# WDM

## Wavelength Division Multiplexing

*-CWDM vs DWDM-*

# Agenda

- 1. Overview
- 2. Fiber Cable WDM Characteristics
- 3. CWDM – Course WDM
- 4. DWDM – Dense WDM
- 5. Applications – Best Fit- Future?
- 6. Summary

# 1 - Overview

- Long and dense routes provided the economic drivers to maximize ROI. DWDM was perfected in the 1990's.
  - Undersea cables met this criteria early.
  - Transcontinental fiber routes were next.
  - "Fiber Glut" was a consequence.
- R/W issues and unexpected circuit demand became local applications.

# Overview

- Short and multi-protocol routes had unique drivers in special applications like Metro's and video headends.
  - CWDM has lower density but is also 40% lower in cost than DWDM.
  - Video feeds with a variety of analog, digital, RF and control protocols were perfect for CWDM.
  - CWDM is very cost effective in providing circuit relief in lower density TDM Sonet networks. Original CWDM was developed in the 1980's for MMF.

# Overview

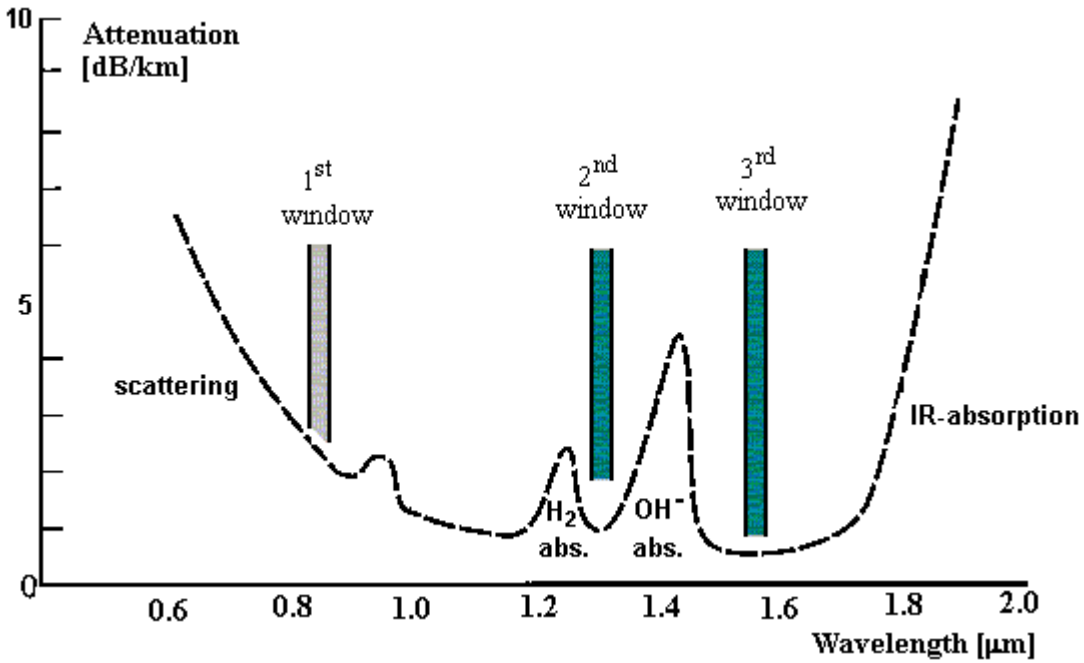
- To fully understand the unique problems and benefits of WDM, the characteristics of legacy and current fiber production will be explored. Section 2 on “Fiber Characteristics” discusses the main issues and today’s answers.
- CWDM development and specs are discussed in section 3. It was an original 1980’s product which is now revitalized.
- DWDM development and specs are discussed in section 4. It was developed in the 1990’s.

# Overview

- Current applications and current strategies are discussed in section 5. The “Best Fit” parameters and current research on WDM improvements provide insight on expected future applications.

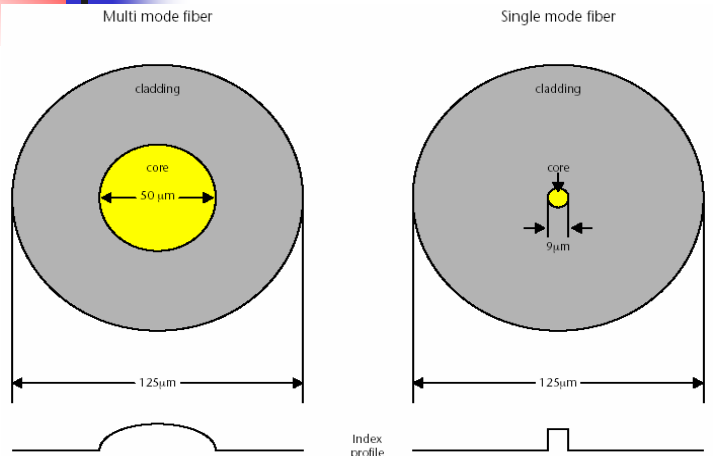
# 2-Fiber Cable WDM Characteristics

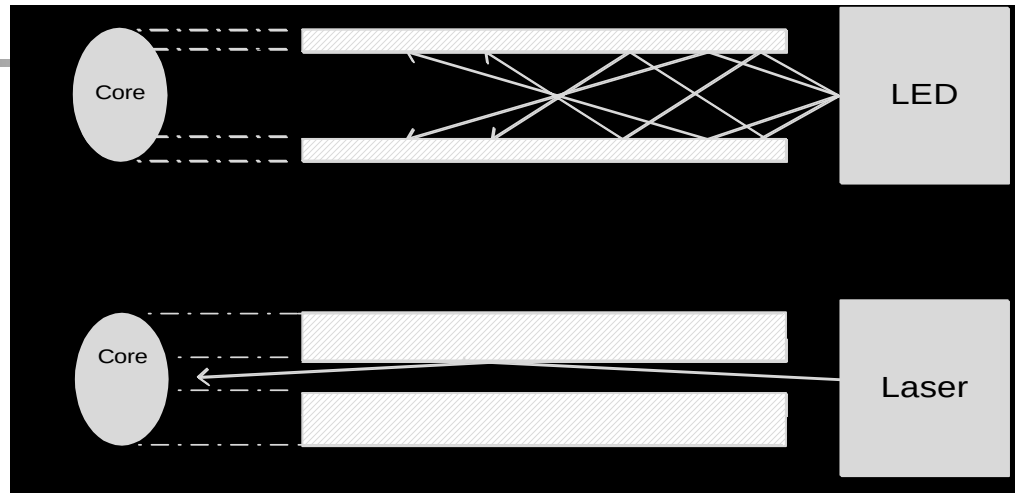
1st window-1970's
2nd window-1980's
3rd window-1990's




***Each "Window" provides a historical perspective on cable technology***

# Fiber Types - Construction




## Multi-Mode

- 50/62.5um core, 125um clad
- Atten-MHz/km: 200 MHz/km
- Atten-dB/km: 3dB @ 850nm
- **MMF has an orange jacket**

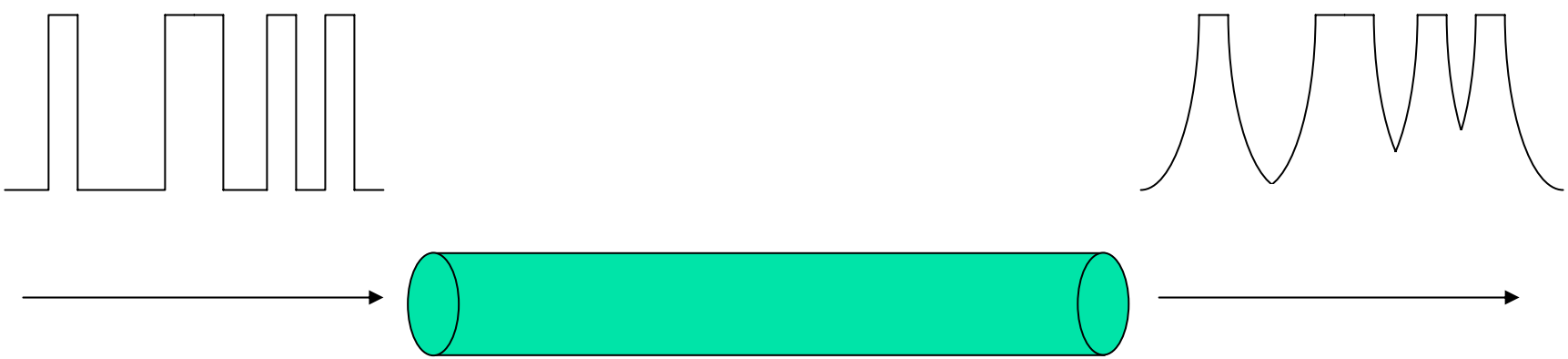
## Single-Mode

- 9um core, 125um cladding
- Atten-dB/km: 0.4/0.3dB 1310nm/1550nm
- **SMF has a yellow jacket**

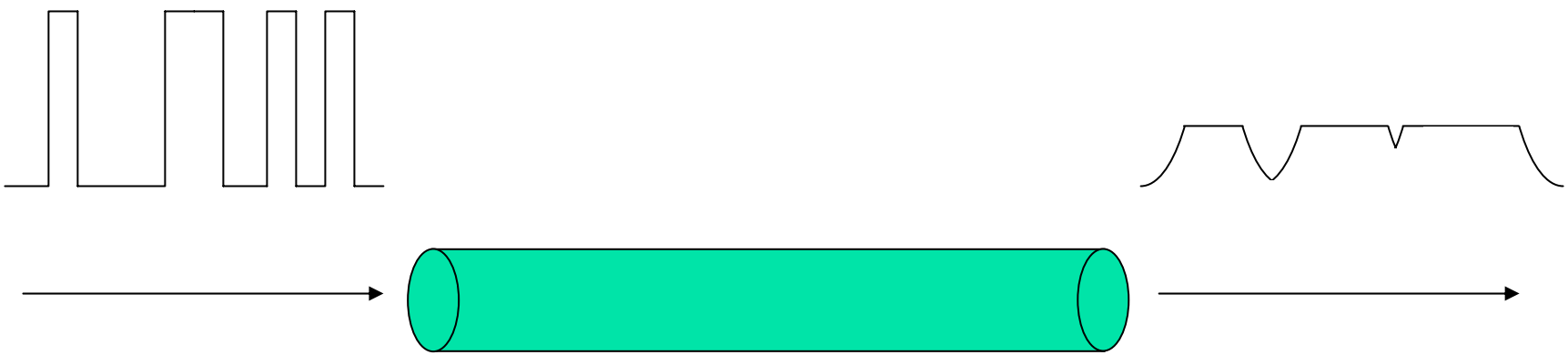
# Degradation In Fiber Optic Cable

- Attenuation
  - Loss of light power as the signal travels through optical cable
- Dispersion
  - Spreading of signal pulses as they travel through optical cable

# Dispersion



# Dispersion + Attenuation



# Dispersion Causes

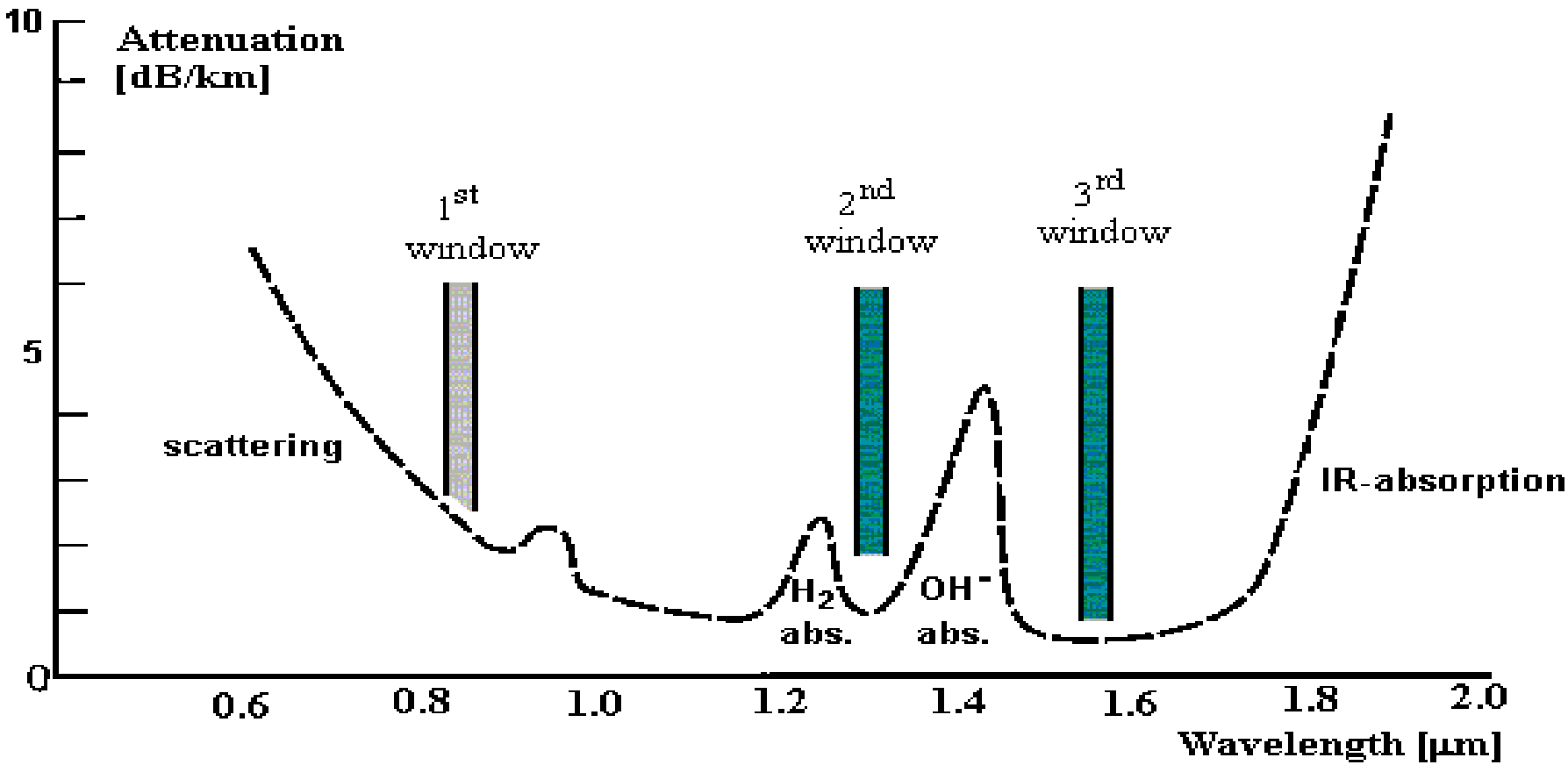
- Modal effects
  - Intermodal dispersion
  - Intramodal dispersion
  - Chromatic
  - Waveguide
  - Polarization mode

# Dispersion causes

- Scattering effects
  - Raleigh
  - Raman (SRS)
  - Brillouin (SBS)
- Miscellaneous effects
  - Linear crosstalk
  - Four wave mixing
  - Cross phase modulation
  - Self phase modulation

# Attenuation vs. Wavelength

”classic” non-dispersion shifted SMF cable



# Low Water Peak Nondispersion Shifted Fiber

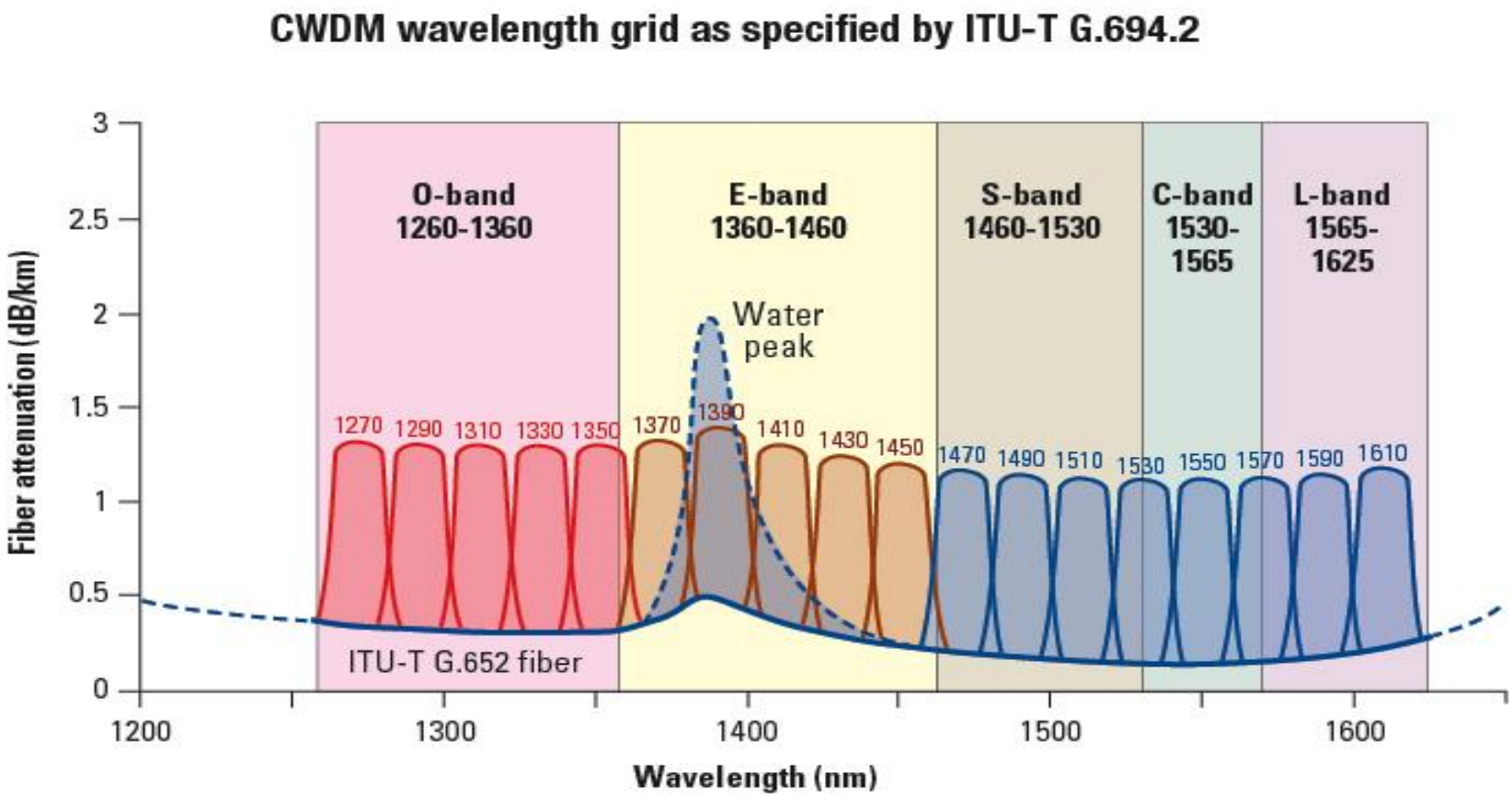
- Optimizes SMF fiber for WDM applications in the 1285nm to 1625nm region by reducing the classic OH peak.
- ITU standard typically 0.2 dB/ Km at 1550nm. (ITU-T G.652.C)
- Zero dispersion wavelength is in the standard 1310nm region.
- Reduces / eliminates the water peak by improved manufacturing process.

# Dispersion shifted fiber

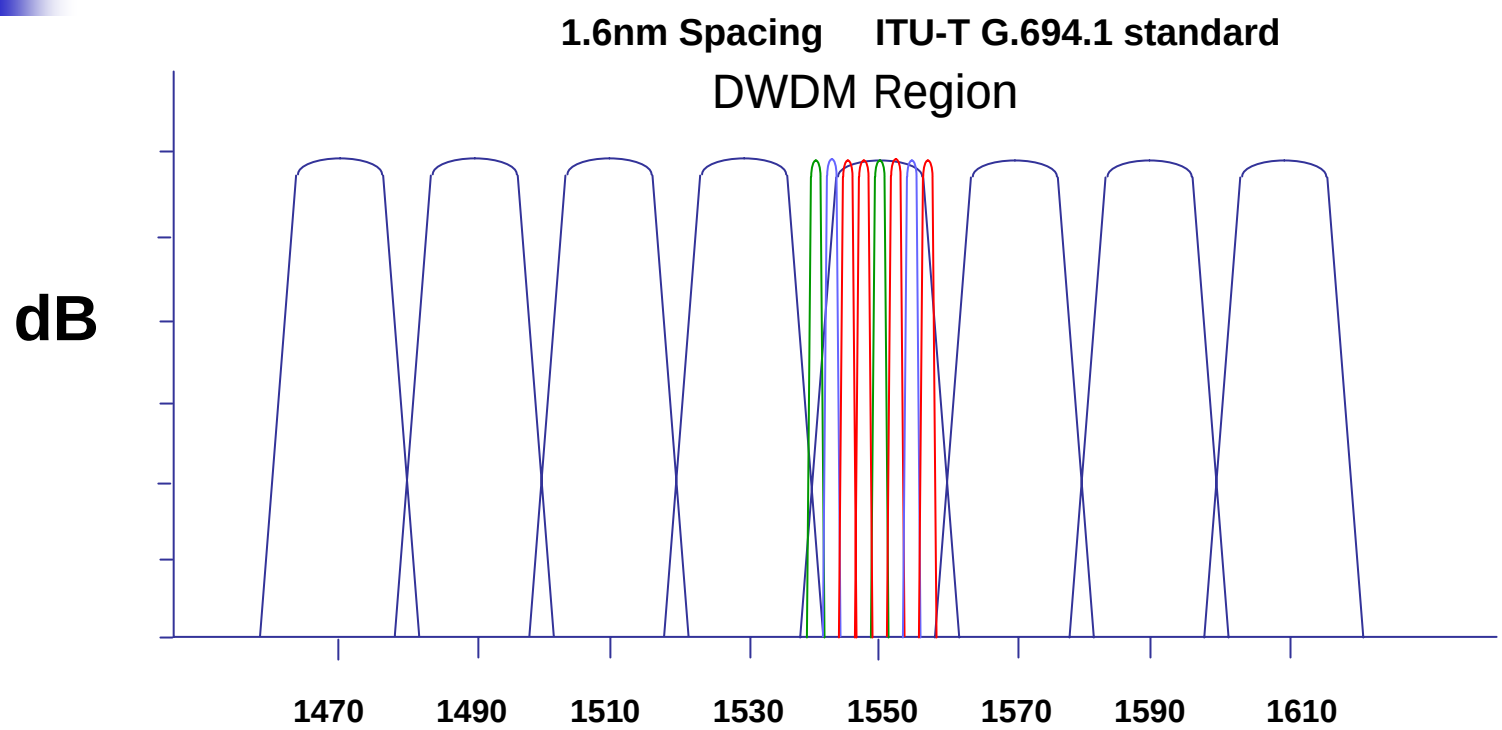
- Zero dispersion shifted fiber moves the “neutral” dispersion wavelength to the 1550 low attenuation window. (ITU G.653)
- Because of DWDM FWM (Four Wave Mixing) newer Nonzero Dispersion shifted fiber was developed and replaces Zero dispersion shifted fibers. (ITU G.655)
  - NZD- and NZD+ fiber move the zero dispersion wavelength to either side of the 1550nm point.

# CWDM Optical Spectrum

- 20nm spaced wavelengths



# DWDM vs. CWDM Spectrum



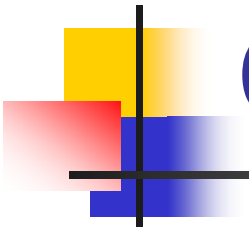

CWDM 20nm channel spacing

# 3 – CWDM

- Originally developed in the 1980's for adding capacity to multi-mode fiber cable routes in campus LAN's.
  - 25nm spacing in the 850 nm window.
- About 1995, CWDM was revitalized with SMF wavelengths for metro area fiber route capacity increases.
  - The "original" band at 1310nm was used.
- Currently the latest ITU spec G.694.2 defines 18 channels in 5 bands with 20nm spacing.
  - The bands are the O, E,S,C and L.
  - The E band includes the 1385nm water peak so is the last one implemented unless low WP cable is used.
  - Typical capacity of 50Mb to 2.7Gb

# CWDM

- Advantages
  - Simpler technology allows:
    - Lower power consumption- 20%
    - Smaller space requirements- 30%
    - Can use SMF or MMF cable
    - Can use LED's or Laser's for power
    - Larger individual payloads per channel
    - Smaller and cheaper wave filters
    - Cost savings on start up and expansion



# CWDM

- Disadvantages
  - Less capacity than DWDM
  - Less range
  - Regeneration vs. amplification
  - O, A and M functions are not carrier class

# 4 – DWDM

- Developed in the early 1990's to add capacity to undersea and transcontinental routes.
- Uses the 1500nm to 1600nm band which has minimum attenuation for long distance routes.
- Operates in the prime EDFA region
- EDFA amps provide maximum distance
- Can provide typical 2 to 128 channels of capacity
  - Channel spacing is likely 0.8nm for economy
- Typically operates at 2.4Gb and 10Gb
- ITU channel plan is  G.694.1 (1200ch @ 0.1nm)

# DWDM

- Advantages
  - Maximum capacity system available
  - Maximum distance capability with EDFA's
  - Repeater "amp" sites can be reduced
    - MCI and ATT reduced sites by 30%
  - Pay as you grow expansion
  - Mature O, A and M systems are developed

# DWDM

- Disadvantages
  - Complex technology requires:
    - more space
    - more power
    - high accuracy lasers and wave filters
    - Expensive EDFA’s for amplifiers
  - Start up costs are more than equivalent CWDM

# 5- Applications- CWDM

- CWDM is very flexible and has adapted to specialized applications such as:
  - Video headend feeds for multi protocol signals
  - Campus LAN expansion
  - Lower density capacity “fixes”
  - Short distance capacity “fixes”
  - Metro area distribution and expansion
  - Data center storage routes
  - Spur routes for DWDM systems
  - Applications where low start up and expansion rules vs the alternative DWDM choices

# Applications - DWDM

DWDM is the proven “workhorse” of the high capacity and long distance carrier’s.

- Many products are available from most traditional transport suppliers.
- The O, A and M capabilities are world class.
- Secondary market systems are available which can significantly reduce costs.

# Applications – Future?

- CWDM continues to evolve into specialized applications.
  - Combination transport and optical routers or switches are being developed now.
  - Add- on  CWDM cards are being included in more transport devices as low cost options.
  - Suppliers are continuing to drive down costs and increase capacity.

# Applications- Future?

- DWDM research is working on increasing the capacity and distance of future DWDM products.
  - Wide Spectrum DWDM is on the future horizon and will offer more channels.
  - The electronics and chip industry is constantly increasing quality yields which will drive costs lower and increase capability.
  - Combination systems with CWDM and DWDM capabilities are being produced now.
  - FTTP technology intends to expand capacity with a “wavelength per home”.

# 6- Summary

- CWDM and DWDM technology continues to advance and provide solutions to applications not imagined or feasible years ago. Each technology provides a unique “fit” and will complement not replace the other.

# Thank You!

- *Special thanks is due to many authors and vendors who have provided source material for this presentation. This presentation is not meant as original research but as a compendium of many sources.*