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Glossary of Terms Used in WDM Technology

Wavelength Division Multiplexing (WDM)
A technology that multiplexes (combines) onto a single fiber optical transmission from two or more sources each operating at different optical wavelengths. Transmission from combined sources is separated at a remote location according to the individual wavelengths by de-multiplexing onto multiple fibers. WDM is often used to refer to filtering products that perform multiplexing or de-multiplexing.

Mux
A WDM filtering product that performs a process of multiplexing or combining two or more optical sources having different wavelengths onto a single fiber.

Demux
A filtering product that performs the process of de-multiplexing or separating optical transmission comprised of multiplexed wavelengths onto individual fibers assigned to each wavelength.

Note: Most filters used in WDM filtering products are bi-directional in their filtering operation. Therefore, a MUX product can in fact function as a DEMUX, and vice versa. However, CommScope designs WDM products, which employ concatenated, discrete thin film filters, to help balance the link losses across all channel wavelengths by inverting the filter concatenation order between the MUX and DEMUX products.

Coarse Wavelength Division Multiplexing (CWDM)
CWDM is a specific WDM technology defined by the International Telecommunication Union in ITU-T Recommendation G.694.2 Spectral grids for WDM applications: CWDM wavelength grid. The grid is specified as 18 central wavelengths starting at 1271 nm and spaced 20 nm apart.

Note: The current ITU designation of the CWDM grid specifies wavelengths ending in a "1", i.e. 1271, 1291, 1311…etc.

Dense Wavelength Division Multiplexing (DWDM)
DWDM is a specific WDM technology defined by the International Telecommunication Union in ITU-T Recommendation G.694.1 Spectral grids for WDM applications: DWDM frequency grid. The grid is specified as frequency in THz, anchored at 193.1 THz, with a variety of specified channel spacing from 12.5 GHz to 200 GHz, among which 100 GHz is common. In practice, DWDM frequency is usually converted to wavelength. Most DWDM wavelengths in use are found in the C-band, i.e. 1530 – 1565 nm.

Wavelength
In its electromagnetic wave form, the wavelength of light is the distance spanned by one complete cycle of the electric field magnitude. The wavelength λm of monochromatic light travelling in a dielectric medium (e.g., optical fiber) is expressed:

$\lambda m = \lambda / n = v / f$
λ = optical wavelength in a vacuum,
n = the refractive index of the dielectric medium,
v = phase velocity, given by c / n
c = the speed of light in a vacuum: 2.99792458×10^8 m/s,
f = the optical frequency.

In WDM practice, wavelengths such as the wavelength of a communications laser, the wavelength specifications for optical filters, and the wavelengths of optical transmission channels over fiber are all given as λ, the wavelength in nanometers as would occur in a vacuum.

Channel
In WDM systems, a channel is a single, unique transmission at a designated wavelength that may occur along with other channels having different wavelengths. A transmission channel can also refer to the end-to-end physical path.

Circuit
Sometimes used to identify a group of WDM wavelengths that are combined and associated with a single fiber path or span. For example, a "dual" or "double" MUX or DEMUX product will have two circuits comprised of two groups of WDM wavelengths, each circuit having its own separate common port and fiber. Ports appearing on such WDM products will be labeled in a manner to identify the circuit associated with that port.

Common Port
The connection point of a WDM product where combined channels appear. For a MUX product, combined channels are transmitted from the common port. For a DEMUX, the combined channels are received at the common port.

CWDM Express or Upgrade Port

For CWDM products, there will normally be either an upgrade or an express port, but not both. The upgrade or express port on a CWDM MUX or DEMUX is used to add, drop, or pass through additional channels. For instance, on a CWDM MUX product, this port will provide a way to add transmit channels to the fiber circuit. On a CWDM DEMUX product, the express or upgrade can be used to pass downstream channels that are not locally DEMUXED. Or, it can also be used to add return channel(s) on a bi-directional circuit span.

DWDM Express and Upgrade Port

For DWDM products, the purpose of an upgrade port is to be able to add, drop, or pass through C-band DWDM channels not already in use, i.e., only channels that reside in the band 1530-1565 nm.

If the DWDM product also has an express port, then that port is normally used for additional channels residing outside the C-band, such as most of the CWDM channels.

1310 Port

Early fiber optic communication systems operated in the original O-band (1260 – 1360 nm) just above the cutoff wavelength of single-mode optical fiber. The availability of inexpensive, O-band Fabry-Perot diode lasers has sustained current use of this band as an operating channel, especially in FTTH and HFC applications. Filters that separate the O-band from longer wavelengths are often referred to as WWDM (Wide-WDM) filters and when used in MUX or DEMUX products provide a port for the 1310 channel. The wide, 1310 channel (1310 +/- 50 nm) should not be confused with the narrower 1311 nm CWDM channel (+/- 6.5 nm), nor can they co-exist.

Test Port

WDM products may provide test ports. The test port monitors a low-power sample of the optical signal occurring at the common port, usually at a 5% or less power level. The test port can also be used to inject an out-of-band test signal. If the product has two test ports for the same circuit, the ports will be directional. One port will monitor the transmit signal and the other the receive signal. If the circuit has a single test port, then it is almost always bi-directional and will monitor both transmit and receive optical signals.

Single Fiber

When referring to a fiber optic communication system, a single fiber system places all optical transmissions onto a single optical fiber span. Individual channels residing on the single fiber system may propagate in either direction. See also the definition of a Circuit.

Dual Fiber

A fiber optic communications system comprised of two, single fibers. The second fiber may serve as a backup fiber as in a redundant system, or it may provide an optical path in the opposite direction.

Ring Topology

A type of network topology consisting of a closed loop. Fiber ring networks are comprised of a series of fiber spans that terminate at network nodes spread throughout the loop. Each node in the ring will connect to two, and only two, adjacent nodes. Ring networks are often dual fiber systems. Contrast ring topology with an unclosed, end-to-end or point-to-point fiber span.

Add/Drop

The add/drop terminology may refer to a single wavelength filter, or to a multi-channel WDM product. In the case of the filter, it is just another way to describe the bi-directional nature of the filter, in which a particular channel wavelength may be either added, as in multiplexed, or dropped as in de-multiplexed.

There also is a particular WDM product configuration that provides the ability to drop off (or de-multiplex) any number of channels at a location and, with the same product, add back those or other channels at that location along a fiber span. Hence, the add/drop product will have for the same circuit two common ports for incoming and outgoing transmission, sometimes referred to as the East and West ports. If the add/drop product is configured for a redundant, dual fiber system, then it is called a redundant add/drop WDM. Usually, add/drop WDMs add and drop the same channels. When referring to the number of channels associated with that product, only the unique channels are counted. Therefore, if an add/drop WDM can drop off, say, 8 channels and then add back the same channels, it will have 16 channel ports but is referred to as an 8 channel add/drop product. This is also the case for a redundant add/drop product, i.e., a redundant 8 channel will have 32 channel ports.

Pass Band

WDM filters are characterized by many parameters. Pass band is a specification that gives the range of wavelengths about the nominal, central wavelength of the filter that adhere to the specified insertion loss. In practice, it is the tolerance of the filter for laser drift away from the center wavelength. For example, a typical pass band for CWDM filters is ± 6.5 nm about the center wavelength. So a 1551 nm laser could operate within a range of 1544.5 nm to 1557.5 nm without encountering extra channel loss.

Insertion Loss

The wavelength-dependent optical power loss introduced by inserting a WDM filter, expressed in dB. It is normally specified as the maximum insertion loss occurring across the filter pass band. The insertion loss of a WDM product is given as the maximum insertion loss occurring at the channel port with the highest loss. In WDM networks, insertion loss is one of several contributors to the total loss of the communication link. Thin film filters exhibit fairly wide manufacturing variance in their insertion loss values and are screened prior to use in WDM products.

Polarization Dependent Loss (PDL)

The loss exhibited by a WDM filter is dependent on the optical polarization of the light. PDL is the largest difference in maximum insertion loss occurring at all states of optical polarization. PDL for a WDM product is specified as the largest allowed PDL for any channel.

Ripple

Ripple is defined as the maximum peak-to-peak variation in dB of insertion loss across a filter pass band. WDM product ripple is specified as the largest allowed ripple occurring in any channel.

Return Loss

When light is incident on a refractive index discontinuity in the medium, reflection occurs. Light entering a WDM filter experiences a discontinuity, however small, and some of the incident light is reflected. By definition, return loss is the ratio of incident optical power to the reflected optical power in dB. Hence, it is always (correctly) positive and can be thought of as the attenuation in reflected light. A large value of return loss is desirable for preventing problems with source lasers and reducing transmitted loss. Return loss for a WDM product is the smallest, measured return loss at all ports.

Isolation

As implied, the isolation parameter for a WDM filter quantifies its ability to prevent light power at wavelengths outside the pass band from passing through the channel pass band port. Expressed in dB, it is the difference of the maximum insertion loss within the filter pass band and the minimum loss occurring within other filtering pass bands. Isolation is measured by applying a swept optical power source to the filter's common port and measuring the loss within the filter's pass band and the pass bands of other filters. When other filters are those with pass bands nearest to the filter's pass band, it is called the Adjacent Channel Isolation. For the remaining ports, it is called the Non-Adjacent Channel Isolation.

Thin-Film Filter

A thin-film filter (TFF) is a 3-port passive optical branching component that distributes optical power into two separate wavelength-dependent paths. The three ports are identified as the Common, Pass, and Reflect ports. Optical power within the operating wavelength range of the TFF can appear at the Common port of the filter. Optical power at wavelengths within the filter pass band will appear at the Pass port, while optical power at wavelengths outside the pass band will appear highly attenuated. Optical power at wavelengths outside the pass band and within the operating wavelength range will appear at the Reflect port. Thin-film filters are available with CWDM, DWDM, and non-standard center wavelengths.

Band Split or Skip Filters

These filters are TFFs that have wide pass bands, which contain multiple channels. For example, a particular BS filter may have as its pass band the entire C-band (1530 – 1565 nm). Sometimes BS filters are called "skip filters" to refer to their special use in large channel count WDM designs to help minimize insertion loss. BS filters are used to build BWDM (Band WDM) products.

Compact WDM

As the name implies, these are multi-channel WDM products that have relatively small footprints. For example, a compact CWDM, or CCWDM product can provide 10 or more channels with a device footprint small enough to fit within a FOSC splice tray splice holder. CCWDM products utilize a free-space multiple bounce technology in which light reflects from each filter element directly onto the next filter element instead of being collimated and launched into a fiber as in individual, discrete TFF components. In other compact WDM products, bend insensitive fiber permits the use of smaller housings for joining (concatenating) individual TFFs into a multi-channel product.

Network Topologies

WDM products bring higher efficiency to fiber networks through multiple channel usage of fiber. Networks are identified by their fiber layout or topology. Network topologies such as Mesh, Ring, Point-to-Point, and Point-to-Multipoint will sometimes use WDM products particularly designed for the network. So, it is important to understand the intended network use when selecting WDM products. Entire networks are often comprised of several kinds of sub-network topologies.

Node

In network topology, a node is a termination of a single branch or multiple branches of the network. (A branch is just a fiber span).

In HFC/CATV terminology, a node, or optical node, is a powered media converter that converts CATV services carried over optical fiber cable from the head end to an RF-modulated signal delivered over coax cable for customer access. The use of WDM on the fiber side allows the node to be segmented or divided into additional serving areas thus expanding the customer base and available bandwidth.

Upstream/Downstream (Forward/Return)

This refers to the direction of a communication signal. The downstream direction is defined as communication originating at a service provider and sent to the service user. Upstream is in the opposite direction. In HFC/CATV terminology, the term forward is used to identify the downstream direction and return identifies the upstream.

Passive Optical Network, or PON

Describes a network in which there are no active (powered) elements. Such networks may utilize passive optical splitters, passive WDM filters, and other passive optical components. In common practice, a PON is a kind of access network directly serving customers.

Water Peak

A peak in optical fiber attenuation in dB/km occurs at a narrow range of wavelengths within the telecommunication spectrum 1260 – 1625 nm. For Corning® SMF-28™, and with other brands of similar single-mode fiber, the peak occurs at 1383 ± 3 nm. Attenuation at and near the water peak can exceed 2 dB/km compared with attenuation values of <0.2 dB/km as can occur in the C-band (1530 – 1565 nm). For this reason, it is common practice to avoid WDM channels with pass bands within or near the water peak. In the case of CWDM, this means avoiding 1371, 1391, and 1411 nm CWDM channels.

Time Division Multiplexing, or TDM

TDM is an alternative to WDM. Instead of multiple channel wavelengths, TDM protocols define multiple time-slots which different channels occupy each at the same wavelength. TDM is used, for example, to manage many upstream transmissions from multiple users in FTTH PON systems transmitting at 1310 nm. Some network systems operate with a combination of TDM and WDM.

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WP-320893.2-EN (11/15) [Revised from 320893]