Rajasthan Technical University, Kota
B.Tech. VI Semester ECE
Fiber Optics Communication

Unit 5: Lecture 01
WDM AND DWDM

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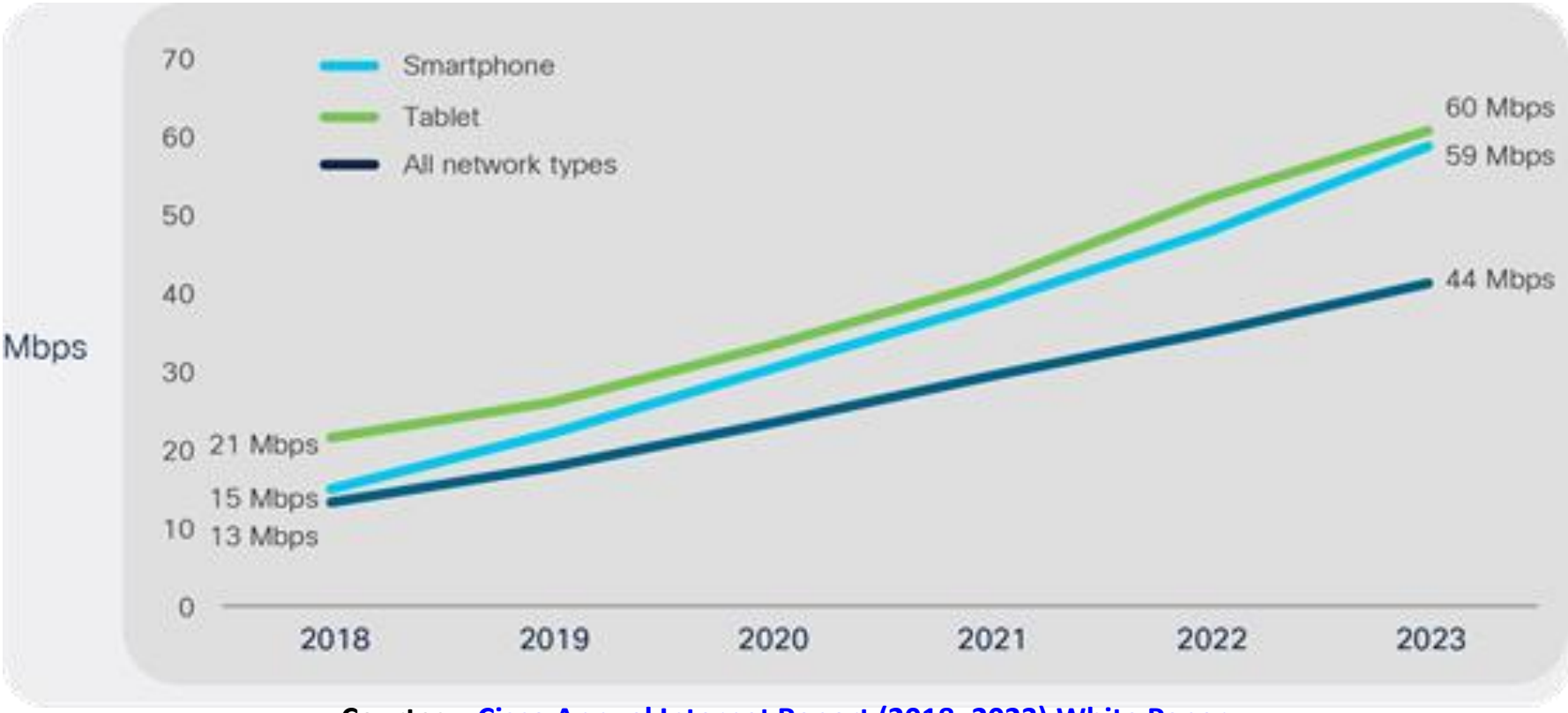
Growing Network Usage Patterns

Issue:

- Exponential increase in user demand for bandwidth



Courtesy: [Cisco Annual Internet Report (2018–2023) White Paper]

Solution:

- Increase the channel capacity.

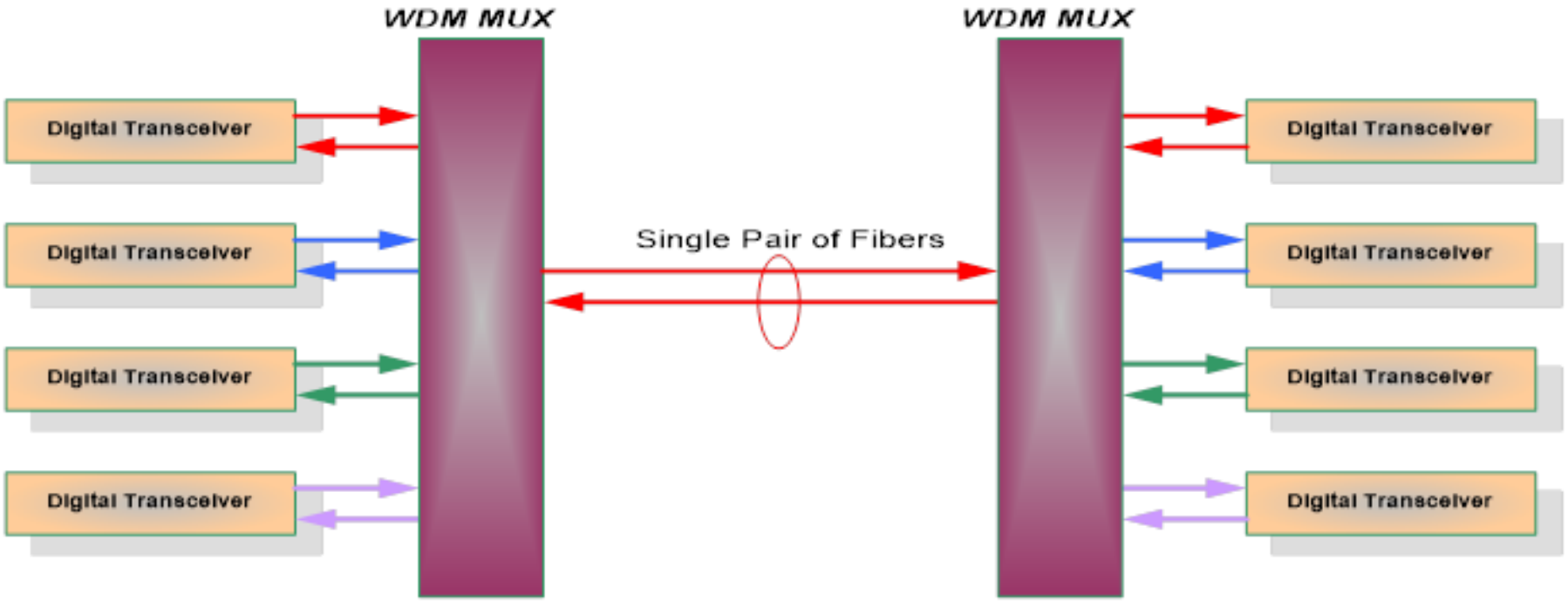
How to increase the channel capacity??

- Adding more and more fibers to the network

- Disadvantages
  - Increased cost of laying additional fiber
  - Increased cost of maintenance of these additional fibers

How to increase the channel capacity??

- Using multiplexing techniques to minimize the cost and increase channel capacity



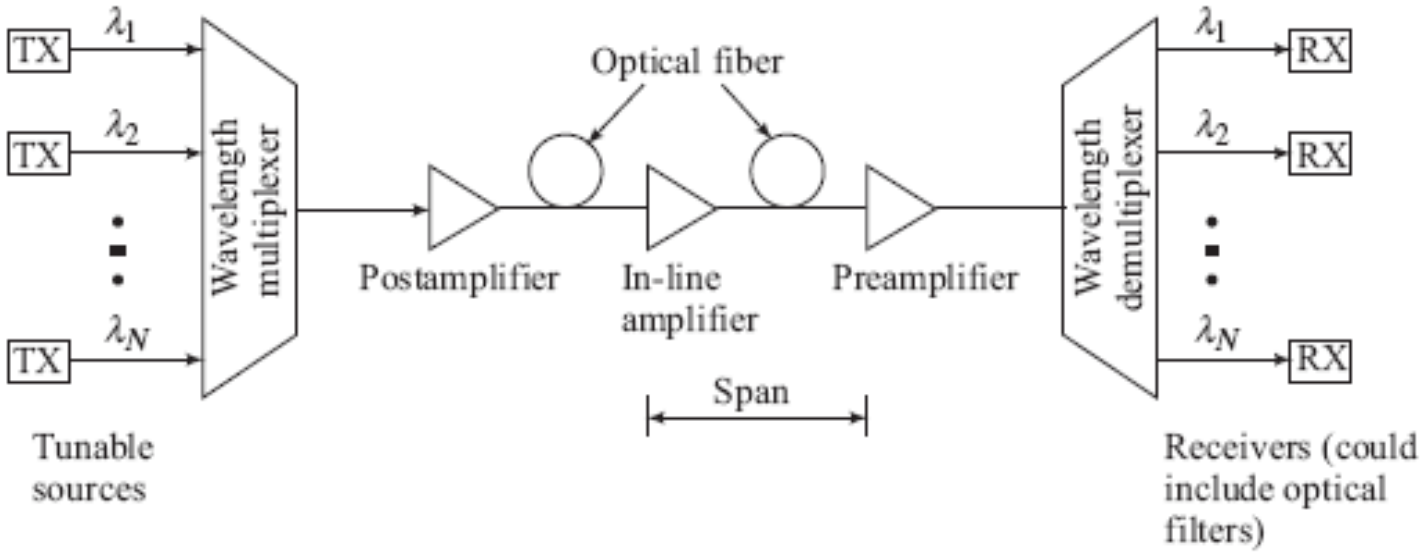
This technique is called Wavelength Division Multiplexing (WDM).

Advantages:

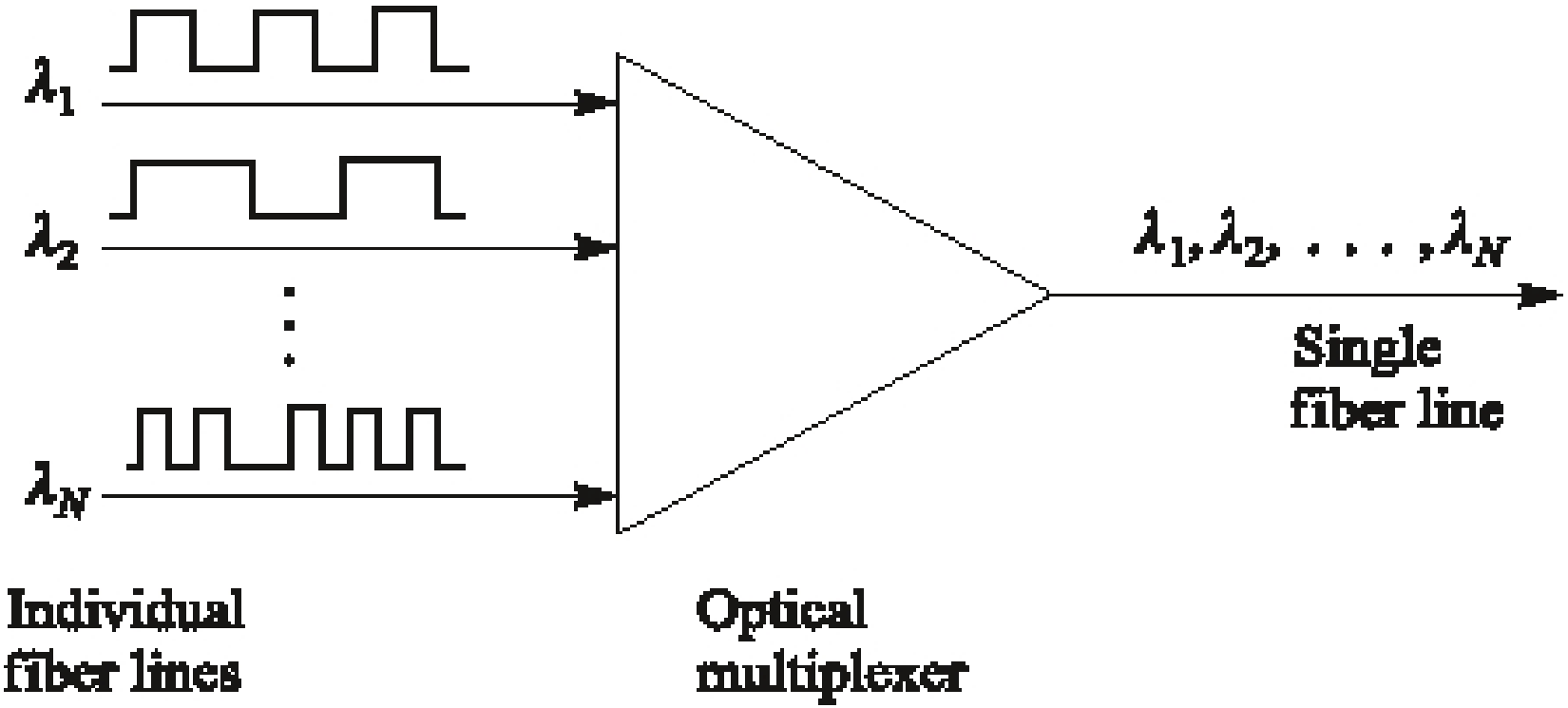
- Data of multiple users / transmitters can be transmitted over a single fiber.
- Cost of laying additional fibers and maintenance is thus reduced.
- Maintenance of single fiber pair is easy and cost effective over a long link distance.

Overview of WDM

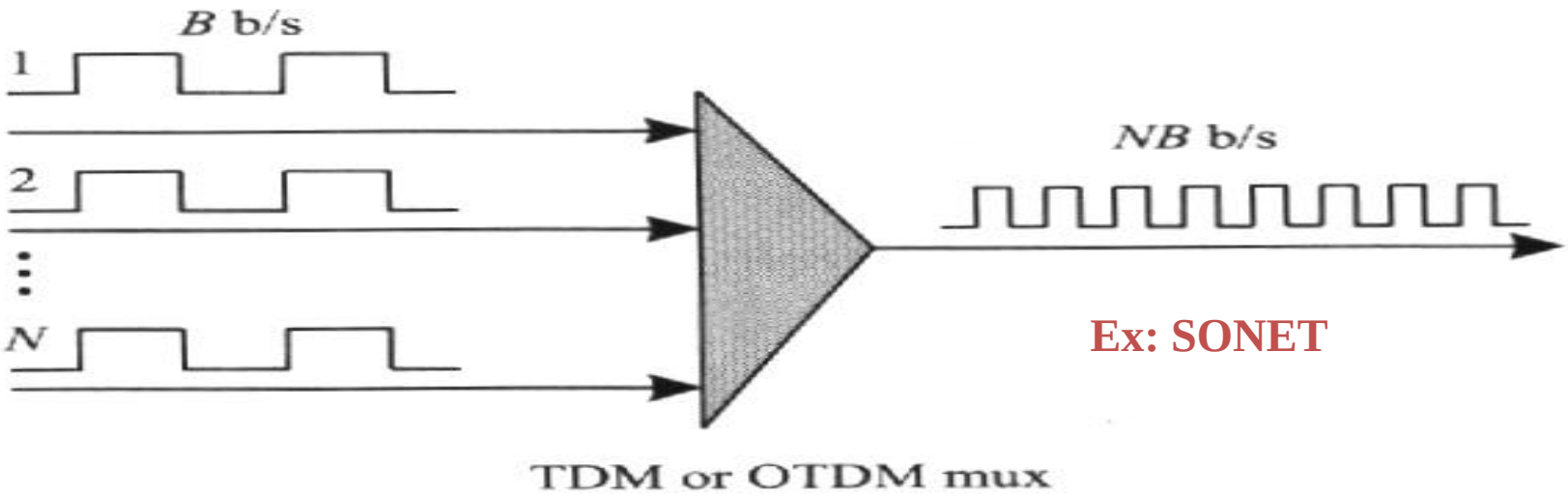
- **Wave Division Mutiplexing (WDM) multiplexes multiple optical carrier signals on a single optical fiber by using different wavelengths (colors) of laser light to carry different signals.**
- **A characteristic of WDM is that the *discrete wavelengths form an orthogonal set of carriers* that can be separated, routed, and switched without interfering with each other.**
- **WDM networks require a variety of *passive and active devices* to *combine, distribute, isolate, and amplify optical power at different wavelengths*.**



Wavelength Division Multiplexing

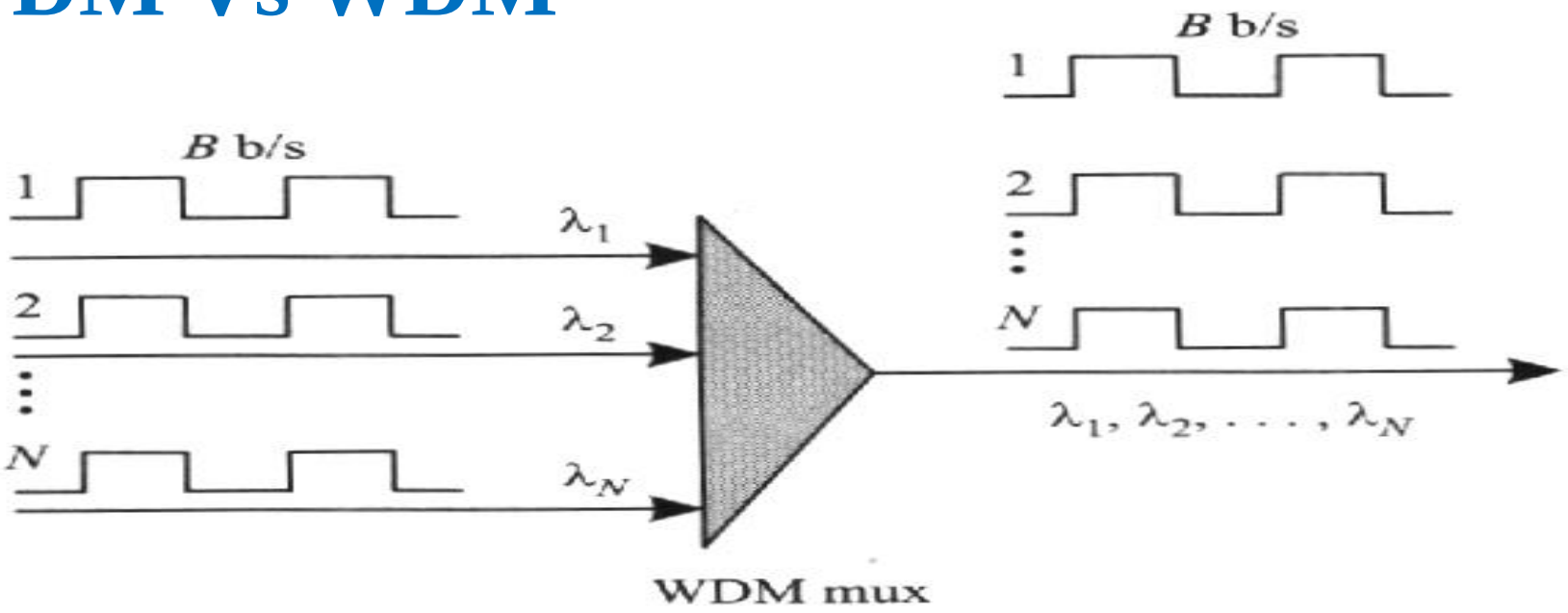


Each wavelength is like a separate channel (fiber)

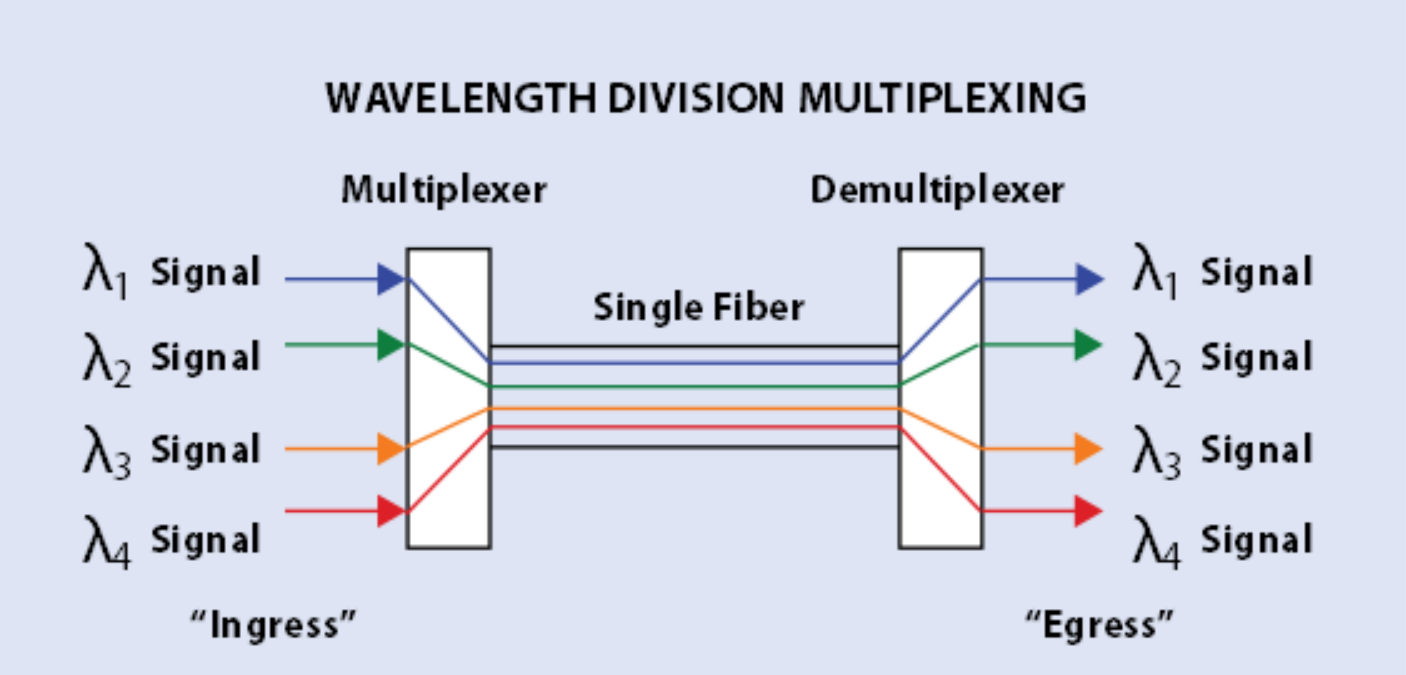


Ex: SONET

TDM Vs WDM

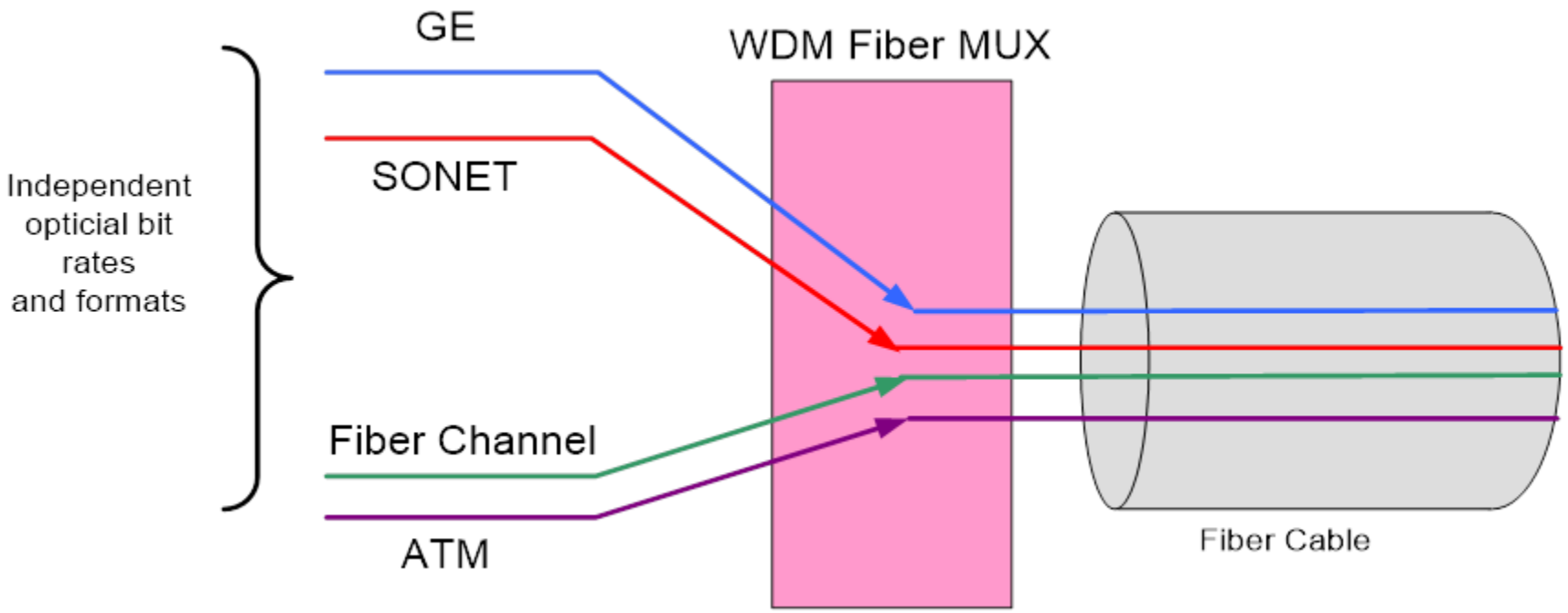


Wavelength Division Multiplexing

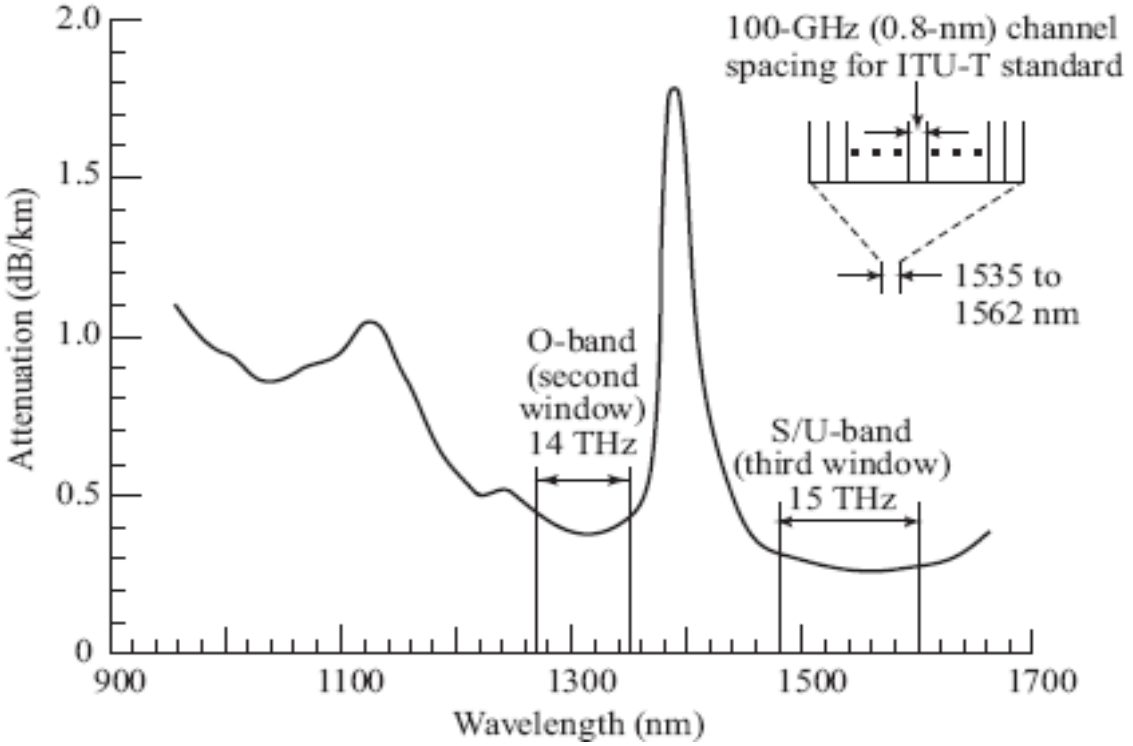


- Passive/active devices are needed to combine, distribute, isolate and amplify optical power at different wavelengths

Bit Rate and Protocol Independent



WDM Spectral Bands



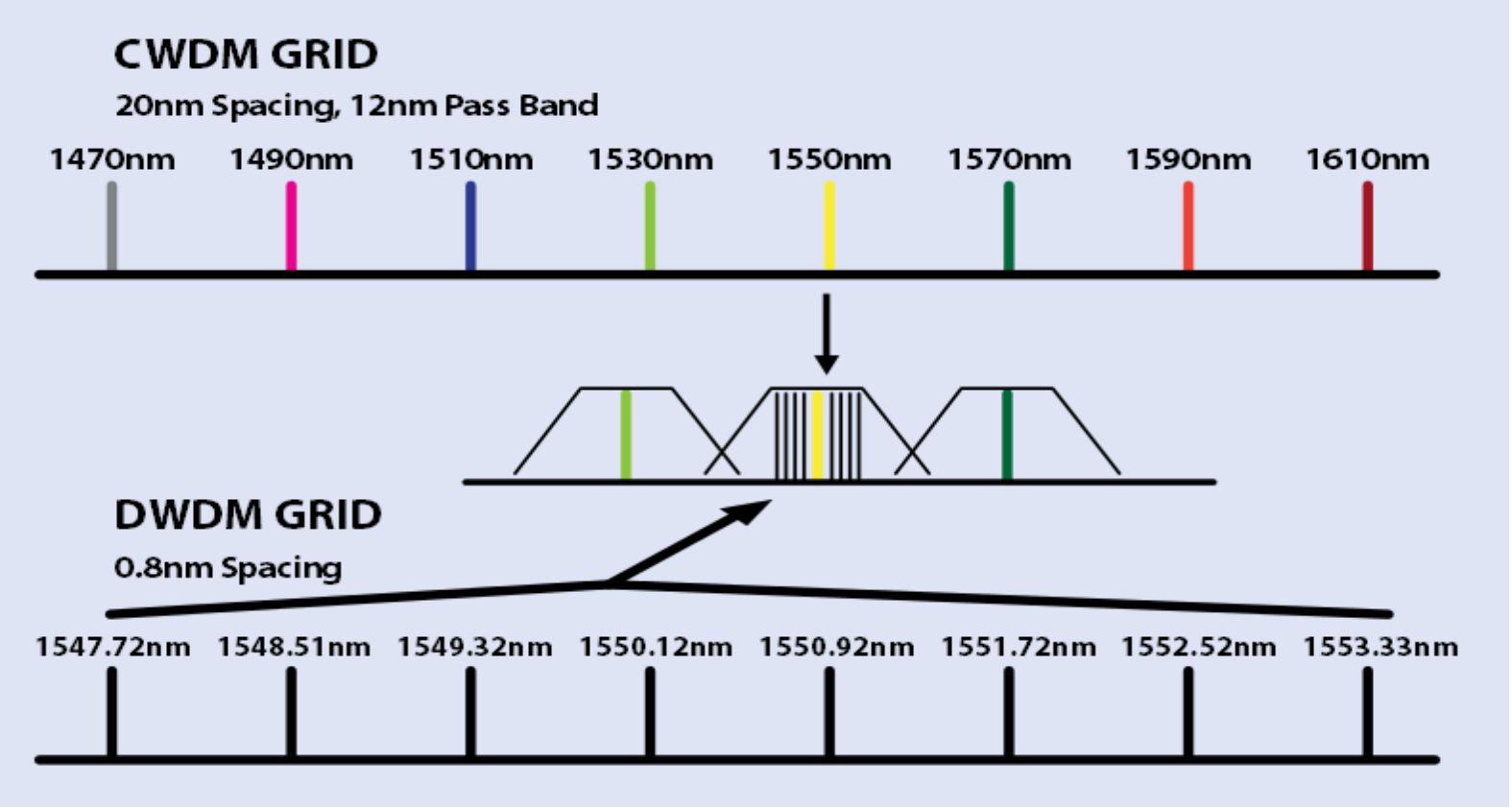
- **Many independent and narrowband regions in the O- through L-bands can be used simultaneously.**
- **These regions are designated either in terms of *spectral width* or *optical bandwidth*.**
- **The optical bandwidth Δν related to a particular spectral width Δλ is found by differentiating $c = \lambda\nu$; for $\Delta\lambda \ll \lambda^2$**

$$|\Delta\nu| = \frac{c}{\lambda^2}|\Delta\lambda|$$

Types of WDM

There are two types of WDM:

1. **Coarse WDM (CWDM): Larger passband, larger guard band**
2. **Dense WDM (DWDM): Narrow passband, narrow guard band**



WDM Standards

- **ITU-T Recommendation G.694.1 specifies DWDM operation in the S-, C-, and L-bands for frequency spacing of 100 to 12.5 GHz (or, equivalently, 0.8 to 0.1 nm at 1550 nm).**
- **The number NM is used by ITU-T to designate a specific 19N.M-THz C-band 100-GHz channel, e.g., the frequency 194.3 THz is ITU channel 43.**

Table 10.1 *Portion of the ITU-T G.694.1 dense WDM grid for 100- and 50-GHz spacings in the L- and C-bands*

L-band				*C-band*			
100-GHz		*50-GHz offset*		*100-GHz*		*50-GHz offset*	
THz	*nm*	*THz*	*nm*	*THz*	*nm*	*THz*	*nm*
186.00	1611.79	186.05	1611.35	191.00	1569.59	191.05	1569.18
186.10	1610.92	186.15	1610.49	191.10	1568.77	191.15	1568.36
186.20	1610.06	186.25	1609.62	191.20	1576.95	191.25	1567.54
186.30	1609.19	186.35	1608.76	191.30	1567.13	191.35	1566.72
186.40	1608.33	186.45	1607.90	191.40	1566.31	191.45	1565.90
186.50	1607.47	186.55	1607.04	191.50	1565.50	191.55	1565.09
186.60	1606.60	186.65	1606.17	191.60	1564.68	191.65	1564.27
186.70	1605.74	186.75	1605.31	191.70	1563.86	191.75	1563.45
186.80	1604.88	186.85	1604.46	191.80	1563.05	191.85	1562.64
186.90	1604.03	186.95	1603.60	191.90	1562.23	191.95	1561.83

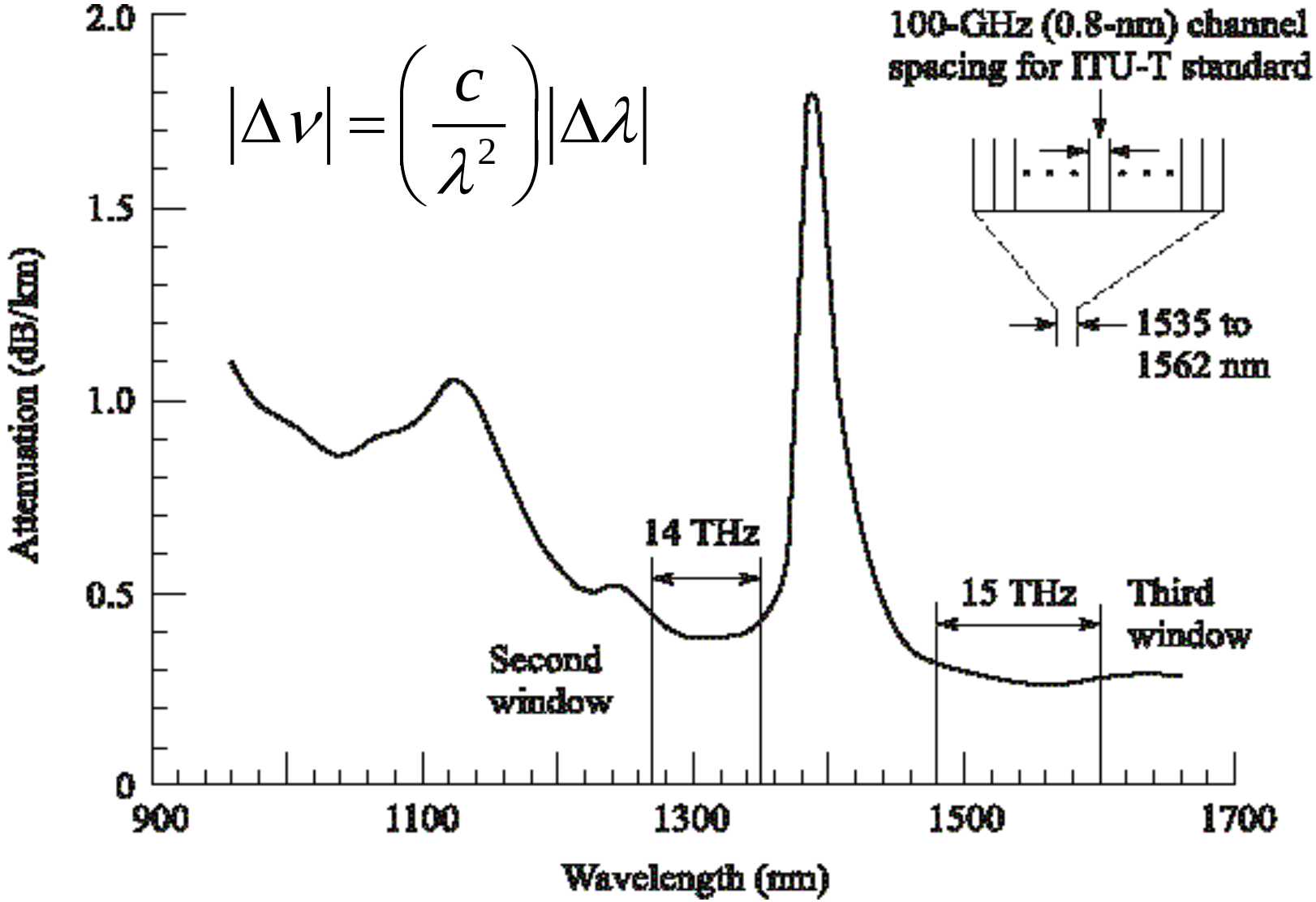
Advantages

- Capacity upgrade of existing fiber networks without adding fibers
- Transparency: Each optical channel can carry any transmission format (different asynchronous bit rates, analog or digital)
- Scalability– Buy and install equipment for additional demand as and when needed
- Wavelength routing and switching: Wavelength is used as another dimension to time and space for routing and switching applications

DWDM

- First WDM networks used just two wavelengths, 1310 nm and 1550 nm
- Today's DWDM systems utilize 16, 32,64,128 or more wavelengths in the 1550 nm window
- Each of these wavelength provide an independent channel (Each may transmit 10 Gb/s)
- The range of standardized channel grids includes 50, 100, 200 and 1000 GHz spacing
- Wavelength spacing practically depends on:
  - laser line-width
  - optical filter bandwidth

ITU-T Standard Transmission DWDM windows



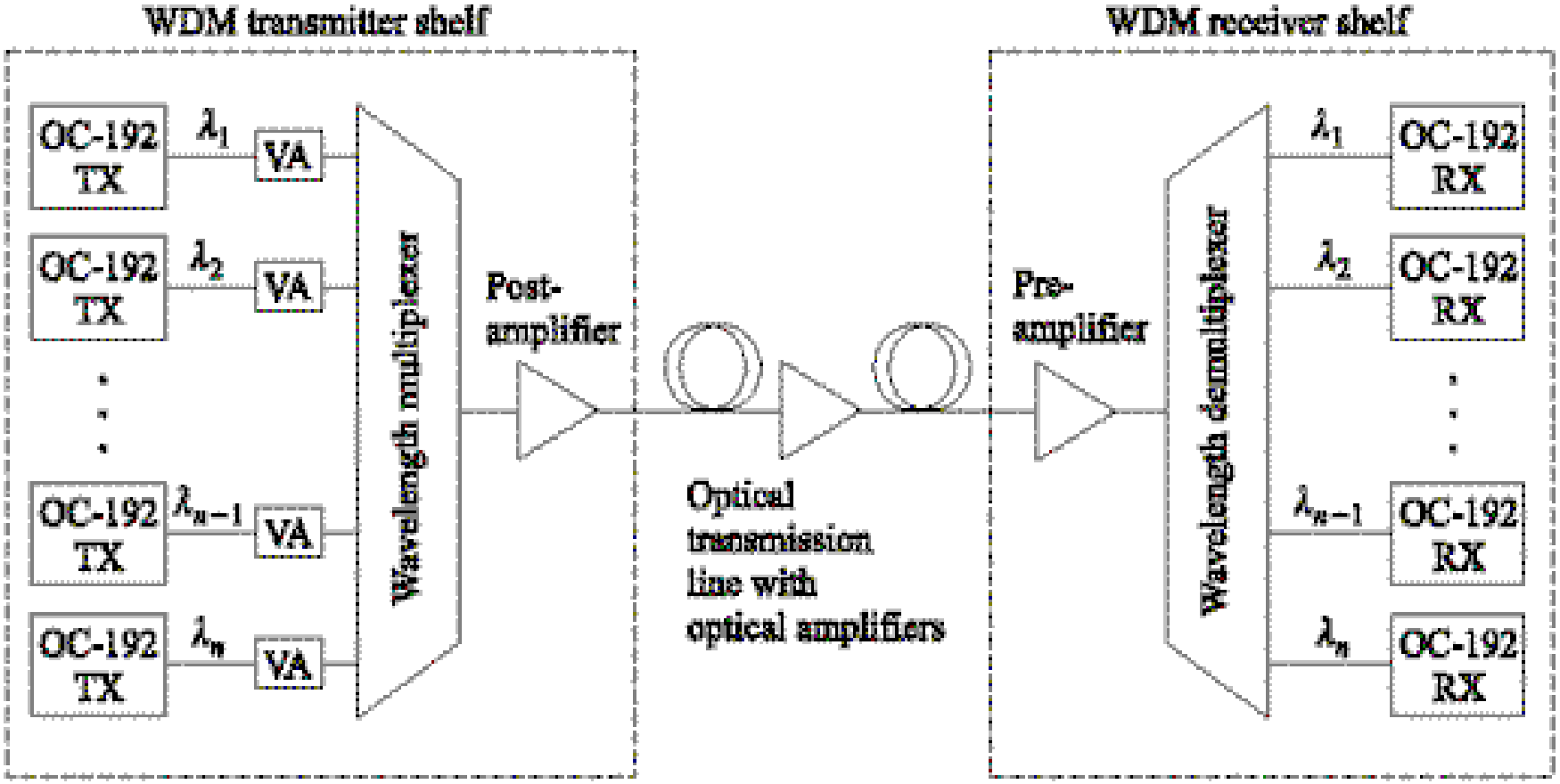
Principles of DWDM

- Spectral width of a modulated laser: 0.001 nm
- Typical Guard band: 0.4 – 1.6 nm
- 80 nm or 14 THz @1310 nm band
- 120 nm or 15 THz @ 1550 nm

$$|\Delta \nu| = \left(\frac{c}{\lambda^2} \right) |\Delta \lambda|$$

- Discrete wavelengths form individual channels that can be modulated, routed and switched individually

Nortel OPTERA 640 System



TX: Optical transmitter
RX: Optical receiver
VA: Variable attenuator

64 wavelengths each carrying 10 Gb/s

DWDM Limitations

- For physical realization of DWDM networks we need precise wavelength selective devices
- High Cost

Thank You

For more details please visit
www.chetanselwal.com