The Evolution to 800G and Beyond

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The demand for data and other digital services is rising exponentially. From 2010 to 2020, the number of Internet users worldwide doubled, and global internet traffic increased 12-fold. From 2020 to 2026, internet traffic will likely increase 5-fold. To meet this demand, datacom, and telecom operators need constantly upgrade their transport networks.

400 Gbps links are becoming the standard for links all across telecom transport networks and data center interconnects, but providers are already thinking about the next steps. LightCounting forecasts significant growth in shipments of dense-wavelength division multiplexing (DWDM) ports with data rates of 600G, 800G, and beyond in the next five years.

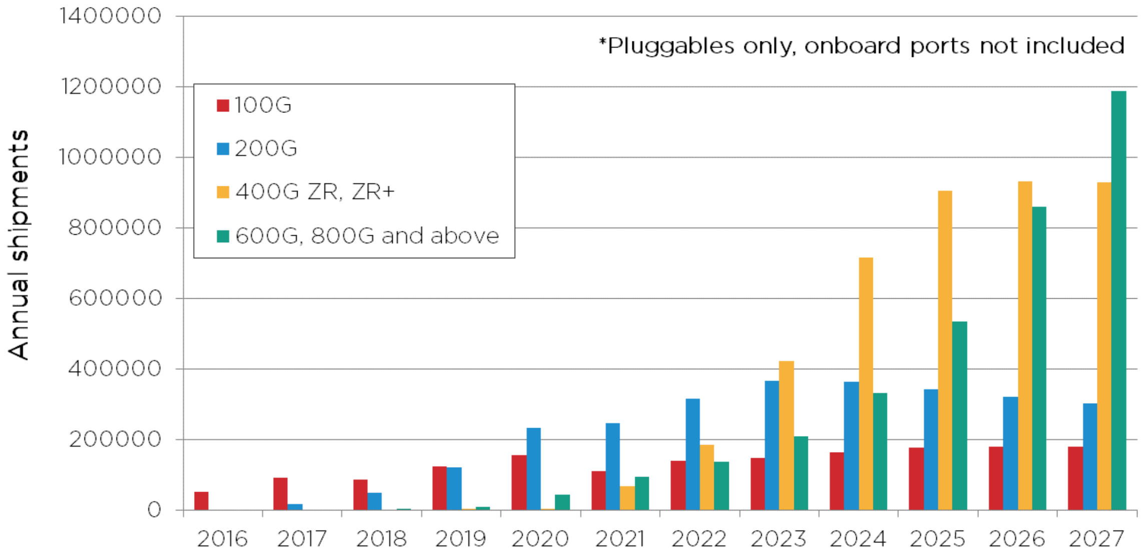

Figure 1: Shipments of high-speed DWDM ports by data rate (historical data and forecast). Source: LightCounting Optical Communications Market Forecast, April 2022.

The major obstacles in this roadmap remain the power consumption, thermal management, and affordability of transceivers. Over the last two decades, power ratings for pluggable modules have increased as we moved from direct detection to more power-hungry coherent transmission: from 2W for SFP modules to 3.5 W for QSFP modules and now to 14W for QSSFP-DD and 21.1W for OSFP form factors. Rockley Photonics researchers estimate that a future electronic switch filled with 800G modules would draw around 1 kW of power just for the optical modules.

Thus, many incentives exist to continue improving the performance and power consumption of pluggable optical transceivers. By embracing increased photonic integration, co-designed PICs and DSPs, and multi-laser arrays, pluggables will be better able to scale in data rates while remaining affordable and at low power.

Direct Detect or Coherent for 800G and Beyond?

While coherent technology has become the dominant one in metro distances (80 km upwards), the campus (< 10 km) and intra-data center (< 2 km) distances remain in contention between direct detect technologies such as PAM 4 and coherent.

These links were originally the domain of direct detect products when the data rates were 100Gbps. However, as we move into Terabit speeds, the power consumption of coherent technology is much closer to that of direct detect PAM-4 solutions.

A major reason for this decreased gap is that direct detect technology will often require additional amplifiers and compensators at these data rates, while coherent pluggables do not. This also makes coherent technology simpler to deploy and maintain. Furthermore, as the volume production of coherent transceivers increases, their price will also become competitive with direct detect solutions.

Increased Integration and Co-Design are Key to Reduce Power Consumption

Lately, we have seen many efforts to increase further the integration on a component level across the electronics industry. For example, moving towards greater integration of components in a single chip has yielded significant efficiency benefits in electronics processors. Apple's M1 processor integrates all electronic functions in a single system-on-chip (SoC) and consumes a third of the power compared to the processors with discrete components used in their previous generations of computers. We can observe this progress in the table below.

Mac Mini Model	Power Consumption (Watts)	
	Idle	Max
2023, M2	7	5
2020, M1	7	39
2018, Core i7	20	122
2014, Core i5	6	85
2010, Core 2 Duo	10	85
2006, Core Solo or Duo	23	110
2005, PowerPC G4	32	85

Table 1: Comparing the power consumption of a Mac Mini with an M1 and M2 SoC chips to previous generations of Mac Minis. [Source: Apple's website]

Photonics can achieve greater efficiency gains by following a similar approach to integration. The interconnects required to couple discrete optical components result in electrical and optical losses that must be compensated with higher transmitter power and more energy consumption. In contrast, the more active and passive optical components (lasers, modulators, detectors, etc.) manufacturers can integrate on a single chip, the more energy they can save since they avoid coupling losses between discrete components.

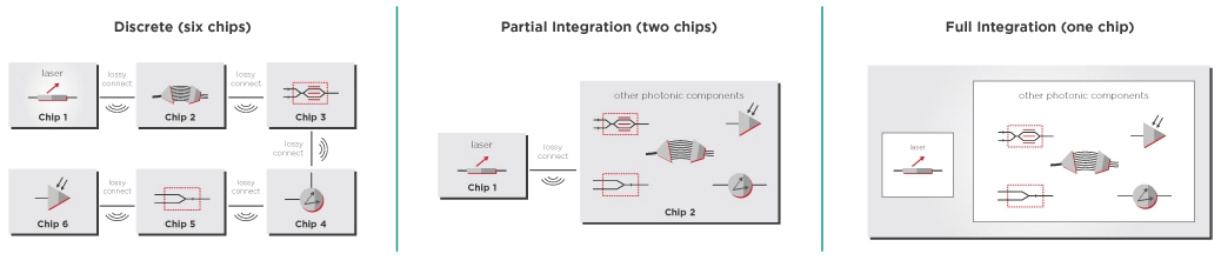

Figure 2: Example of integrating a laser to other photonic components through different integration approaches. The approach of full integration (right side) is the one that minimizes losses.

Reducing Complexity with Multi-Laser Arrays

Earlier this year, Intel Labs demonstrated an eight-wavelength laser array fully integrated on a silicon wafer. These milestones will provide more cost-effective ways for pluggables to scale to higher data rates.

Let's say we need a data center interconnect with 1.6 Terabits/s of capacity. There are three ways we could implement it:

- **Four modules of 400G:** This solution uses existing off-the-shelf modules but has the largest footprint. It requires four slots in the router faceplate and an external multiplexer to merge these into a single 1.6T channel.
- **One module of 1.6T:** This solution will not require the external multiplexer and occupies just one plug slot on the router faceplate. However, making a single-channel 1.6T device has the highest complexity and cost.
- **One module with four internal channels of 400G:** A module with an array of four lasers (and thus four different 400G channels) will only require one plug slot on the faceplate while avoiding the complexity and cost of the single-channel 1.6T approach.

	4x400G	1x1.6T	1x4x400G
# of modules	4	1	1
Cost/complexity	Medium	High	Low
Faceplate density	Low	High	High
External MUX	Yes	No	No

Same spectral efficiency

Table 2: Comparison of different ways to implement a 1.6 Terabit/s link: four modules of 400G, a single-channel 1.6T module, and a module with four channels of 400G.

Multi-laser array and multi-channel solutions will become increasingly necessary to increase link capacity in coherent systems. They will not need more slots in the router faceplate while simultaneously avoiding the higher cost and complexity of increasing the speed with just a single channel.

Takeaways

The pace of worldwide data demand is relentless, with it the pace of link upgrades required by datacom and telecom networks. 400G transceivers are currently replacing previous 100G solutions, and in a few years, they will be replaced by transceivers with data rates of 800G or 1.6 Terabytes.

The cost and power consumption of coherent technology remain barriers to more widespread capacity upgrades, but the industry is finding ways to overcome them. Tighter photonic integration can minimize the losses of optical systems and their power consumption. Finally, the onset of multi-laser arrays can avoid the higher cost and complexity of increasing capacity with just a single transceiver channel.

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