The Rise of PAM4 and 64 QAM: A Competitive Analysis of Optical Modules & Components from 25/100G to 400/600G

EXECUTIVE SUMMARY

The shift to cloud services and virtualized networks has put the data center in the middle of our world and meant that connectivity within data centers and between data centers has a huge impact on the delivery of business and personal services. Hyperscale data centers are being installed across the world and these all need connecting. To meet this demand, optical module and component suppliers are delivering new solutions based on PAM4 coding and 64 quadrature amplitude modulation (QAM), providing coherent modulation that will drive down the cost of connectivity and increase the bandwidth of each connection.

Connections to many servers are already 25 gigabits per second (Gbit/s) and links between switches in large data centers are already 100 Gbit/s. The introduction of SFP28 and QSFP28 modules integrating new technologies and built using efficient manufacturing techniques has driven down the cost of these connections and allowed massive growth in the market. The next stage is the introduction of 100G single lambda solutions and cost-effective 400G modules for links between switches. The physical layer (PHY) devices needed for this next step are already becoming available, 12.8 terabits per second (Tbit/s) switch devices are in production, and the first 400G Octal Small Form Factor Pluggable-Double Density (QSFP-DD) and OSFP optical modules are sampling.

The rise of the hyperscale data center operator has dramatically changed the market. The switch to 25G and 100G from 10G and 40G has happened very quickly. The sheer scale and numbers of data centers being installed or upgraded means that the new technologies can be shipped in volume as soon as the price is right, the components have been qualified, and the production lines are operational. We are now seeing the first 400G PHY devices and optical modules for data centers becoming available and companies are vying for market position as we wait for the leading hyperscale operators to commit to large deployments.

Many of those companies that have benefited from 25G and 100G are putting their investments into single lambda PAM4 100G and 400G solutions for the data center. This has required new PAM4 PHY devices designed to meet the power constraints of 400G OSFP and QSFP-DD modules. A few companies have also invested in 50G and 200G PAM4 PHYs, enabling a cost-effective upgrade from 25G and 100G. Heavy Reading expects 50G SFP56 and 200G QSFP56 modules to be interim solutions, but it is unclear how widespread their use will be or for how long. 40G was an interim solution that lasted for many years.

Coherent technology, originally developed for 100G long-haul networks, is now widely used for long-haul connections, including subsea, metro networks, and data center interconnect (DCI) between data centers. The market for DCI has grown rapidly, with many systems vendors offering solutions with 80 kilometers (km) to 500 km reach. For long-haul and metro applications, several leading equipment manufacturers continue to use in-house coherent digital signal processor (DSP) designs. Ciena has made its coherent DSP solution available to optical module vendors and Lumentum is now shipping 400G modules based on this design. The latest DSP application-specific integrated circuits (ASICs) are enabling 600G 64-Gbaud 64-QAM solutions and CFP2-DCO modules. The next step is the introduction of the 7 nanometer (nm) DSPs that will enable the cost-effective 400ZR modules planned for 400G links up to 100 km starting in 2020.

This continues to be a market in flux. Lumentum has completed the acquisition of Oclaro, Cisco has announced its intent to acquire Luxtera, and several Chinese optical module vendors have joined the charge to 400G in the data center. The PAM4 PHY devices required for 100G single lambda and 400G in the data center are proving to be very challenging to deliver. PAM4 PHY solutions in 28 nm and 14/16 nm technology have been sampling for more than 6 months and these are now being joined by 7 nm solutions.

The Rise of PAM4 and 64QAM: A Competitive Analysis of Optical Modules & Components identifies key networking, optical module, and semiconductor technologies, and details their application to 25G, 100G, 200G, 400G, and 600G ports, identifying and analyzing the full spectrum of vendors developing optical modules and components. The report includes not only granular information on the optical modules and components themselves—of interest to telecom equipment manufacturers, service providers, optical module vendors, and semiconductor vendors—but also insights into how the overall market and ecosystem is developing—of interest to a wide audience, including investors. The report evaluates and analyzes the products and strategies of 50 leading vendors in this rapidly growing market, including almost 500 optical modules and more than 150 semiconductor components.

1.1 Key Findings

The key findings of this report are as follows:

Data center operators are pushing for cost-effective 400G solutions. 400G CFP8 modules and 400G coherent modules for DCI are available, but the cost and real estate is too high for the data center market. This is pushing component vendors to deliver more attractive 400G solutions as soon as possible.

The first 400G QSFP-DD and QSFP Modules are becoming available. Several vendors are sampling 100GBASE-SR8, 100G-FR4, and 100GBASE-LR8 modules. Many more vendors are planning to introduce 400G QSFP-DD and QSFP modules during 2019.

100G single lambda is coming. The first 100GBASE-DR and 100G-FR modules are sampling and multiple vendors have the 100GS/s PAM4 PHYs needed. The 100G Lambda Multisource Agreement (MSA) Group showed multi-vendor solutions at the European Conference on Optical Communication (ECOC) Exhibition in September 2018 and will be pushing these solutions forward**.** These developments are also driving cost-effective 400G solutions using four optical lanes.

50G and 200G optical modules are widely available. 200G QSFP56 modules and 50G SFP56 modules are shipping from multiple vendors. A couple of vendors also have 200G QSFP-DD modules.

QSFP28 is clearly the dominant 100G module, with almost 30 vendors shipping modules. QSFP28 modules are used across much of the network for 100G connections from a few meters to 40 km. The high density and cost-effectiveness offered by these modules is unmatched at the moment. It will be some time before these are replaced by small form factor pluggable (SFP) modules.

400G is set to take over from 100G/200G for DCI and metro connections. The leading equipment manufacturers have developed their own coherent transceiver solutions. At the same time, Acacia, Inphi, Menara, and NEL have 400G/600G coherent DSPs with support for DP-QPSK, 16 QAM and 64 QAM modulation in various stages of development with several already available. Ciena has agreed to make its 400G coherent DSP available to two optical module vendors, changing the market dynamics and providing alternative solutions. 400ZR promises to enable cost-effective 400G for DCI links up to 100 km.

CFP2-DCO modules are replacing CFP2-ACO for metro applications. CFP2-ACO modules provided an attractive upgrade for 100G and 200G coherent connections by neatly packaging the optical components and working with any DSP. The introduction of CFP2-DCO modules with 16 nm coherent DSPs integrated has completely changed this equation by delivering a cost- and real estate-efficient solution and reducing system development costs.

Extended temperature range modules readily available from wireless back/fronthaul applications. Many vendors have extended temperature range (-40° C to -85° C) 25G/28G SFP28 modules shipping. Some also support enhanced Common Public Radio Interface (eCPRI)/CPRI for wireless fronthaul applications. A couple of vendors are shipping or developing 50G and 100G modules.

PAM4 has been quickly adopted for high-speed links. The industry has adopted PAM4 for the next generation of interfaces in data center and enterprise systems. Multiple vendors have PAM4 PHY/Mux and clock data recovery (CDR) devices, and modules are shipping for 100G, 200G and 400G using 50G PAM4. The industry is now sampling solutions for 100G PAM4 that enable single lambda 100G, cost-effective 400G and 800G.

7 nm silicon technology is key for a vibrant 400G PHY market. The first 7 nm PHY devices are becoming available and all the leading vendors have active 7 nm development programs. 400G PAM4 PHYs are available in 14/16 nm technology, but a 7 nm solution will increase the competition, and many believe these are needed to lower the power consumption and cost of 400G. Most coherent DSP developments for 400ZR are based on 7 nm.

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