Data Center Interconnects Reach 400G Speeds
New Standards Adopt Coherent Optical Technology for DCIs

Internet traffic continues to grow exponentially, and communication networks must evolve to meet the need for more and faster data. Emerging technologies such as 5G, the Internet of Things (IoT), and virtual reality place unprecedented demands on data centers to manage higher volumes of traffic and provide faster response times than ever before. Distributed data centers need to communicate with each other to share data, balance workloads, provide backups, and scale capacity when needed. In a campus or metropolitan area, distributed data centers need to increase interconnection capacity significantly.

Using coherent optical transmission technology, data center interconnects (DCIs) can transport terabytes of information across a single fiber line, significantly reduce power consumption, and provide flexibility to address growing data demands. The Optical Internetworking Forum (OIF) and the Institute of Electrical and Electronics Engineers (IEEE) are working on new standards, 400ZR, 100GBASE-ZR, and 400GBASE-ZR, that will enable 100G and 400G DCI speeds to reach up to 80 km.
**400ZR Enables 400G DCI**

Data center interconnects currently provide data transmission speeds of 100 gigabits per second (Gb/s) with optical signaling using on-off keying modulation techniques. The growing demand for higher-capacity data flows requires that data center operators and service providers move to 400 Gb/s speeds and find ways to decrease the relative power consumption. Developments in integrated photonics technology and new standards pave the way for a new class of cost-effective DCIs based on coherent optical technology with terabit-level speeds and greater efficiency.

**What is 400ZR?**

The OIF is developing the 400ZR networking implementation agreement (IA) for pluggable digital coherent optical (DCO) modules. The 400ZR standard will enable the transmission of multiple 400 gigabit Ethernet (GE) payloads over DCI links up to 80 km using dense wavelength division multiplexing (DWDM) and higher-order modulation. The intent is to ensure an affordable and long-term implementation based on single-carrier 400G using dual-polarization 16-state quadrature amplitude modulation (16 QAM) at approximately 60 gigabaud (Gbaud). This is only possible using coherent detection and advanced digital signal processing (DSP). The 400ZR IA will reduce the cost and complexity of high-bandwidth data center interconnects and promote interoperability among optical module manufacturers.

On the host-side, 400ZR uses the 400GAUI-8 interface. The 400ZR IA details the full data path from this interface to the coherent optical signal on the line side. This also includes the full definition of a concatenated forward-error correction (FEC) scheme, which consists of a hard-decision (HD) outer FEC and a soft-decision (SD) inner FEC.

There is a strong interest by data center operators to use the 400ZR coherent interface to link distributed data centers, which are up to 80 km apart. While the IA does not target a specific form factor, the specifications are written such that the use of QSPF-DD, OSFP, or COBO modules are possible. This allows to directly connect to data center switches just like client-side optics and will remove the need for costly and bulky transport networking equipment inside the data centers. Also, the telecommunications industry wants to use 400ZR for residential backhaul traffic of 200 Gb/s streams using 64 Gbaud signaling and quadrature phase shift keying (QPSK).
What is 400GBASE-ZR and 100GBASE-ZR?

In 2018, the IEEE approved the 802.3ct project. IEEE 802.3ct will leverage the OIF’s 400ZR IA to create the 400GBASE-ZR standard for 400 Gb/s transmission on a single wavelength up to 80 km in a DWDM system. A DWDM system involves multiplexing data signals from different transceivers using a single optical fiber.

For 100GBASE-ZR, the IEEE leverages the International Telecommunication Network's (ITU's) work for a 100 Gb/s transmission standard that uses a dual-polarization differential quadrature phase shift keying (DP-DQPSK) modulation scheme, as well as CableLabs full duplex coherent optics specification.
Benefits of 400ZR

Although 400ZR technology is in its infancy, it is expected to significantly impact a number of industries once rolled out:

Hyperscale Data Centers/Cloud Service Providers

A large part of the demand for high-speed data center networking comes from hyperscale data centers owned by companies such as Google, Amazon, Microsoft, and Facebook, as well as Baidu, Tencent, and Alibaba. These massive data centers need to increase connection speeds to accommodate the exponential growth in cloud services, IoT devices, streaming video, and more. Developments in DCI and networking technology help cloud and hyperscale data centers adapt to the ever-increasing network need for more bandwidth.

Distributed Campuses and Metropolitan Areas

For many organizations, building a hyperscale data center is not feasible. This is especially true for distributed campuses and metropolitan areas, where managing multiple data centers is the new norm because of space constraints and disaster recovery requirements. Distributed data centers need to communicate with each other to share data, balance workloads, provide backups, and scale data center capacity when needed. 400ZR technology will enable high-bandwidth interconnects essential to connect distributed data centers.

Telecommunications Providers

Like data centers, telecommunications companies grapple with the explosive growth in networking traffic, as consumers demand higher connectivity at home, in the office, and soon from 5G mobile. Applications such as streaming video, online video games, videoconferencing, and online backup services will benefit from 400 Gb/s speeds enabled by 400ZR.

The 400ZR standard will allow telecommunications companies to backhaul residential traffic. When operating at 200 Gb/s, using 64 Gbaud signaling and QPSK modulation, 400ZR increases the reach of high-loss spans. For 5G networks, 400ZR offers mobile backhaul by aggregating multiple 25 Gb/s streams.

400ZR Plus and 400ZR Minus

Beyond the interoperable 400G mode, 400ZR transceivers are expected to support additional modes to increase the range of addressable applications. Those modes are referred to as 400ZR+ and 400ZR-. The plus means that the module consumes more power than the 15W required by the IA (and some of the pluggable form factors), enabling the modules to use more powerful signal processing techniques to span distances of several hundreds of kilometers. On the other hand, the minus refers to the modules supporting lower speed modes, like 300G, 200G, and 100G, which provide valuable flexibility to network operators.
Testing 400G Coherent Optical Components and Transceivers

Arbitrary Waveform Generator and Optical Modulation Analyzer

In telecommunications and data communications, it is important to optimize coherent optical transmitters for reach, spectral efficiency, and power consumption. Performing common measurements, such as error vector magnitude (EVM), IQ offset, IQ imbalance, quadrature error, and skews, is complex in coherent optical signal analysis. To thoroughly test an optical transmitter, it is necessary to stimulate it with complex waveforms using different modulation formats and data sources. It is also important to de-skew and pre-distort input signals to account for any linear impairments in the test setup and measure the true performance of the optical transmitter. A flexible and scalable test solution ensures fast and accurate testing of optical transceivers.

Testing 400G coherent optical transceivers and its sub-components requires test equipment capable of clean signal generation and analysis, and a measurement bandwidth of at least 40 GHz. Test instruments need to offer the flexibility to address many different modulation schemes and pulse shapes on four synchronized channels for dual-polarization in-phase and quadrature (IQ) signals both on the stimulus as well as on the analysis side. This is provided by instruments based on high-speed digital-to-analog converters (DAC) and analog-to-digital converters (ADC), as well as software tools that provide a comprehensive set of general-purpose algorithms along with efficient interfaces to work with self-developed specialized algorithms.

Coherent Optics Device Test

Optoelectrical components used in coherent optical transmission systems have unique test challenges. For example, to test dual-polarization IQ modulators and intradyne coherent receivers, it is necessary to measure the electrical-to-optical (E/O) and optical-to-electrical (O/E) conversion efficiency, respectively. Measurements such as bandwidth, gain, imbalances, group delay, and skew characterize coherent optical devices. These measurements are complex and time-consuming. Selecting the right test equipment saves valuable time and reduces costs for the development and qualification of coherent optical devices.
The Future of Data Center Interconnects

With networks reaching new levels of data traffic each year, 400G coherent optical technology promises to provide faster data flow between data centers. 400G solutions, enabled by new standards such as 400ZR and 400GBASE-ZR, provide many advantages and the flexibility needed to address growing data demands. These new standards substantially increase the bandwidth capacity and reduce operating costs (fewer transceivers), footprint, and power consumption. 400ZR and 400GBASE-ZR will allow hyperscale data centers, physically separated data centers, and metro telecommunications networks to provide the 400G interconnect speeds emerging technologies require.

Optical component and device manufacturers face new test challenges. Test equipment that generates and analyzes 16-QAM signals at 60 Gbaud with optical impairments enables manufacturers to test their components and devices for 400G applications in multi-terabit-per-second DWDM networks. It is essential to accurately test new 400 Gb/s optical coherent components and transceivers to optimize designs for next-generation DCI.

Learn how Keysight’s solutions can help you address your optical and photonic test challenges:

- Understand how integrated photonics and new standards drive next-generation DCI; read the white paper Coherent Optical Transforms Data Center Interconnects
- Discover how to accurately and efficiently test your transceivers so you can design the next generation of high-speed interconnects; visit Optics and Photonics

Learn more at: www.keysight.com

For more information on Keysight Technologies’ products, applications or services, please contact your local Keysight office. The complete list is available at: www.keysight.com/find/contactus