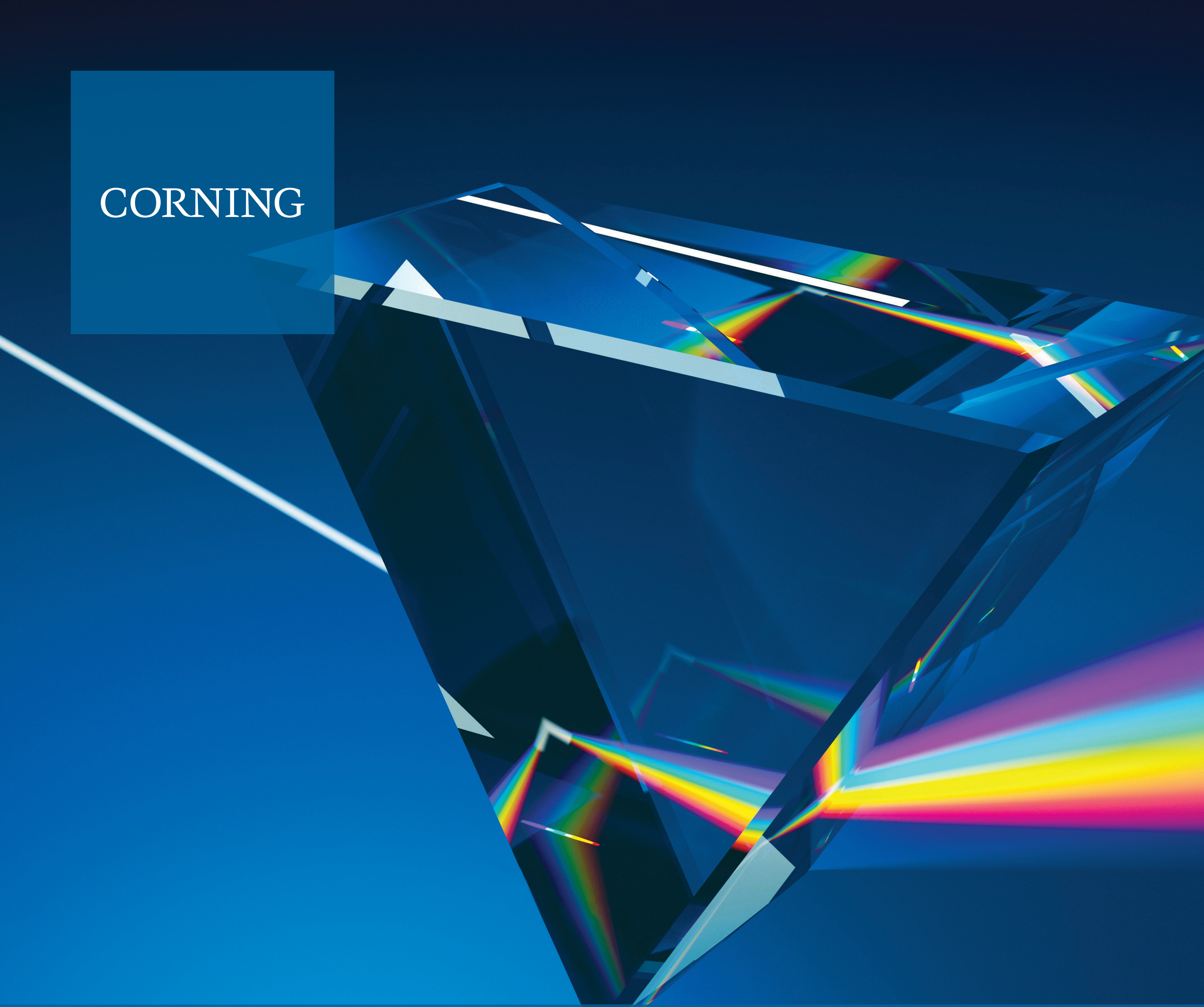
CORNING



Connect to wavelength management

As consumers purchase more and more devices (cell phones, televisions, laptops, etc.) communication networks supporting these devices need to evolve to supply enough bandwidth for the increasing demand. One of the leading technologies allowing network operators to increase network density while leveraging current infrastructure is wavelength-division multiplexers (WDM). The WDM devices are placed within fiber optic hardware solutions which are typically located within the central office, headend, and the outside plant (OSP). As networks continue to evolve, WDM solutions become critical in maximizing the density and functionality required for modern optical distribution networks. You may ask, how do WDM solutions work? Similar to how prisms break out the visible light spectrum, WDM devices combine or break out wavelengths on a single fiber, enabling you to maximize fiber usage. A multiplexer (mux) combines these wavelengths over the fiber. A demultiplexer (demux) takes the combined wavelengths separating these into the individual signals. Therefore, a mux and demux are used to transmit and receive wavelengths between devices to exploit the full range of capabilites of the fiber within the network.

WDM Device

Individual wavelengths, carrying different services and data, are either combined or separated with the use of a WDM, which has a series of thin-film filters inside (Photo 1).

Photo 1: Thin-Film Filter

The filters are tuned to allow specific bands of light (entered through the common port) to pass through (via the add/drop port) or be reflected off (via the reflect port) shown in **Figure A**. Individually tuned devices can be concatenated, creating a system that separates (demux) or combines (mux) multiple wavelengths one at a time, resulting in one signal separated into multiple frequencies, or multiple signals combined and carried over a single fiber **(Figure B)**.

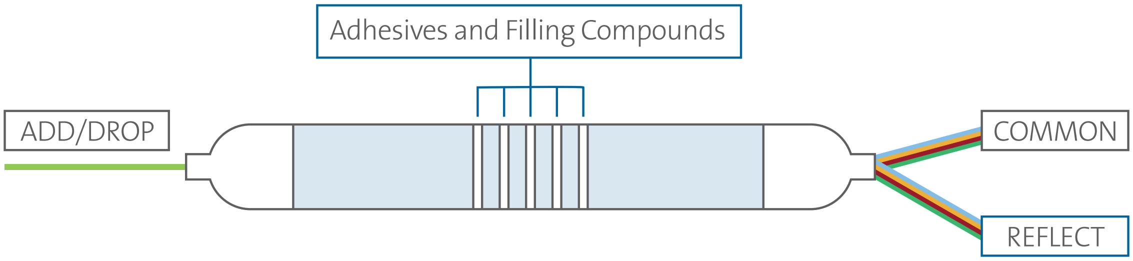


Figure A

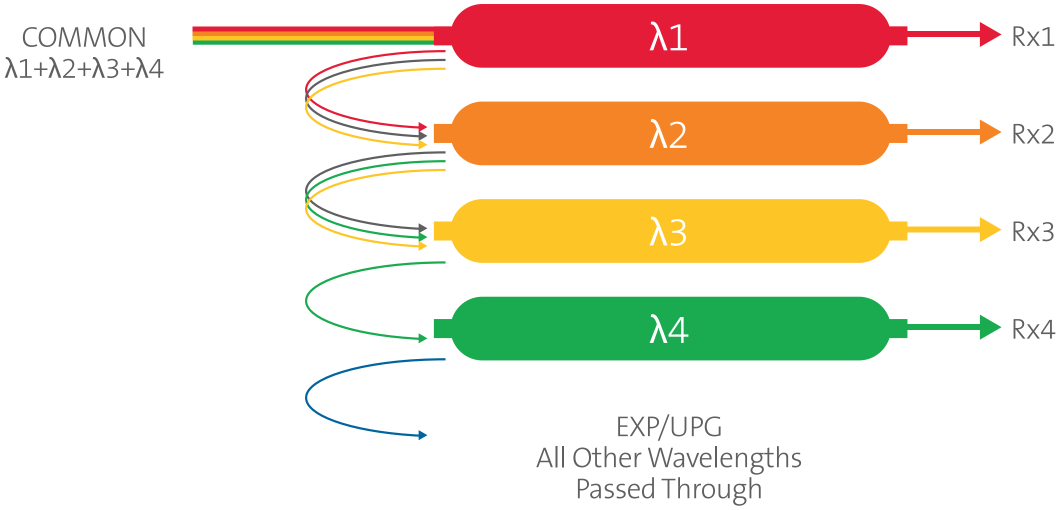


Figure B

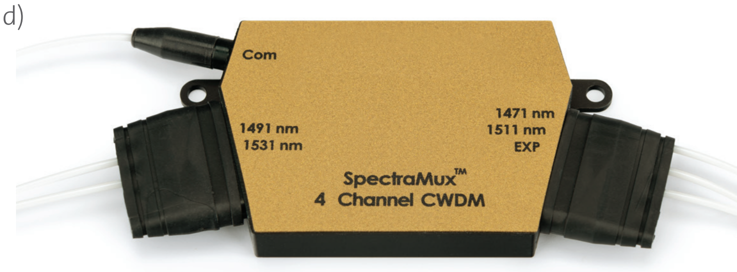
The WDM filters are placed into a device (CWDM and DWDM devices shown on next page). Dependent on the WDM type, the devices are then packaged in cassettes, modules, splice trays, etc. These different packages enable either splice or connectorized solutions.

Types of Wavelength-Division Multiplexers (WDMs)

In order to accommodate differing needs for carrier networks, multiple types of WDMs have been developed, most prominently the coarse WDM (CWDM) and dense WDM (DWDM). As mentioned in the prior section, the filters are tuned to bands in order to distribute services to the proper locations. Each type of WDM device operates within a specific band. CWDMs are wider channel devices that are useful in short distance applications with fewer channel obligations. DWDMs have narrower channel widths, allowing for more capacity with higher electronics costs.

Coarse Wavelength Division Multiplexing (CWDM)

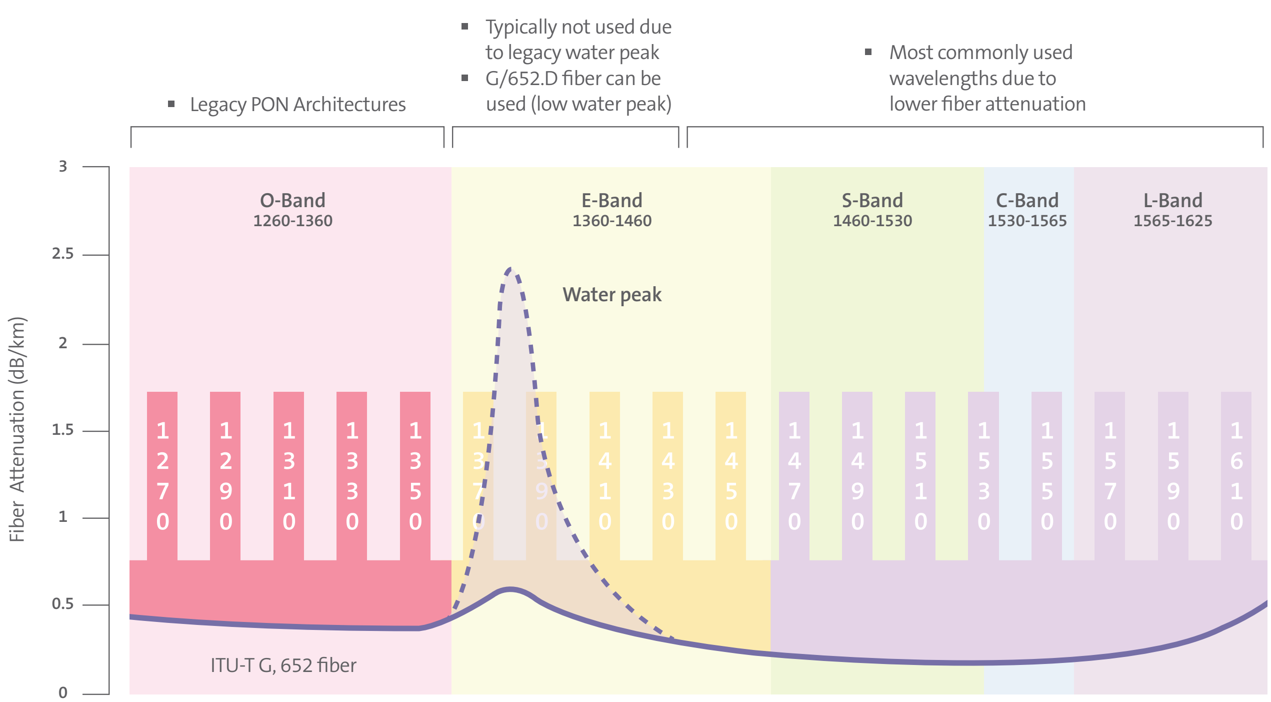
- CWDM devices function in any band (O-, E-, S-, C-, or L-band) between 1271 nm-1611 nm, with the S-, C-, and L-bands most commonly used
- Channel spacing (defined by wavelength):
  - 20 nm spacing = 18 channels



CWDM Facts

Max Active Wavelengths per Fiber	18
Application	Space-constrained environments
Distance	Shorter distances and/or smaller channel counts
Wavelength Structure	Spread far apart
Light Signal	Not amplified
Active Electronic Cost	$
Transport Capability	Up to 18 channels from 1271 nm to 1611 nm with a 20 nm channel spacing
Spectrum	Larger sections
Lasers	Uncooled lasers due to wider channel spacings

CWDM Bands



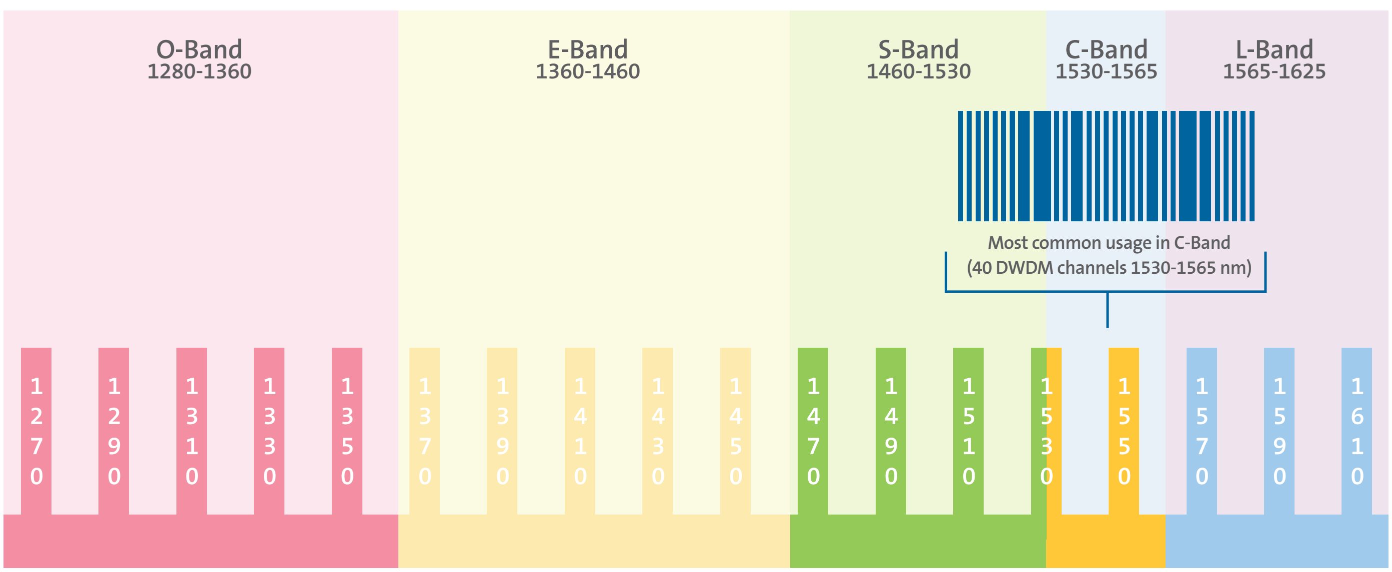
Dense Wavelength-Division Multiplexing (DWDM)

- DWDM devices are set to function in the C- and L-bands between 1531 nm-1611 nm
- Channel spacing (defined by wavelength and frequency):
  - 200 GHz = 1.6 nm spacing = 40 channels
  - 100 GHz = 0.8 nm spacing = 80 channels
  - 50 GHz = 0.4 nm spacing = 160 channels

DWDM Facts

Max Active Wavelengths per Fiber	160
Application	High-density networks ▪ No space constraints
Distance	Long-haul and/or higher channel counts
Wavelength Structure	Tightly packed
Light Signal	Amplification may be used (EDFA; C-band)
Active Electronic Cost	$$$ - laser performance
Transport Capability	Up to 80 channels with 100 GHz spacing and up to 160 channels with 50 GHz spacing in the C-band through L-band spectrum
Spectrum	Smaller sections
Lasers	Cooled lasers due to tighter control of wavelengths

DWDM Bands



Optimizing Fiber

Due to the evolution of communication networks over the last 10 years, a major concern in today's connected world is fiber exhaust, where the demands for fiber exceed the amount of available fiber in the network. WDM technology can alleviate fiber exhaust, by requiring fewer fibers to transmit and receive multiple services. **Figure C** demonstrates multiple signals transmitting over multiple fibers from one device to another. **Figure D** illustrates how multiplexing combines multiple channels at the transceiver device to transmit multiple signals over a single fiber. At the receiving device, a demultiplexer separates the signals. Overall, the use of WDMs allows you to take further advantage of your network, utilizing the untapped capacity of existing fiber, as well as the coexistence of multiple services across the same network.

Figure C

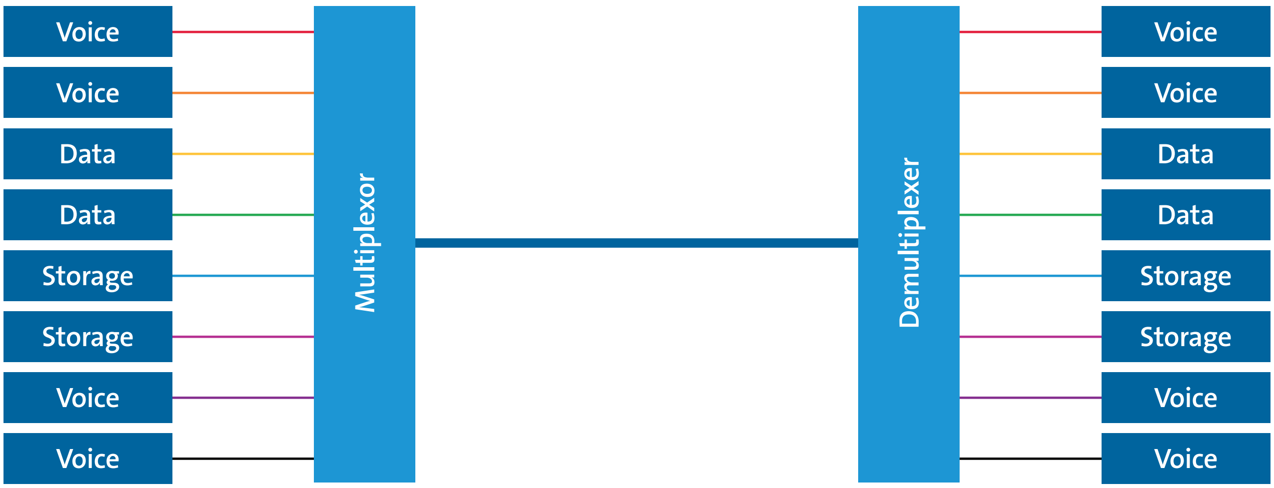


Figure D

WDM in Fiber Optic Hardware

While WDMs work to optimize current fiber usage, when placed into fiber optic hardware, there are many configurations and functionalities that these devices can take on that determine the fiber requirements later in the network. Most commonly are dual or single functionality, where services and signals are sent over two fibers or one fiber respectively. A dual-function device has mux and demux capabilities over two fiber transmission **(Figure D)**. A single function device has mux or demux capabilities over single-fiber transmission **(Figure C)**.

Dual Functionality

Seen in **Figure E**, dual functionality utilizes two fibers to transfer data to and from the end user. One fiber, at the top of **Figure E**, is used for downstream transfer while another fiber is devoted to upstream data. With this method, specific to this example, the same wavelength can be used for both directions of data traffic. From a hardware standpoint, **Figure F** shows that two common ports at different ends of the network are used for each direction of data traffic.

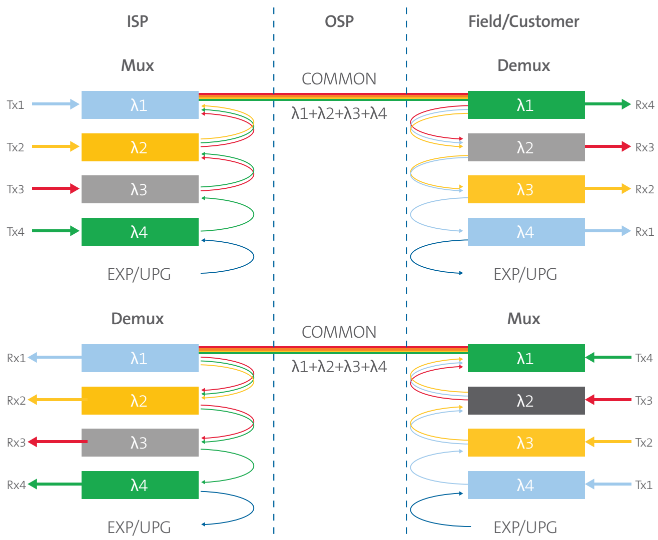


Figure E

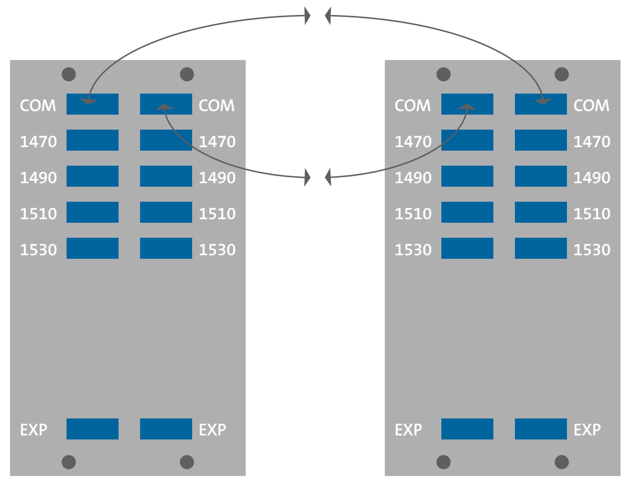


Figure F

Single Functionality

Seen in **Figure G**, single functionality transmits and receives all data in both directions on a single fiber. Due to the single-fiber use, now the downstream and upstream wavelengths must be different, to avoid interference during simultaneous transmission. **Figure H** illustrates an example of where the common ports are located on fiber optic hardware for single functionality. Instead of two common ports on each hardware device shown in **Figure F**, this figure only has one common port per hardware since it is leveraging one fiber instead of two.

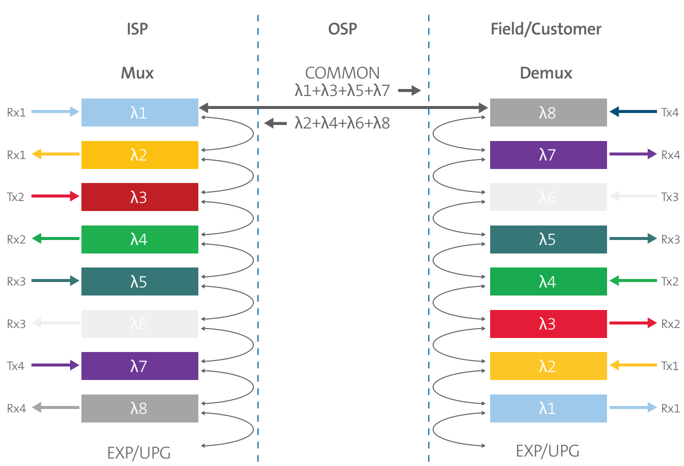


Figure G

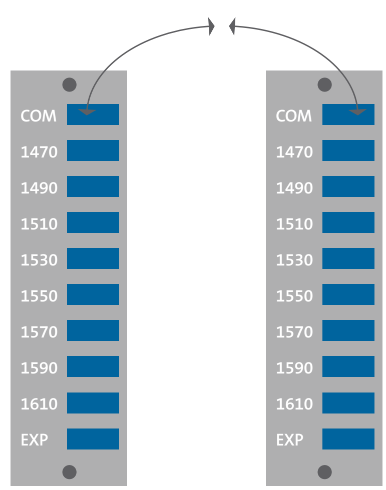
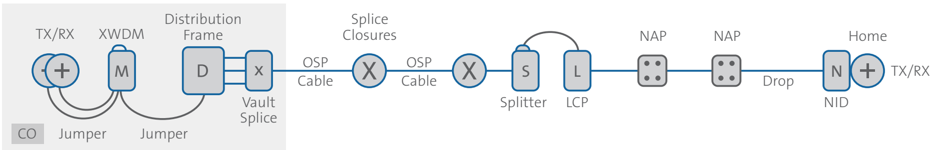


Figure H

WDM Applications

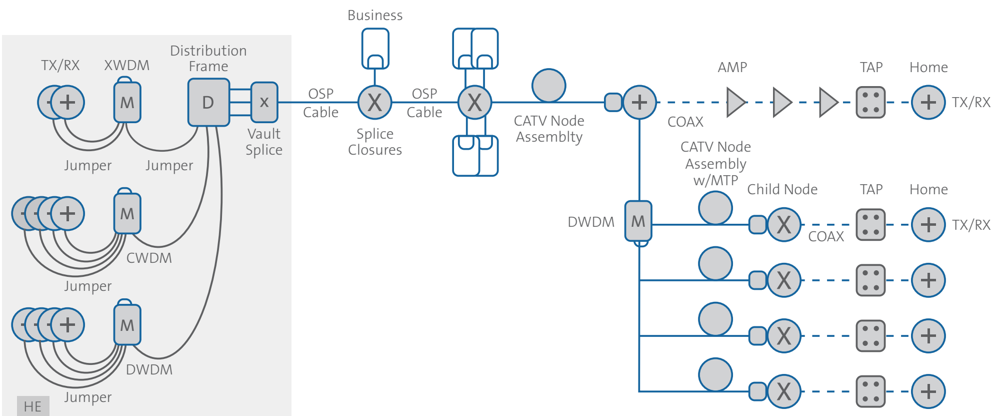
Service providers can leverage WDM technology in any part of their network including long-haul, metro, distribution, and access networks. As fiber demands in fiber to the home (FTTH), Cable TV (CATV), and long-haul networks increase with the rise of more connected technology, WDMs can fully utilize existing fiber by reducing the number of fibers required to transmit and receive signals. Because much of a network's fiber constraints begin at the start of the network, WDM devices are frequently placed at the central office/headend, as demonstrated in the diagrams below.

FTTH Network



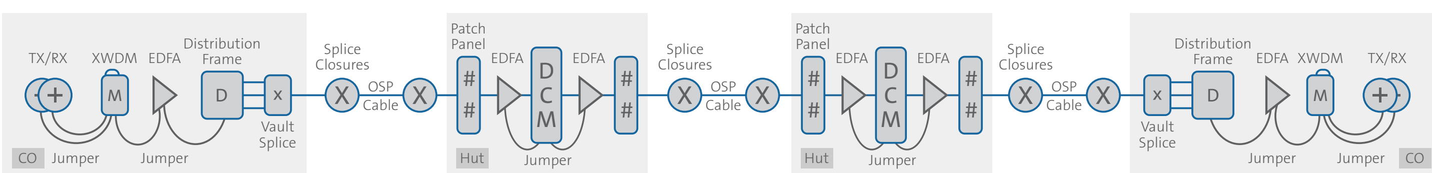
FTTH networks have relied on splitters and WDM devices for years. When evolving from a splitter-based PON to a next-generation PON technologies, more micro-optic devices are required for long-term future proofing of the network. These devices allow operators to reuse existing infrastructure while enabling more services to more customers.

CATV Hybrid Fiber COAX (HFC) Network



Transformation is occurring within HFC networks due to movement away from traditional RF cabling. CATV networks are currently capacity-constrained which poses concern for network designers and installers. As the headend and the OSP transition to new network architectures, designers and installers can replace traditional coax with high-density fiber optic cabling, cross-connects, and DWDM devices.

Long Haul



Legacy long-haul architectures have consistently leveraged WDM technology throughout their optical infrastructure. These technologies have provided cost savings and allow operators to service metropolitan, long-haul, and submarine networks.

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