Solution Brief

From 100G Pluggable DWDM to 800G and Beyond

What was once state of the art data rates for optical links between data centers and in metro networks is now superseded by the even higher rates of 400G and 800G DWDM. The new standards can bring you four and eight times the capacity of 100G links, which however still may be the most economical rate to choose on less loaded routes.

Smartoptics offers a wide range of open optical solutions for data centers, communication service providers, and other users of ultra-high speed DWDM connectivity. Read on to learn more!

smartoptics

The Ever-Ongoing Demand for More Bandwidth

Technology has certainly taken major leaps forward since the first WDM systems were demonstrated in the 1980:s. Pluggable transceivers for 1G DWDM were introduced in 2001, followed by 10G DWDM and SFP+ transceivers in 2009. These advances in pluggable optics were crucial for the rise of the open optical solutions designed by Smartoptics.

The next major step towards higher data rates was taken around 2017 when PAM4 modulation transceivers allowed for cost efficient DWDM transport of 100G. Advances in transceiver technology then allowed for an even higher rate of 400G in 2021, using coherent modulation according to the ZR/ZR+ standards. Today we are at the 800G data rate boundary, and we are still not even close to the theoretical limit of information that can be carried over an optical fiber.

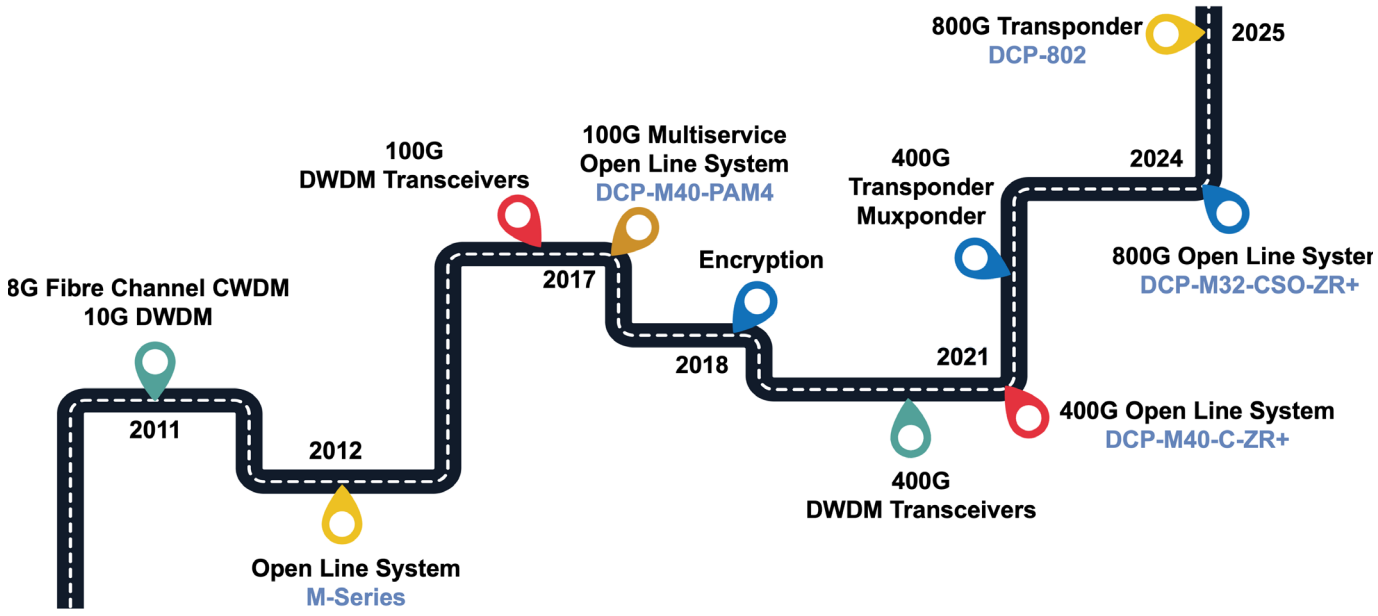


Figure 1. On the Smartoptics road towards higher data rates

Who Needs Ultra-High Speed DWDM?

Data Centers

High performance computing, artificial intelligence (AI), machine learning (ML), and the integration of on-premises data centers with cloud-based services all drive the demand for more capacity in data centers and in data networks globally. Especially, the growth of AI applications sets new standards for how data centers must be built. The demands for computing capacity, power, and reliability by AI have necessitated the transition of many previously single-site data centers into multi-building clusters. In such clusters the processing can be distributed to locations providing adequate availability of electrical power and cooling. The distribution requires the deployment of ultra-high speed data links, not only within the data center itself, but also between sites, typically 2 – 80 km apart.

When this is combined with the requirements for low latency, redundancy, and disaster recovery it is easy to see why data centers are continuously looking at new technologies for interconnections at higher data rates.

Figure 2. Data center

Traditionally, data center connectivity focused on securing high-speed connections within the data center itself. In this environment, establishing 100G and higher data rate links is straight forward. Standard grey – uncolored – transceivers can easily be plugged directly into the switches, routers, and servers and connected over in-house fibers.

When the need arises to interconnect several geographically separate data centers with high-capacity links, enterprises face new challenges. Ninety percent of all Data Center Interconnect (DCI) cases must cover a 2 to 80 km range which causes problems for some signal formats, if using grey transceivers. And with grey transceivers, an individual fiber pair must be acquired for each connection between the sites.

This is when DWDM becomes the attractive solution. Data center traffic takes on many forms: voice, video, and data, running over Fiber Channel and Ethernet switches at data rates spanning from 1G to 400G and beyond. If each individual service was connected over its own fiber, the number of fibers required would equal the number of services. When the cost of dark fiber is brought into the calculation, this becomes an expensive way of transporting traffic between sites.

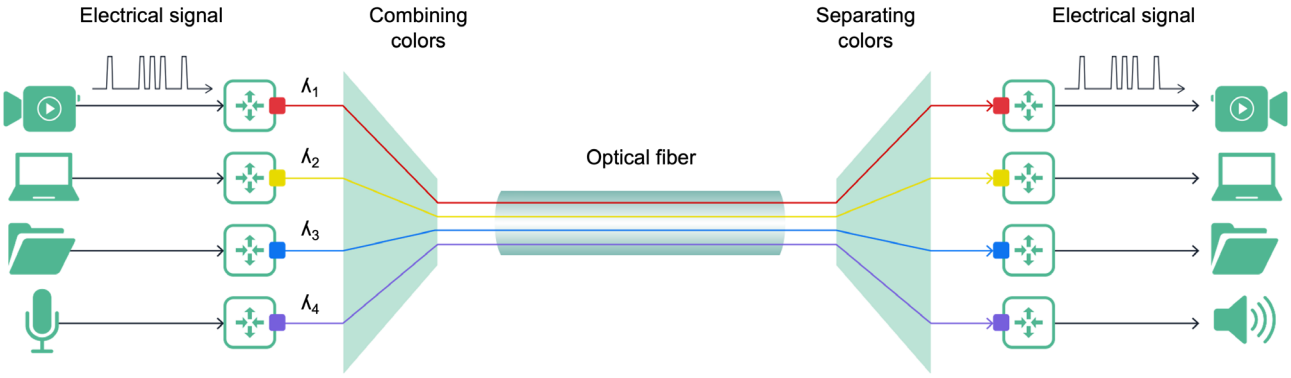


Figure 3. Wavelength Division Multiplexing

The benefits of allowing different types of traffic to be multiplexed together, sharing one common fiber connection, makes DWDM the obvious alternative for transporting 100G, 400G, and 800G in a DCI application. As an additional benefit, using DWDM also allows for the use of amplifiers, making it possible to bridge any distance between the data centers.

However, many of the DWDM products on the market are financial and technical overkill for use in enterprise DCI. Their capabilities are just far beyond the needs. Furthermore, some traditional DWDM products use chassis-based hardware, which do not fit with the building practices using white box switches and 1 U rack mounted servers in the data center. Finally, the need for simplicity and automated configuration of the DWDM links are far more important in an enterprise environment, which often lacks dedicated optical networking personnel, than for a telco operator investing in DWDM.

All these things together drive the demand for a new, open approach for DWDM connectivity supporting today's DCI applications.

Communication Service Providers

Communication service providers, telco operators, and wholesale carriers connecting business subscribers to metro and long-distance networks also face an increased demand for more bandwidth. The accelerating interest in cloud services and data replication, along with even more media consumption at higher quality, drives the need for 100G and above connectivity, especially in the metro and regional networks.

The communication service providers' networks are typically hierarchically structured, aggregating traffic from the subscribers via access and metro networks towards regional and long-distance interconnections.

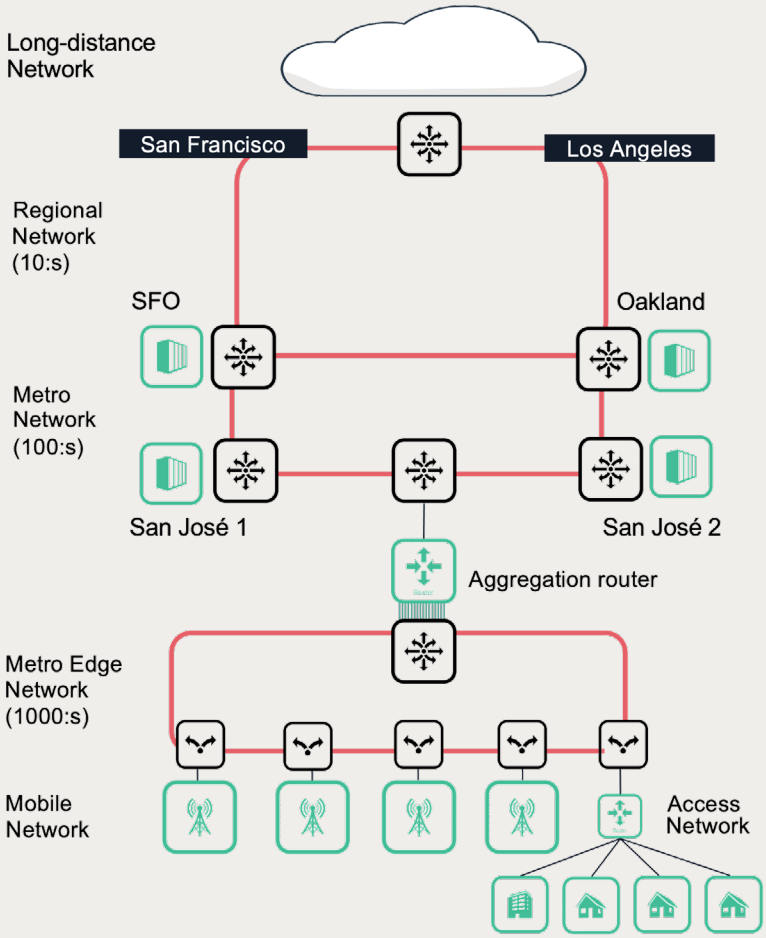


Figure 4. A communication service provider network and its typical number of nodes

The Metro and Regional Networks

In the metro area, service providers and operators typically serve the traffic from different data centers. These are spread out over a metropolitan area and interconnected by high-speed fiber optical links. While some data centers are seen as "main sites" and given nation-wide connectivity via the operator's core DWDM network, other data centers primarily serve as connection points for enterprises, content providers, and for capacity wholesale.

To increase the capacity in the metro area and to provide their customers with high-speed 100G and 400G links, service providers are now faced with two alternatives. The first option is to increase capacity by allowing the traffic between data centers to run over their existing core networks. A second option is to offload the core network by creating a separate network for the metropolitan area, a metro network layer.

While the first alternative might seem like an attractive option to avoid adding more complexity than necessary, connecting data centers in the metropolitan area or even connecting enterprise customers directly to the core network introduces the risk of losing capacity in the core network. This is why most service providers today opt for having a dedicated metro network.

When looking into creating the metro network, service providers face many of the same challenges as an enterprise does with DCI. Most traditional telco solutions are just overkill when building metro networks. Communication service providers are therefore, just as much as enterprises, beginning to look for new, innovative solutions. Solutions that are tailored to create cost-efficient, high-capacity links for short to medium distances and solutions that make the most cost-efficient use of their already deployed fibers.

Metro Edge Networks - From Analogue Signals to Standardized Connectivity

Consumer demands for a richer internet experience, increased video streaming, and emerging applications for the Internet of Things (IoT) and connected homes are driving end user expectations for more broadband access capacity – without having to pay more. Cable TV, mobile network, and broadband access providers are all under pressure to find new, smarter ways to offer high-capacity connectivity to their end-users.

To address the increasing bandwidth requirements, many service providers are opting for an architecture that positions network aggregation points nearer to the subscriber. These aggregation points are then typically back-hauled to the metro or regional network over high-capacity links. Consequently, the backhaul capacity in the access network between the last mile connections and the metro/regional network requires an upgrade. Today, the trend is clearly in favor of using 10G, 25G, and even 100G Ethernet solutions for this purpose.

Much in the same way mobile network access connectivity is moving towards standardization. And while most operators have previously turned to passive DWDM solutions with passive multiplexers and filters for access network aggregation, standardized, Ethernet-based communication is opening up new possibilities. New hybrid active/passive WDM access network solutions can increasingly address the challenges associated with relying completely on passive solutions.

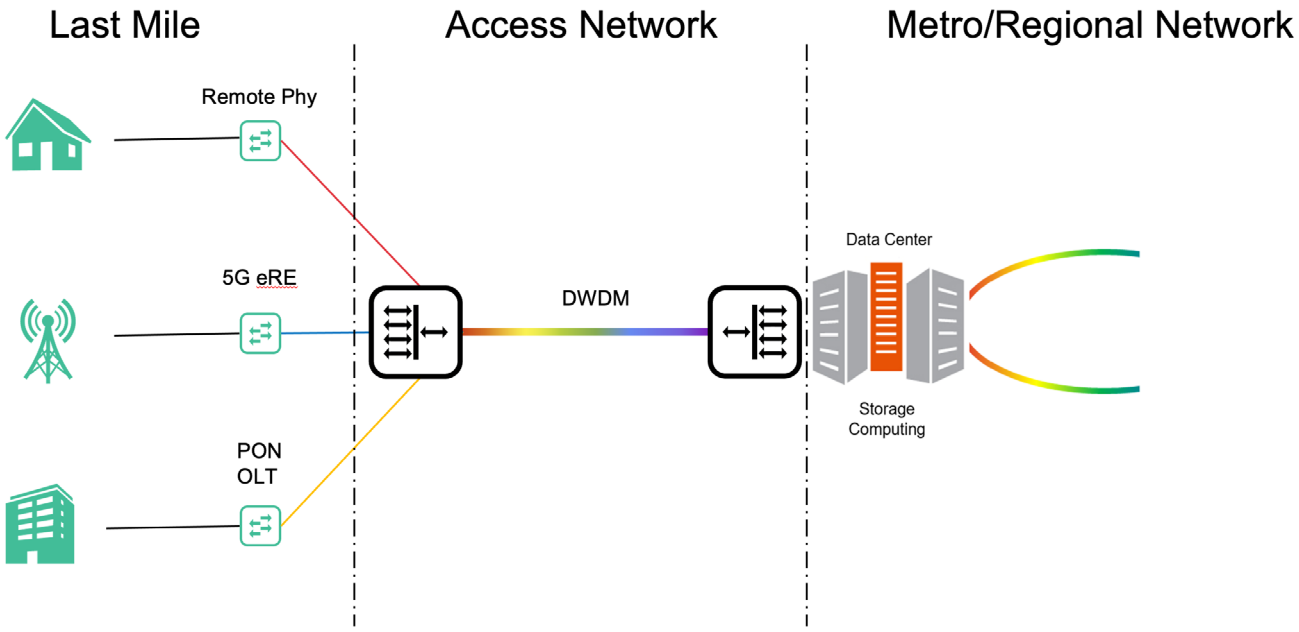


Figure 5. An active DWDM access network

Higher up in the network architecture, forward-thinking organizations are beginning to seize the opportunity of 400G and 800G connectivity. Here, one common approach is to practice an architecture similar to that used to connect data centers in an enterprise or metro environment. Meshed network topologies, with data centers distributed throughout the access area, allow the operator to create an access network with good coverage and aggregation points at a reasonable distance from the end-user.

And the requirements for such solutions? Not too different from those for enterprise DCI or service provider metro access networks. There are many sites to deploy and manage at this network level, driving the need for simplicity and cost-efficient solutions. Another vital requirement is also to minimize the latency in the access network.

Internet Content Providers and Internet Exchanges

The landscape for content delivery has evolved rapidly and streaming video has since long overtaken traditional broadcast TV when it comes to the number of viewers. Real time video traffic accounts for a huge peak in bandwidth requirements, a peak that can only be handled by adequate investments in 400G and 800G connectivity.

Figure 6. Content delivery is two thirds of all Internet traffic.

From a technical perspective, the requirements of a content provider or internet exchange also have much in common with the data center interconnect (DCI) case. The preference for a data center-oriented building practice, simplicity, and automation of the optical equipment are the same, while the demands on ultra-high data rates, such as 400G and 800G, between sites are even more explicit. Often the very high requirements on network reliability put rigid demands on redundancy and alternative routes and fiber links in the optical network. To summarize, also for content delivery networks and internet exchanges new types of optical networking solutions are of high interest.

An Open Approach

Smartoptics, a pioneer in open optical networking, has from the start recognized the benefits of leveraging open architectures for optical networks. With an open architecture the functionality of once monolithic optical transport systems is disaggregated, using pluggable transceivers, open line systems and Software Defined Networking (SDN) control, resulting in optimal price/performance. This “IP over DWDM” approach, i.e. pluggable transceivers in routers and switches combined with open line systems carrying the DWDM channels over longer distances, is now becoming the new standard when deploying optical networks.

An open optical network is also ideally suited to carry wavelengths from multiple sources over the same infrastructure. With a separate open line system, there is no penalty or licensing fee for carrying “alien wavelengths” alongside the wavelengths emanating from your own transceivers.

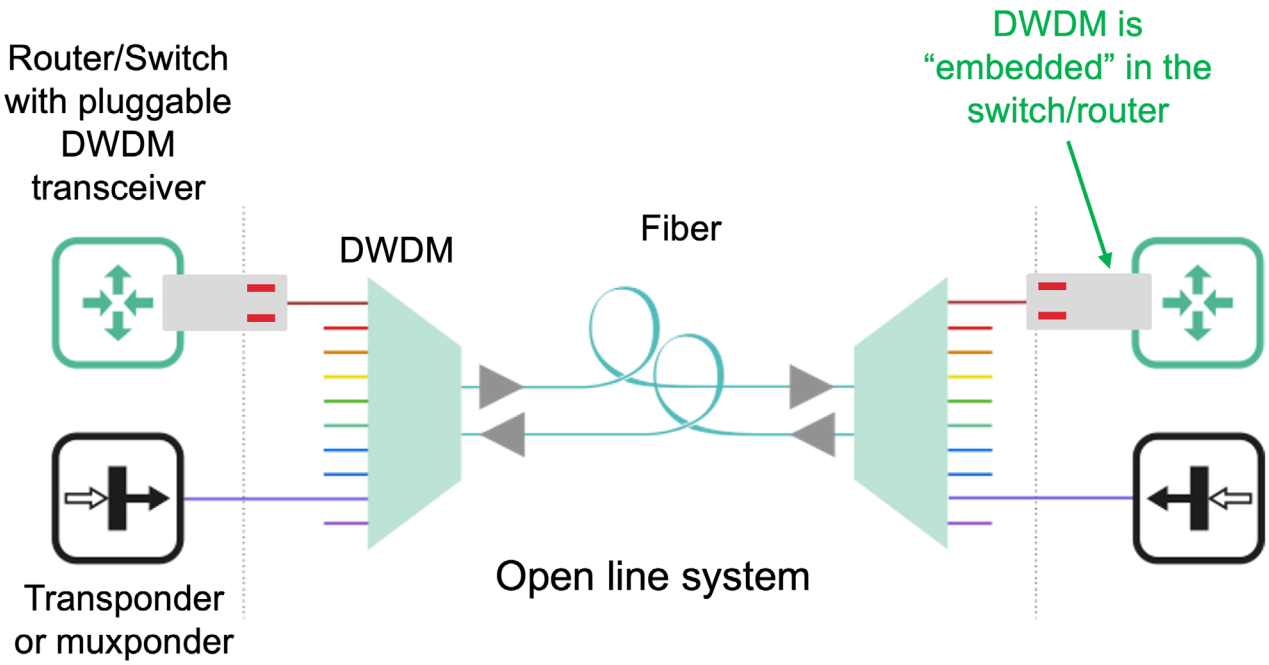


Figure 7. The Open Optical Networking Model

The Smartoptics line systems and transponders/muxponders are designed for a maximum level of automation and “plug-and-play”, while at the same time enabling advanced functions, such as encryption at the optical layer. And to simplify the integration in the data center or metro network, they all adhere to the rack mount building practice.

An open approach also means adhering to relevant standards. Smartoptics has actively designed its products according to standards such as the OpenROADM Multi-Source Agreement (MSA), the OpenZR+ Multi-Source Agreement (MSA), the Telecom Infra Project (TIP), the Optical Internetworking Forum (OIF) standards, as well as other standards to ensure maximum interoperability with other vendors in this industry.

The fundamental cost advantage of higher data rates lies in the fact that you can multiplex several lower speed connections over the same optical channel. For example, ten 10G Ethernet connections can be multiplexed over one 100G channel and eight 100G connections can be multiplexed over one single 800G channel. In addition, the higher data rates also decrease the time it takes to transmit a data packet over the connection. And given that your switches support 400G or 800G interfaces, you may now directly leverage the full capacity between sites and towards your customers.

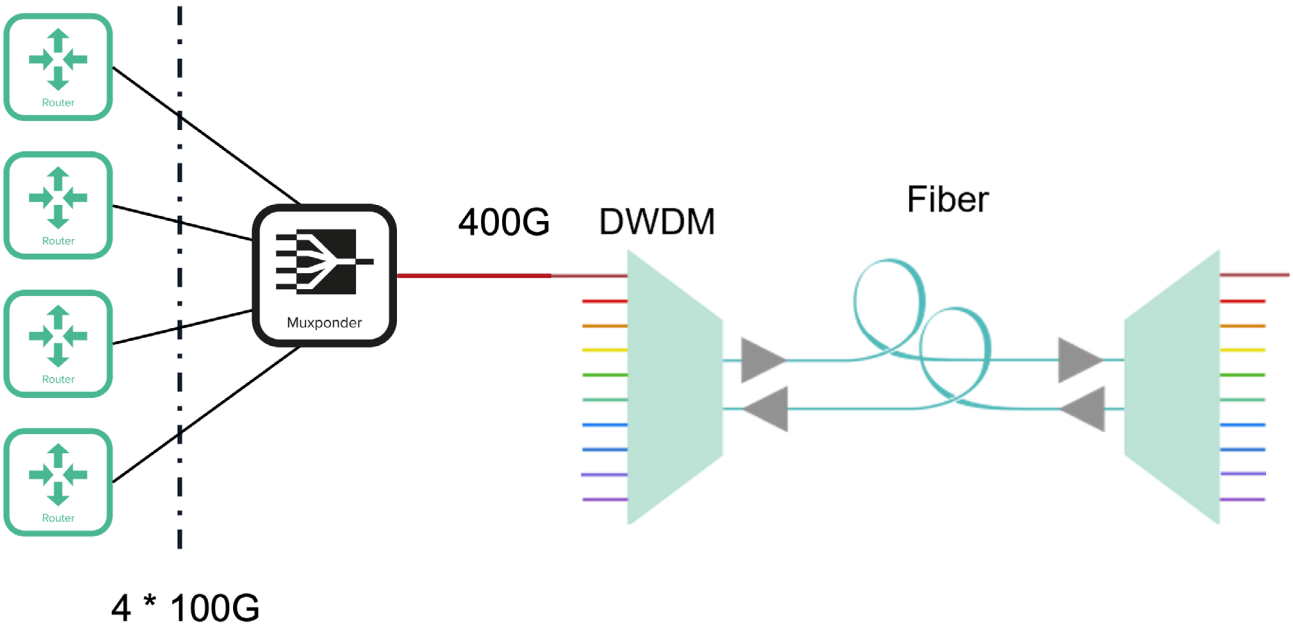


Figure 8. 400G allows you to multiplex four 100G connections over one single wavelength.

The Technologies

The evolution towards ultra-high DWDM data rates is primarily driven by the development of the pluggable optical transceivers and related innovations in transmission technologies. To better understand the available alternatives, we need to take a closer look at the main modulation types used for the transmission of optical signals.

Pulse-amplitude modulation (PAM) is a signal modulation where the information is encoded in the amplitude of a series of signal pulses. The number of possible pulse amplitudes in analog PAM is theoretically infinite, but digital PAM reduces the number of pulse amplitudes to some power of two. For example, in 4-level digital PAM (PAM4) there are four possible discrete pulse amplitudes (levels) which each can be used to carry two bits of information.

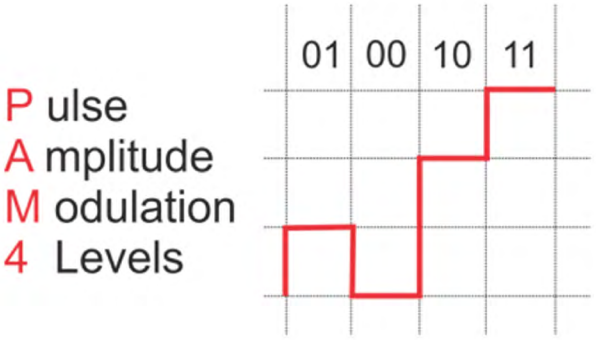


Figure 9. PAM4 modulation transmits two bits of information per pulse

100G PAM4 was introduced in transceivers with the QSFP28 form factor in 2017 and gained initial traction as the dominant modulation format for this data rate, due to its then superior cost/performance ratio. However, PAM4 has lost some of its cost advantages and today 100G coherent modulation transceivers are also available in the QSFP28 form factor.

Quadrature phase-shift keying (QPSK). Any digital modulation scheme uses a finite number of distinct signals to represent digital data. QPSK conveys data by changing the phase of a constant frequency carrier wave, where each phase represents a unique pattern of binary digits. QPSK uses four positions on the constellation (phase) diagram, equally spaced around a circle. With four phases, QPSK can encode two bits per symbol, as shown.

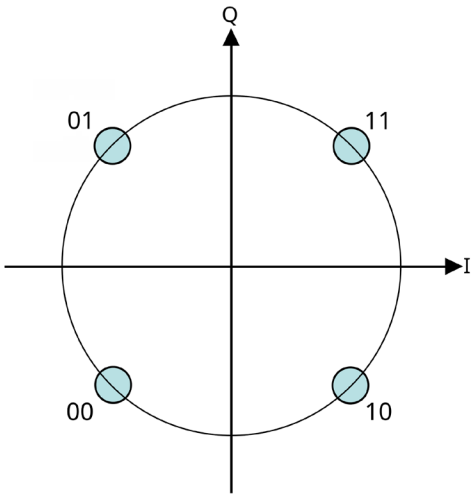


Figure 10. QPSK modulation

Dual-polarization quadrature phase shift keying (DP-QPSK) involves the polarization multiplexing of two different QPSK signals, thus improving the spectral efficiency by a factor of 2. Currently DP-QPSK is used to encode 100G, 200G, and 400G signals. 100G DP-QPSK transceivers were first available in the “legacy” form-factor CFP but are now also available in the QSFP28 and QSFP-DD/OSFP form factors. In terms of standards - OpenZR+, OpenROADM, and IEEE802.3 all define different types of 100G QPSK encoding. 200G DP-QPSK transceivers are available in QSFP-DD, OSFP, and CFP2 form factors and defined in standards like OpenZR+ and OpenROADM. 400G DP-QPSK transceivers are available in the QSFP-DD form factor and defined in the OpenROADM standard.

Coherent optical modulation is the general term for one of the most significant innovations in DWDM system development. Coherent optical systems utilize advanced optics and digital signal processors (DSP:s) to transmit and receive data encoded as coherent[1] light waves, enabling ultra high-speed data transmission. Coherent modulation continues to be the driving force behind ultra high-speed optical devices, including 400G, 800G, and beyond.

[1] In physics, two wave sources are perfectly coherent if their frequency and waveform are identical and their phase difference is constant. Coherence contains several distinct concepts that describe all properties of the correlation between physical quantities of a single wave, or between several waves or wave packets.

Quadrature amplitude modulation (QAM) is a family of different coherent optical modulation techniques. It conveys two digital bit streams, by modulating the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation. The two carrier waves are of the same frequency and are out of phase with each other by 90°, a condition known as orthogonality or quadrature. The transmitted signal is created by adding the two carrier waves together. At the receiver, the two waves can be coherently separated because of their orthogonality.

With QAM modulation, such as DP-16QAM, several bits can be encoded per transmitted light pulse, hence increasing the overall bit rate (Gbit/s) for a given baud rate (GHz). Some coherent transceivers can also fall back to simpler modulation techniques such as on-off keying (NRZ) and/or PAM4 when appropriate. This is used, for example, when it is discovered that the transceiver at the other end of the link does not support coherent modulation.

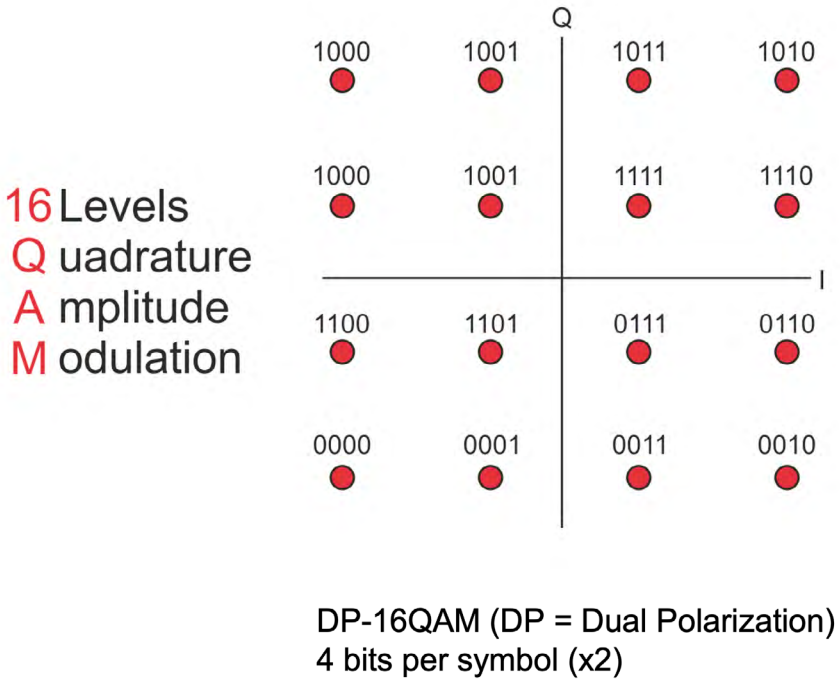


Figure 11. Coherent 200G, 400G, and 800G DWDM uses 16 Quadrature Amplitude Modulation and Dual Polarization (DP-16QAM)

The Pluggable 100G DWDM Alternatives

When considering upgrading your connections to 100G DWDM you can choose between using 100G PAM4 transceivers in the QSFP28 form factor or using 100G coherent transceivers in QSFP-DD or QSFP28 form factors, depending on what is supported by your switches/routers.

Figure 12. QSFP-DD (left) and QSFP28 (right) transceivers

PAM4 modulation requires an active line system that can handle the low optical power and the dispersion properties of the optical signal. The PAM4/multiservice versions of the DCP-M Flexible Open Line Systems from Smartoptics are therefore designed to handle the PAM4 signals and can be used when covering distances of up to 80 km. However, PAM4 transceivers are not standardized, which means that you normally must rely upon the same vendor's transceivers at both ends of the connection.

100G coherent DWDM transceivers were originally only available in the larger CFP form factor, but improved power management has now enabled the use of the smaller QSFP-DD and QSFP28 form factors. The major advantages of the 100G coherent QSFP-DD transceivers are that they are standardized by the OpenZR+ implementation agreement and in general have a much longer reach than their PAM4 equivalents. The 100G coherent QSFP28 transceivers have an even lower power consumption and are the given choice if your switches/routers only accept this form factor. It should also be noted that coherent 400G QSFP-DD transceivers according to OpenZR+ can operate in 100G mode providing ultra long-haul reach (4 200 km).

When comparing the PAM4 and coherent 100G DWDM alternatives from a cost perspective, the PAM4 transceivers are lower cost than the 100G coherent transceivers, but on the other hand they require an advanced line system. Hence, the total cost of a PAM4 system may be higher than for a 100G coherent system. PAM4 was an early 100G technology that found its use in the 10 – 80 km distance span for data center interconnect and metro network aggregation, but the development of the coherent technologies is now overtaking many of its advantages.

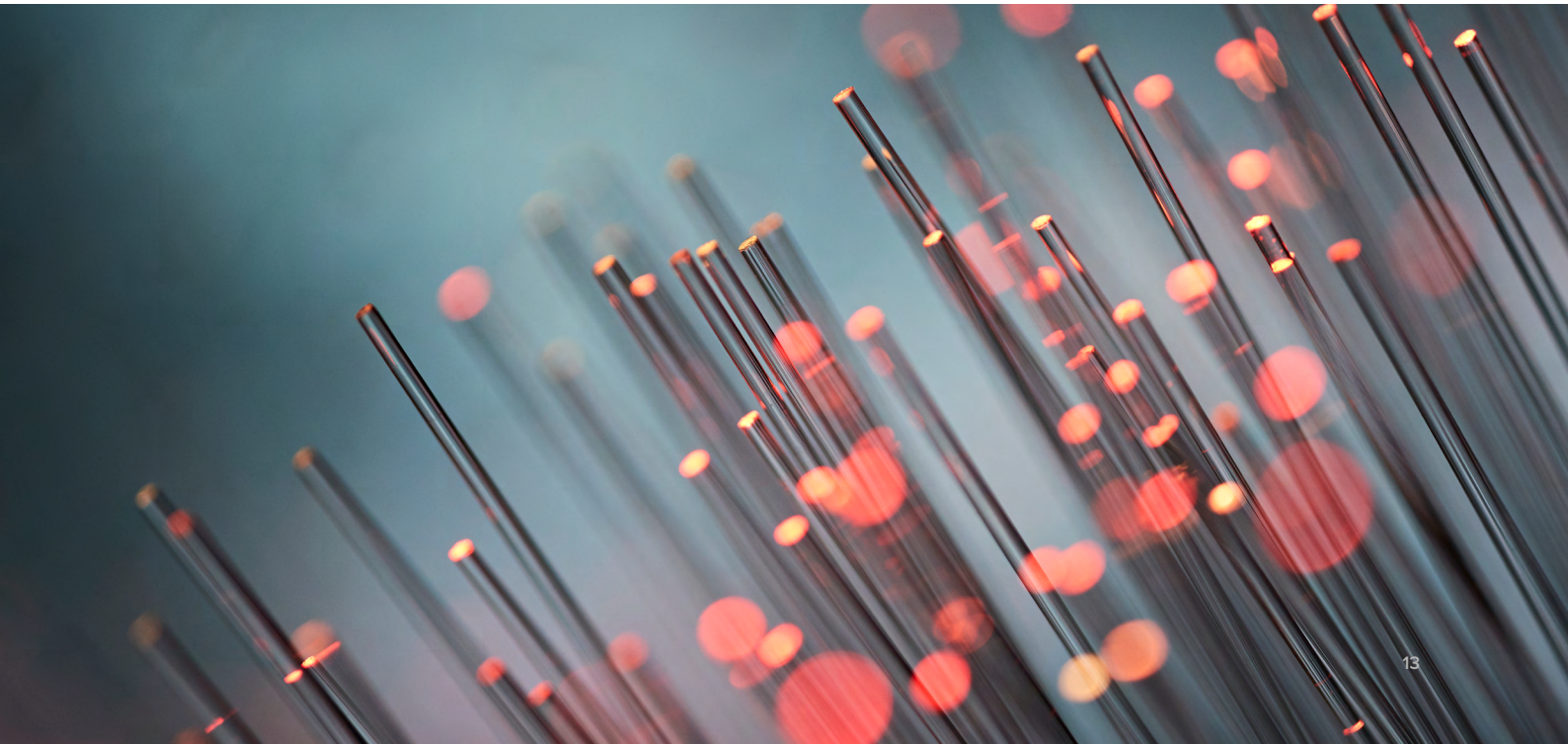
The Pluggable 400G DWDM Alternatives

For 400G and higher data rates, coherent optical modulation must be used. One of the major advantages when stepping up to 400G DWDM is that it is based on a new optical connectivity standard, named 400ZR, defined by the Optical Internetworking Forum (OIF). This is the first time since the introduction of 10G DWDM such a standard has been agreed upon, a fact that will secure interoperability between systems from different vendors and keep costs down.

Further, 400G DWDM according to the 400ZR standard is also ideally suited to leverage disaggregated optical networking as advocated by major equipment vendors such as Cisco, Juniper and Arista. 400ZR therefore defines two new form factors for such pluggable transceivers, QSFP-DD and OSFP, capable of handling the higher power required for 400G.

For an operator, typically serving some 5-10 data centers and associated end customers in a metro area, 400G DWDM offers the possibility to increase the overall network capacity as well as to introduce new transport services. Your 400G networks may be built with point-to-point links or use mesh or ring topologies, just as before with 10G, 40G or 100G DWDM, and even with the same open line system that you already have in place.

Several standardization initiatives now exist to ensure the full interoperability of coherent 400G DWDM systems. First out was the Ethernet-based fiber optic networking standard **400ZR** published by the Optical Internetworking Forum (OIF) in April 2020. The standard was primarily designed for transmitting 400G Ethernet over amplified point-to-point links up to 120 km and unamplified single wavelength links with a loss budget of 11 dB, published by OIF under the Implementation Agreement (IA) for a 400ZR coherent optical interface. **400ZR+** was designed to add more functionality to the original OIF 400ZR standard, such as expanding the reach beyond 120 km and enabling a



4 x 100G client rate. **OpenZR+** was then born out of the goal of taking the best of the 400ZR+ and the Open ROADM standards to achieve simplified functionality, high performance oFEC, and interoperability tailored to the needs of service providers. Open ZR+ adds more flexibility to the line rate and line modulation along with interoperability missing in 400ZR+. When referring to 400ZR broadly, we mean all the above standardization initiatives. They collectively play a crucial role in facilitating next-generation data center interconnect (DCI) and metropolitan network solutions meeting current and future bandwidth demands.

400ZR interoperability is at its best when using the QSFP-DD transceivers, because they are backwards compatible with previous QSFP-DD transceiver modules. As a result, 400ZR transceivers can be easily connected to existing switches and other infrastructure without having to replace anything. This is well aligned with the open networking trend and the needs of enterprise data center and metro network operators to make upgrading network infrastructure less expensive and less complex. However, should your switch/router not allow for direct installation of QSFP-DD transceivers, Smartoptics offers cost-efficient transponders and muxponders with support for QSFP-DD transceivers.

	OIF 400ZR	OpenROADM	OpenZR+
Target application	Edge, DCI/Campus	Metro/Regional, DCI	Metro/Regional, DCI
Reach	Single Hop	Long-haul	Long-haul
Line capacity	400G	100G/200G/300G/400G	100G/200G/300G/400G
Client formats	400GE	100GE-400GE + OTN	100GE/200GE/400GE
FEC	CFEC	oFEC	oFEC
Line modulation	16QAM	QPSK/8QAM/16QAM	QPSK/8QAM/16QAM

Figure 13. The three principal initiatives to provide interoperable 400G solutions and the 400G transceiver form factors.

400G Transceivers from Smartoptics

Coherent 400G pluggable transceivers are extremely complex devices comprising sophisticated silicon optical sub-systems, DSP:s for signal processing, and associated software for control and management. Smartoptics offers QSFP-DD transceivers that support all the three standardization initiatives that provide interoperable 400G links:

- The Smartoptics OIF 400ZR transceiver in QSFP-DD form factor for OIF 400ZR amplified and un-amplified links
- The Smartoptics OpenZR+ transceiver in QSFP-DD form factor with support for 11 different operational modes including both the OIF 400ZR amplified and un-amplified mode as well as various modes supporting the data rates specified by the Open400ZR+ multi-source agreement. The flexibility of this transceiver allows for not only a line rate of 400G with DP-16QAM modulation but also for 300G, 200G and 100G line rates using DP-8QAM and DP-QPSK modulation enabling significantly longer reach in e.g. core network applications.
- The Smartoptics 400ZR ultra long-haul transceiver in QSFP-DD form factor. This is an 800G capable transceiver run in 400G modes with higher baud rates (~120GBd) and QPSK modulation, which enables better OSNR performances and therefore longer reach.

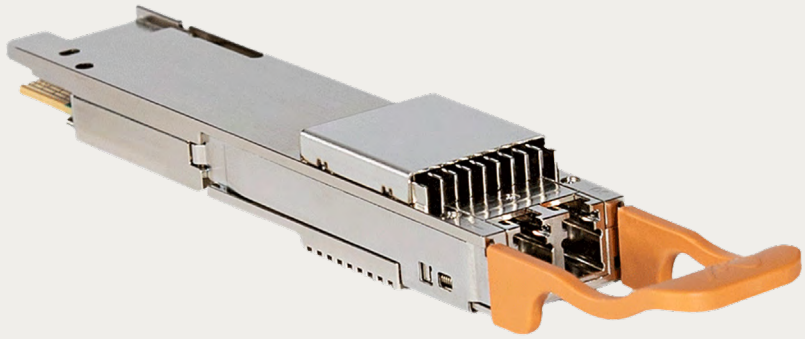


Figure 14. The QSFP-DD form factor

The actual data rates possible in a disaggregated optical network depends on the capabilities of the host systems, i.e. on the switches and routers, using the optical link. The Smartoptics transceivers announce their operating modes to the host system, which in turn decides which mode to use. Contact your Smartoptics reseller for more information about host systems capable of leveraging coherent 400G DWDM.

What about 800G Pluggable DWDM?

Coherent 800G DWDM relies upon the same modulation formats as 400G, i.e. QPSK and 16QAM, but with a higher baud rate enabling the doubled bit rate. Since the baud rate is higher, the passband of the optical line system must be wider than for 400G, a fact that has been considered in the design of the Smartoptics DCP-M32-CSO-ZR+ open line system, which is 800G-ready.

There are currently (2025) two principal initiatives to provide standardized 800G DWDM solutions, one by the Open Internetworking Forum (OIF) and one by the Open ROADM Forum.

	OIF 800G COHERENT	Open ROADM
Target application	Edge DCI/Campus	Metro/Regional DCI
Reach (amplified)	Pont-to-point 80 – 120km	Long-haul >120km
Line capacity	800G	400/600/800G
Client formats	100GE/800GE	100GE-800GE + OTN
FEC	oFEC	oFEC
Line modulation	16QAM	QPSK/8QAM/16QAM/PCS-16QAM

Figure 15. 800G standardization initiatives

PCS-16QAM leverages an innovative technology referred to as Probabilistic Constellation Shaping (PCS) where algorithms embedded in the transceiver DSPs code/decode with priority to use the points in the constellation diagram with lower noise and therefore providing a better link performance. Such a transceiver can also use proprietary PCS for lower-level modulations, such as QPSK, to enable 400G with improved performance and longer reach.

Smartoptics releases the first 800G transceivers during 2025. Initially the 800G transceivers are available in the OSFP and QSFP-DD form factors. Together with the transceivers, the DCP-802 transponder from Smartoptics is available to convert 100GbE, 400GbE, and 800GbE client optics to 800G DWDM.

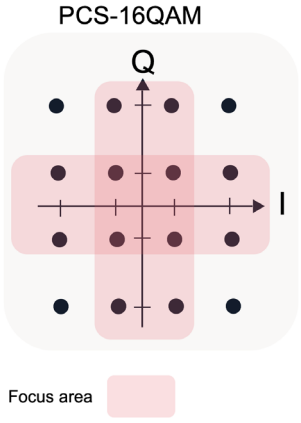


Figure 16. Constellation diagram illustrating Probabilistic Constellation Shaping (PCS)

Open Optical Solutions for 100G to 800G

Smartoptics specializes in innovative solutions and devices for the new era of open networking, based on disaggregated optical networks with pluggable transceivers embedded directly into the switches and routers. As one of the first on the market we can therefore offer a portfolio of complete 100G, 400G, and 800G pluggable transceiver solutions and compatible flexible optical line systems based on the DCP-family products DCP-M, DCP-F, and DCP-R.

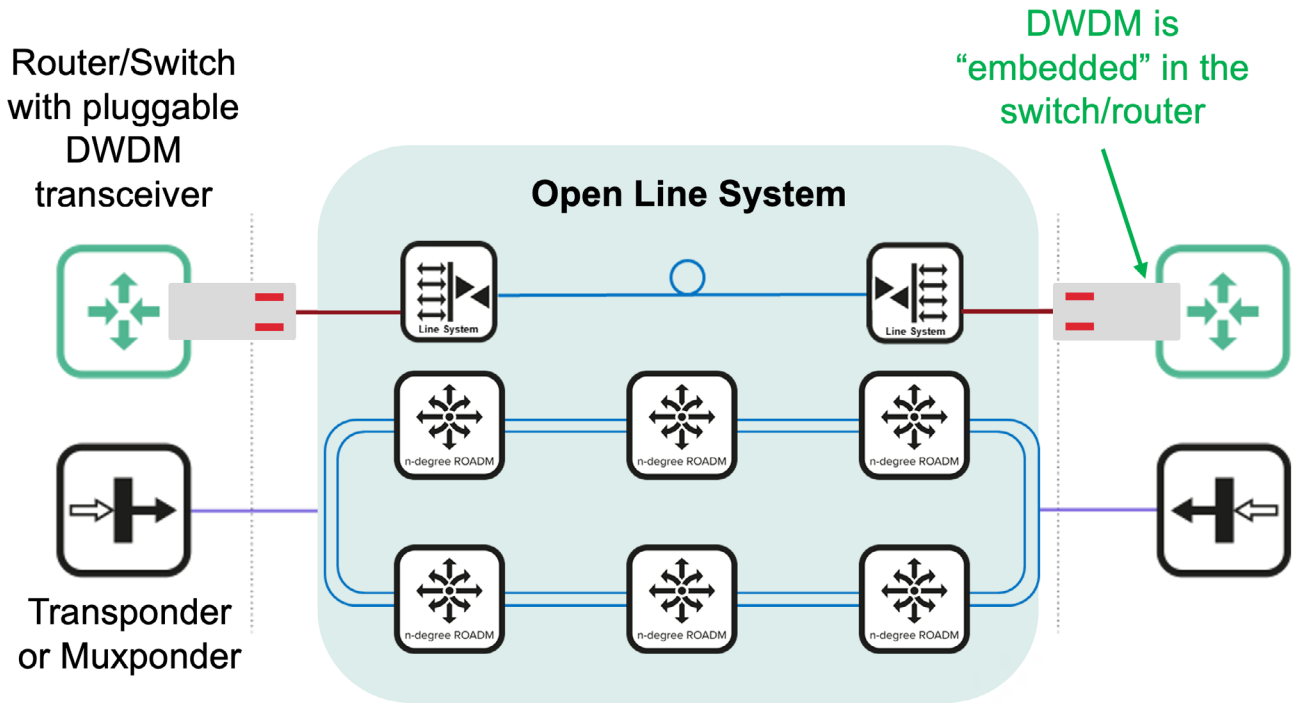


Figure 17. An open optical solution ("IP over DWDM") is based on pluggable transceivers and an open line system.

The use of pluggable transceivers directly embedded in the switches/routers ensures low power consumption, small footprint and low latency, hence it is the most cost-efficient solution and should be leveraged whenever possible. Transponders and muxponders may then be used for adding value, for example if the switch/router does not support the desired type of pluggable transceiver, for aggregation of several lower data rate links, and if the optical channel shall be encrypted. A further advantage of the open optical solution is that there is no penalty or licensing fee for carrying "alien wavelengths" alongside the wavelengths emanating from your own transceivers.

An example and a more detailed view of how an open optical networking solution is implemented by Smartoptics products is shown in the following illustration. Smartoptics provide pluggable transceivers at speeds up to 800G for Ethernet and up to 32G for Fibre Channel connections, transceivers that are approved for use by major switch/router vendors such as Cisco and Brocade. If the switch/router does not have a suitable interface for the colored DWDM transceiver needed, a range of transponders and muxponders are available for signal conversion and multiplexing of lower speed channels. And for the line system, anything from passive filters to advanced point-to-point and ROADM active line systems can be chosen.

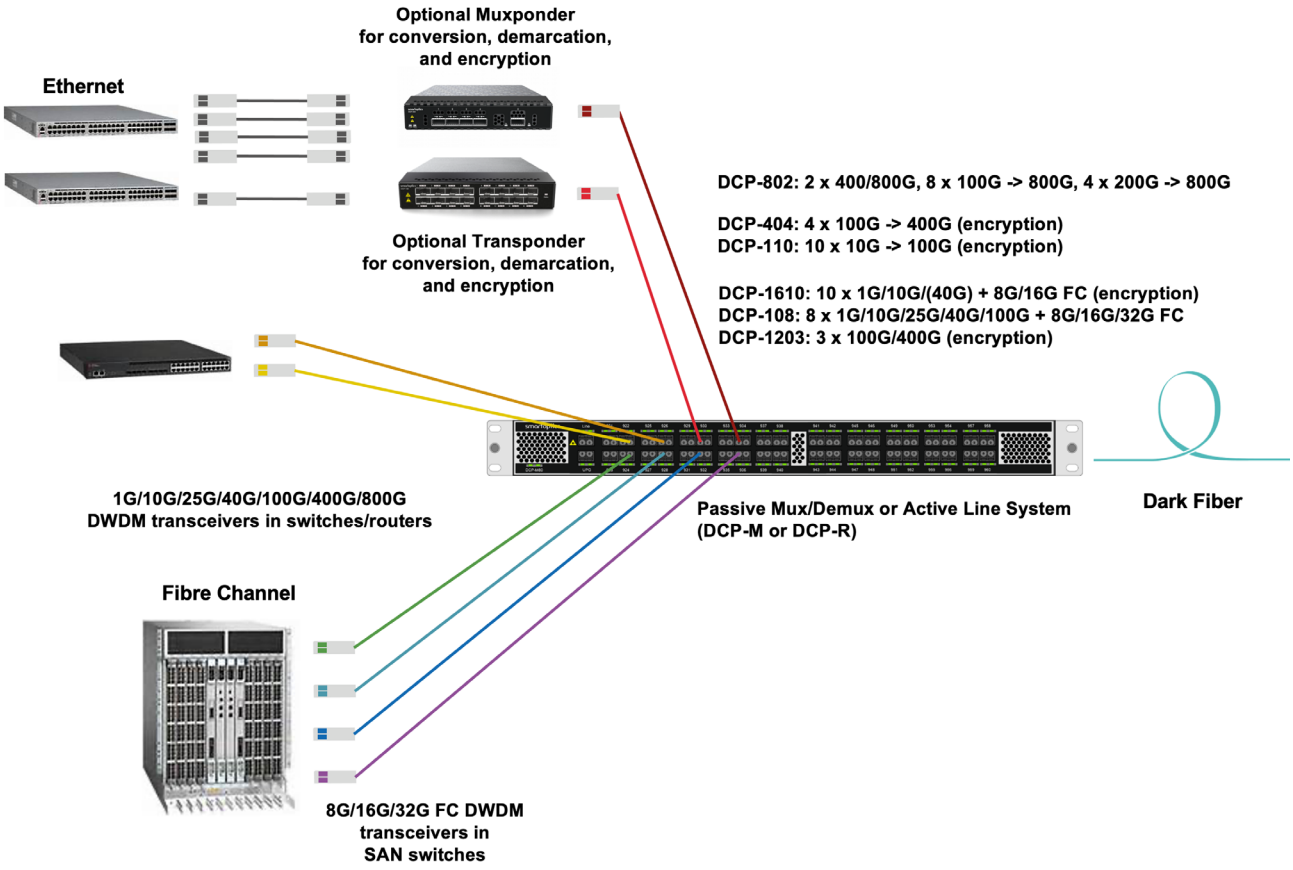
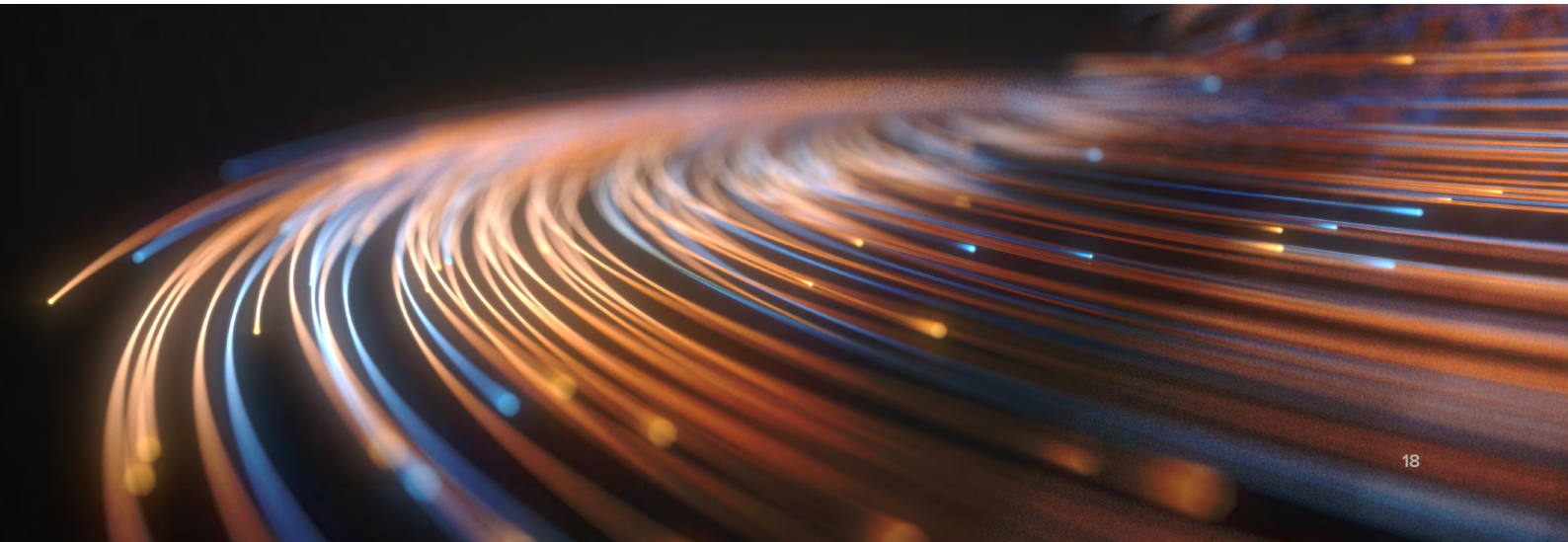


Figure 18. Open optical networking from Smartoptics



Solutions for 100G

Today, 100G Ethernet is very much the “bread-and-butter” solution for connectivity, both within the data center and between datacenters (DCI). When dark fiber pairs are available[2] pluggable 100G coherent DWDM transceivers in the QSFP-DD or QSFP-28 form factors can bridge distances of up to 170 km, depending on the attenuation of the fiber. Adding the Smartoptics optical amplifiers DCP-F-A22 or DCP-F-VG extends the reach of the connection even further.

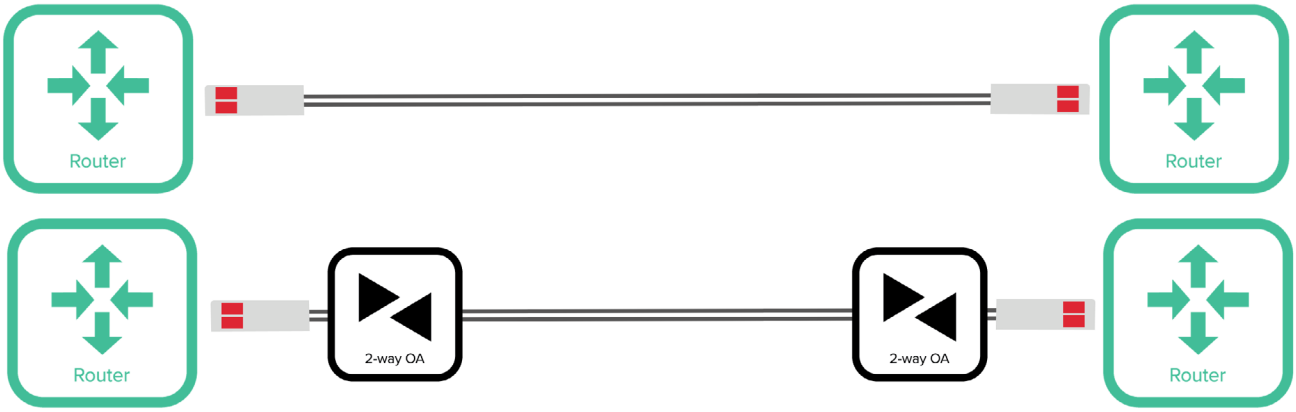


Figure 19. 100G DWDM over dark fiber pairs without and with optical amplifiers

If fiber pairs are scarce, a passive DWDM multiplexer for 2 – 40 channels from the Smartoptics H-Series allows several individual DWDM channels to make use of one single pair of fibers. An excellent example of the cost savings possible by smart use of DWDM. The distance possible to bridge depends on the multiplexer used and the attenuation and quality of the fiber.

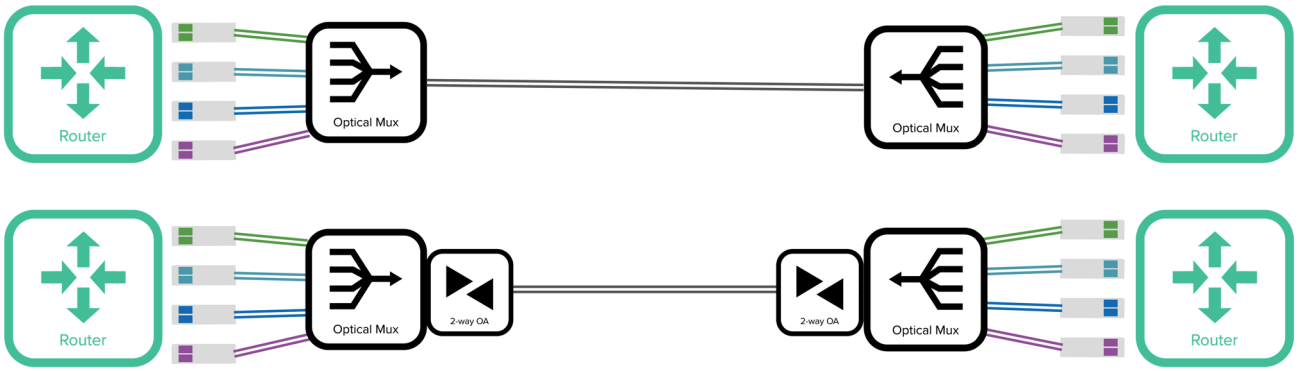


Figure 20. Multiplexing of 100G over dark fiber using passive multiplexers without and with optical amplifiers

[2] The dark fiber must follow the G.652/G.654/G.655/G.657 recommendations. Dispersion shifted fiber according to G.653 cannot be used.

If you instead opt for a 100G solution with PAM4 transceivers in the QSFP28 form factor, an active open line system such as Smartoptics DCP-M40-PAM4 will be required to handle the low optical power and the dispersion properties of the optical signal. The DCP-M40-PAM4 supports up to 40 individual PAM4 DWDM channels if you have access to a fiber pair between the sites and up to 20 full duplex channels when using a single fiber. In both cases distances of up to 80 km can be bridged.

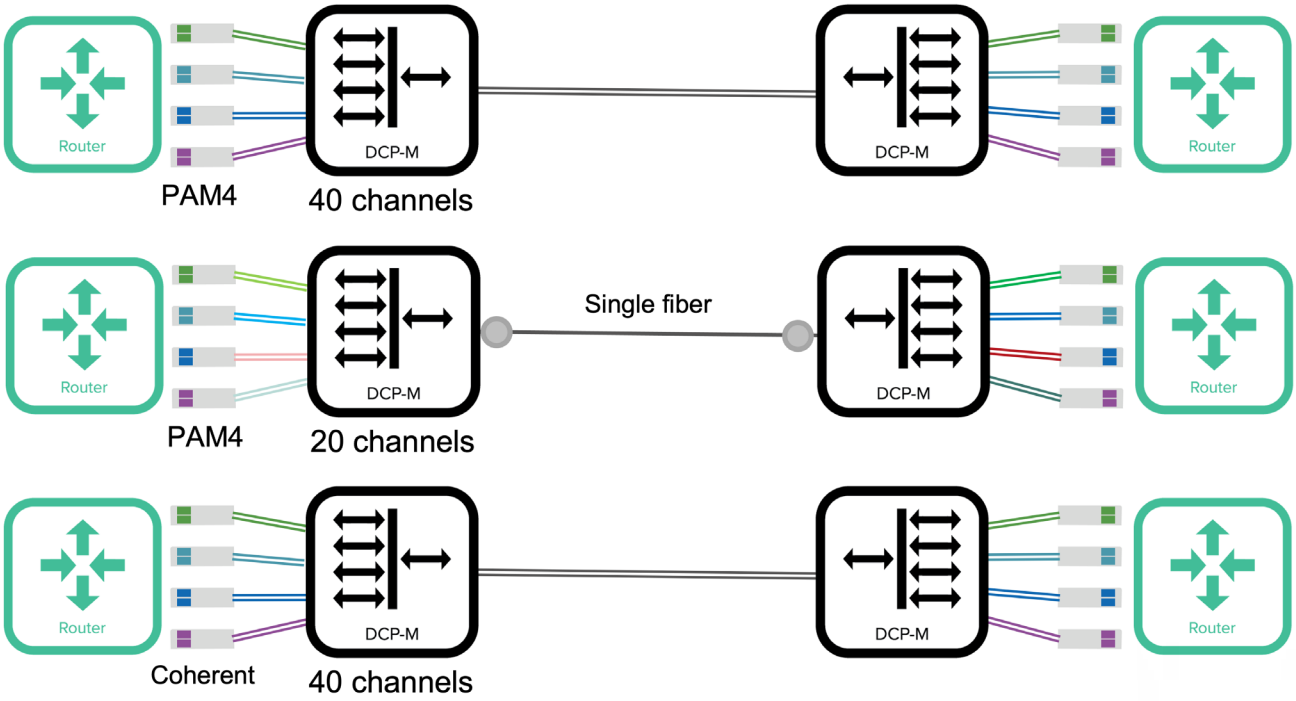


Figure 21. 100G with PAM4 DWDM using an active open line system (DCP-M40) and (bottom) 100G with coherent DWDM

Alternatively, you can go for a solution with coherent 100G capable transceivers and use the DCP-M40 line systems to handle up to 40 DWDM channels over a fiber pair. Since you are now using an active line system, a fiber loss of up to 29dB can be tolerated between the sites[3]. And if you choose to use the DCP-M40-PAM4 line system you may even mix pluggable PAM4 and coherent transceivers on the same DWDM connection.

[3] Coherent signals are not limited by dispersion; hence it is only the fiber loss that determines the distance that can be bridged.

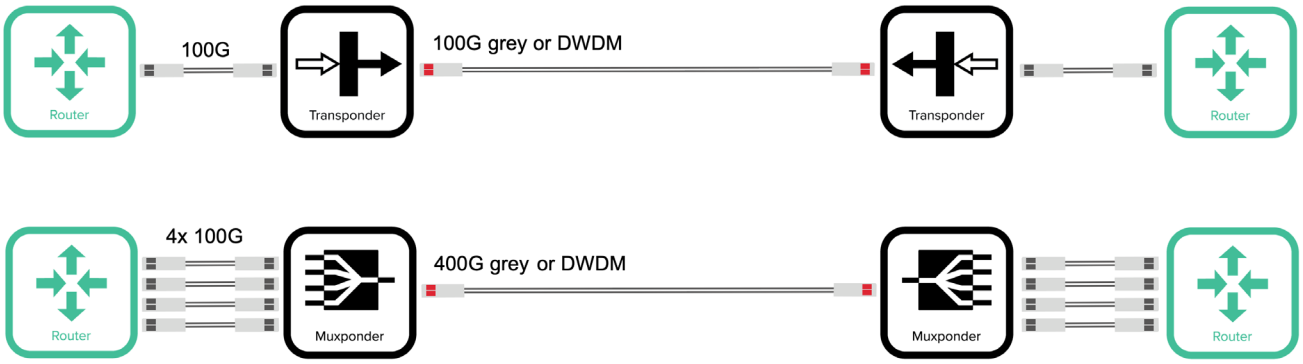


Figure 22. 100G via transponder (DCP-108, DCP-1203) or muxponder (DCP-404)

A transponder or a muxponder can add significant value to a 100G DWDM solution. Your switch/router may for example not support the type of pluggable DWDM transceiver required, you may want a clear demarcation device between your router and the optical network, or you may want to invest in 400G optics for future router upgrades to 400G. A transponder or a muxponder may also offer better bandwidth efficiency, aggregation of signals, or include other desired features such as encryption at the optical layer.

The Smartoptics DCP-108 transponder supports eight 100G QSFP28 transceivers in one compact unit and the Smartoptics DCP-1203 has three individual transponders on the same card. Each of these transponders can be used in 100G or 400G mode and the client side can use a flexible range of QSFP28 client types for 100G and QSFP-DD for 400G.

In 100G configurations where low-cost multiplexing and bandwidth utilization are important factors, the DCP-404 muxponder is the ideal solution. Equipped with 400G OpenZR+ DWDM transceivers, the DCP-404 is the ideal product for multiplexing 100G services in a cost-efficient way at the subscriber premises.

Solutions for 400G

Just as for 100G an open solution with pluggable transceivers is the simplest and most cost-efficient way to create a coherent 400G DWDM connection. The OIF 400ZR standard allows for distances up to 120 km to be covered in this way. A passive multiplexer with sufficient broad passband, for example the Smartoptics H-MD-40-921-960, can be used to multiplex up to 40 channels over the same dark fiber pair. However, the signal reach will be dependent on the type of multiplexer and the fiber used, so the addition of optical amplifiers may be required.

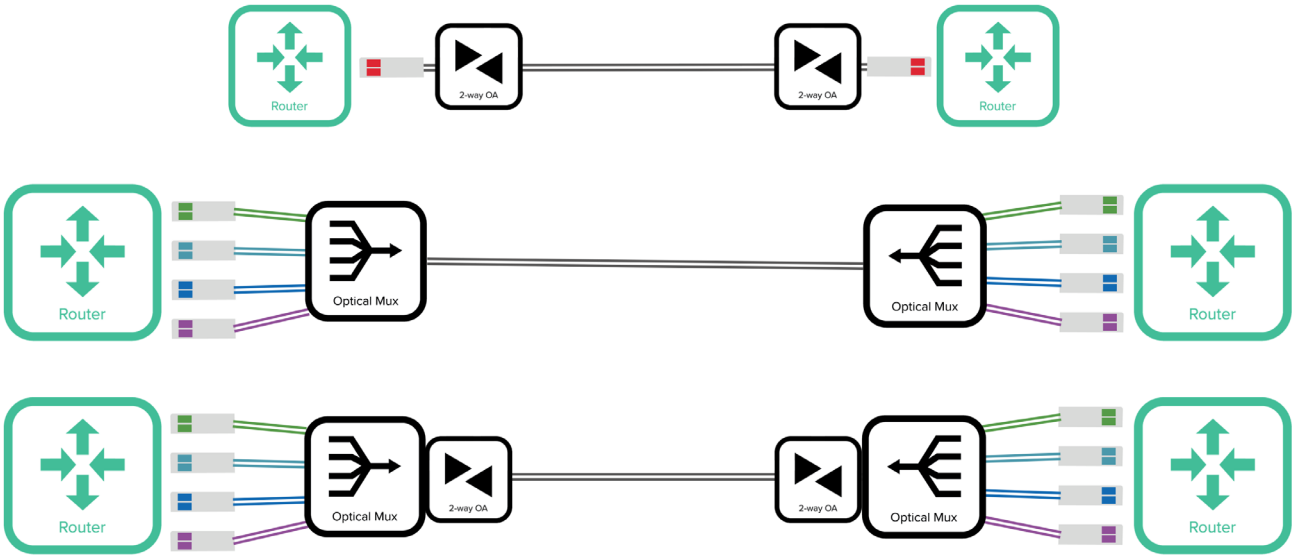


Figure 23. 400G over dark fiber pairs with pluggable optics and passive multiplexers

400ZR transceivers implemented in the QSFP-DD form factor makes it easy to upgrade to 400G by just switching transceivers. But it is even easier with the flexible DWDM-based open networking from Smartoptics. The Smartoptics solution combines the benefits of pluggable 400ZR and PAM4 transceivers with the flexible DCP-M and DCP-R open line systems. This enables highly automated, low-cost 100G PAM4 and 100G coherent networking while at the same time supporting 400ZR, so that existing 100G channels will not be impacted at all while adding 400G channels alongside them. This way, you do not have to replace your existing optical infrastructure.

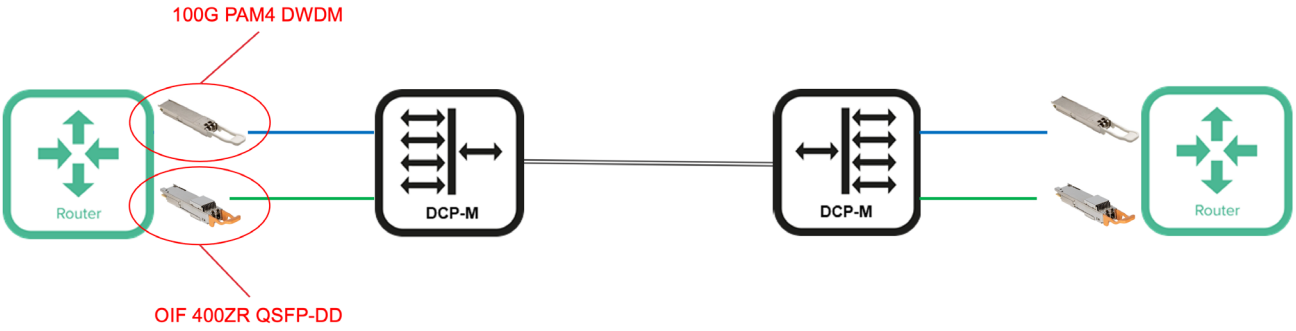


Figure 24. The DCP-M40-PAM4 flexible open line systems allow mixed use of 100G PAM4 DWDM and coherent 400G DWDM transceivers.

DCP-M for Point-to-point Links

Since the 400ZR standard has less stringent optical signal requirements than 100G PAM4 DWDM, it is always possible to run a 400ZR based coherent 400G DWDM link over the same DCP-M40 flexible open line system that you have already been using for 100G PAM4 DWDM. And even better, the two modulation formats can co-exist on the same flexible open DCP-M line system without interference or distance penalties.

This means that all existing DCP-M-40-PAM4 line systems from Smartoptics are ready for coherent 400G DWDM links based on the 400ZR standard without any further action. The same simple and automated set up of links between sites that you are used to for 100G PAM4 also applies to 400G.

To further leverage the optical characteristics of 400ZR Smartoptics has also introduced the DCP-M40-C-ZR+/DCPM40-CSO-ZR+ and the DCP-M32-CSO-ZR+ open line systems[4] optimized specifically for coherent 400G and 800G DWDM.

Figure 25. The DCP-M40-C-ZR+ flexible open line system optimized for 400ZR

The DCPM40-C-ZR+ 40 channel, 16 Tbit, open line systems have been designed for situations where you explicitly want to leverage the longer reach possible with coherent 100G, 200G, and 400G DWDM compared to 100G PAM4 DWDM. In addition to the coherent modulation, the DCP-M40-C-ZR+ also supports NRZ modulated formats, although with less optical reach.

The DCP-M32-CSO-ZR+ is designed with 150GHz channel spacing, making it the perfect choice for supporting data rates up to 800G in modern optical networks. Built to handle the most demanding data requirements, the DCP-M32-CSO-ZR+ offers seamless compatibility with coherent DWDM signals ranging from 100G to 800G, including QPSK, 8QAM, and 16QAM formats. With its versatile architecture, this platform provides up to 160 km of reach, depending on the modulation format, ensuring reliable long-distance connectivity.

[4] The ”O” in the product name indicates that the line system has an Optical Time Domain Reflectometer (OTDR) filter.

Engineered for simplicity and efficiency, both the DCP-M40-C-ZR+/ DCPM40-CSO-ZR+ and the DCP-M32-CSO-ZR+ feature automated configuration and zero-touch provisioning, delivering the ease of use of a passive multiplexer while integrating the advanced functionality of a modern DWDM system. Its pluggable OSC port and OTDR filter for network diagnostics further enhance its adaptability and performance in various scenarios. Both line systems are built with a compact 1U form factor unit, simplifying rack mounting.

The following table gives an overview of the entire DCP-M family and the supported formats for each of the open line systems.

DCP-M Model	Supported formats and data rates			
	100G PAM4	100G Coherent	400G	800G
DCP-M40-PAM4-ER	Yes	Yes	Yes	No
DCP-M40-PAM4-ER+	Yes	Yes	Yes	No
DCP-M40-PAM4-ZR	Yes	Yes	Yes	No
DCP-M40-C-ZR+	No	Yes	Yes	No
DCP-M40-CSO-ZR+	No	Yes	Yes	No
DCP-M32-CSO-ZR+	No	Yes	Yes	Yes

Figure 26. The DCP-M family of flexible open line systems

DCP-R as ROADM for Ring and Mesh Networks

ROADMs (Reconfigurable Optical Add/Drop Multiplexers) are used in bus, ring and mesh shaped optical networks to enable flexible add/drop of individual wavelengths and for adding new wavelengths without affecting the traffic on adjacent channels.

ROADM-based metro/regional and metro access networks can easily be built by the Smartoptics DCP-F family of versatile active optical units, by the dedicated DCP-R family ROADMs or by a combination of products from both families.

The Smartoptics DCP-R family comprises compact 9 degree and 34 degree, 1U per degree ROADMs having Flexgrid support and colorless, directionless, and contentionless capabilities. The ROADMs, with integrated mux/demux for local add/drop, are true multipurpose units, designed for a mixture of modulation formats such as 100G and 200G coherent signals, 400ZR OIF, 800G and NRZ. The DCP-R ROADMs use the same compact chassis as the well-known Smartoptics DCP-M family.

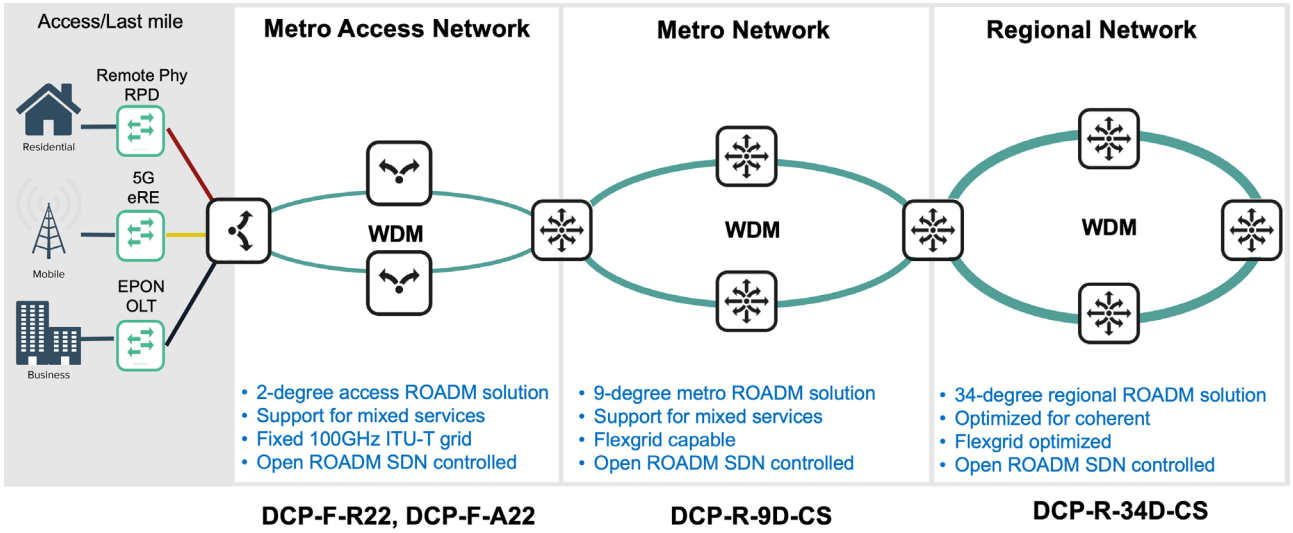


Figure 27. Smartoptics' ROADM portfolio

All members of the DCP-R family support a high level of automation and openness. The ROADMs are typically controlled through the NetConf protocol compliant with the principles outlined by the OpenROADM MSA architecture and with TransportPCE as the SDN controller. The configuration of the ROADMs is further simplified by the integrated automatic fiber distance measurement.

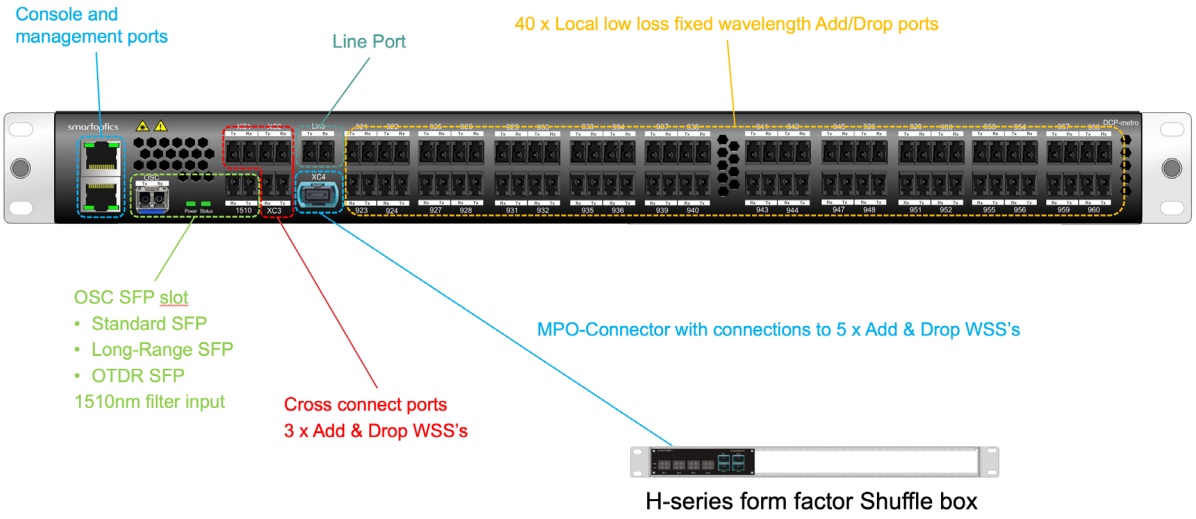


Figure 28. The DCP-R-9D-CS unit

A prominent characteristic of the DCP-R family is the great flexibility with which traffic formats can be mixed within the same ROADM. This unique flexibility of the DCP-R family allows for efficient handling of legacy formats such as NRZ and coherent 100G, while offering an excellent upgrade path when new traffic formats based on new technologies are introduced in the network.

The achievable optical reach and supported number of ROADM hops are traffic format dependent as well as DCP-R model dependent.

The DCP-404 Muxponder

The DCP-404 layer 1 muxponder has been specifically developed for the multiplexing of four 100 GbE client signals over one 400G link.

The muxponder supports any type of QSFP28 form factor transceiver for 100GbE on the client side and requires the OpenZR+ QSFP-DD transceiver on the line side. The OpenZR+ transceiver allows for a 400G line rate, but it also supports 300G, 200G and 100G line rates, if extended operating distances are to be covered.

The DCP-404 muxponder offers an excellent upgrade path for those who want to leverage the lower cost per bit and the higher data rate of 400G without any costly changes of the existing switches and routers. Just connect the switch/router to the muxponder with 100G grey transceivers, and the muxponder then allows for use of 400G on the longer connection. And should multiple 400G connections be needed, the Smartoptics DCP-M and DCP-R open line systems will provide the necessary multiplexing at the optical layer.

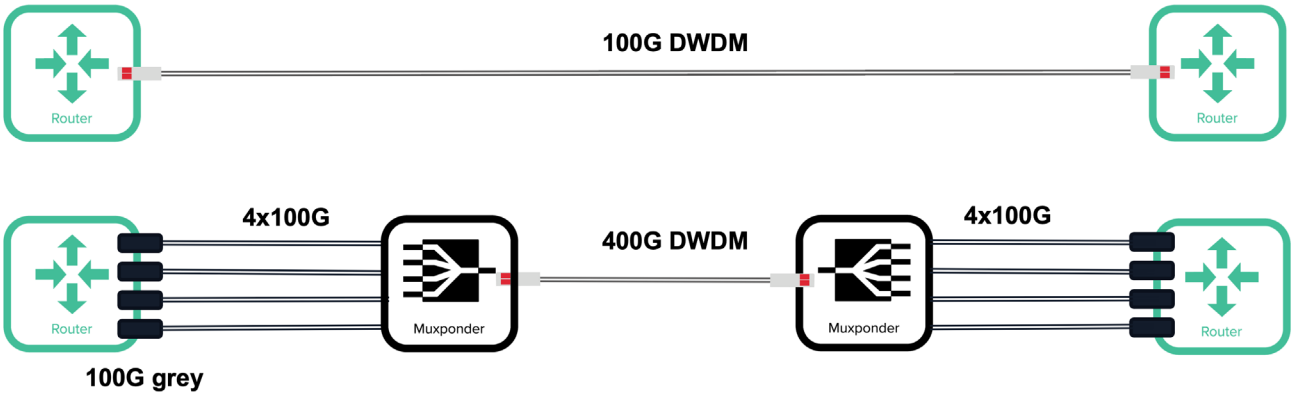


Figure 29. Using muxponders for upgrading from 100G to 400G

The low power and low latency muxponder is accommodated in the Smartoptics DCP-2 chassis, occupying one out of two slots in a 1RU chassis .

Ready for 800G

Leveraging the flexibility of open optical networking, Smartoptics was able to introduce coherent 400G DWDM based on the 400ZR standards earlier than most other players on the market. Once again, the advantage of disaggregated optical networking, where transceivers and line systems can make immediate use of advances in their respective technologies, has enabled Smartoptics to develop solutions having superior performance without excessive costs.

800G coherent line specifications for campus and DCI applications are just now being developed by OIF, using the same modulation format as 400G, but with higher baud rates. The new higher baud rates (~120GHz) in combination with QPSK modulation can also be used to enable a better optical signal/noise tolerance, a fact that can also be leveraged to create ultra long-haul 400G optical links.

The new baud rates will require an even wider channel passband than 400G connections in the optical line system. This fact has been taken into consideration when designing the DCP-M flexible open line systems, where the DCP-M32-CSO-ZR+ is already “800G-capable”. So, when coherent 800G pluggable transceivers are available, you can stay with your already deployed optical line system when upgrading to 800G. Once again, a clear cost benefit of the disaggregated “IP over DWDM” approach taken by Smartoptics.

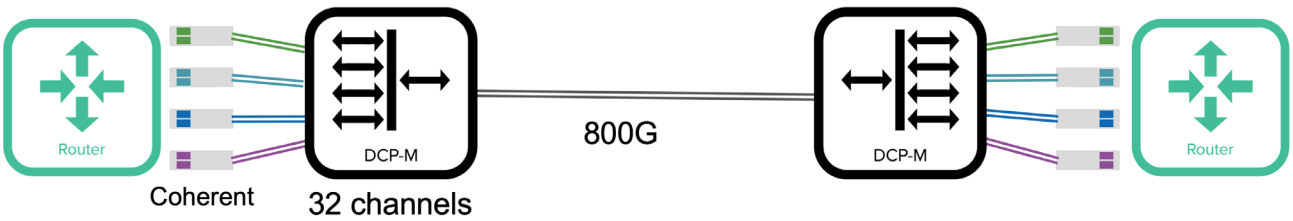


Figure 30. The DCP-M32-CSO-ZR+ flexible open line system is 800G-ready

The DCP-802 Dual 400G/800G Transponder

For those wanting to take immediate advantage of the 800G data rate, Smartoptics offers the dual DCP-802 transponder, a versatile unit comprising two individual 400G/800G transponders which also can operate in breakout mode on the client side.

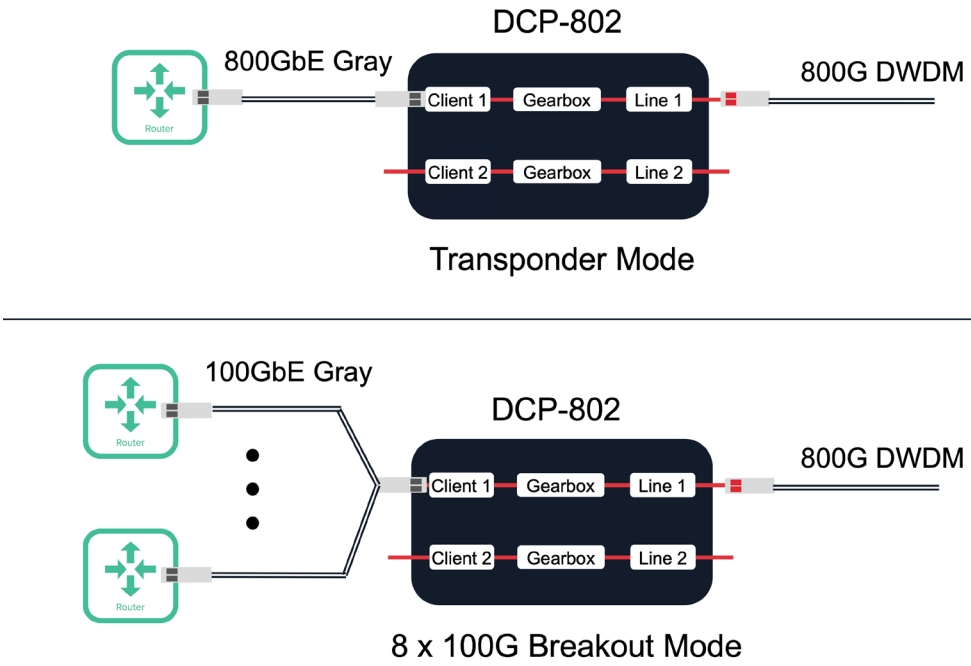


Figure 31. DCP-802 in transponder mode and in 8 x 100G breakout mode

The DCP-802 transponder is used to convert a 400GbE or 800GbE client signal to a 400G (DP-QPSK) or 800G (DP-16QAM) DWDM channel, or alternatively to multiplex and aggregate 8 client 100GbE signals or 2 client 400GbE signals to 800G DWDM, when operating in breakout mode. This allows for even further aggregation of 100G ports, where 8x100GbE is transmitted over one channel of 800G (150 GHz), extending the life of existing 100G switch/router ports and optimizing the allocation of optical bandwidth in the network. The compact form factor and low latency DCP-802 transponder is prepared for optional Layer 1 encryption to secure data in transit.

Managing Your Network with the SoSmart Software Suite

The disaggregation of the optical network requires a similarly open approach to the management of the network elements in your 100G, 400G, or 800G network. Smartoptics has therefore developed the SoSmart Software Suite, an SDN-based tool for optical network visualization, configuration, and management of Smartoptics' products in an open, multi-layer and multi-vendor optical network environment. The SoSmart Software Suite includes a Manager with an advanced GUI for point-and-click provisioning of services, a separate Planning tool and a Controller for the interaction with the network elements. Thanks to its standardized north-bound interfaces and modular structure, the SoSmart Software Suite can easily be integrated with already deployed orchestrators and other management solutions for your transport network.

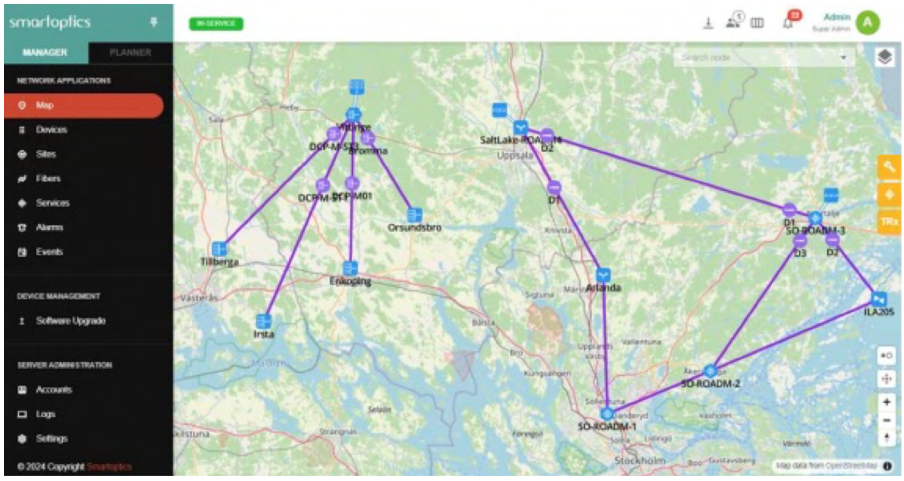


Figure 32. The SoSmart Manager graphical user interface

Summary

More bandwidth is in constant demand for data center interconnect, by communication service providers for their access and metro/regional networks as well as by Internet content providers. An open optical DWDM network with pluggable transceivers and an open line system is the most economical and future-proof way to meet this demand. Thanks to recent advances in transceiver technologies using coherent modulation schemes it is now possible to cover the full range of data rates from 100G to 800G with pluggable DWDM transceivers in convenient form factors such as QSFP-DD. To let you leverage this development towards higher data rates, Smartoptics offers a complete set of transceivers, passive and active open line systems, as well as transponders and muxponders adapting your existing equipment to the ultra-high data rates available. Choosing Smartoptics for your DWDM network guarantees you the most cost-effective solution for any future capacity requirements.

About Smartoptics

Smartoptics provides innovative optical networking solutions for a new era of open networking. We focus on solving network challenges and increasing the competitiveness of our customers. Our customer base includes cable and telecom operators, cloud providers, Internet exchanges, governments, and thousands of enterprises.

At Smartoptics, we leverage modern software design principles and expand network horizons by taking an open approach in everything we do. This empowers our customers to break free from unwanted vendor lock-in, remain flexible, and minimize costs.

Our solutions based on open networking standards and protocols are used in metro and regional network applications as well as in metro access networks. The products we deliver are based on in-house developed hardware and software and enhanced by associated services.

Smartoptics is a Scandinavian company founded in 2006. We partner with leading technology and network solution providers and hold numerous certifications and approvals from major switching and storage solution providers such as Brocade, Cisco and Dell. We have a global reach through our salesforce and more than 100 business partners including distributors, OEMs and VARs.

As a challenger, we take pride in our open approach, smart design principles and ambitious customer service.

For additional information about Smartoptics, please visit us at https://www.smartoptics.com/

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