On the Road to Holy Cup of 100GbE Single Lambda

source PHOTONICS

The Quest for More

Compelled by an ever-increasing need for networking bandwidth, today's hyperscale datacenters are seeing tremendous growth in deployments of higher network density to support the increase in server I/O bandwidth.

The future of 100GbE for data center connectivity truly depends on cost, power and space requirements which has led to increases in research and development in technologies like silicon photonics, and use of advanced modulation formats like four level pulse amplitude modulation (PAM4) to make connectivity affordable and feasible for cloud data center applications.

The Institute of Electrical and Electronics Engineers (IEEE 802.3bs task force) has recently adopted PAM4 as the signaling standard going forward for next generation 100Gb/s and 400Gb/s Ethernet networks for 2 km and above distances. This signaling standard is commonly referred to as 53GBaud (equivalent to 2-bits/symbol=106Gb/s) due to the need to have extra bandwidth over 100Gb/s for forward-error correction (FEC) requirements.

To encourage innovation, Ethernet Alliance created a prize: "The Holy Cup of 100GbE".

Photo credit: Ethernet Alliance

Figure 1: The Holy Cup

This is the Ethernet Alliance prize to be awarded to the first company who publicly demonstrates a true 100Gb/s QSFP+ module. Bragging rights also included.

This prestigious honor will be awarded for the first demonstration of a 3.5W QSFP28 transceiver module with CAUI-4 electrical interface using a single wavelength of light. True 100G single lambda offers the simplest architecture, reliability and upgrade path to 400G optical Ethernet while enabling commercially viable lowest cost 100G pluggable transceiver technology.

Rising to the Challenge

Source Photonics has taken the first important step towards realizing a true 100G QSFP28 single lambda with its real-time demonstration at OFC Conference in March 2017. The demo consisted of 53GBaud PAM4 transmission over single-mode fiber using an electro-absorption modulated laser (EML) based compact transmit optical subassembly (TOSA) and PIN photodiode based compact receive optical subassembly (ROSA).

Supporting Quote:

> The demonstration confirms that 53Gbaud PAM-4 PHYs can enable a production grade EML laser to do the work of four 25G NRZ lasers; substantially improving the scalability of 100G transceivers as well as providing the building blocks for duplex single mode fiber for 400G small form factor modules. PAM-4 technology will pave the way for the next generation of 100G and 400G transceiver modules enabling explosive growth in data centers.
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> Source: http://www.businesswire.com/news/home/20170320005456/en/Source-Photonics-MACOM-Demonstrate-53Gbaud-PAM-4-Optical

The high-speed EML integrates a DFB laser with an electro-absorption modulator on a single chip and is designed and fabricated at Source Photonics' fabrication facility. The TOSA and ROSA housings are designed ground-up for the QSFP28 form factor considering signal integrity and bandwidth requirements for 53GBaud PAM4 and operate error free under KP4 FEC threshold with a pre-FEC bit-error rate (BER) better than 1×10^{-5}.

With a demonstrated link budget of 6dB and margin over the proposed 100GBASE-DR specifications coming from the transmitter's optical modulation amplitude (OMA), we believe that EML based architectures are poised to support single mode applications while meeting the 3.5W power target.

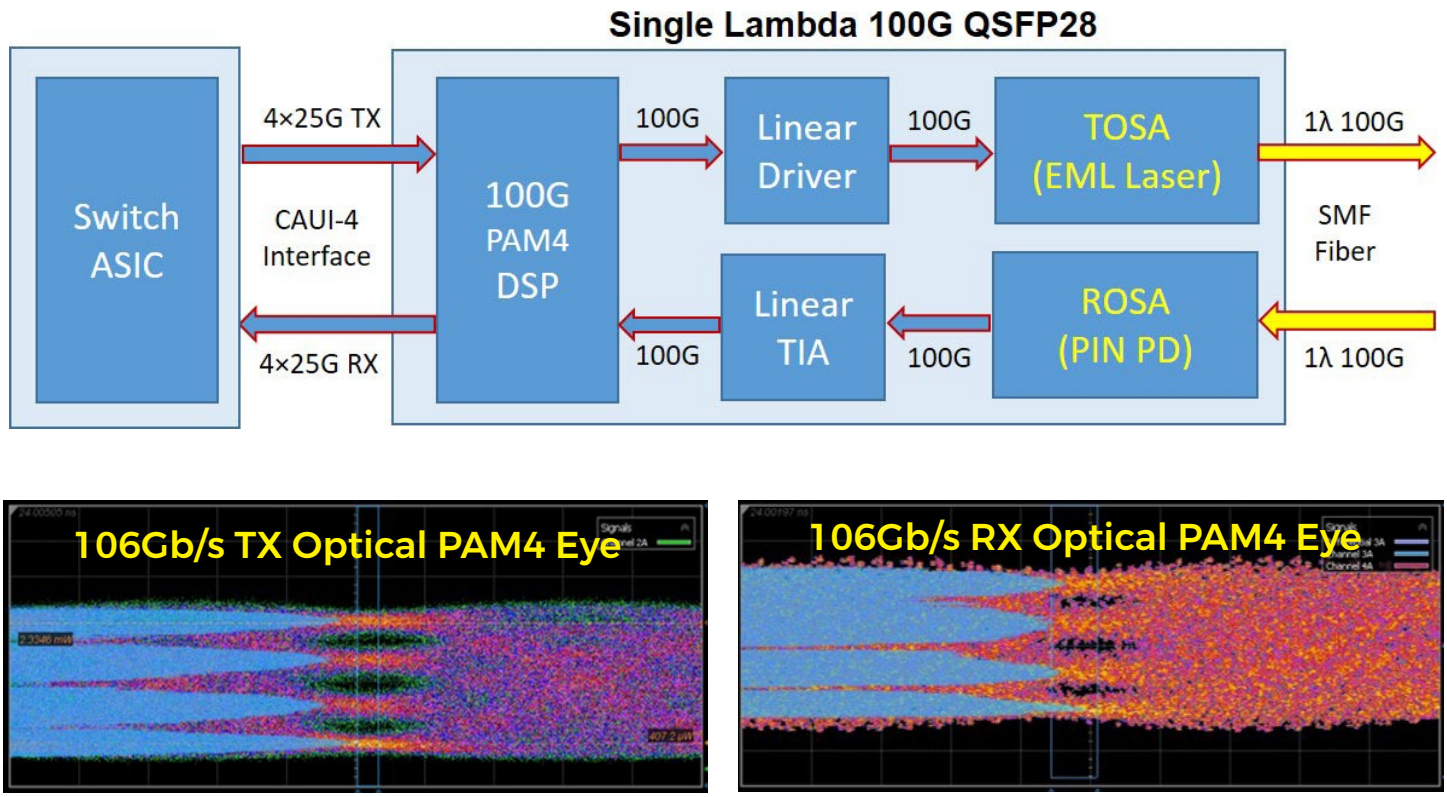

Figure 2: Schematic representation of a single-lambda 100G QSFP28 module. ASIC: Application-specific Integrated Circuit, PAM4: 4-level Pulse Amplitude Modulation, DSP: Digital signal processing IC, TIA: Trans-impedance Amplifier, TOSA: Transmit Optical Subassembly, ROSA: Receive Optical Subassembly, EML: Electro-Absorption Modulated Laser, PIN PD: Photodiode, SMF: Single Mode Fiber

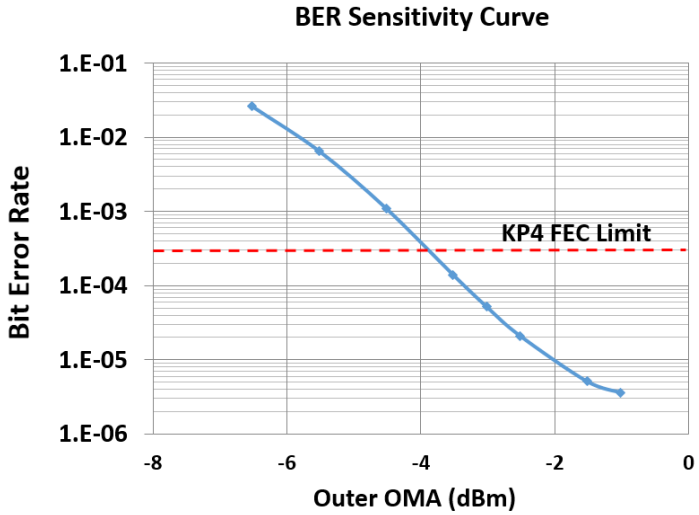

Figure 3: BER measurement taken with Source Photonics TOSA and ROSA in an optical loopback configuration.

Considerations and Key Factors for Success

With cost-effective 100G digital signal processing (DSP) based PAM ICs co-located inside the optical module with FEC, link budgets supporting intra data center connections at 500m and 2km will be attainable. As bit rates have increased, it has become necessary to include complex equalization methods in the transceiver which optics vendors must become more adapt at implementing and insuring interoperability.

> "True 100G PAM4 QSFP28 single lambda will not only offer significant reduction in component count and assembly costs but it will also allow for the optics industry to better ramp volumes to support the rapidly increasing demand for 100G transceivers."

DSP compensation techniques are becoming essential for correcting issues such as inter-symbol interference, non-linear behavior of optical components, and electrical reflections within the optical module. In addition, DSP-supported FEC allows for the correction of errors associated with the reduced signal to noise ratios from both the use of PAM4 and residual thermal noise at these higher data rates.

However, use of these powerful DSPs comes at the cost of size, latency and power limitations which drives the need for smaller IC node sizes. Additionally, optics vendors will need to utilize increasingly expensive equipment for characterization and optimization.

Victory: Benefits to the Industry from True 100G Technology

True 100G PAM4 QSFP28 single lambda will not only offer a significant reduction in component count and assembly costs, but it will also allow for the optics industry to better ramp volumes to support the rapidly increasing demand for 100G transceivers. Additionally, effective deployment of 400G to support 12.8Tb/s on the faceplate of one rack-unit (IRU) switch in the data center will require a true 100G per lambda optical technology. While there are various

optical devices capable of reaching these speeds, the more proven technologies of silicon photonic Mach-Zehnder Modulators (MZM) and InP EMLs are the top contenders to service this application. It is likely that due to performance trade-offs both devices will find applications in 400G.

Anyone involved with construction of or upgrades to data centers has a vested interest in true 100G per lambda technology, as it plays a key role in enabling the optics industry to meet demand.

Source Photonics: On the Road to the Holy Cup

Source Photonics has taken the first important step towards realizing a true 100G QSFP28 single lambda with a real-time demonstration at OFC Conference in March 2017. The demo consisted of 53GBaud PAM4 transmission over single-mode fiber using an electro-absorption modulated laser (EML) based compact transmit optical subassembly (TOSA) and PIN photodiode based compact receive optical subassembly (ROSA).

This solution marks several important milestones, including:

- Meets signal integrity and bandwidth requirements for 53GBaud PAM4
- Operates error free under KP4 FEC threshold with a pre-FEC bit-error rate (BER) better than 1×10^{-5}
- Offers demonstrated link budget of 6dB
- Poised to support single mode applications while meeting the 3.5W power target

Requirements for the Holy Cup of 100GbE Lambda

- Public demonstration at a major conference
- Housed in 3.5W QSFP28 with CAUI
- Uses a single wavelength of light
- Supported distance could be:
  - 2km over duplex SMF with a 4.0dB insertion loss or
  - 100m over duplex MMF with a 2.0dB insertion loss
- Winner will be recognized by the Ethernet Alliance publicly
- The Ethernet Alliance Board determines the winner