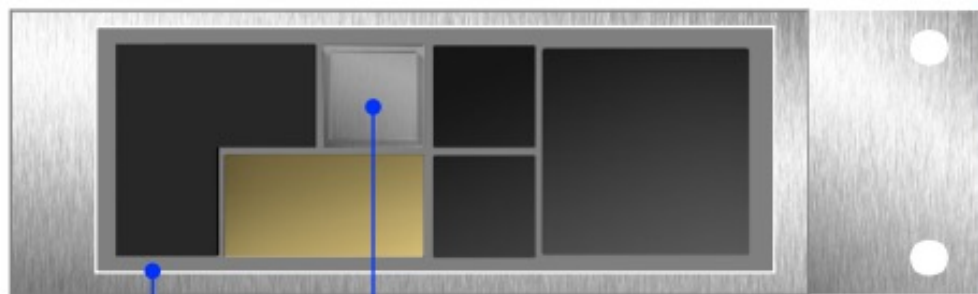
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COHERENT TECHNOLOGY IS MOVING CLOSER TO THE EDGE

- **Data Center Interconnect (DCI) – 400G ZR being widely deployed at hyper-scalers**
- **Access network: wireless back-haul, business services, cable access networks, PON backhaul**
  - Migrate from 10G/25G DWDM direct-detect to 100G ZR coherent technology over next 5-10 years
- **Carriers/Network operators are driving disaggregated/open networks and inter-operability that allow pluggable coherent transceivers from various vendors to operate in host platforms (i.e. IP routers)**

coherent technology

THE EDGE

Core Network

Optical Transport Nodes

Metro Network

Routers, etc.

Access Networks

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MULTI-TERABIT COHERENT TRANSCEIVER TECHNOLOGY FOR THE SUSTAINABILITY OF FUTURE DATACENTERS

1.6 T
Transceiver

DSP from 7 nm CMOS to less than 3 nm

From printed circuit boards to multi-chip module level of integration

A 1.6T transceiver could consume as little as one-tenth the power of 16 older-generation transceivers at 100G.

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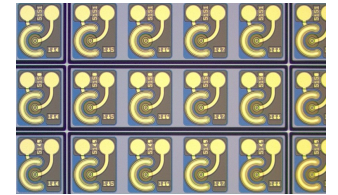# COHERENT LEADERSHIP IN TRANSCEIVERS AND A.I. OPTICS

- **Pioneer and Technology Leader**
  - We (Coherent/Finisar) have been the market leader in transceivers for decades
  - We are the largest transceiver manufacturer in the world

- **Decades of Investments Leading to Recognized Innovation**
  - Unique next gen laser platforms enabling 200 G/lane and beyond
  - Broad technology base and multiple platforms

- **Value Leader enabled by Optical Technologies and Manufacturing Scale**
  - Materials, optical components, transceivers, subsystems
  - Coherent offers a range of multigenerational products

- **Next gen transceivers for Emerging AI/ML Architectures**
  - We are the leader in the current generation of 800G transceivers for A.I.
  - VCSELs, Silicon Photonics, EMLs, DFB-MZ, LPO, ICs, Advanced Optics, Thermal Management Materials,…
  - Coherent expects to be the first transceiver manufacturer with a 200G/lane module in volume production (Mid 2024)

- **US Based Company with Southeast Asia Manufacturing capabilities for geographic diversity**
  - Ipoh Malaysia is our primary offshore manufacturing site for transceivers
  - Additional optics facilities in Vietnam, Philippines, China and Thailand

800G Transceiver
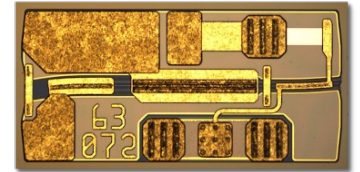
200 G Laser

> 1 B VCSELs shipped

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