Optical Communications
Lecture 10

Engr. Madeha Mushtaq
Department of Computer Science
Iqra National University

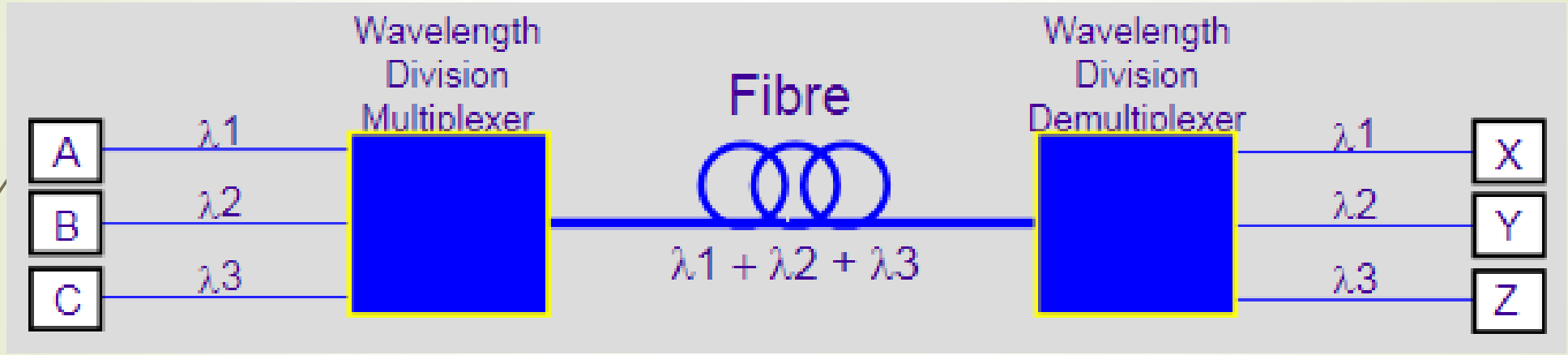
Wavelength Division Multiplexing (WDM)

- Time division multiplexing (TDM) pack many channels into a SONET/SDH network.
- A practical upper limit using developing technology is 40 Gbps.
- An alternative is to assign different frequencies to different channels, multiplex them for carrying information over fibers and finally demultiplex at the receiver end.
- The wavelength division multiplexing (WDM) is the same as frequency division, except that the terminology is used for optical frequencies.

Wavelength Division Multiplexing (WDM)

- WDM is a technology which multiplexes a number of optical carrier signals onto a single optical fiber by using different wavelengths of light.
- This technique enables bidirectional communications over one strand of fiber.

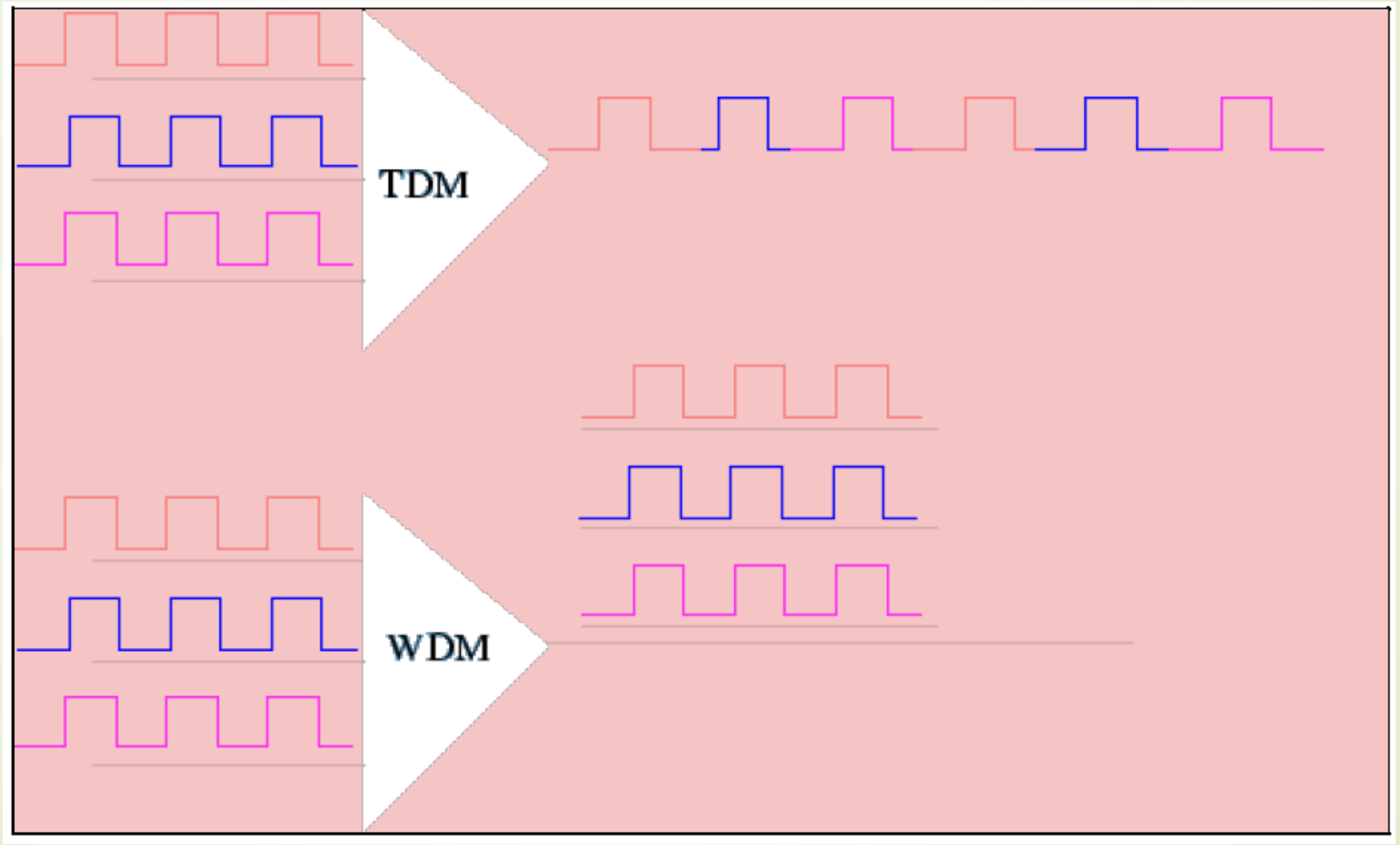
Wavelength Division Multiplexing (WDM)



Features of WDM

- **Bandwidth:**
- The fact that one can use different wavelengths over the same channel increases bandwidth capacity enormously.
- Most WDM systems work in the C-band around 1550 nm.
- Since WDM carries each signal independently of other signal, each channel has a dedicated bandwidth.
- Signals arrive at the destination at the same time and not in different time slots as is the case with TDM.

Features of WDM



Features of WDM

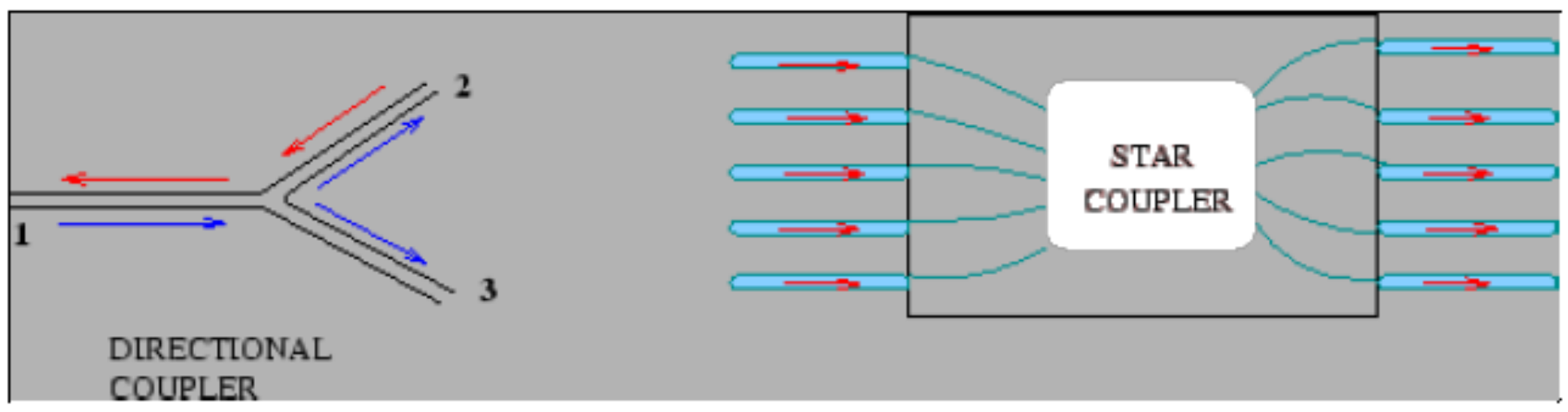
- **Independent of bit-rates and formats:**
- WDM can support multiple protocols.
- Each signal can be carried at different bit rates. For instance, one signal can be carried a OC-12 while another at OC-48.
- Similarly, signals can be carried over different formats like SONET, ATM etc.

WDM Components

- The essential components of a WDM system are primarily those of any network i.e. transmitters, link and receivers.
- In addition, the system would require other components such as switches, modulators, amplifiers etc.
- In case of WDM technology, the transmitters are laser sources with stable tunable wavelengths.
- Before sending the signal through the link, multiplexers mix the wavelengths.
- Link is low loss optical fiber while at the receiver end there are photo detectors and wavelength demultiplexers.

Optical Couplers

- Optical couplers are devices which split light to divert them into multiple paths or combine light from multiple paths to channel them into a single path.
- Light signal propagates differently from electric signal.



Optical Couplers

- **Directional Couplers:**
- In Directional couplers , light energy generally flows in one direction though they are capable of allowing flow in the other direction as well.
- For instance, in the Y-shaped coupler shown here, a signal arriving at port 1 would be distributed to port 2 and 3 and would travel from left to right.
- However, if a signal arrives at port 2 (or 3), it would only go to port 1 because of geometry.
- Directional couplers can be designed such that a predetermined percentage of optical power is output into a particular port.

Optical Couplers

- **Star Couplers:**
- Star couplers are passive devices which connect multiple inputs with i multiple outputs.
- Star couplers can be both directional and non-directional.
- Couplers may be designed to be wavelength selective which channel different wavelengths in different directions.
- These are used in making wavelength division multiplexers and demultiplexers.

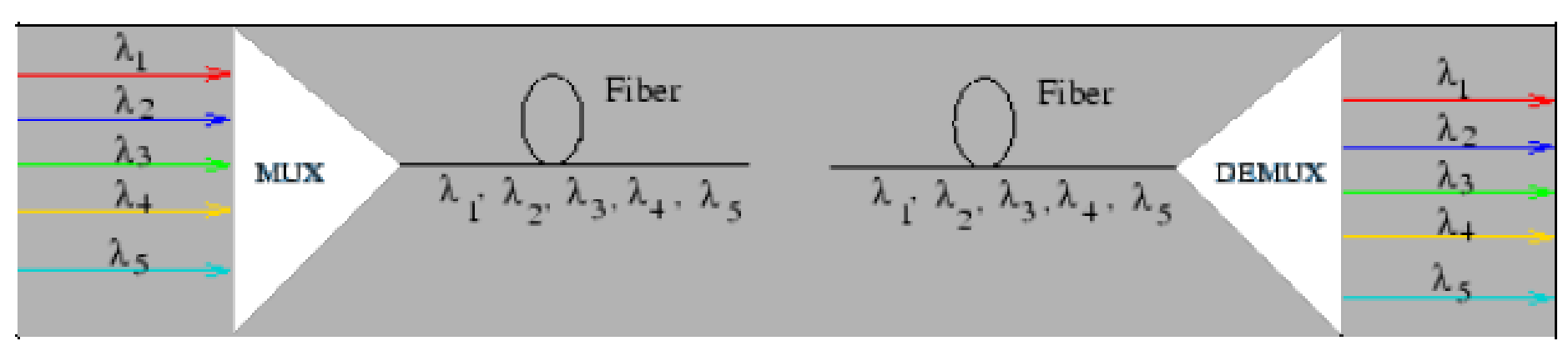
Optical Amplifiers

- Inline signal amplification is done by placing optical amplifiers along the fiber span.
- Erbium doped fiber amplifiers (EDFA) are generally used in WDM applications.
- Key performance parameters of amplifiers are gain, gain-flatness, noise level and power output.

Multiplexers (MUX)

- Multiplexing different wavelengths seem a relatively simple job of simply allowing different wavelength signals to fall on an opical fiber within the latter's angle of acceptance.
- However, one has to take care to see that the noise associated with each channel is kept to a minimum.
- Channels must be isolated to ensure that noise at a different wavelength does not interfere with the signal that is being carried.

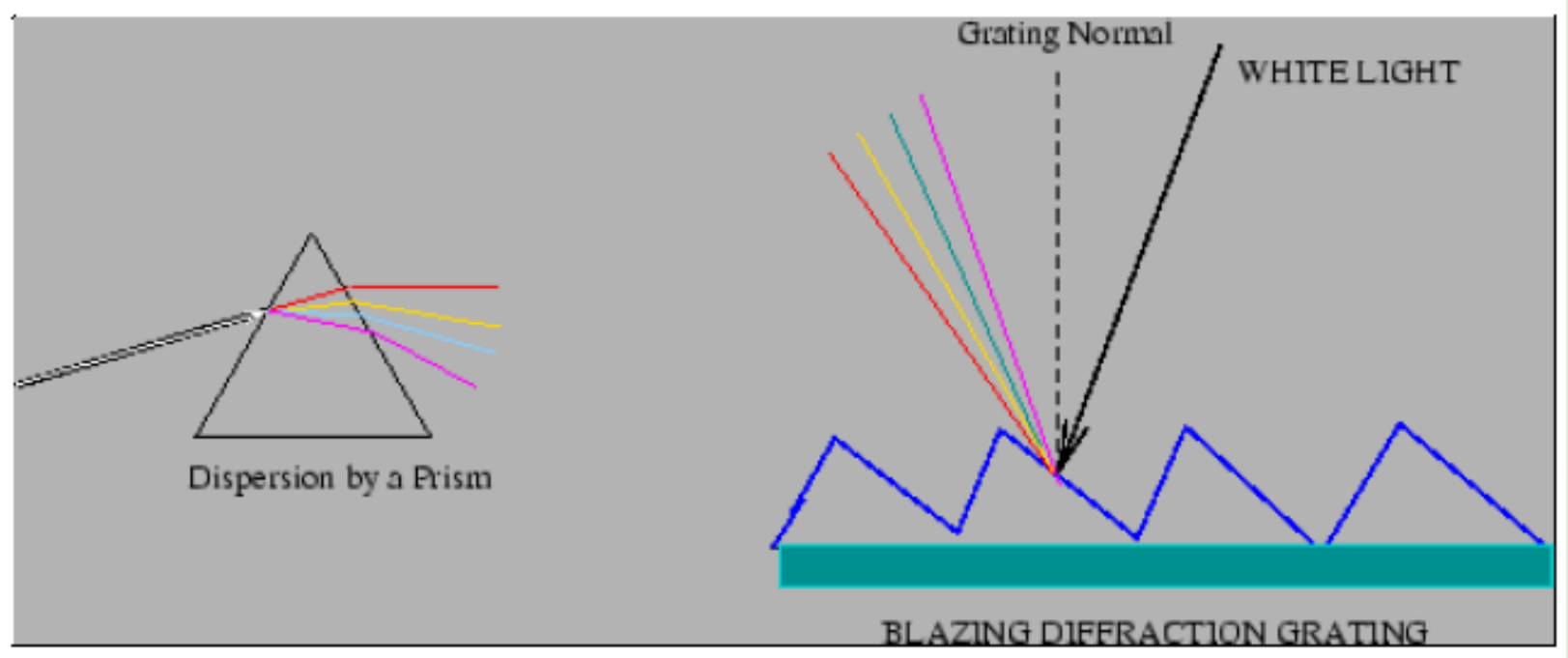
Multiplexers (MUX) and Demultiplexers



Multiplexers (MUX) and Demultiplexers

- A wavelength multiplexer (MUX) combines incident wavelengths and launches the output to the fiber.
- At the receiving end a demultiplexer (DEMUX) reverses the above and separates the signal into the components.
- Multiplexers are generally based on one of two principles, angular dispersion and optical filtering.
- Prism and reflection gratings are used for separating wavelengths.
- The same elements can combine wavelengths on reversing the direction of the beams.

Multiplexers (MUX) and Demultiplexers



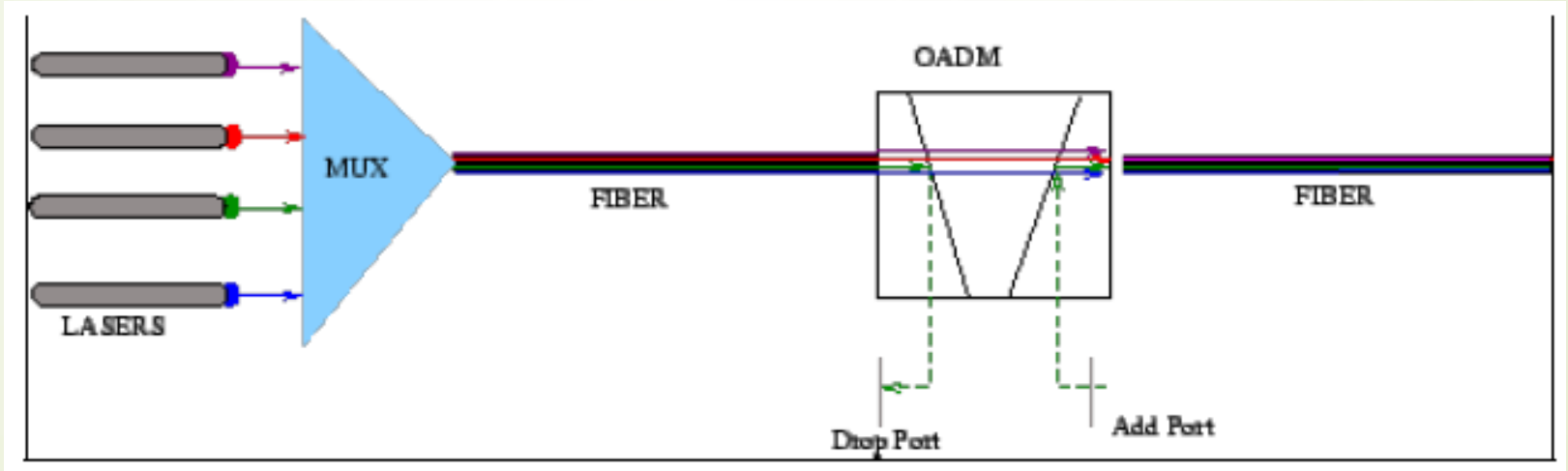
Optical Add-Drop Multiplexer (OADM)

- In its passage from the MUX to DEMUX, the signal passes through one or more Optical Add-Drop Multiplexer (OADM) .
- The function of an OADM is to selectively drop one or more wavelengths by rerouting its data content to another fiber.
- The OADM may just allow the remaining traffic to pass or add a different data set at a wavelength equal to that of a dropped data.
- This helps to create a virtual point-to-point circuit.

Optical Add-Drop Multiplexer (OADM)

- An OADM is generally a device such as a Bragg grating which could be used to selectively reflect a wavelength that is to be dropped while allowing the others to be transmitted.
- OADMs are passive components of the network.
- They are manufactured to operate either at fixed wavelengths or at dynamically selectable wavelengths.
- In case of fixed wavelengths, the wavelengths to be dropped or added are pre-selected.

Optical Add-Drop Multiplexer (OADM)



Wavelength Converters

- Wavelength converters are devices which changes the wavelength of an input signal.
- There are several ways in which a wavelength conversion can occur.
- Usually, wavelength conversion takes place from a shorter wavelength to a longer wavelength.
- For instance, certain material can absorb radiation and re-radiate at a lower frequency.
- In WDM network, frequency converters are used for better utilization of available wavelengths.

Dense Wavelength Division Multiplexing (DWDM)

- The two key WDM technologies are coarse wavelength division multiplexing, CWDM and dense wavelength division multiplexing, DWDM.
- In DWDM channels are much closer together.
- CWDM supports up to 18 wavelength channels transmitted through a fiber at the same time.
- To achieve this, the different wavelengths of each channel are 20nm apart.

Dense Wavelength Division Multiplexing (DWDM)

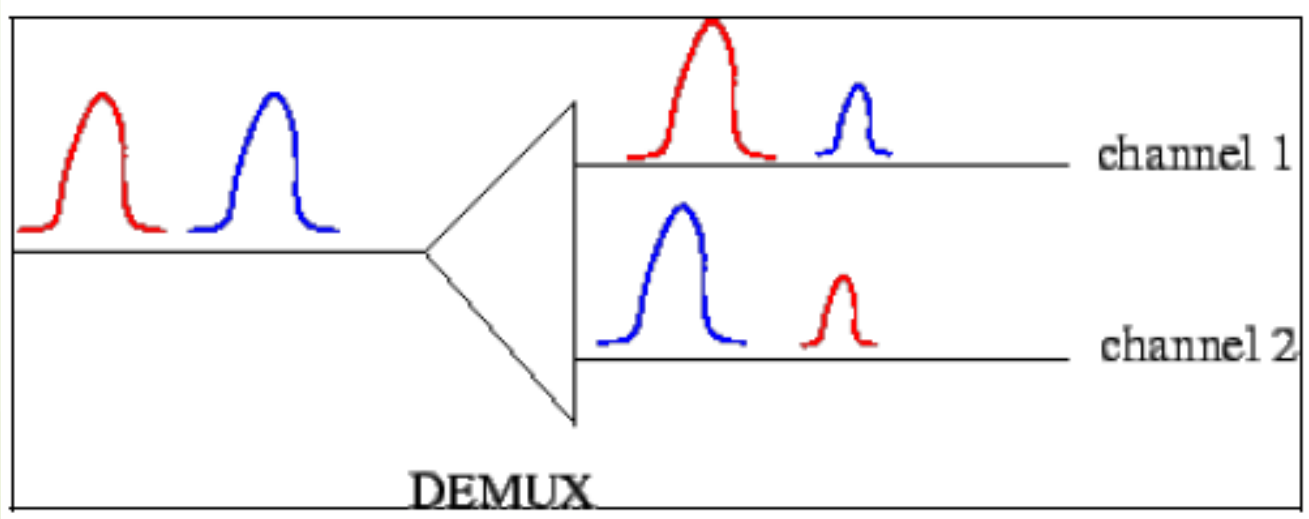
- DWDM, supports up to 80 simultaneous wavelength channels, with each of the channels only 0.8nm apart.
- CWDM technology offers a convenient and cost-efficient solution for shorter distances of up to 70 kilometers.
- DWDM connections can be amplified and can therefore be used for transmitting data much longer distances.

Potential Problems

- Loss, crosstalk and non-linear effects are potential problems.
- A multiplexer should have low insertion loss and should not allow back scattering of light to any of the input ports.
- Insertion loss is the attenuation in the signal in travelling from the input port to the output port.
- Back reflection can be avoided by use of **optical isolators** , which allow light to propagate only in one direction, similar to a diode in an electronic circuit which allow current in one direction.

Potential Problems

- A demultiplexer should give rise to minimum **cross talk** , i.e., the amount of input power associated with a particular wavelength (say λ1) which reaches a channel for a different wavelength (λ2) should be minimum.



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