Challenges Along the Path to Density

By Jon Anderson

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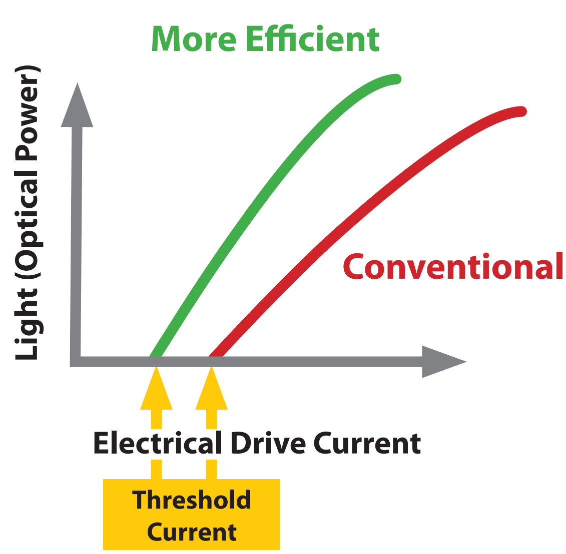
The growth of the Internet, mobile computing and high-bandwidth intensive applications such as video, have placed substantial requirements on traditional telephone networks for transporting increasing amounts of data traffic. These new bandwidth-hungry applications drive increased network utilization across the core and at the edge of wireline, wireless and cable networks -- challenging network service providers to supply much more bandwidth to their customers. As a result, network service providers are installing fibre-optic cable connections closer to the end user in an effort to transmit more data at a lower operating cost. This fibre-optic equipment must deliver more data to end users without requiring network providers to update their facilities.

The continuing trend toward higher density - more information per unit footprint - is presenting some major challenges throughout today's communication industry. While optical subsystem, module and component companies strive to meet the challenge within the framework of industry standards, demand continues to increase for more reliable and cost effective solutions, especially those which can be installed in existing network facilities.

Network service providers typically have fixed, limited space within their network central offices, closets, and data centers to house network equipment. So, regardless of data rate, network equipment must operate within the allowable space available. The bottlenecks to higher component densities stem from the physical environment of the equipment and include power consumption, operating temperature and mechanical size. As the industry migrates from 10 Gbps to 40 and 100 Gbps network speeds, overcoming these obstacles is critical for meeting the escalating demands for more data and bandwidth.



Semiconductor laser designers strive to increase the slope efficiency to increase the emitted light for a given electrical drive current while also reducing the threshold current to achieve the lowest power consumption.

Figure 1: Example of Laser Optical Output versus Input Electrical Current

The power challenge

Optical subsystems, modules, and components consume from two to five times more electrical power operating at 10 or 40 Gbps data rates when compared to 1 or 2.5 Gbps data rates. Furthermore, migration to 100 Gbps systems is expected to be even more challenging. With that in mind, network system vendors need highly-efficient optical interfaces that support greater density while adhering to power supply and cooling system constraints. These constraints also drive a need for laser technology with higher temperature tolerance and improved efficiency that will, in turn, reduce power consumption and enable the use of smaller form factor modules.

For every Watt of energy consumed by a data center, at least another 1 Watt of electrical energy is used for cooling the equipment. Thus, many network service providers and system vendors are placing a higher priority on energy-efficient networking equipment. For example, many communication companies have established green programs that award preference to equipment and components that enable them to reduce their carbon footprint through lower power consumption.

The optical components industry leverages the broader semiconductor industry for the electrical components within the optical modules used for transmission and reception of data. The semiconductor industry offers multiple material systems ranging from compound semiconductor materials with high transmission bandwidth and high power consumption such as InP (Indium Phosphide) and GaAs (Gallium

Arsenide) to moderate bandwidth and low power consumption Silicon in CMOS (Complementary Metal Oxide Semiconductor). As more power-efficient materials are able to support the high bandwidth and performance requirements of the fibre optics field, optical component manufacturers transition to next generation materials with superior energy efficiency per bit of transmitted data.

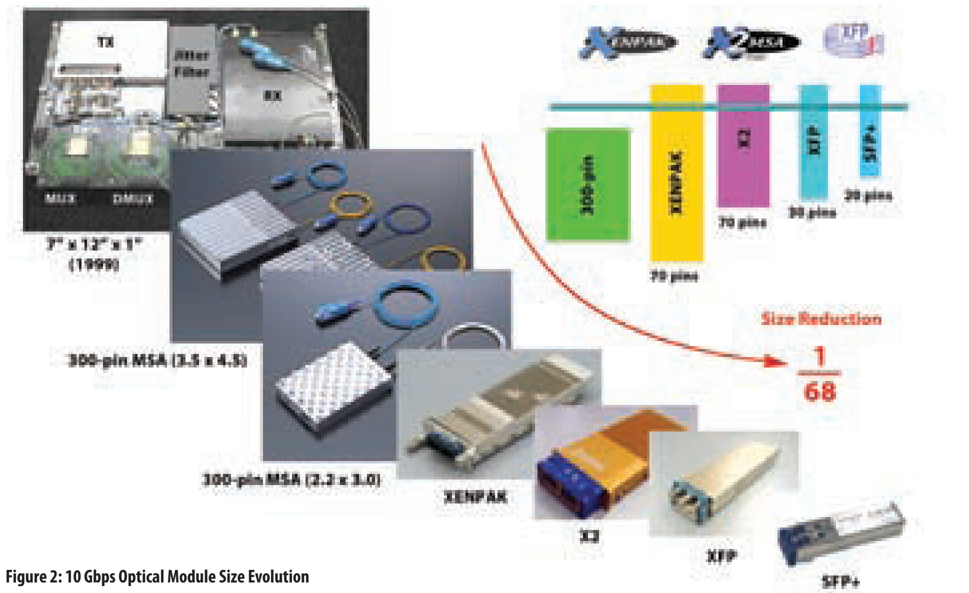


Figure 2: 10 Gbps Optical Module Size Evolution

The temperature challenge

Temperature is a concern within an optical module because the laser diode can be very sensitive. In the past, this has resulted in 10 Gbps modules being limited to a maximum operating case temperature of 70°C. Although temperature-controlled environments help, heat dissipation from neighboring electronic components can raise internal equipment temperatures to levels that degrade optical laser and module performance. Network equipment located outdoors in non-temperature controlled environments requires transceiver modules to operate reliably with operating case temperatures of 85°C and cold start conditions of -40°C.

Network operators demand that optical communications equipment operate reliably at the widest temperature ranges possible to mitigate the possibility of any performance degradation. Additionally, the wavelength or colour of light emitted by a semiconductor laser is proportional to the temperature of the laser within the operating temperature range. This colour shift is known as wavelength drift and forces optical component designers to use cooled lasers for applications such as DWDM or LAN-WDM where the wavelength must be tightly controlled. Generally, network equipment manufacturers prefer using an uncooled laser within optical modules to avoid the need for costly and inefficient thermoelectric coolers. More efficient and uncooled lasers also provide an additional benefit of drawing less current, so they not only address the temperature challenge, but also reduce power consumption to meet environmental goals. Technology that supports these initiatives has recently been extended to reaches of up to 40 kilometers at 10 Gbps in the network.

The size challenge

Bandwidth capacities within a system are defined by its system throughput, the data rate of each port, and the overall chassis dimensions of the system. At current data rates most network service providers and enterprises are already utilizing the limited space they have for housing optical network equipment within an office or equipment closet. The challenge of expanding system capacity includes increasing the number of ports and the data rate for each port – all without adding to space requirements.

Meeting these higher density and speed demands has forced industry leaders to define and design smaller transceiver packages. As package size decreases, the ability to dissipate heat is reduced and it becomes virtually impossible to support circuitry which is not optimized for energy efficiency. Where feasible, optical module and component suppliers use uncooled or semi-cooled laser technology. Additionally, designers substitute compound semiconductor material-based integrated circuits (ICs) with low power silicon-based circuitry. These silicon ICs leverage Moore's Law and the investment of the whole IT industry into optimized low power circuitry and small feature sizes.

Another key factor that constrains the size of the optical module form factor is the digital electrical interface from the network equipment to the module. Today, conventional optical modules for the transmission and reception of data over fibre-optic cable are categorized as transponders or transceivers. Transponders aggregate multiple lower frequency electrical inputs into a higher speed optical data stream. Transceivers have electrical interfaces serially connected to the optical interface, such that there is no aggregation of the signal. Since a transponder has a wide electrical bus, they are usually larger in size than transceivers.

Moving forward

The challenges of power consumption, temperature control and smaller size all work hand-in-hand within any solution. In other words, altering power consumption will typically have some effect on temperature control, size or both. Therefore, solutions to density must meet the challenges presented across the board, all with an emphasis on increasing data rates while still providing performance reliability and overall efficiency of the network.

As networks migrate to 40 and 100 Gbps data rates, cost and performance are key issues for network operators. Overcoming the barriers of power, temperature and size will create a path to higher density that the communications industry can smoothly navigate.

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