



smartoptics

# Passive Multiplexers and OADMs

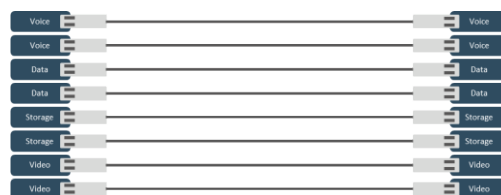
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More flexibility for less cost

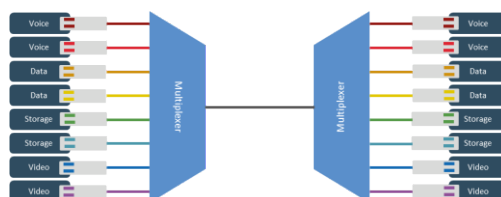
## WDM NETWORKING, BASICS

Wavelength division multiplexing, WDM, has long been the technology of choice for transporting large amounts of data between sites. It increases bandwidth by allowing different data streams to be sent simultaneously over a single optical fiber network. In this way WDM maximizes the utilization of the fiber and helps optimize network investments.

The foundation of WDM lies in the ability to send different data types over fiber networks in the form of light. By allowing different light channels, each with a unique wavelength, to be sent simultaneously over an optical fiber network a single virtual fiber network is created. Instead of using multiple fibers for each and every service, a single fiber can be shared for several services.



In this way WDM increases the bandwidth and maximizes the usefulness of fiber. Fiber rental or purchase represents a significant share of networking costs. So using an existing fiber to transport multiple traffic channels can generate substantial savings.

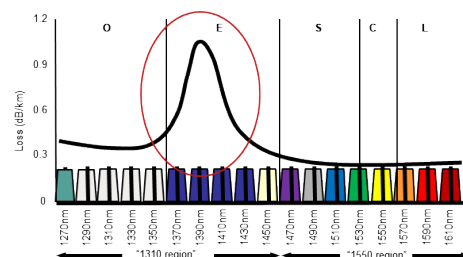


### CWDM and DWDM

WDM comes in two flavors: Coarse WDM (CWDM) and Dense WDM (DWDM).

The CWDM band can be divided into a low channel band (1271nm to 1451nm) and a high channel band (1471nm to 1611nm). The wavelength grid is at 20nm separation as defined in the ITU-T standard G.694.2.

CWDM channels are carried on single-mode fibers where the lower CWDM channel band faces a higher intrinsic attenuation and many older fibers have also a high attenuation area (called “water-peak”) which together will limit the bridgeable distance.

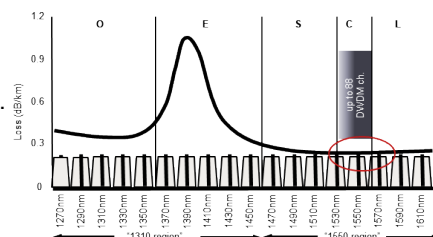


For longer distances or where the link attenuation is high, a CWDM solution could be limited to using the high CWDM channel band where the intrinsic fiber attenuation is lower. It is thus important to measure the actual characteristics (such as attenuation and chromatic dispersion) of the actual fiber link to determine how many CWDM channels that can be deployed and what distance that can be bridged.

There are no cost-effective amplifiers that can span over the wide wavelength band of CWDM and consequently low insertion losses of the CWDM filters are critical to bridge the required distances.

The DWDM band can be divided into many bands, but the most used is the C-band (1530nm – 1565nm) where you have the lowest fiber attenuation and where standard optical EDFA amplifiers can be used to extend the bridgeable distance.

Different channel grids are defined by ITU-T in recommendation G.692.1 and the actual selection is based on a balance of e.g. cost, modulation techniques and bit/ baud rates.

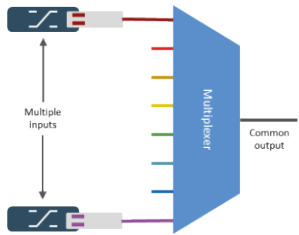


A channel spacing of 100GHz is perhaps the most commonly used in the industry since the cost profile of the involved components (optical transceivers, filters etc.) are lower as compared to e.g. 50GHz components. High capacity links will however require denser channel grids or extend into the adjacent L-band (1565nm – 1625nm) to provide additional channels.

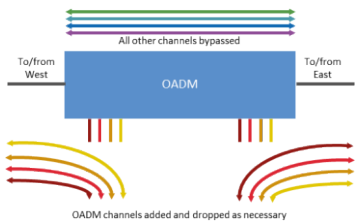
Optical filters

Optical filters are the components used to multiplex and demultiplex the optical channels. There are two main types of optical filters, Mux/Demux and Optical Add/Drop Multiplexer (OADM). The filters are typically passive devices and can be placed in locations without electrical power. They are also vendor solution independent since no SW integration is required. All together this provides an increased reliability as compared to active components.

A Mux/Demux unit terminates all the wavelengths on the WDM system and is typically used as end nodes in a point to point or bus network or as head-end nodes in a ring network.

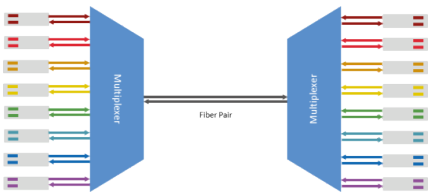


An OADM unit terminates a subset of wavelengths in a WDM network. OADM's typically add/drop 1, 2, or 4 wavelengths and the remaining wavelengths are expressed through the filter. OADM filters are ideal for creating bus or ring networks or where only a few channels are required at specific sites.

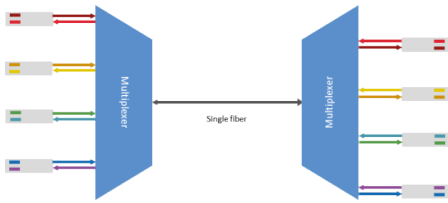


Fiber pair vs single fiber operation

Fiber-optical communication commonly uses fiber pairs for bi-directional communication. In WDM applications single-fiber solutions are also possible and Smartoptics have developed a full range of CWDM and DWDM single fiber Mux/Demux'es and OADM's to accommodate these requirements. In single fiber applications, different wavelengths are used to generate bi-directional connections.



Fiber-pair operation  
Bi-directional configuration using same wavelength on two separate fiber strands.  
1 fiber dedicated for transmit direction  
1 fiber dedicated for receive direction



Single-fiber operation  
Bi-directional configuration using two different wavelengths on a single fiber.  
1 wavelength dedicated for transmit direction  
1 wavelength dedicated for receive direction

Knowing the system losses

Optical path loss calculation example:

The light is attenuated as it travels through the fiber, through fiber splices, through patch panels and as it passed through the optical Mux/Demuxes and OADM filters.

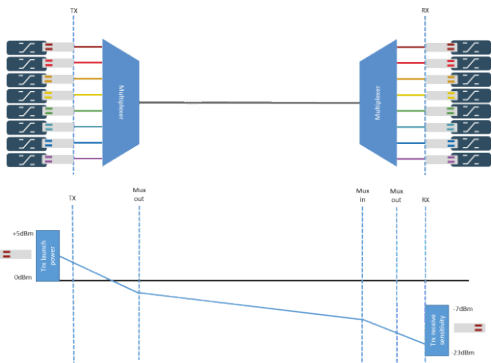
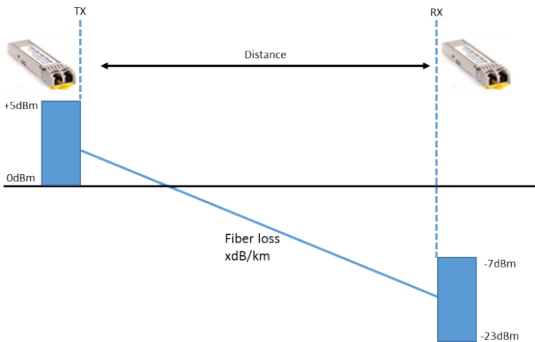
The total optical path loss must include all the above contributors.

The used transceiver has the following optical characteristics:

Transceiver launch power: 0 to +5dBm  
Receiver sensitivity: -7 to -23dBm

The power budget for the transceiver is 12 – 23dB, i.e. an optical path loss of minimum 12dB to avoid the receiver to be overloaded/damaged. The max loss is 23dB to keep the input power above the receiver sensitivity.

An extra system margin of ~2dB should also normally be added to compensate for fiber ageing and extra losses due to fiber splicing etc.



## WIDE RANGE OF PASSIVE FILTERS

Smartoptics offers a wide range of passive filters for CWDM and DWDM applications via the H-Series platform.

The H-Series filters are mounted in a 1 RU mounting bracket solution where the filter module sizes vary depending on type of filter, i.e. the number of optical ports that are required. The filters are thus not wider than necessary. The size of the plug-in filter units runs from 35 to 113mm in width and any combination of the filter modules can be mounted in the 422mm wide slot of the mounting bracket. The 40ch filters are monoliths and have a full 19" rack width.

An adjustable front cover can be placed over the unused slot opening to avoid affecting the airflow within a rack.



*H-Series mounting brackets with different filter modules.*



*H-Series 40ch monolith.*

The H-Series filters can be divided in the following main groups:

- CWDM optical Mux/Demuxes and AD-filters.
- DWDM optical Mux/Demuxes and OADM-filters.
- LANWDM optical Mux/Demuxes.
- Special application filters.

Some CWDM and DWDM filters are provided in a "Low-Loss" option to address cases where the insertion loss is crucial. This can as an example be where multiple filters are cascaded or when the fiber distance is stretched.

See separate documentation for technical data on H-Series filters.

CWDM filters

The H-Series consist of six CWDM Mux/Demux units; three filters covering the low CWDM band (1271 – 1451nm) and three covering the high CWDM band (1471 – 1611nm). There are also a couple of 1ch Add/drop filters for OSC/OTDR applications.

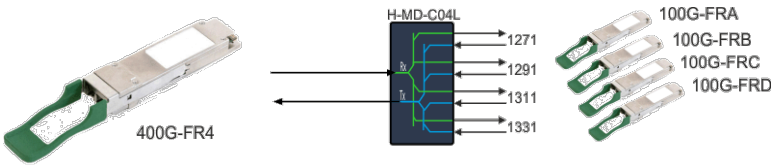
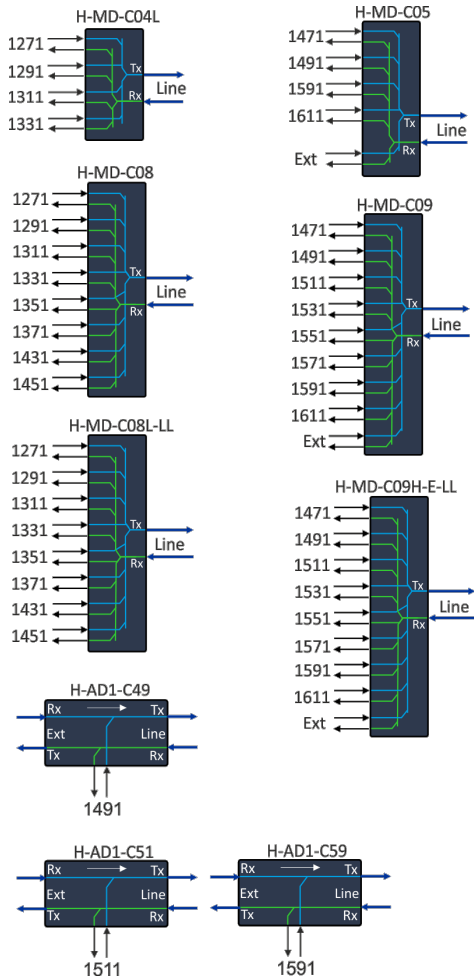
Filters having “LL” in the part number are filters using a more advanced filter design to provide a lower loss. As an example, H-MD-C08L-LL is a low loss version of H-MD-C08.

The H-MD-C08 and H-MD-C08L-LL skip two wavelengths to avoid the higher attenuation in the “water-peak” region that is present in legacy SM fiber types.

The H-MD-C09 and H-MD-C09H-E-LL filters have both an extension port to which the low-band filters can be connected. Alternatively, a 1300nm legacy system can be connected to provide a better utilization of a legacy connection.

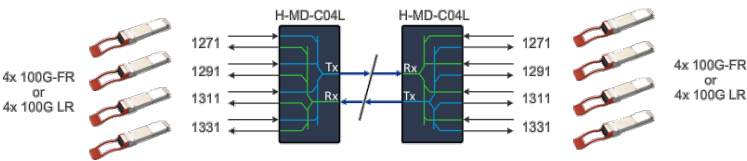
The extension port of the H-MD-C05 filter supports two bands; 1271-1451nm and 1511-1571nm. The lower 1271-1451nm band can be used for a low-band filter or 1300nm legacy. The upper 1511-1571nm band can be used towards e.g. a DWDM filter to provide a combined DWDM and CWDM configuration.

H-MD-C04L is a CWDM Mux/Demux covering the CWDM channels used in e.g. 400G 4-lambda transceivers. H-MD-C04L can thus be used in 400G to 4x 100G breakout configurations as shown in the figure below.



400G to 4x 100G breakout example

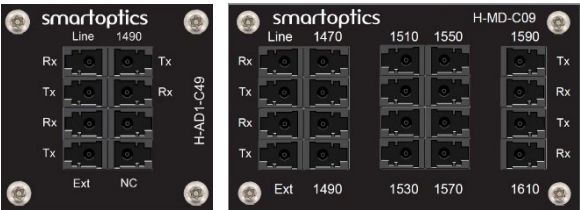
H-MD-C04L can also be used to aggregated 4x 100G channels.



4x 100G transport example

Filters as well as transceivers are available in the Smartoptics portfolio.

The physically smallest filters are the 1ch CWDM AD filters. These filters are only 45mm wide.



The width of the H-Series filters is based on the required number of ports.

Figure 3: Front view of H-AD1-C49 and H-MD-C09 filters

## DWDM filters

The DWDM filters span over the 40 C-band 100GHz channels 921 to 960, corresponding to the ITU-T frequencies 192.1THz to 196.0THz.

The DWDM filter portfolio consists of

- H-MD-09-xxx-yyy: five different 8ch DWDM Mux/DeMux modules.
- H-MD-09-xxx-yyy-EM-LL: a low-loss alternative to H-MD-09-xxx-yyy.
- H-MD-16-xxx-yyy: two different 16ch DWDM Mux/DeMux modules.
- H-MD40-921-960: a 40ch DWDM Mux/Demux rack mounted module. 400G capable.
- M3840-LL: A low-loss alternative to H-MD40-921-960.
- H-OADM1x4-xxx-yyy: 10 different 1-way Add/Drop filters.
- H-OADM2x4-xxx-yyy: 10 different 2-way Add/Drop filters.
- H-MD-BP1x5: 40 to 5x 8ch DWDM BandPass Filter, 921-960.
- H-MD-BP1x10: 40 to 10x 4ch DWDM BandPass Filter, 921-960.
- H-CIRC-3P: A 3-port DWDM circulator.
- H-MD-04-921-928-SFx and H-MD-04-929-936-SFx single-fiber filters.
- H-MD-09-xxx-yyy-4C; 5 different 8ch DWDM Mux/DeMux 400G 16QAM capable.
- H-OADM1x4-xxx-yyy-4C: 10 different 1-way, 4ch OADM 400G 16QAM capable.
- H-OADM2x4-xxx-yyy-4C: 10 different 2-way, 4ch OADM 400G 16QAM capable.
- H-OADM2x2-xxx-yyy-4C: 10 different 2-way, 2ch OADM 400G 16QAM capable.

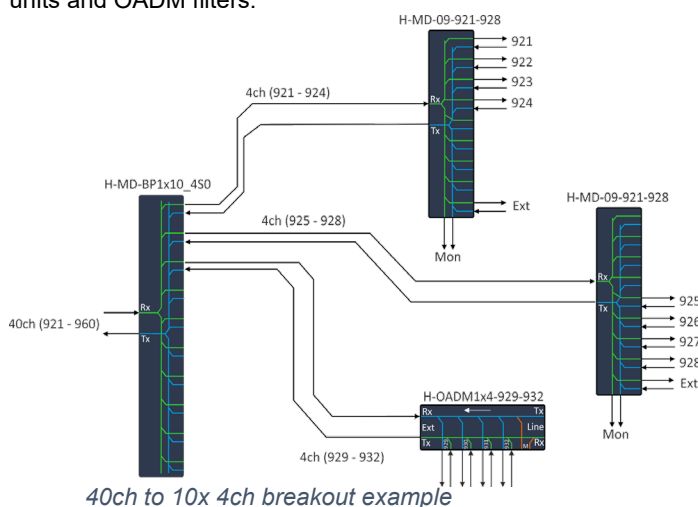
Some of the DWDM filters have a low-loss alternative. These have “LL” in the part number. The filters having a “-4C” suffix have a channel passband wide enough for coherent 400G 16QAM signals.

Most of the DWDM filters have monitor ports. These ports tap off about 1% of the transmitted and received line signal. This provides the ability to monitor the channel power levels via a connected Optical Channel Monitoring (OCM) device or an optical spectrum analyzer.

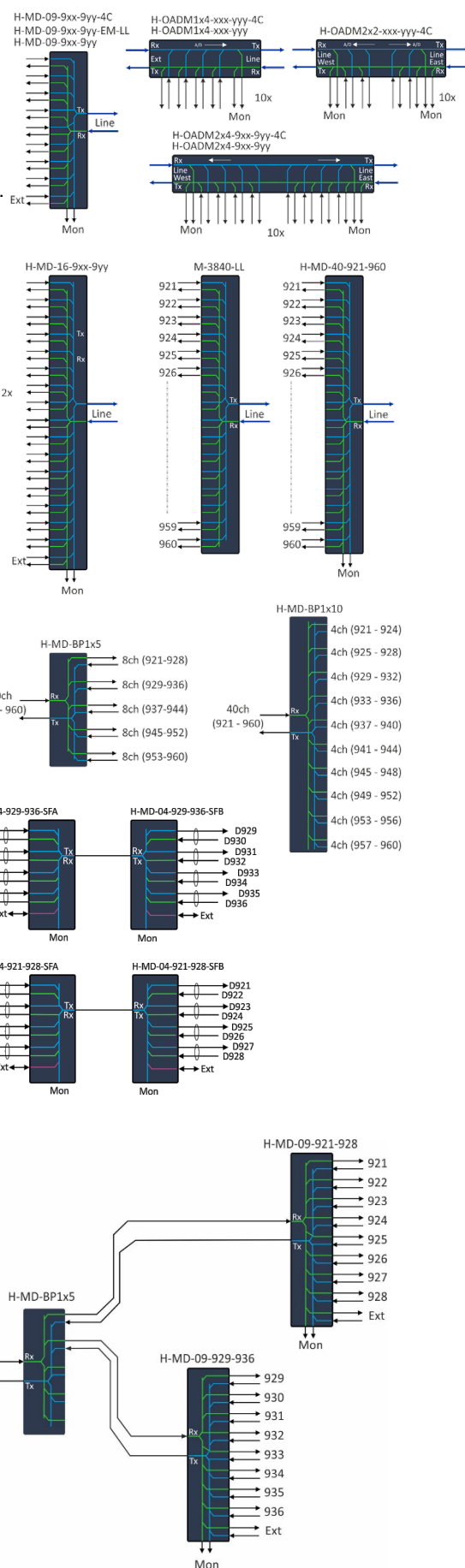
Some Mux/Demux units have an extension port enabling additional Mux/Demux units to be connected to provide an upgrade path to higher capacity. In such cases it could be needed to use the low-loss filters to keep the end-to-end losses low.

Two band splitter/combiners separate (or combines) the 40ch channels into five or ten groups enabling channel fan-outs in access networks.

The figure below shows an example H-MD-BP1x10 configuration where the extracted 4ch bands are terminated using 8ch Mux/Demux units and OADM filters.

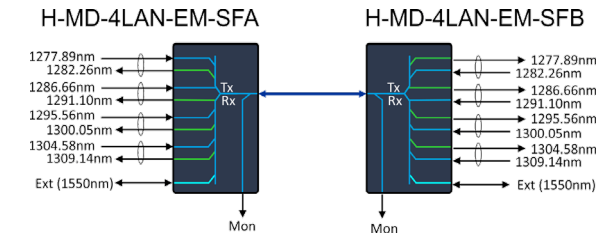


The H-MD-BP1x5 alternative extracts 8ch per band and here the 8ch Mux/Demux units are best used to terminate the channels.



LANWDM filters

The H-MD-4LAN-EM-SFx filters are two LANWDM-filters for single-fiber configurations. The LANWDM channels are located in the 1300nm region where the dispersion properties are the lowest for standard single-mode fiber. As an example, this enables longer distances for 25G Ethernet services in a 5G network.



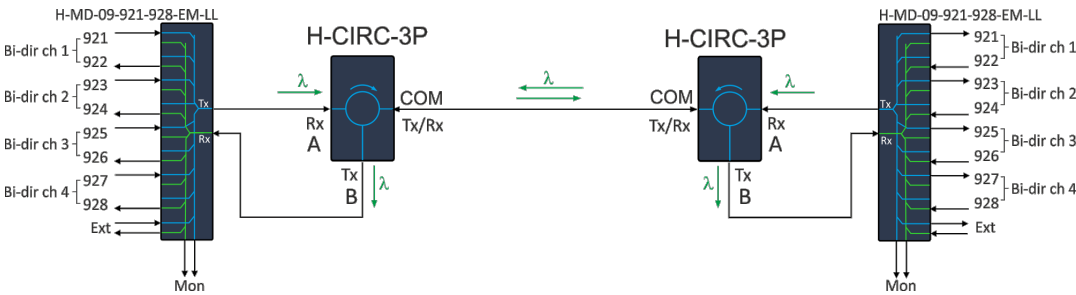
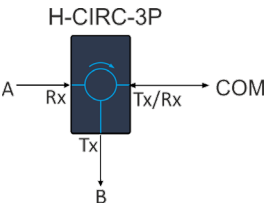
There are eight LANWDM channels defined and the H-MD-4LAN-EM-SFx filters are using one channel in uplink and another in downlink, providing 4 bi-directional channels in total. Consequently, there are two different filters, denoted “A” and “B” where the difference lies in the transmitted and received channels.

The H-MD-4LAN-EM-SFx filters have an Extension port intended for single-fiber DWDM filters. In 5G networks there is typically a need to transport e.g. 10G Ethernet services together with 25G Ethernet services. This Extension port covers the complete C-band which provides a flexible addition of any DWDM channel combination.

The H-MD-4LAN-EM-SFx filters have a Monitor port that tap off 1% of the transmitted and received line signal. This provides the ability to monitor the channel power levels via a connected Optical Channel Monitoring (OCM) device or an optical spectrum analyzer.

Special application filters

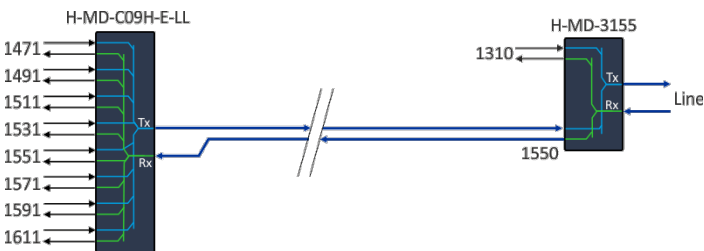
The H-CIRC-3P is an optical circulator that allows light to travel through in only one direction. A wavelength entering port A will only propagate to port COM. A signal entering port COM will only propagate to port B. The typical application is to enable single-fiber operation using filters for fiber-pair configurations. Due to reflections in connectors and splices, one must use different channels in up- and down-link to avoid interference.



Single-fiber configuration example

The H-MD-3155 is a 1310/1550nm band Mux/Demux unit. The H-MD-3155 band filter is intended for cases where a legacy 1310nm channel is to be combined with CWDM channels in the upper CWDM band (1471 nm - 1611 nm) or DWDM channels.

The figure shows an example configuration with the H-MD-C09H-E-LL filter.



## About Smartoptics

Smartoptics offers optical transmission solutions making networks more powerful. Expanding bandwidth without the upfront investment or hassle of traditional WDM. Our products allow corporate data centers, governments, hosting solution providers and ISPs to build simple, straightforward and cost-effective solutions to fulfil their ongoing and future network capacity needs. Headquartered in Oslo, Norway, Smartoptics is an international provider with thousands of installations all around the world. Our award-winning approach has helped companies from every industry sector stay ahead of expanding network demands.

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