SCTE
Greater Chicago Chapter

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SCTE Certified: BPS, BTS, BTCS, BDS, BCT

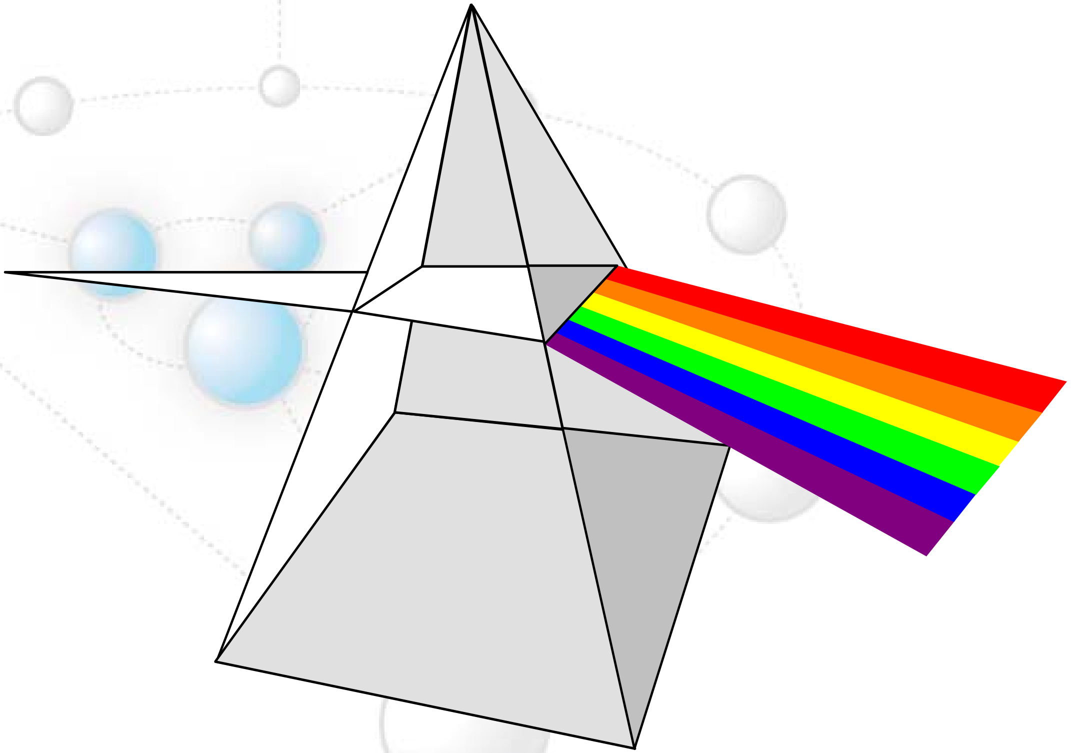
Optical Network evolution

Fiber Optic Principals

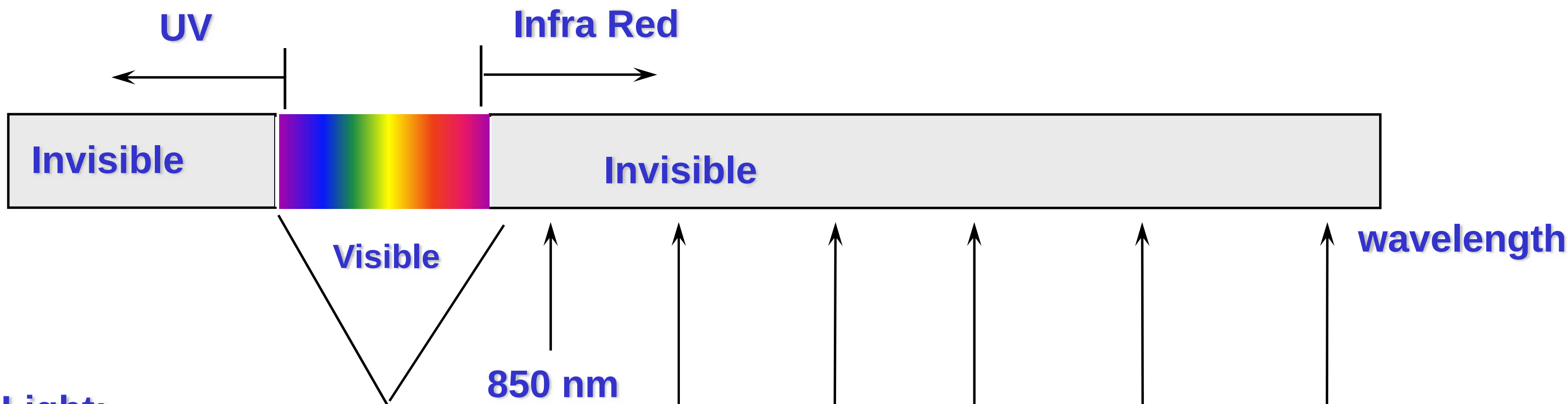
Remember


Relax
Have Some Fun
Learn
Something
Ask Questions
Enjoy Life

What Is Light?



Spectral Characteristics



Light:

- Ultra-Violet (UV)
- Visible
- Infrared (IR)

Communication Wavelengths:

- 850, 1310, 1550 nm
  Low Loss Wavelengths

Specialty Wavelengths:

- 980, 1480, 1625 nm

Optics Fundamentals

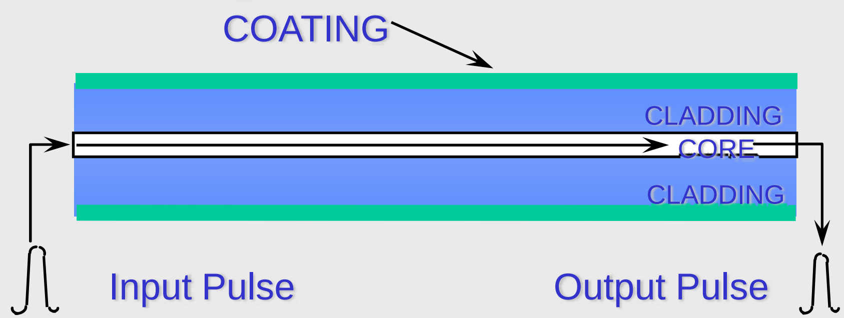
Color

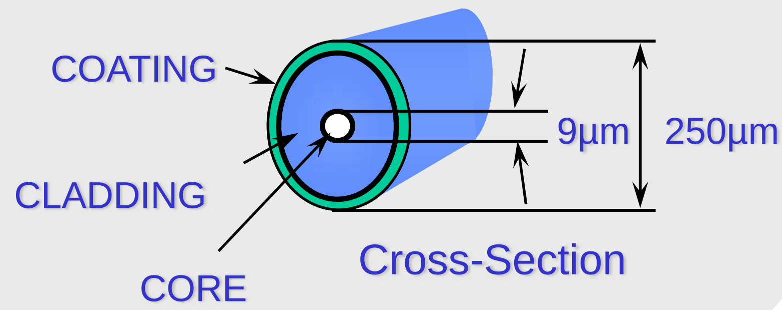
Like a Prism

- Wavelength: λ
- Is measured in nanometers --
  - nano = billionth

- Frequency: f
- Is measured in tera Hertz --
  - tera = trillion

Singlemode Fiber



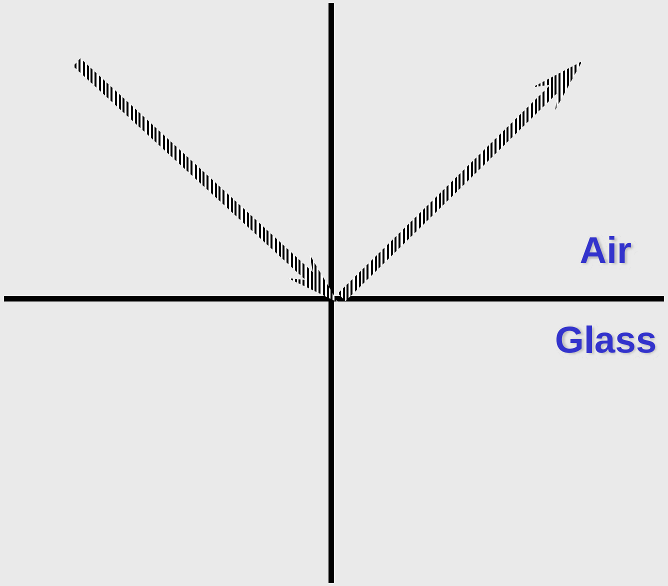


Total Internal Reflection

Optics Fundamentals

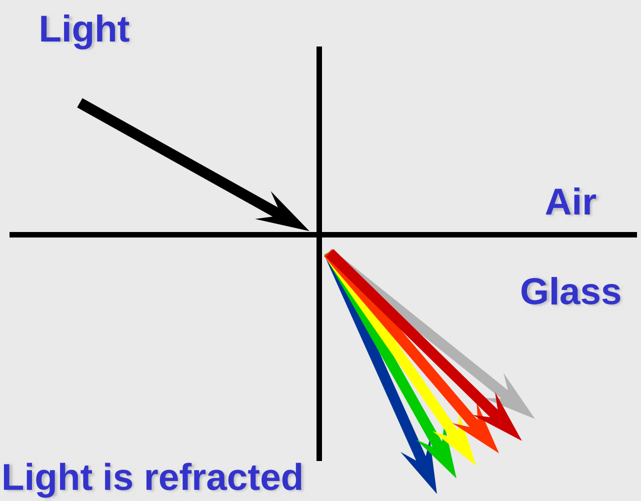
Reflection

Light reflects ***inside*** medium



Refraction

Light passes ***through*** medium boundary;



Total Internal Reflection

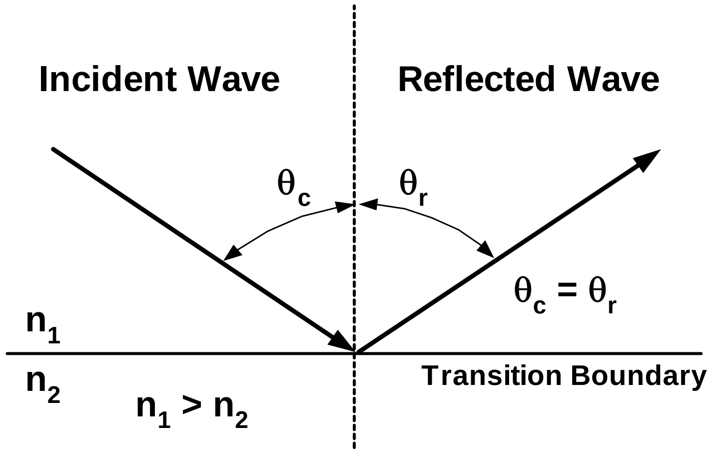
Beyond some maximum incident angle the ray of light cannot pass through the boundary of the two materials and the ray is completely reflected.

When the angle of incidence exceeds the maximum angle or Critical Angle, we have Total Internal Reflection.

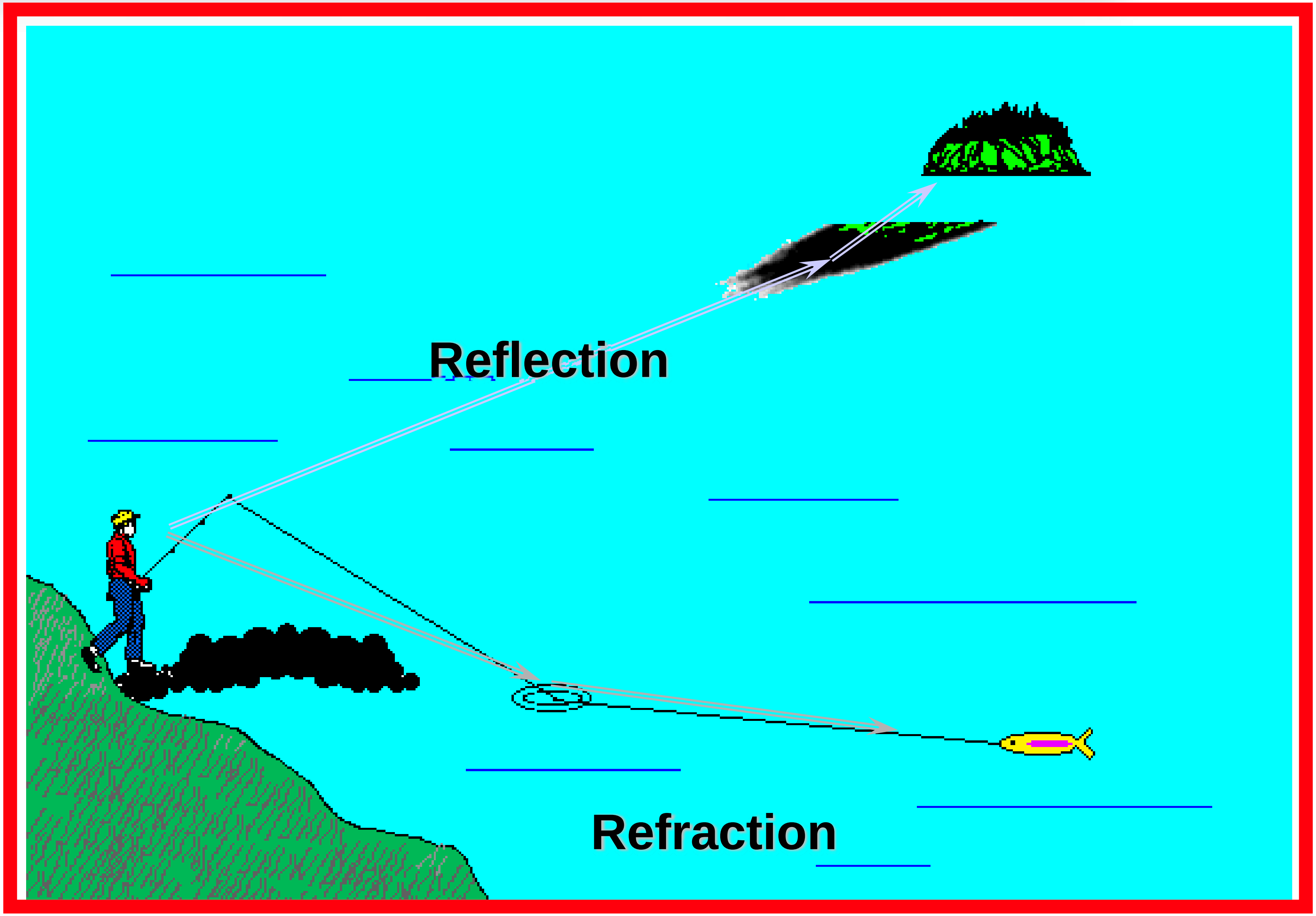
Total Internal Reflection is the property that allows fiber optic communication to occur.

Critical Angle

$$\sin\theta_C = \frac{n_2}{n_1}$$



Reflection - Refraction

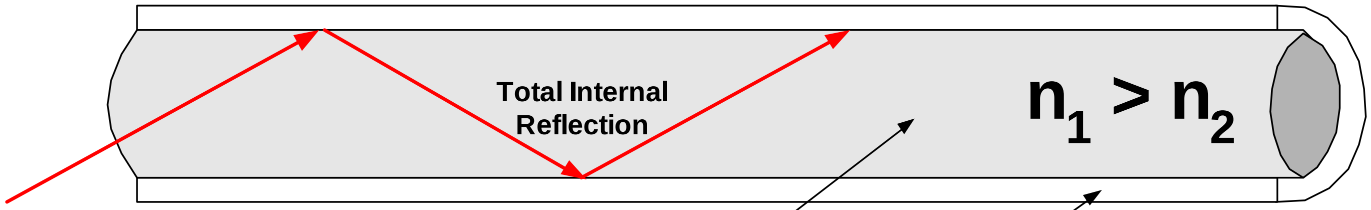


Reflection

Refraction

Fiber Construction

- Optical Fiber is a cylindrical waveguide made of a high purity fused silica.
- The core has a refractive index slightly higher than the cladding which allows the propagation of light via total internal reflection.
- A single-mode core diameter is typically 5-10μm.
- A multimode core diameter is typically over 100 μm.



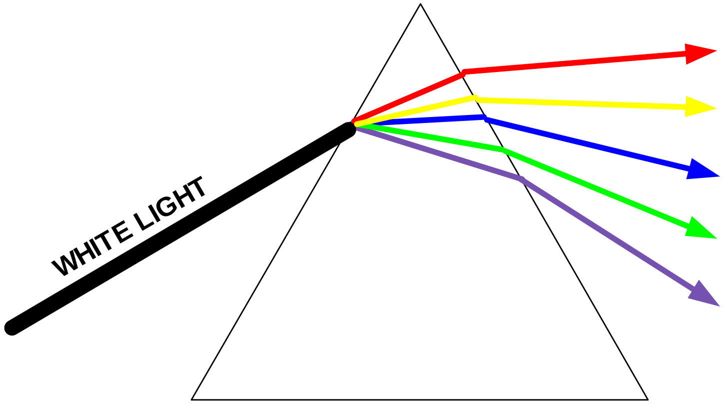
Index of Refraction

The index of refraction (n) is the ratio of the speed of light in a vacuum (c) to the speed of light in the material (v). This is written as: $n = c/v$

Simply, Index of Refraction is a relative measure of the propagation speed of the signal.

For a vacuum: n=1; Air: n=1.0003; Water: n=1.333

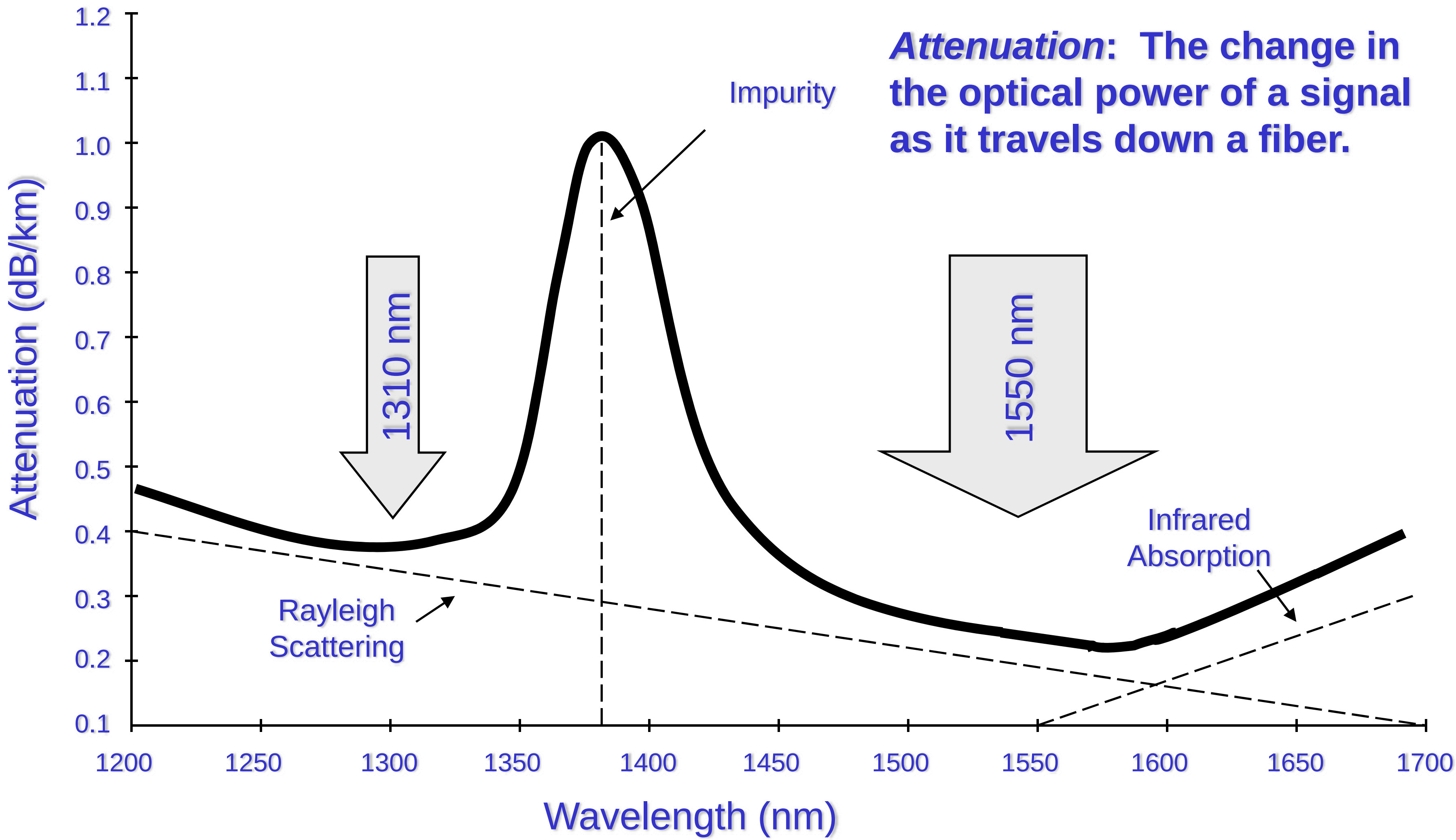
Also, different wavelengths have different indices of refraction. This is why a prism divides the visible colors of the spectrum.



Fiber Attenuation

- Just like Coax, fiber has different loss characteristics at different frequencies
- Unlike Coax, the higher 1550 region optical signals have less attenuation than at the lower 1310 region
- 1310nm loss is .35db per km
- 1550nm loss is .25db per km
- Splice loss is typically engineered at ___db per fusion splice and ___db per mechanical splice

Fiber Attenuation – Standard SMF



Attention: **The change in the optical power of a signal as it travels down a fiber.**

Dispersion

Chromatic Dispersion

- Different wavelengths travel at different speeds
- Causes spreading of the light pulse

Polarization Mode Dispersion

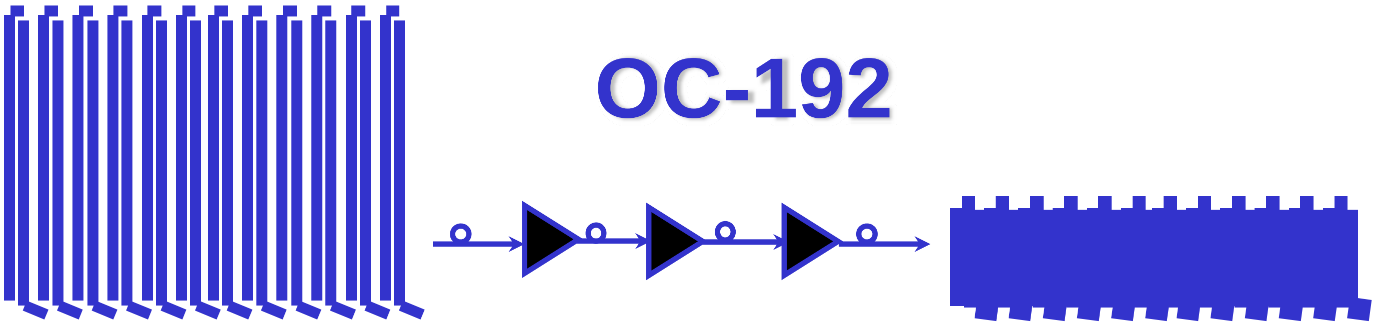
- Single mode fiber supports two polarization states
- Fast and Slow axes have different group velocities
- Causes spreading of the light pulse

Impacts of Speed on Dispersion

2.5 Billion times a second

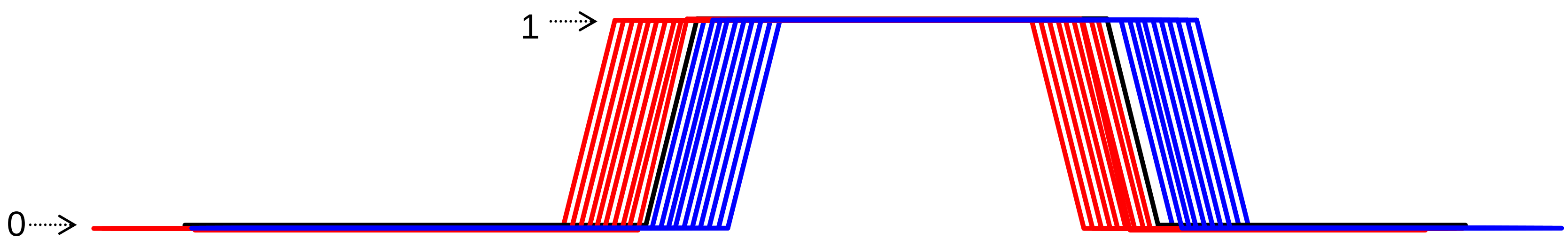
OC-48

10 Billion times a second



OC-192

Impacts of Dispersion

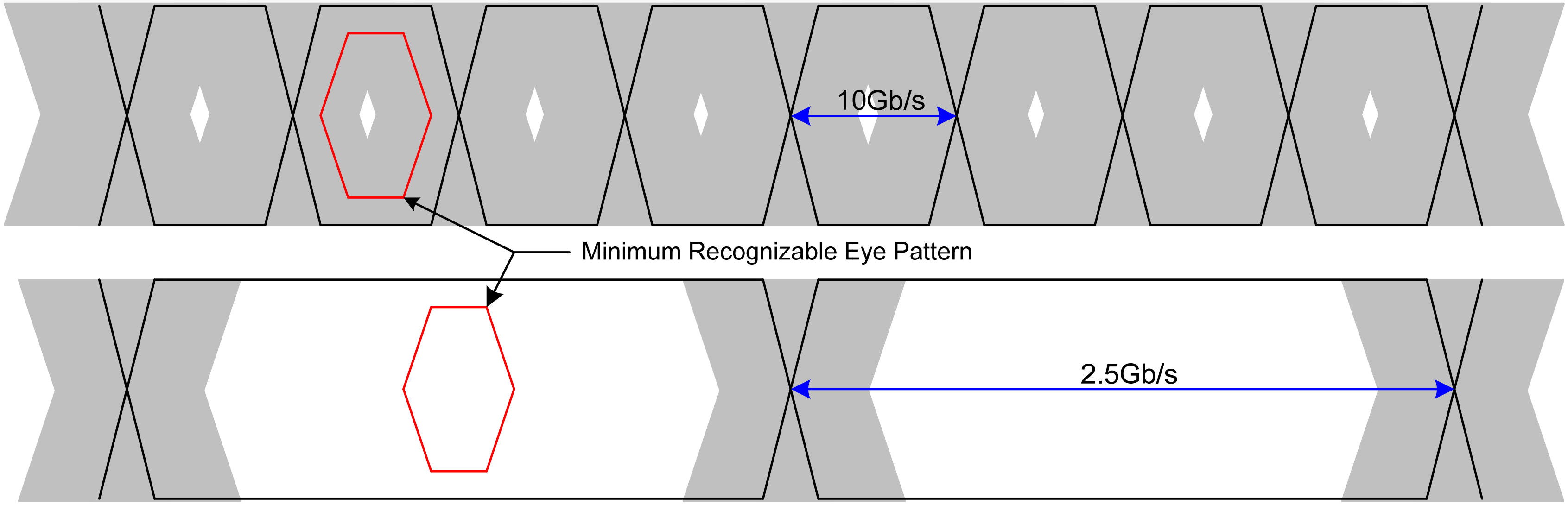


A normal undistorted pulse has a relatively well defined transition between high and low states, making it easy to determine a transition from one state to another.

Once a pulse has encountered the effects of dispersion, the transition between high and low states becomes much less defined as shown above.

When viewed through a data analyzer, the pulse now appears to be "smeared" along the horizontal (time) axis.

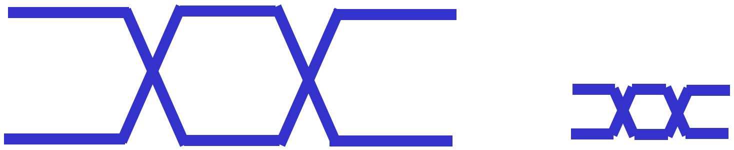
Data Speed and Dispersion



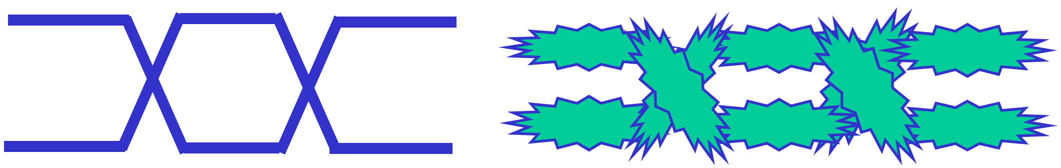
- The amount of transition edge "smearing" will be the same regardless of the data rate.
- However, the resultant signal quality caused by dispersion varies greatly with data rate.
- In the above example, the both 10Gb/s and 2.5Gb/s signals have propagated the same distance.
- A transition between high and low states is still distinguishable on the 2.5Gb/s signal, but not on the 10Gb/s signal.

Effects of Fiber on Digital Signals

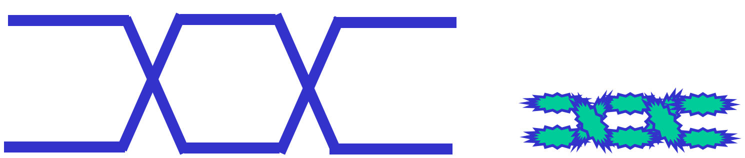
Attenuation: Power level erodes with distance



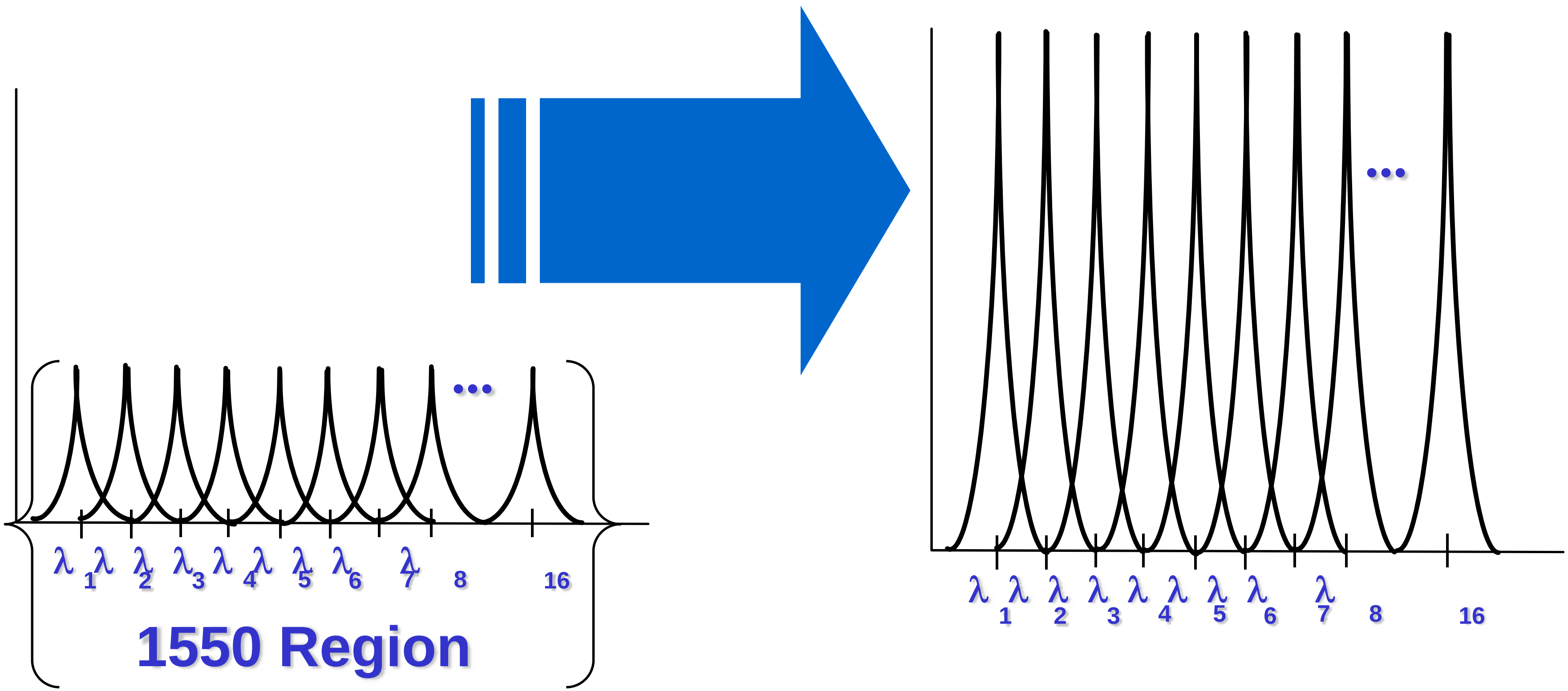
Dispersion: Clarity erodes with distance and speed



Combined effect:



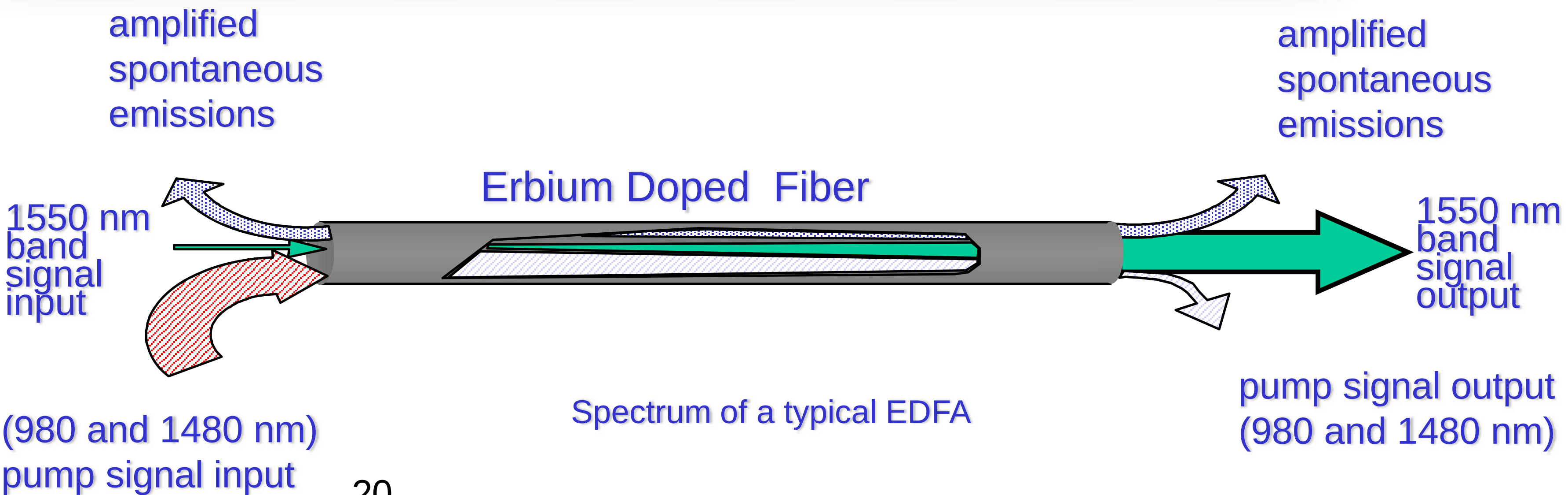
Optical Line Amplification



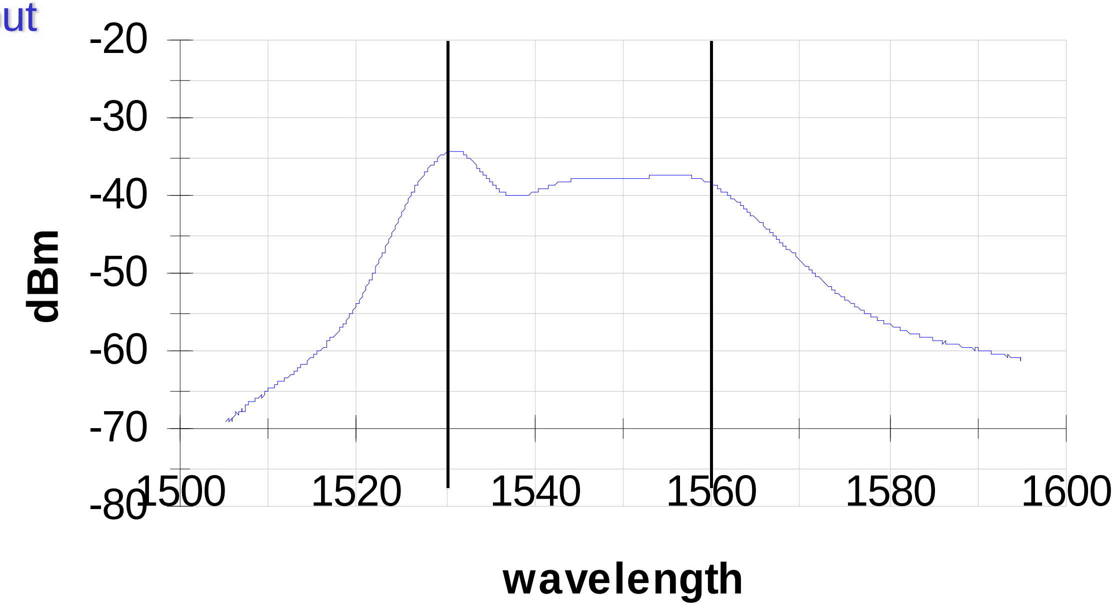
Attenuated Channels **Amplified Channels**

All Wavelengths Amplified with One Amplifier

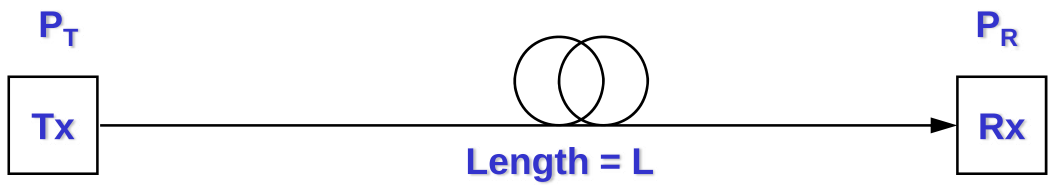
Optical Amplifier Architecture



Spectrum of a typical EDFA

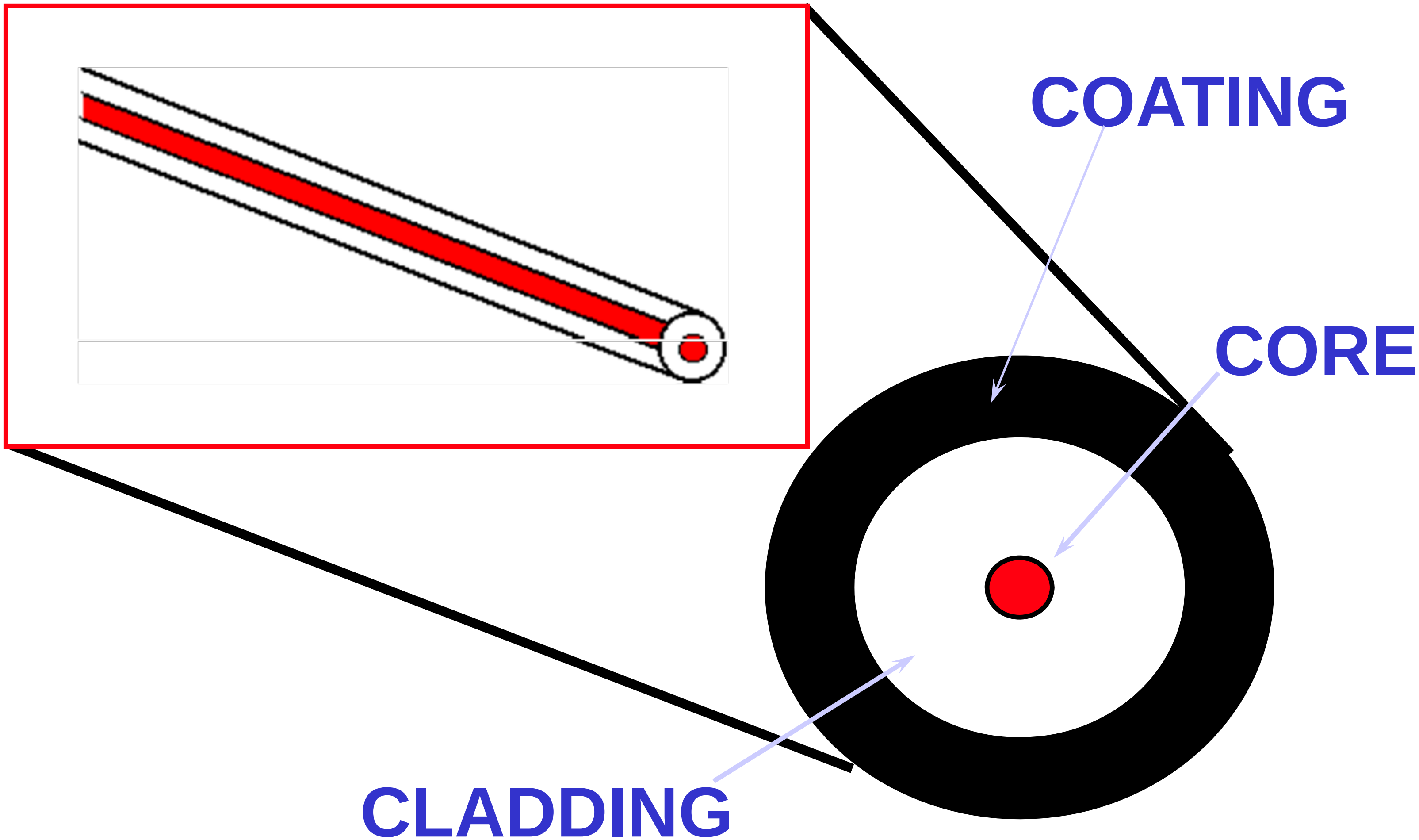


Span Loss (Power Budget)

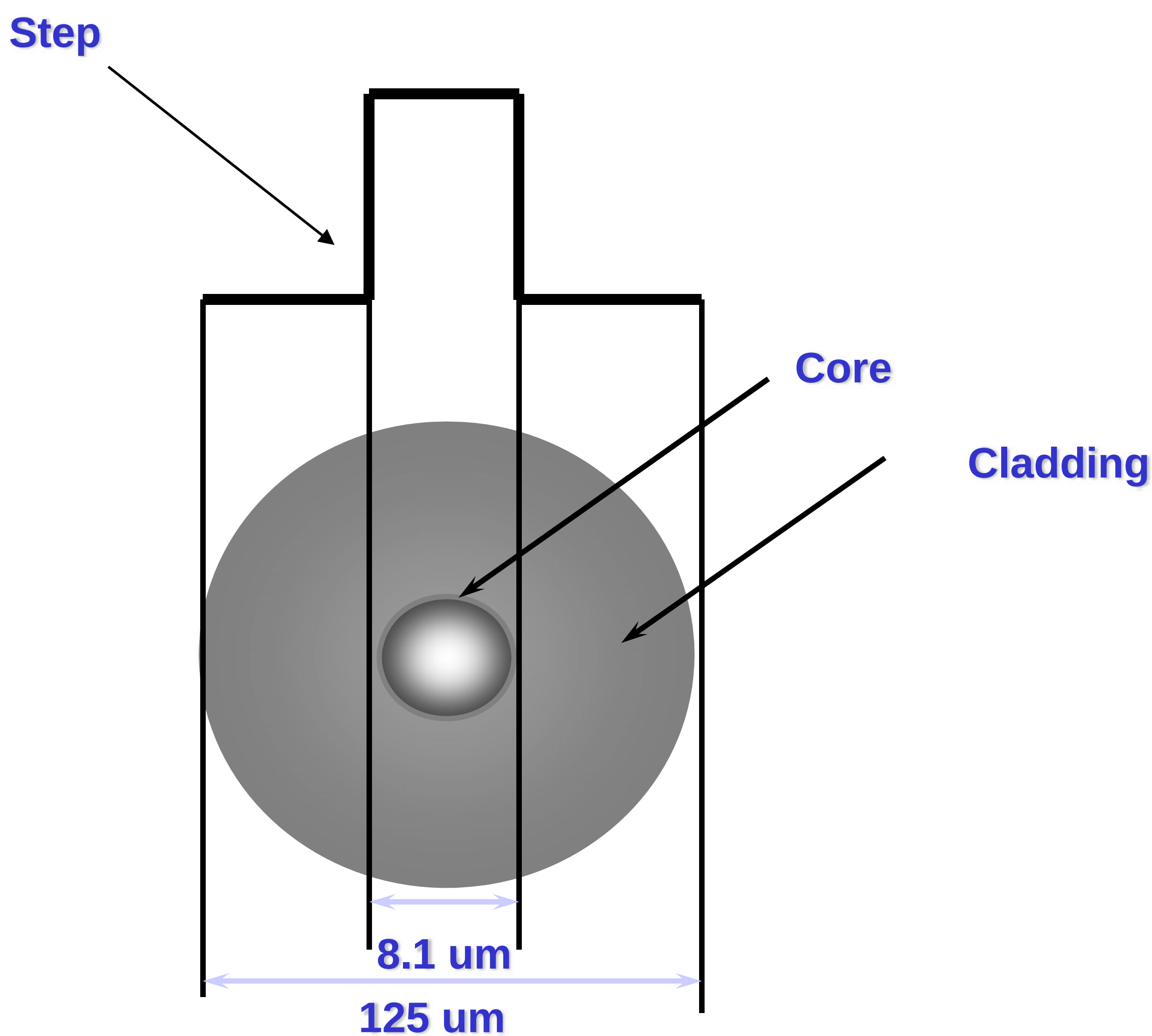


Transmitter power - Minus Fiber Loss = Equals Receiver Input

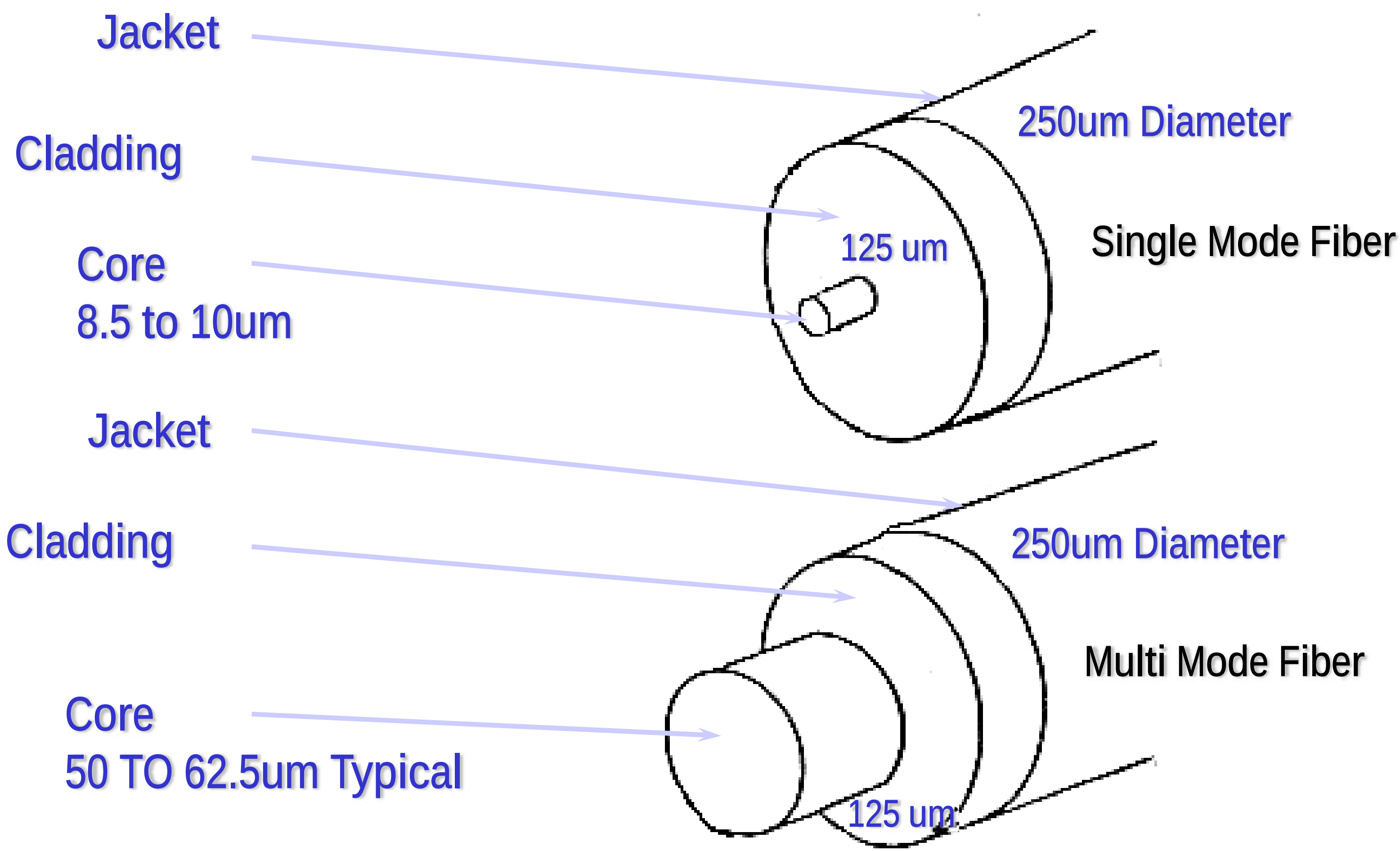
Optical Fiber - Construction



Single Mode Step Index



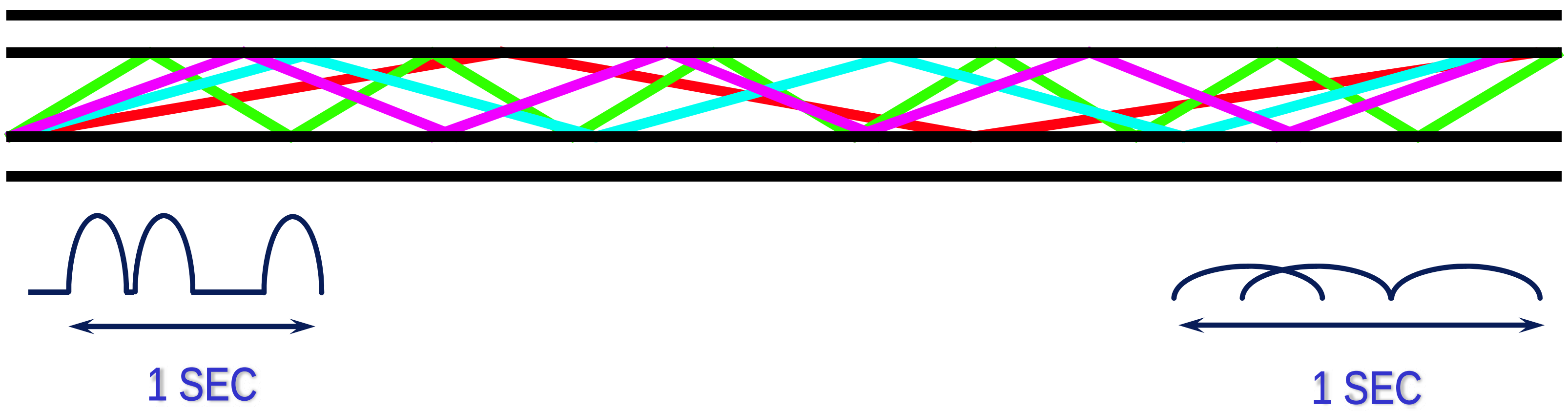
Types of Fibers



Multi Mode Fiber

Multimode - 850nm and 1300nm

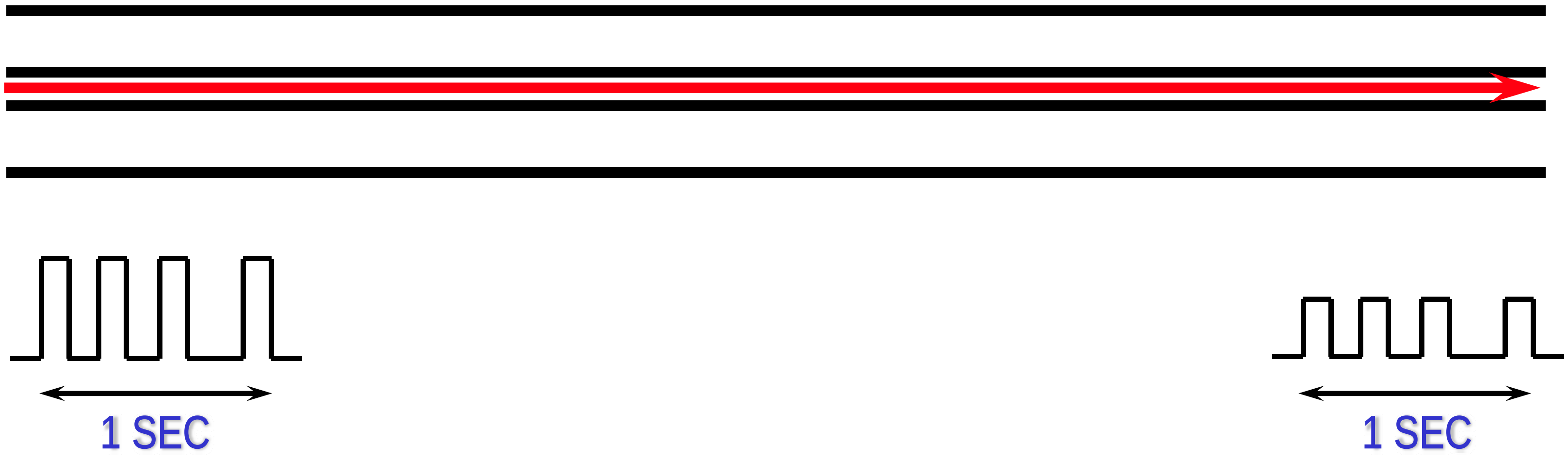
- Short haul - LAN, Low Speed Digital Networks



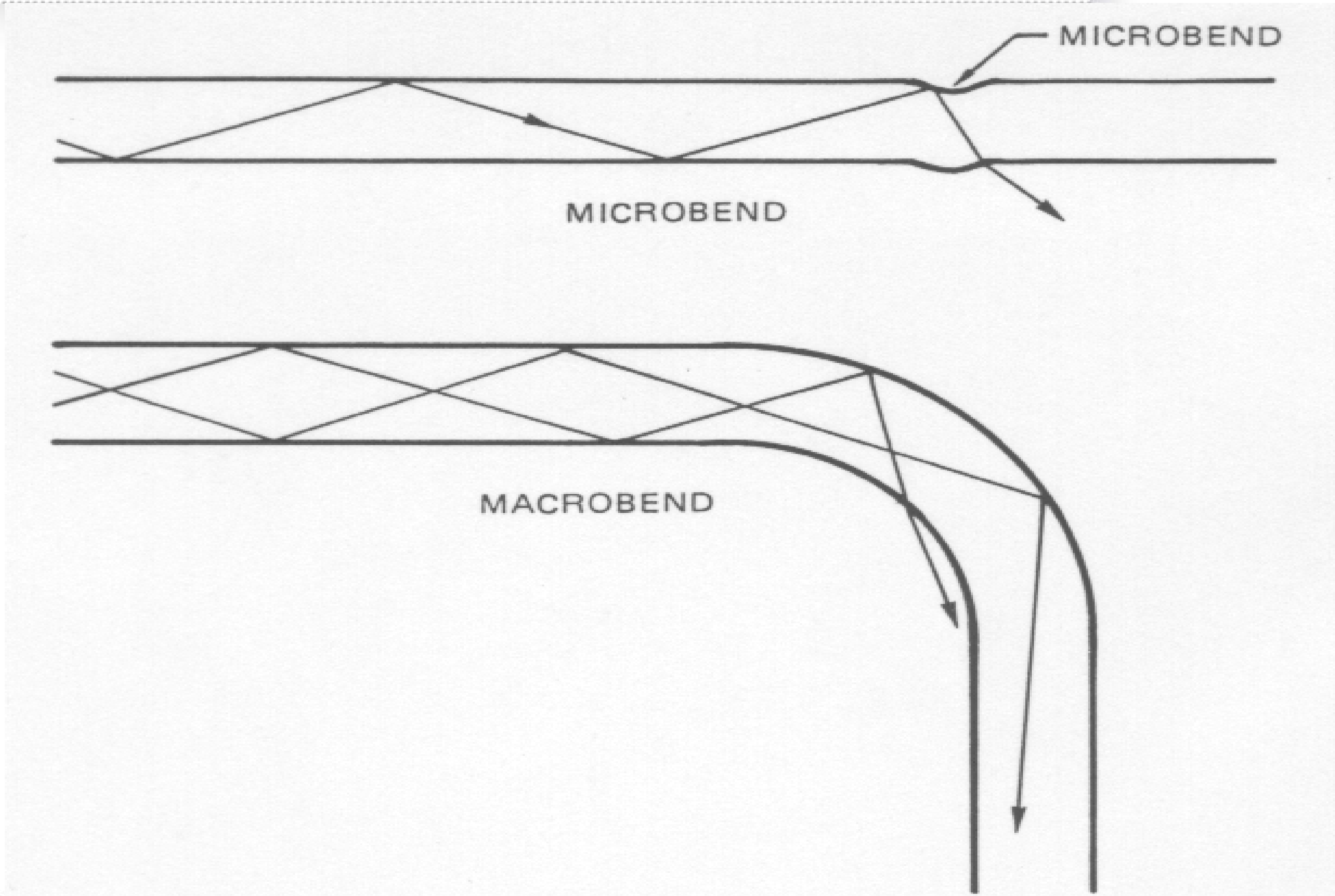
Single Mode Fiber

Singlemode - 1310nm and 1550nm

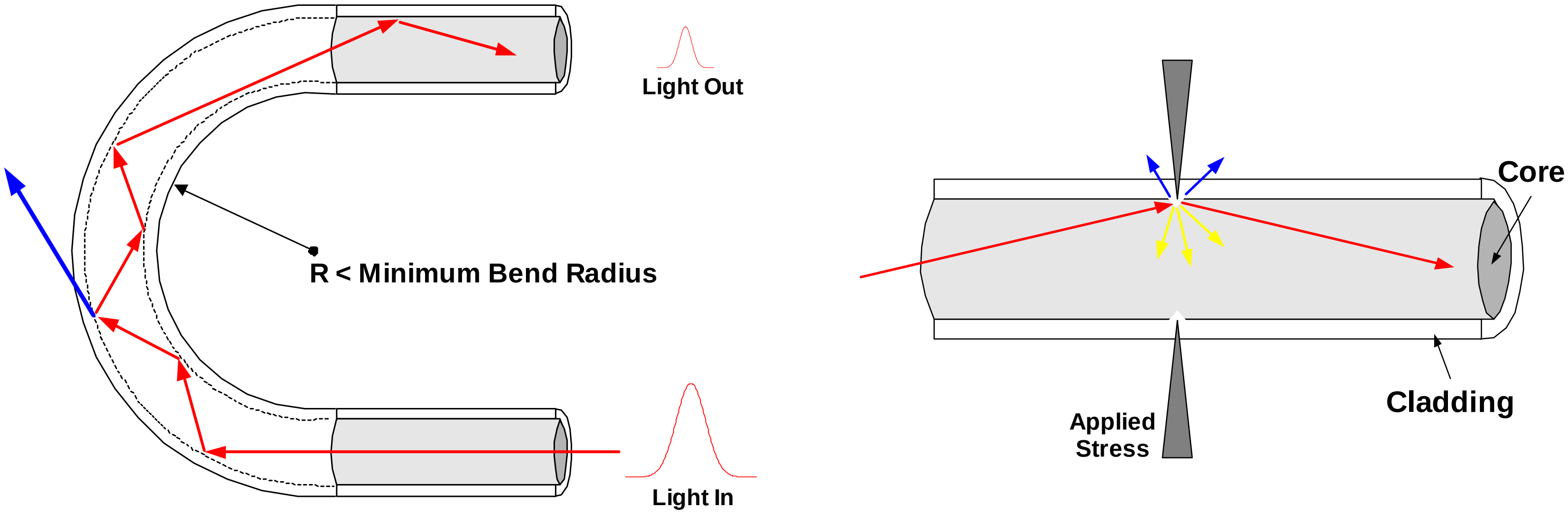
- Long haul - Telephone, CATV, High Speed Data Networks



Bends



Macro and Micro-bends



Macrobend refers to loss caused by bending the fiber beyond a minimum bend radius.

Microbend refers to small bends or minute deviations in the core/cladding interface

Attenuation

Scattering

Absorption

Microbends

Attenuation

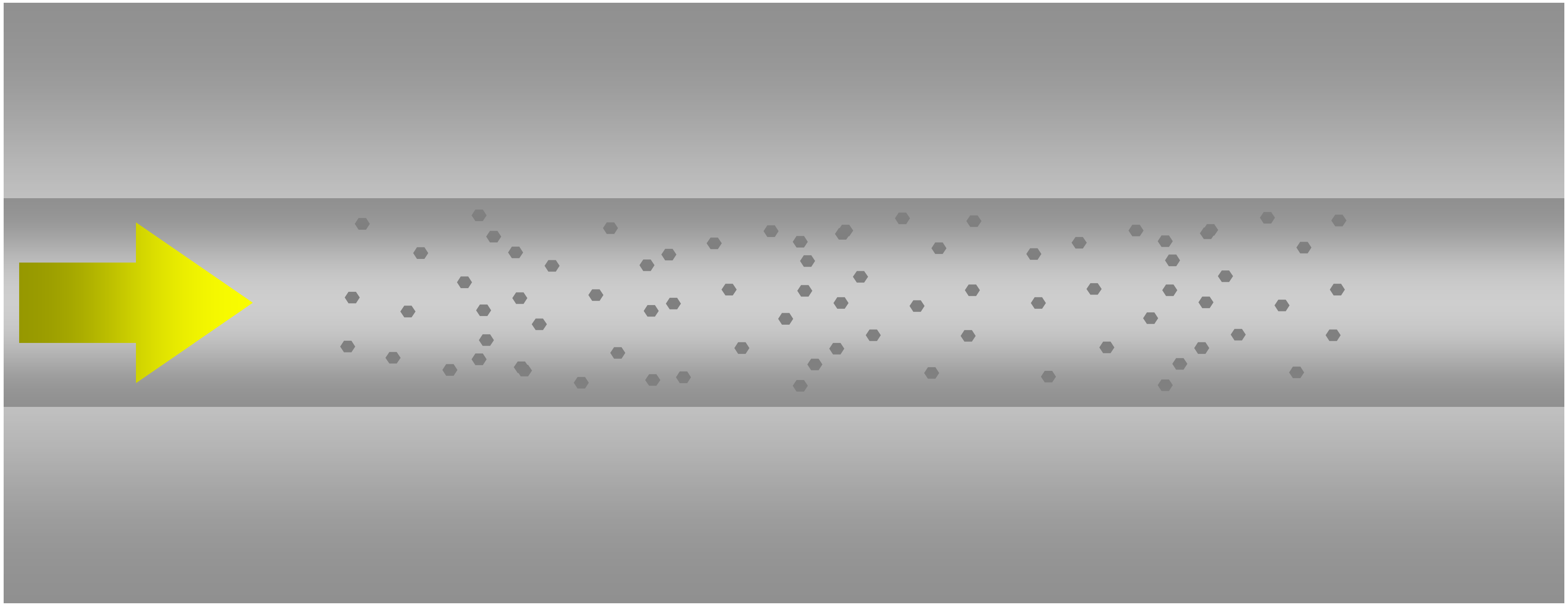
Scattering

- Loss of energy due to imperfections in the fiber
- Rayleigh Scattering
- Theoretical lower limits of attenuation
  - **0.24 dB at 1300 nm**
  - **0.012 dB at 1550 nm**

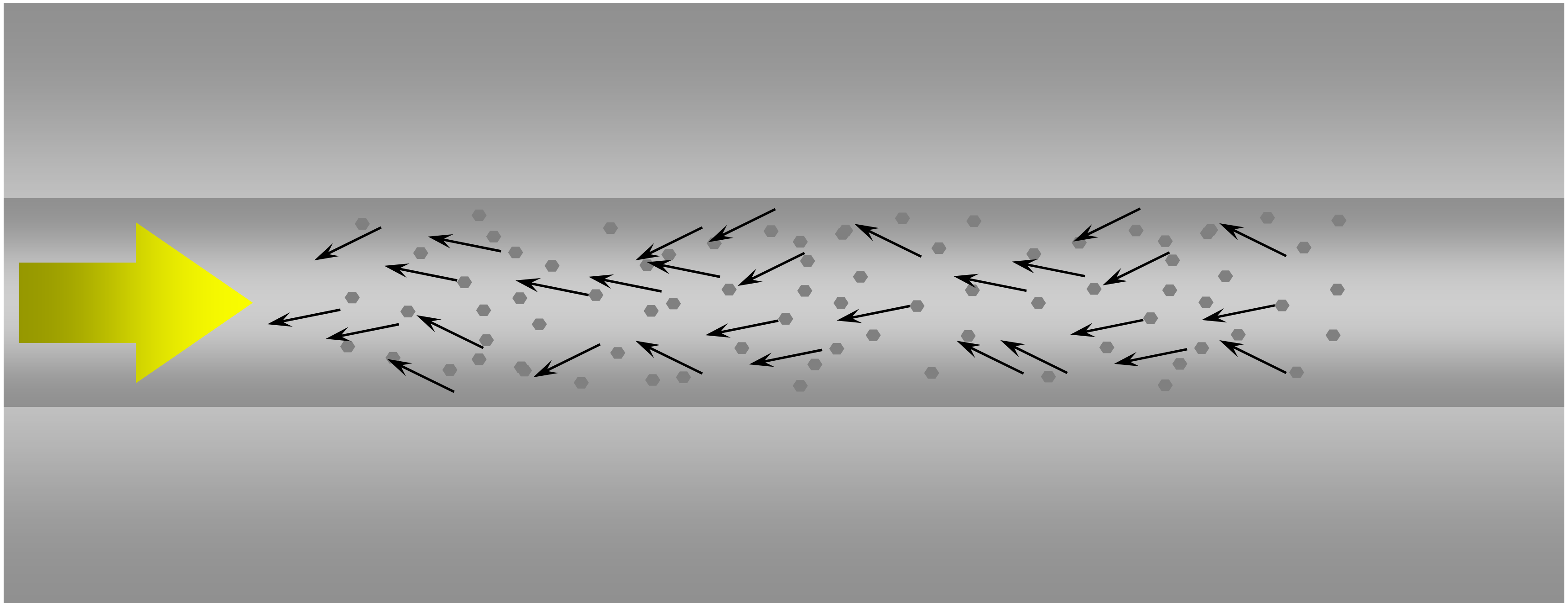
Engineering Rule for Attenuation:

- 1310nm - .35/km
- 1550nm - .25/km

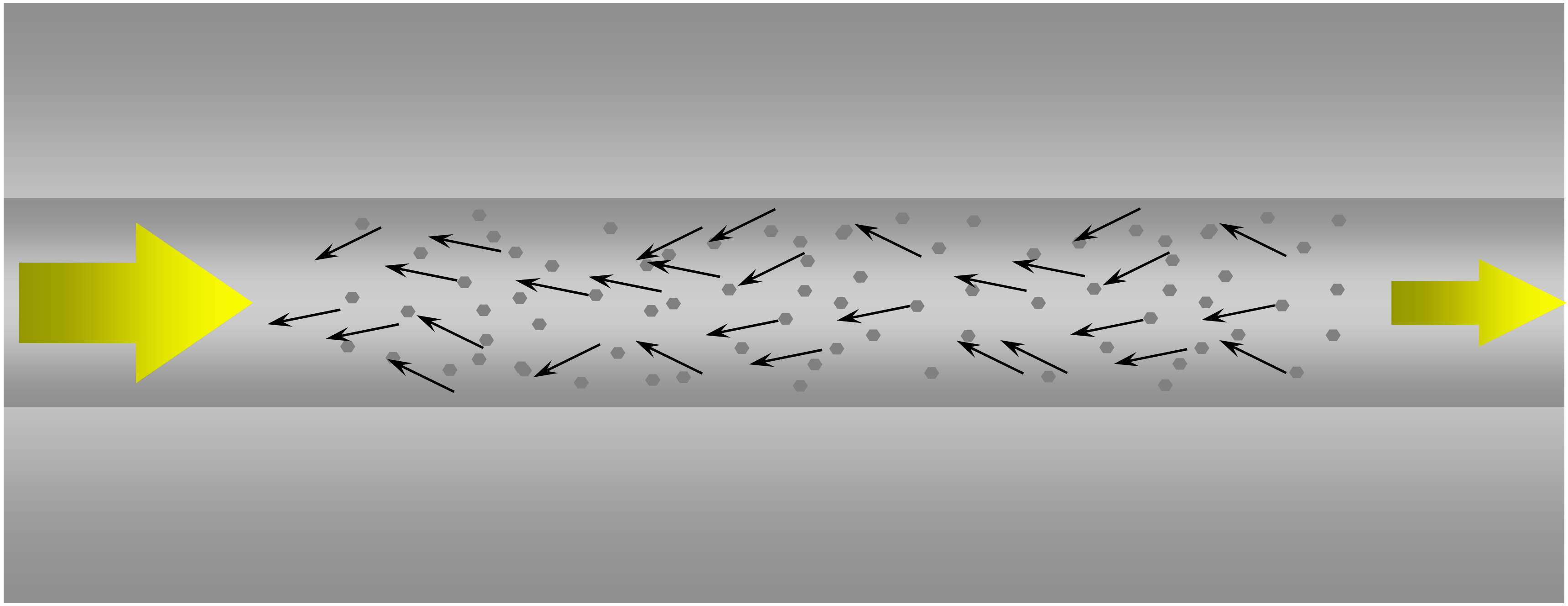
Scattering



Scattering



Scattering



Attenuation

Absorption

- Impurities absorb optical energy and dissipate it as small amounts of heat
  - Hydroxyl molecule, Ions of iron, copper, cobalt, vanadium and chromium
    - **Concentration < 1 part per billion**

Microbends

- Variation in core-to-cladding interface

Splicing

Fusion Splicing

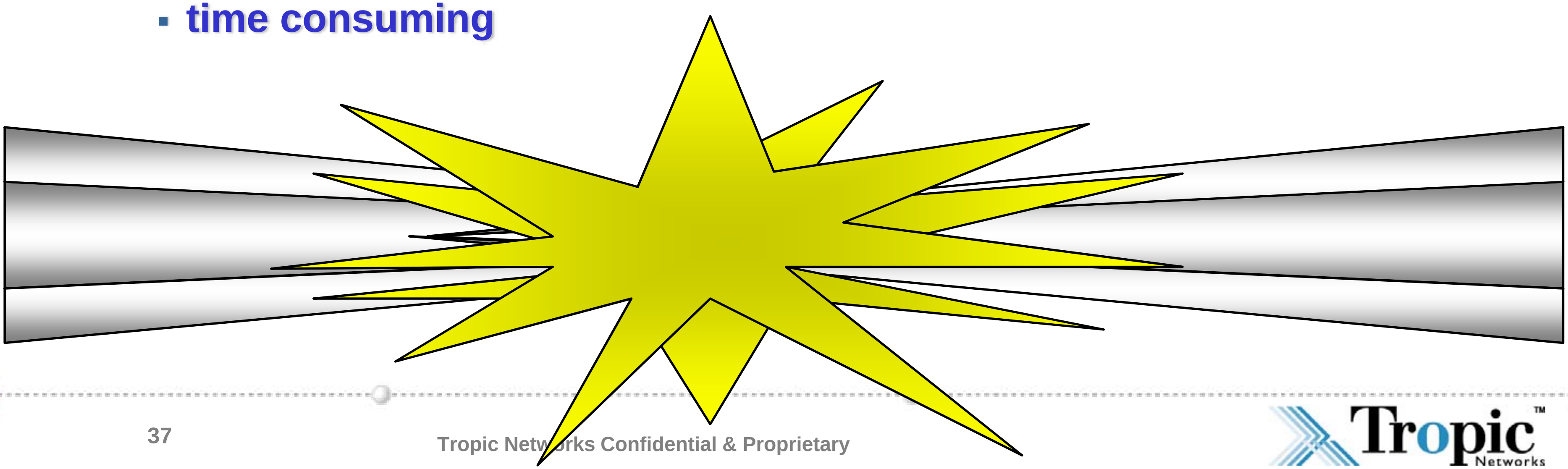
- **Fusing pieces of glass together**
- **losses 0.02 typical**

Mass Fusion Splicing

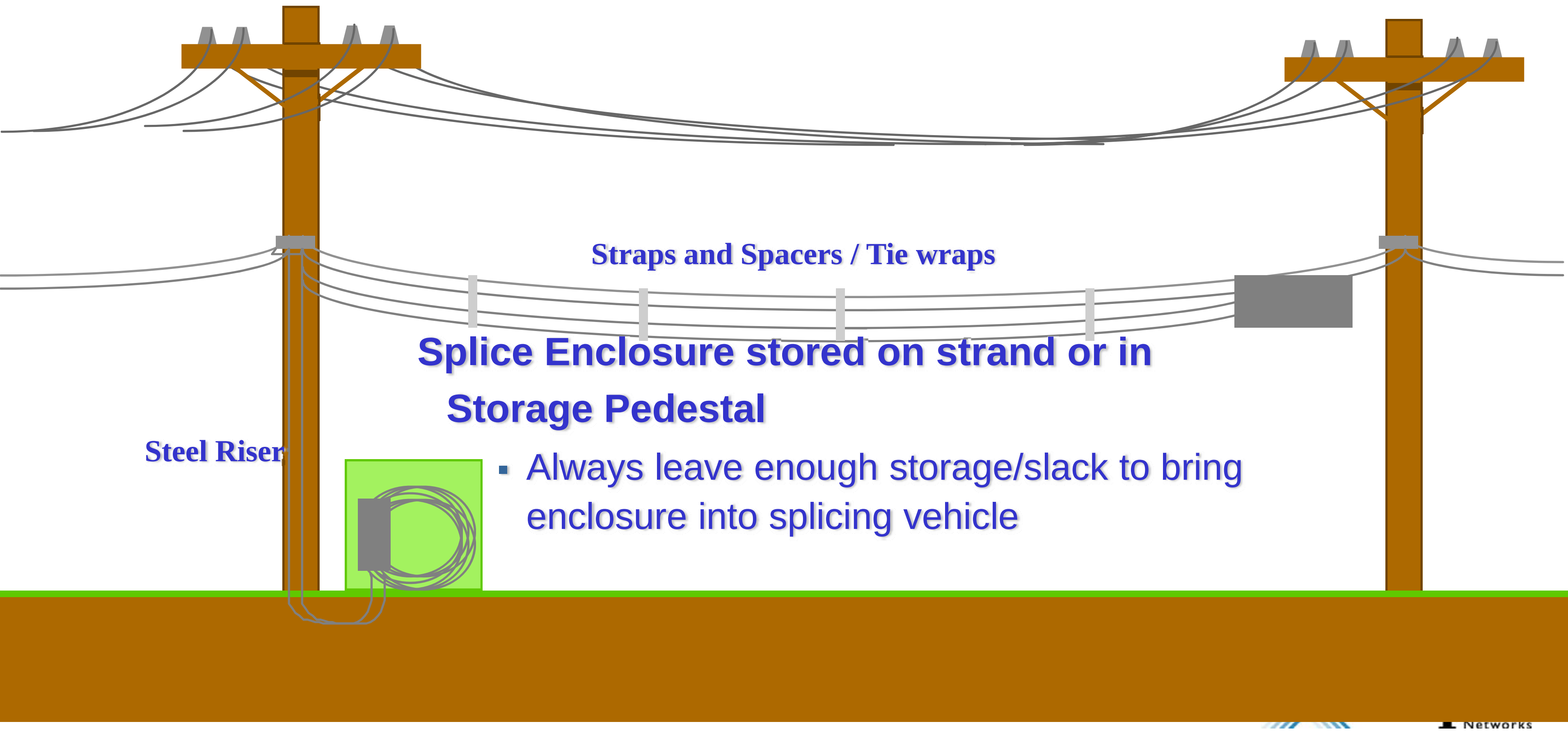
- **Fusing 12 to 16 fibers at one time**
- **Losses 0.04 typical**

Mechanical Splices

- **CSL, RMS, others (vendor specific)**
- **reflective & losses 0.1 typical**
- **time consuming**



Aerial Plant Splicing



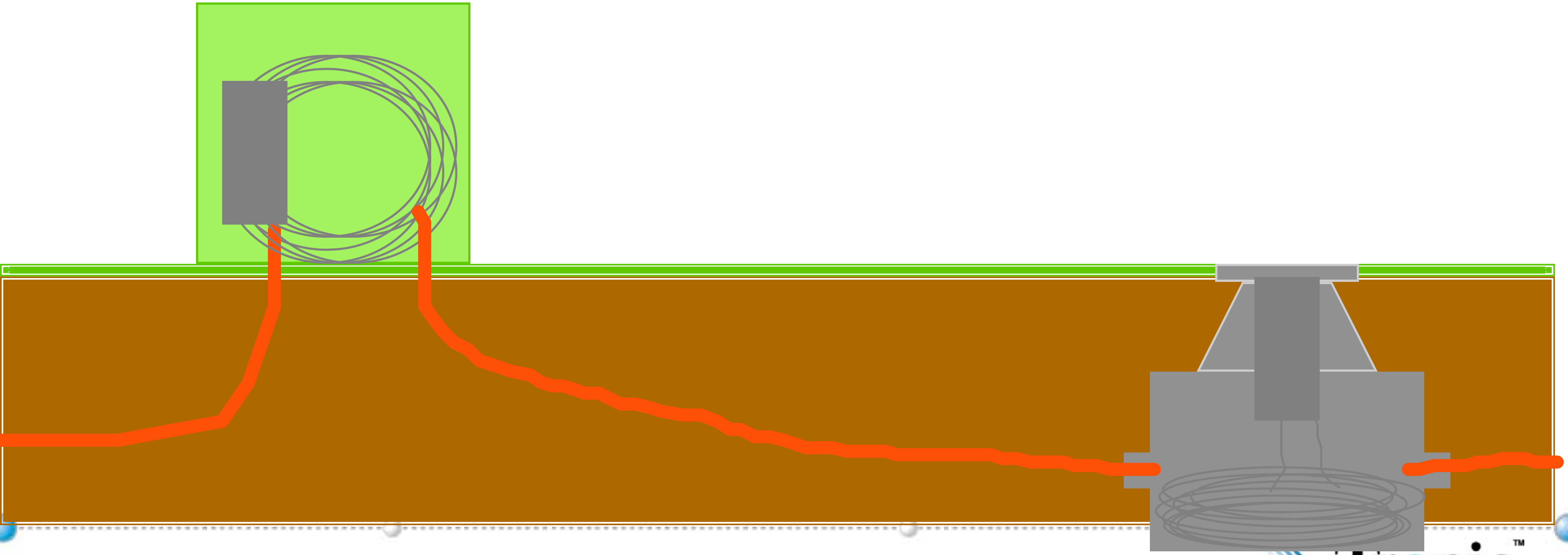
Splice Enclosure stored on strand or in Storage Pedestal

- Always leave enough storage/slack to bring enclosure into splicing vehicle

Underground Plant Splicing

Storage Pedestals or Storage Vaults

- Leave enough slack to move splice enclosure into vehicle



Record Keeping

Maps

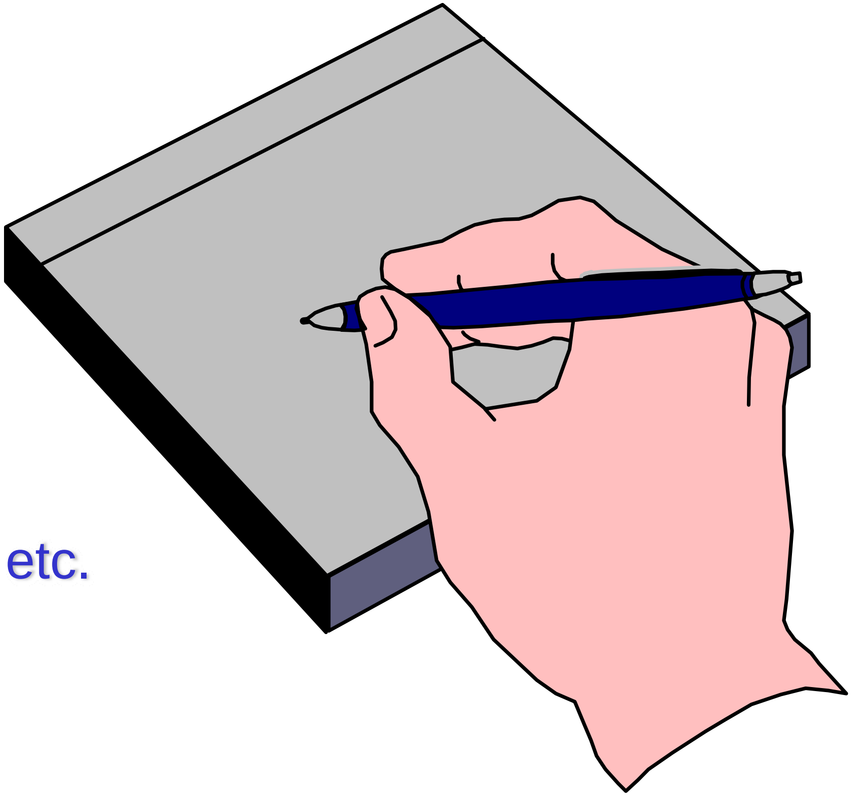
Cable Routing

- Splice Locations
  - Color Codes
- Link Characteristics
  - Lengths & Losses

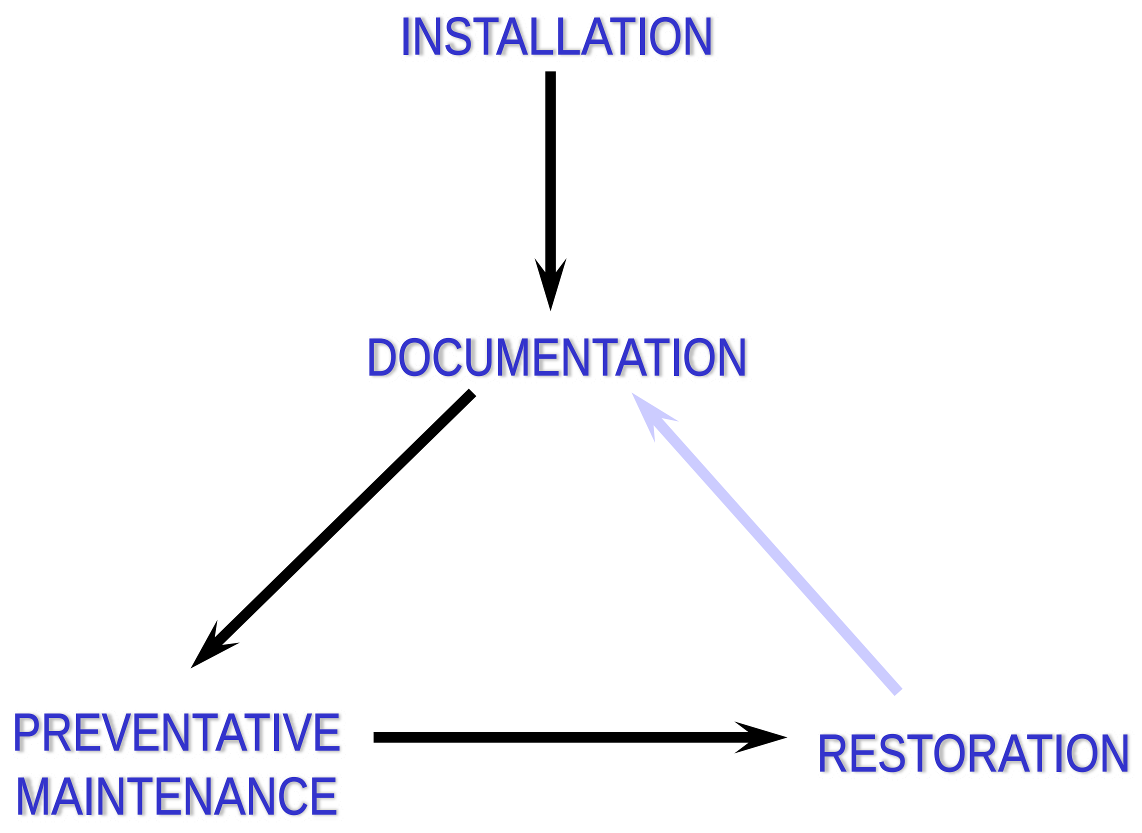
OTDR Traces

Special Forms

- Splicing form, Active fiber list, etc.



Documentation Flowchart



Basics of Restoration

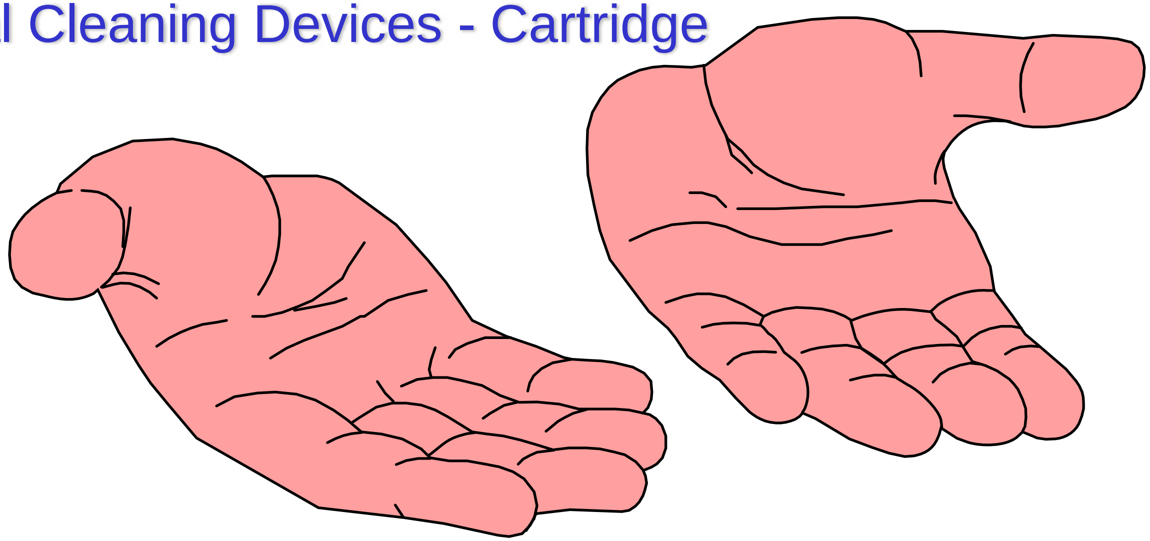
1) Documentation
2) Have a plan
3) Find what went wrong
4) Find the problem
5) Restoration
6) Permanent Repair Kit
7) Prepare for the next cut

Cleaning Connectors

Clean Every Time Exposed to Air

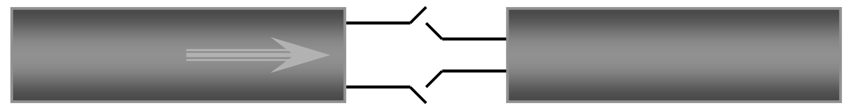
Cleaning Materials

- Lint Free Swab @ Alcohol
- Lens Tissue
- Special Cleaning Devices - Cartridge

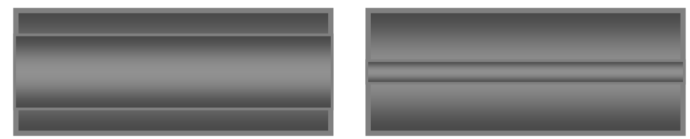


Connectors and Splices

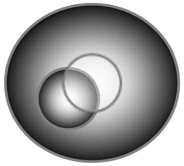
Core size Mismatch



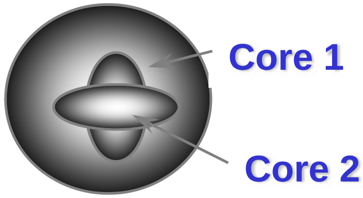
Core Diameter Mismatch



Concentricity



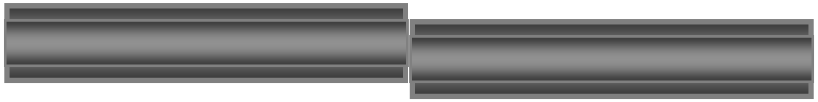
Ellipticity (ovality)



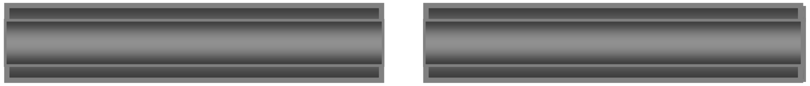
Connectors and Splices

Four Main Causes of Loss in a Connector or Splice

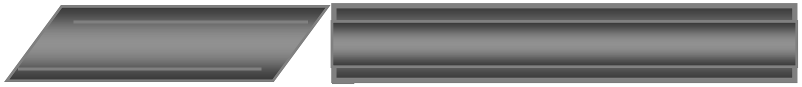
Lateral Displacement



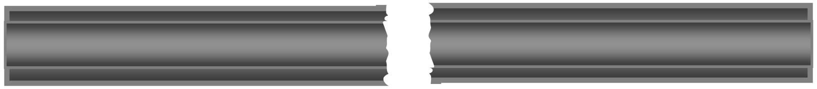
End Separation



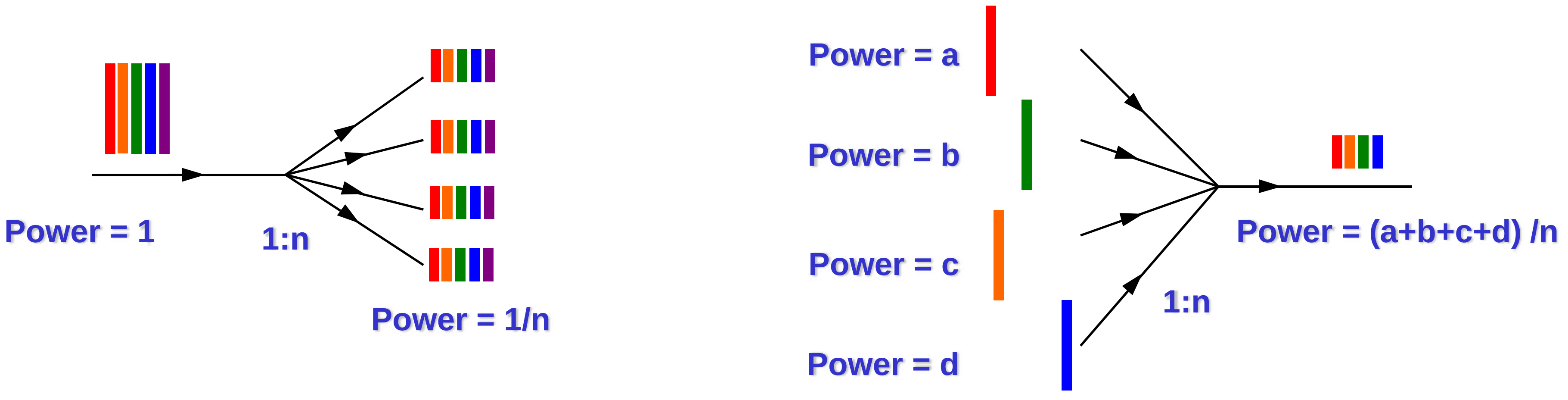
Angular Misalignment



Surface Roughness



Power Combiner / Splitter



1:n splitter **n:1 combiner**

Splitter and combiner are the same device.

They are wavelength agnostic.

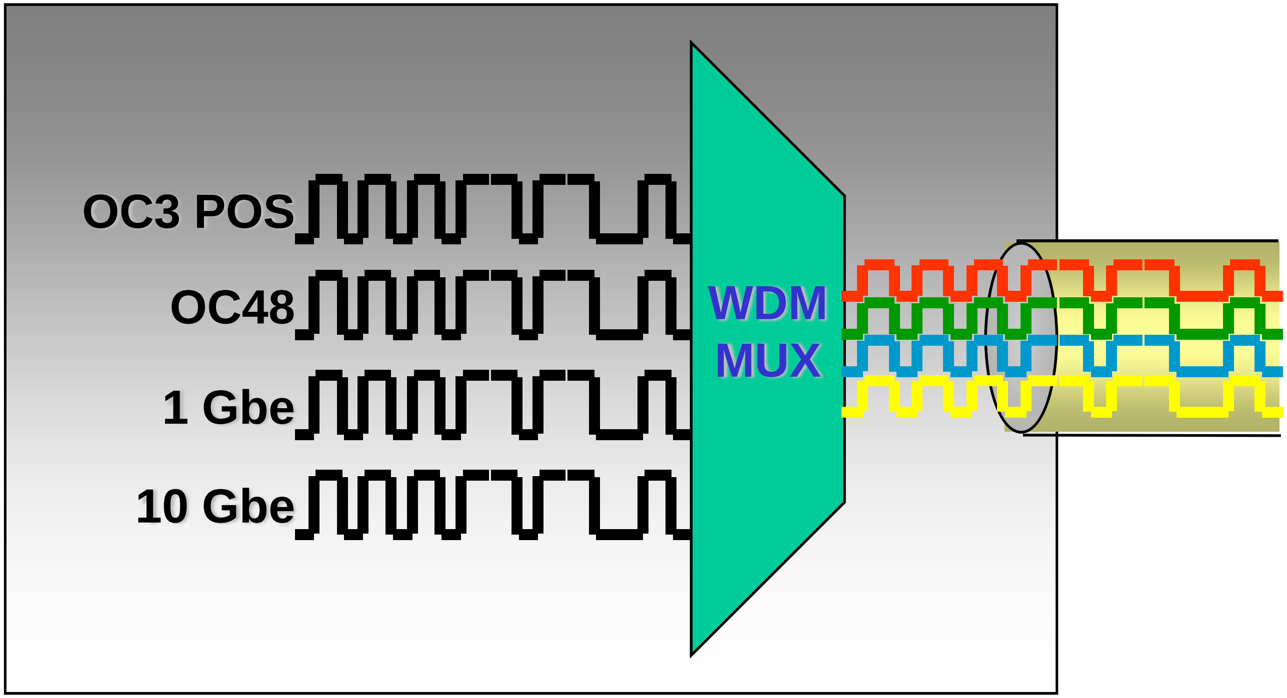
- Any wavelength can go to any port and any port can be multi-wavelength.

The power loss is the same whether it is used as a combiner or splitter.

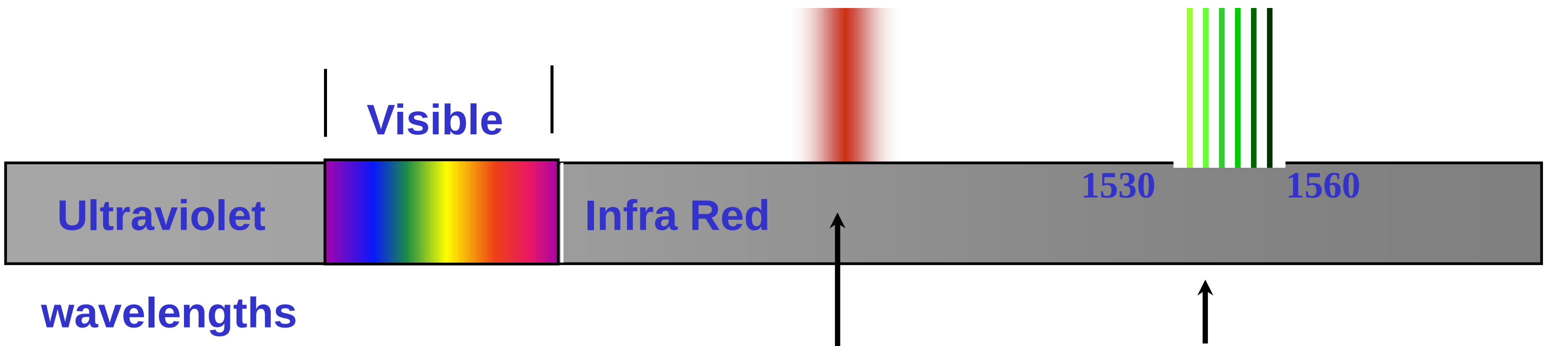
- There is no such thing as wavelength agnostic and lossless combiner.
- Ideal loss 1/n. Add 0.5 dB insertion loss for connectors and splicing.

Wave Division Multiplexing

Dense Wave Division Multiplexing



Wavelengths of Light



1550 nm Region

- Light travels farther than at 1310
- Components are more expensive
- Used mostly for long distance

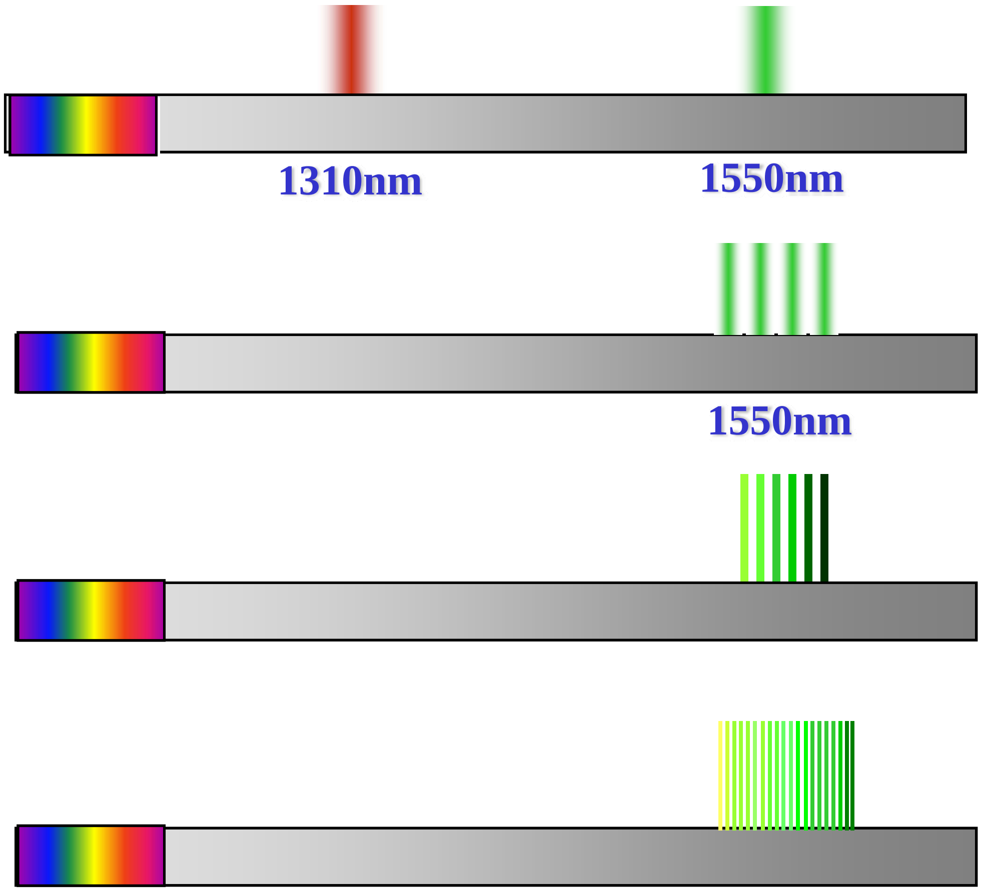
- Light travels farther in fiber at certain wavelengths
- Those wavelengths are used for transmission systems

1310 nanometers

- Used extensively for metropolitan area systems and analog video transport

- DWDM - Between 1530 and 1560
- Wavelengths must be very specific
- Extra components needed to “lock” wavelengths to specific color

Evolution of DWDM Systems



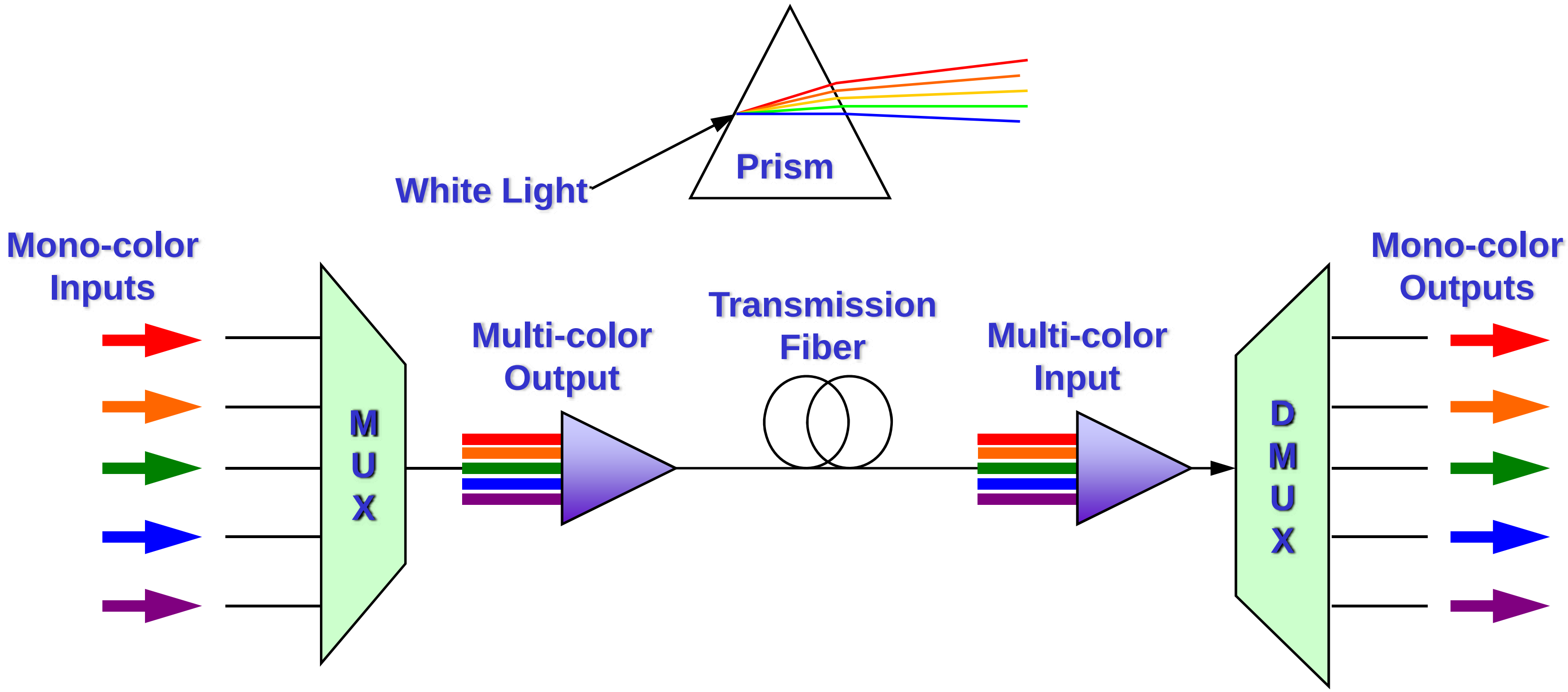
Early WDM – one 1310 and one 1550 channel

2nd Generation – 2-4 Windows, 400+ Ghz spacing with 1 carrier per window

Dense WDM – 20 - 40 Windows, 100-200 Ghz spacing with 1 carrier per window

Next Gen DWDM – Windows, 50 Ghz spacing with as many as 4 carriers per window

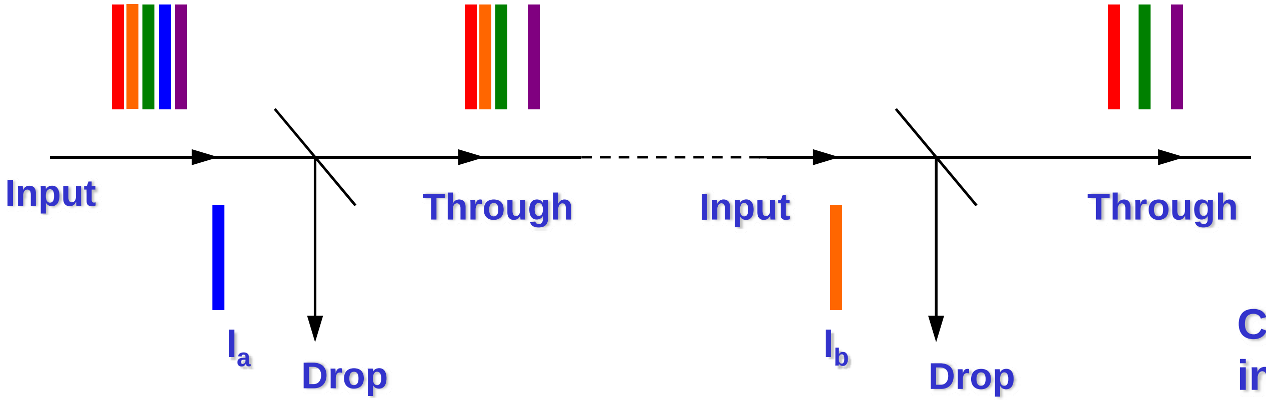
Wavelength MUX / DMUX



- Works like a prism
- Each port has an associated wavelength which is fixed.
- Same device can be both MUX/DMUX
- Theoretically can be lossless. In actuality, insertion loss increases with port count.

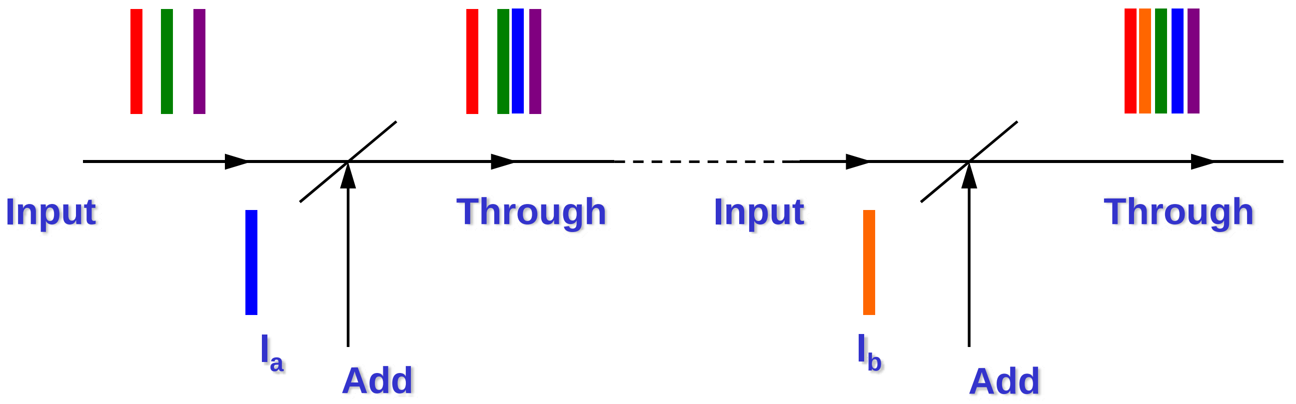
Wavelength Add/Drop Multiplexer

Drop

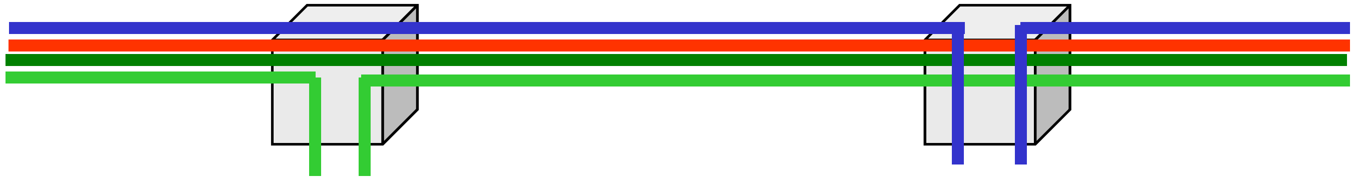


Can be cascaded, insertion loss increases with cascade.

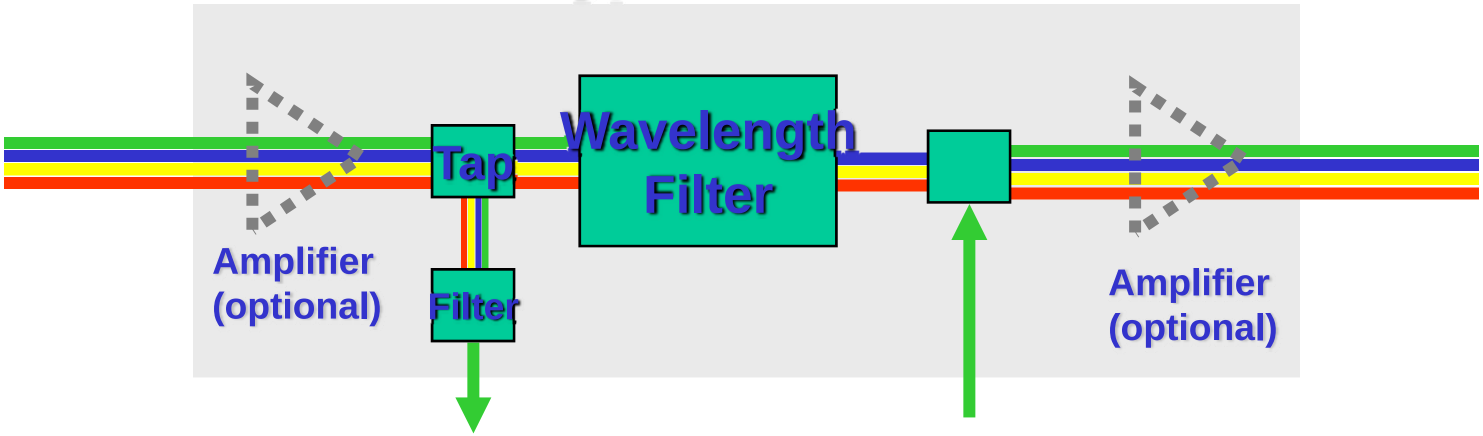
Add



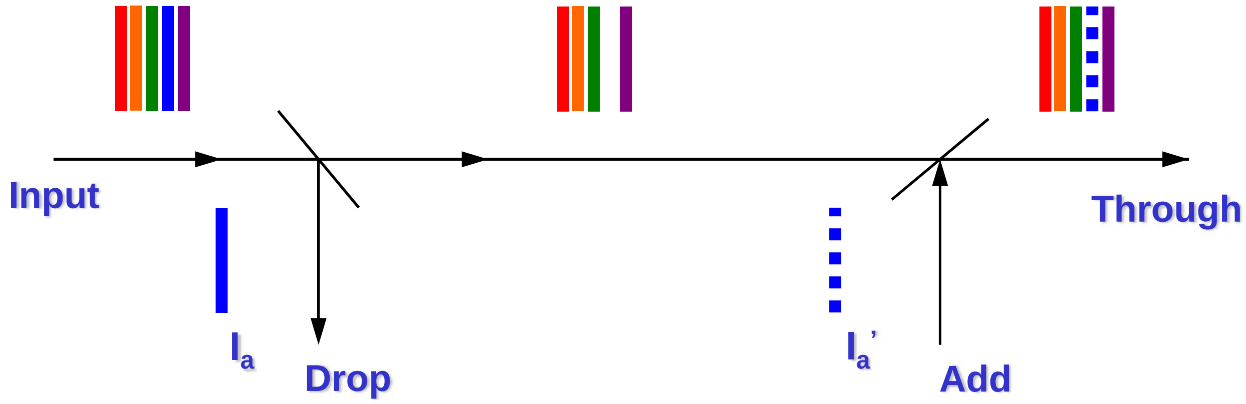
Wavelength Add/Drop Multiplexer



Typical OADM



Wavelength Add/Drop Multiplexer

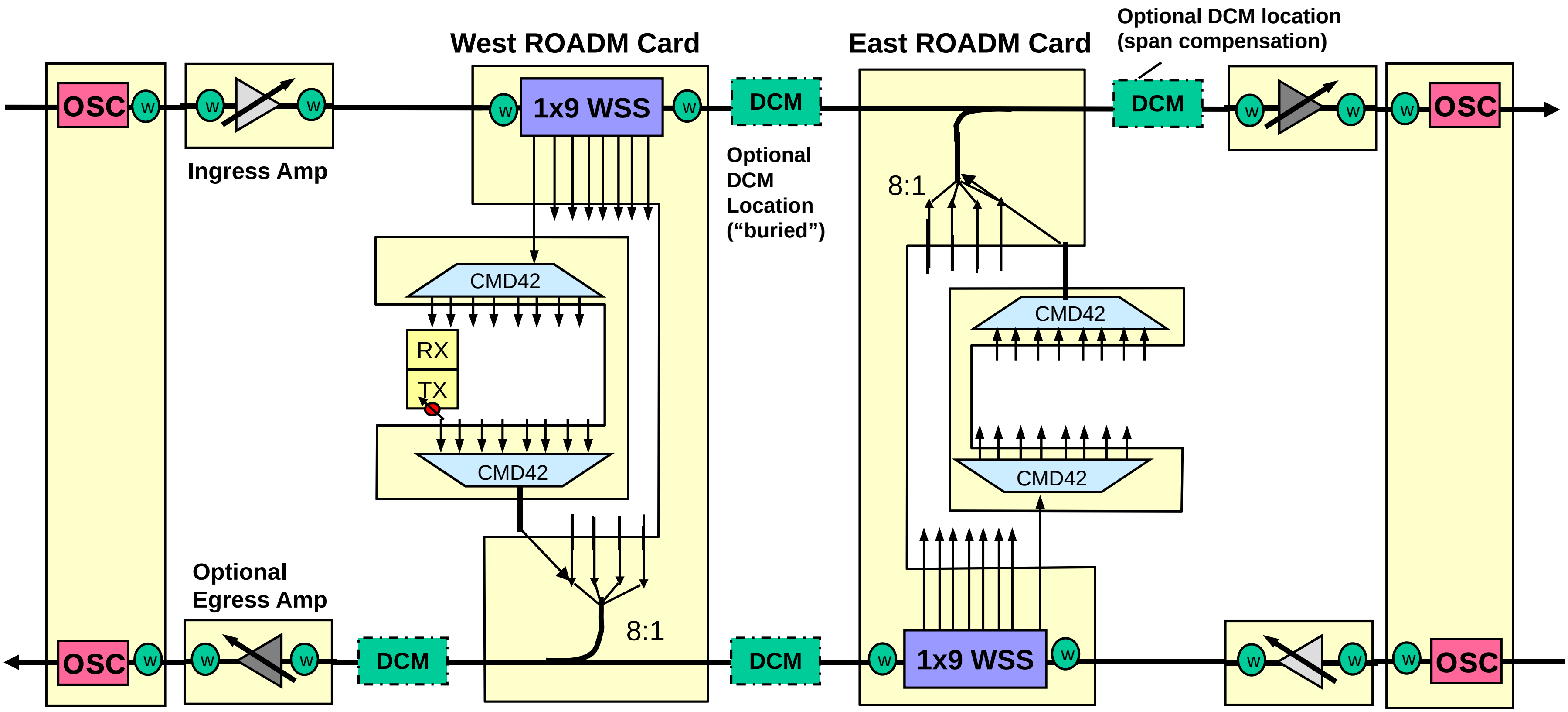


- Same dropped wavelength can be added back to the system (i.e. reuse), except carrying a different traffic signal.
- A wavelength filter is the same as an add/drop multiplexer with only the input and drop ports.

What is a ROADM?

- **Reconfigurable Optical Infrastructure Component**
- **Add / Drop / Pass / Null control of every lambda**
- **Power Level control of every lambda**
- **Optical Switching Fabric**
- **Eliminates stranded bandwidth** **(no optical banding at nodes)**

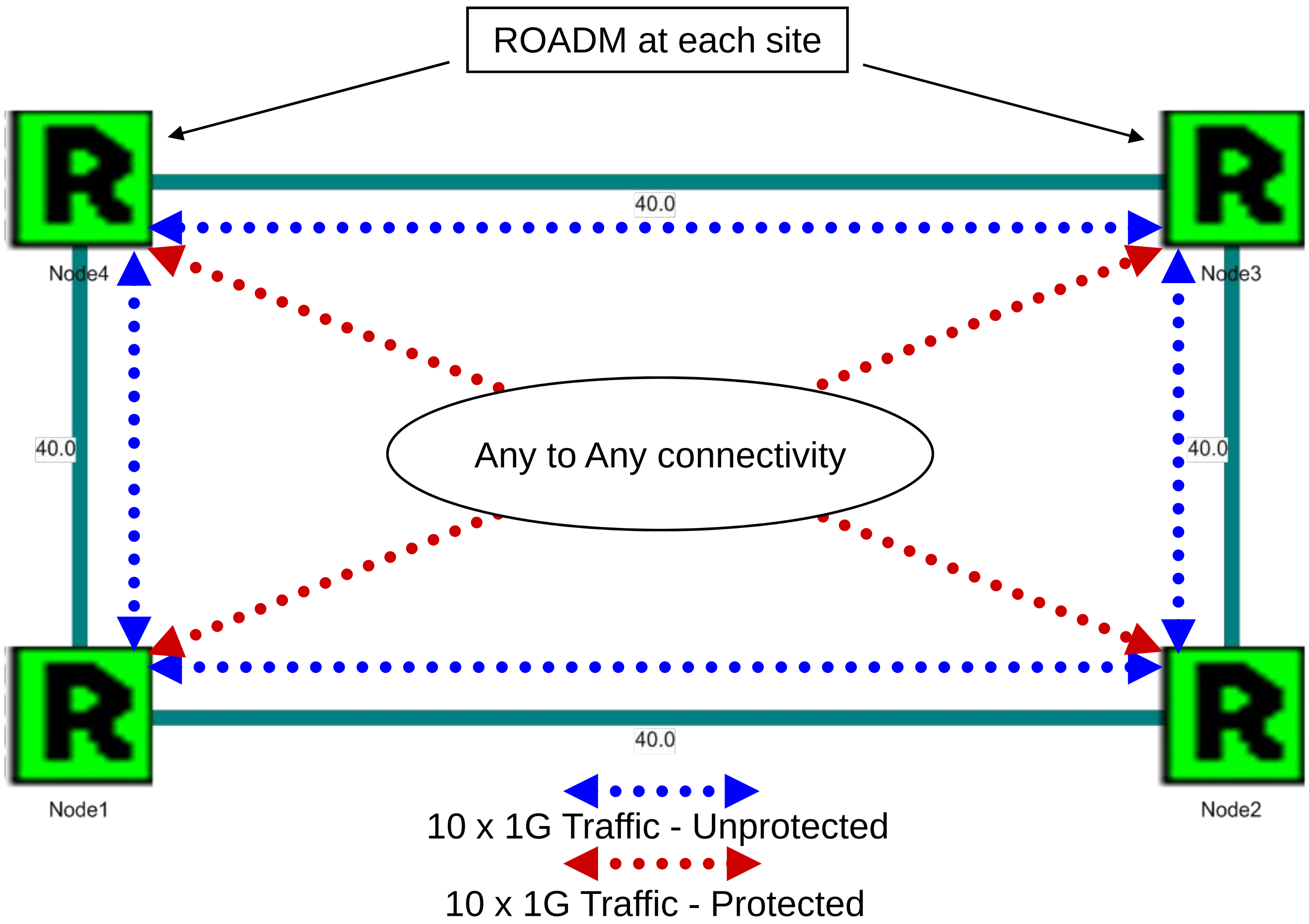
ROADM Block Diagram



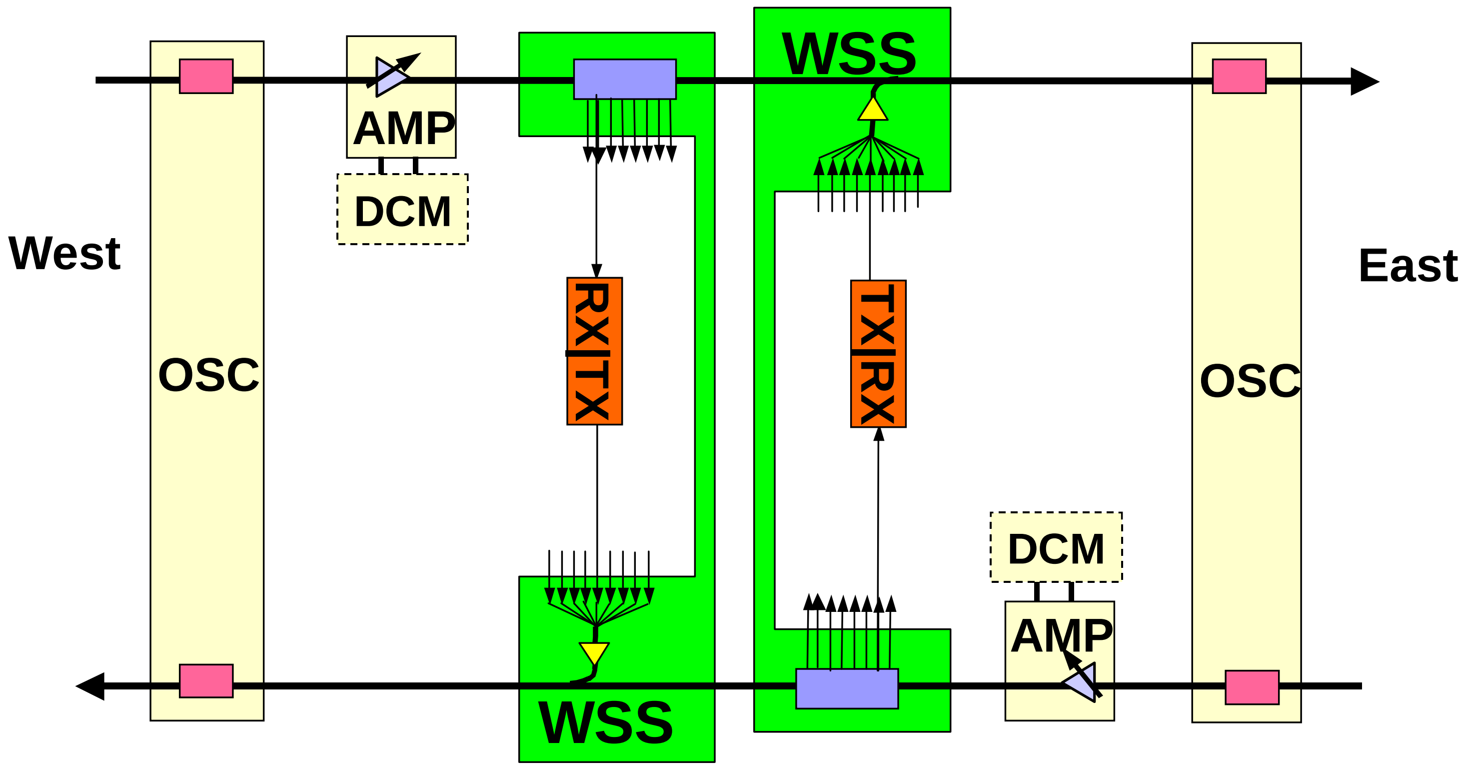
Key Functionality:
- 8 colorless ports, without additional add/drop filtering
- Any wavelength or subset of wavelengths can be added/dropped to these ports
- Mesh capable via colorless add/drop ports

ROADM Metro Transport Network

- 4 node ROADM ring
- 40km between sites

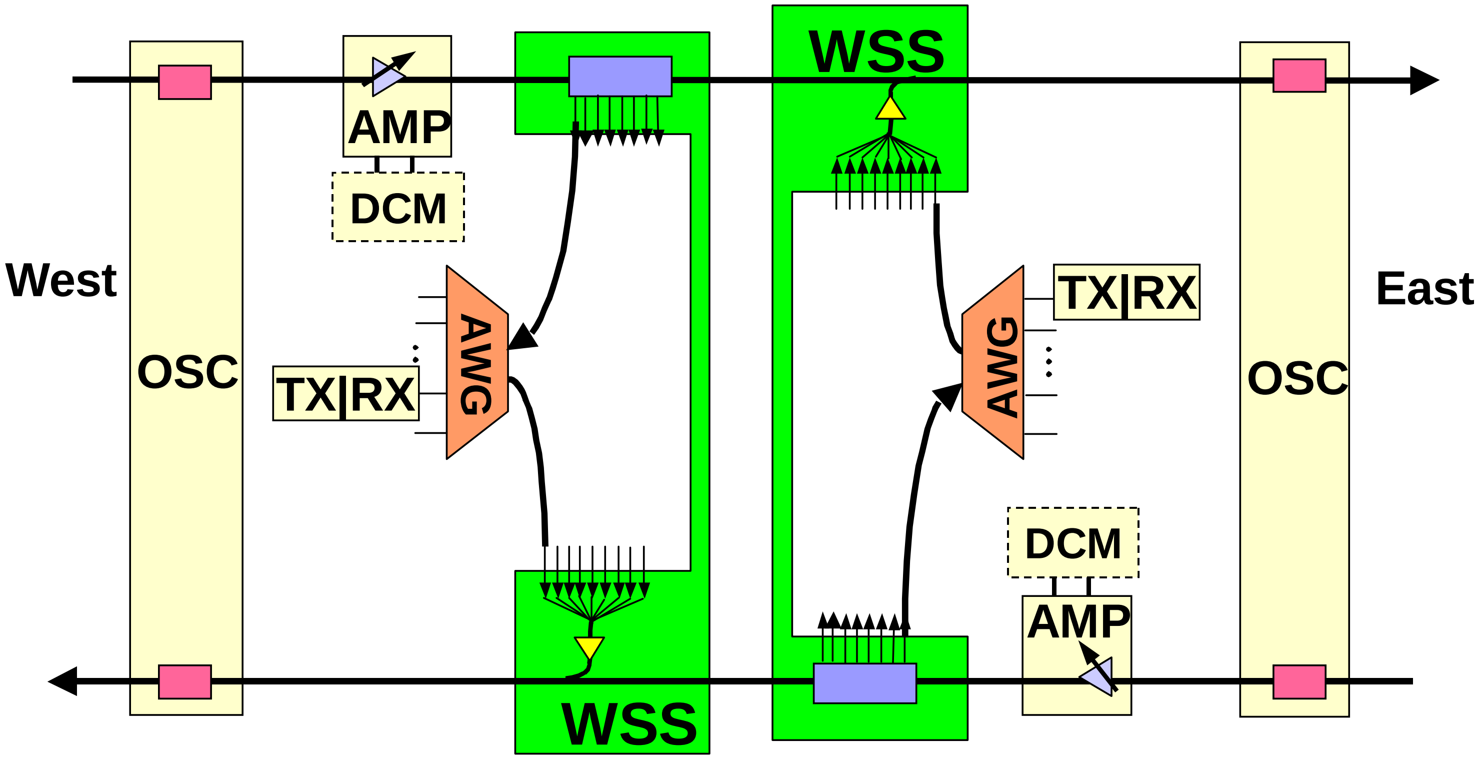


Mini ROADM



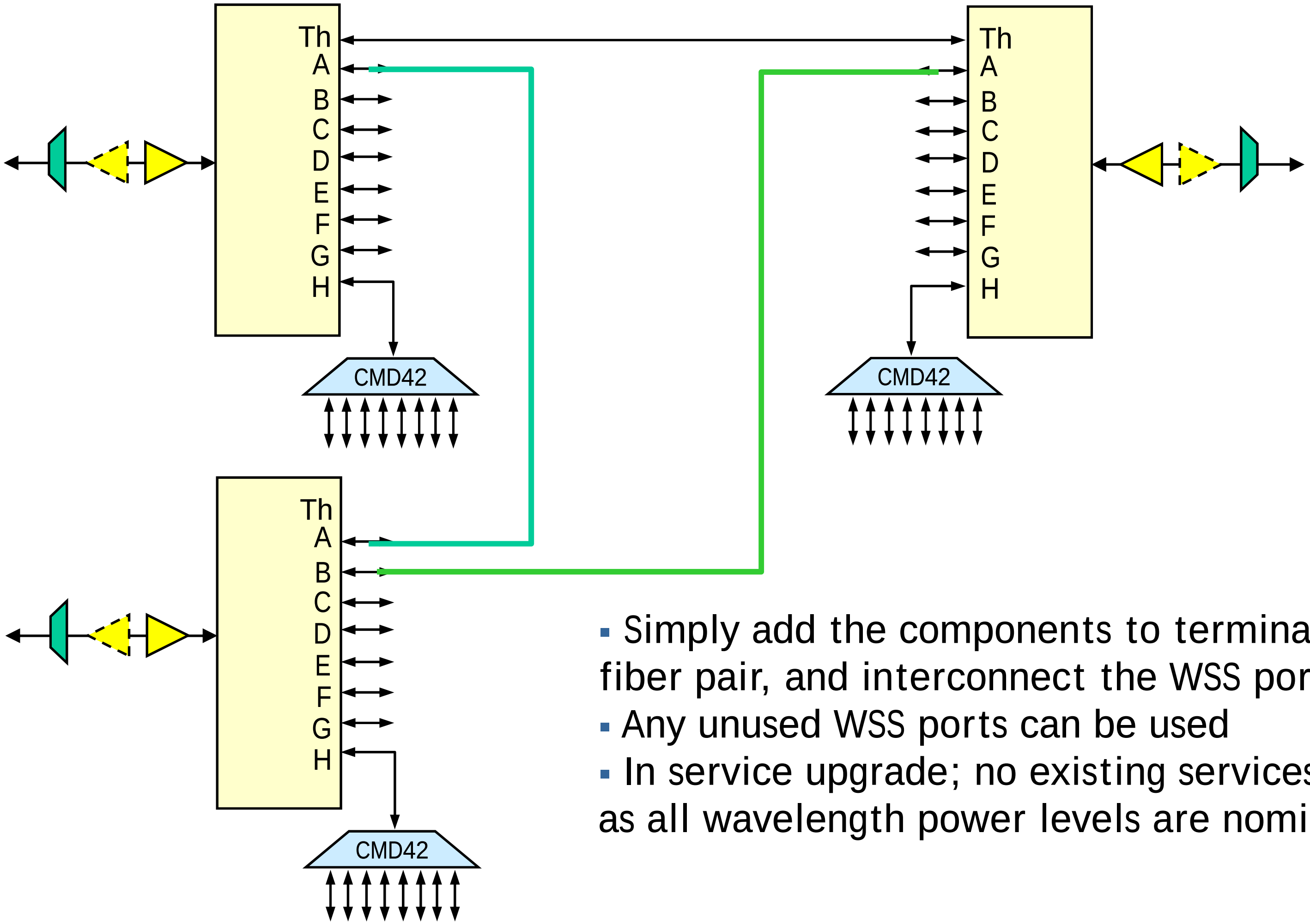
“Mini ROADM” with Colorless Add/Drop

High Capacity ROADM



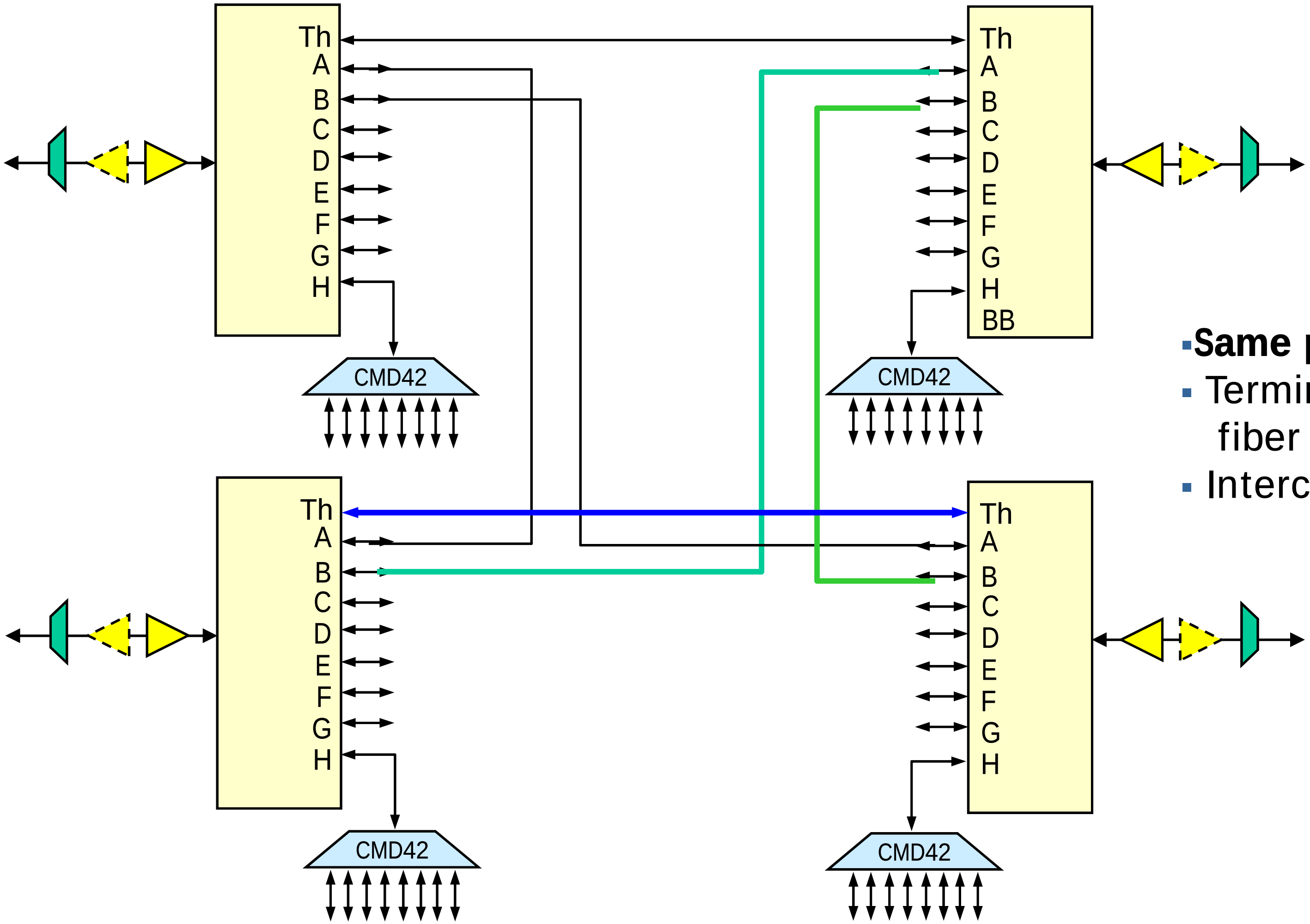
Typical High Capacity Add/Drop WSS ROADM

ROADM Degree 2 to 3 Expansion



- Simply add the components to terminate the additional fiber pair, and interconnect the WSS ports
- Any unused WSS ports can be used
- In service upgrade; no existing services are disrupted as all wavelength power levels are nominally identical

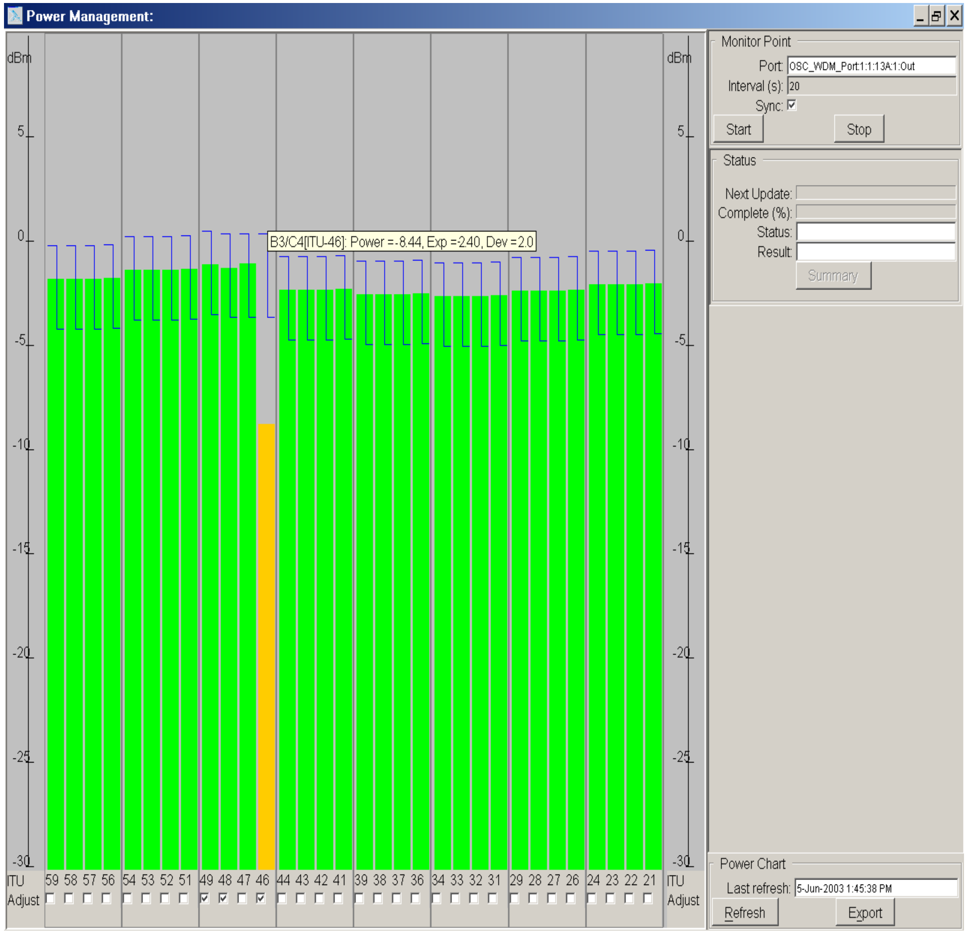
ROADM Degree 2/3 to 4 Expansion

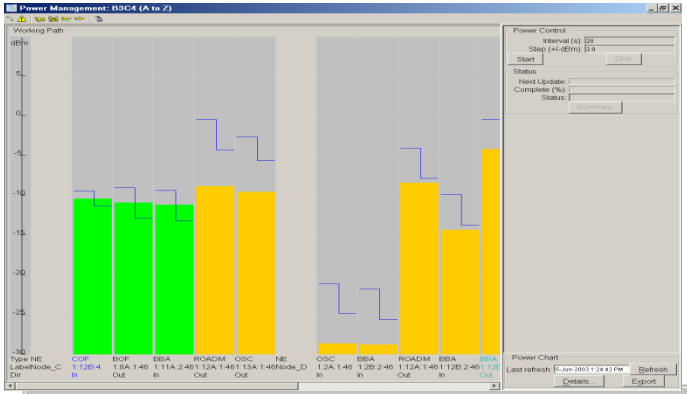


- **Same process:**
  - Terminate the additional fiber pair(s)
  - Interconnect the WSS ports

Layer 1 Optical Management

- **Wavelength Tracker™**
- **Wavelength path trace**
- **Optical fiber view**
- **Fault sectionalization & isolation**
- **Remote optical power control**
- **Threshold alarming**
- **Automated fault correlation**

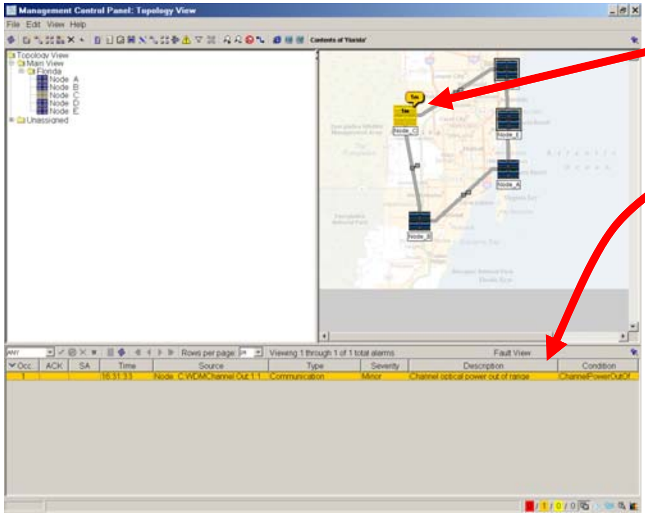




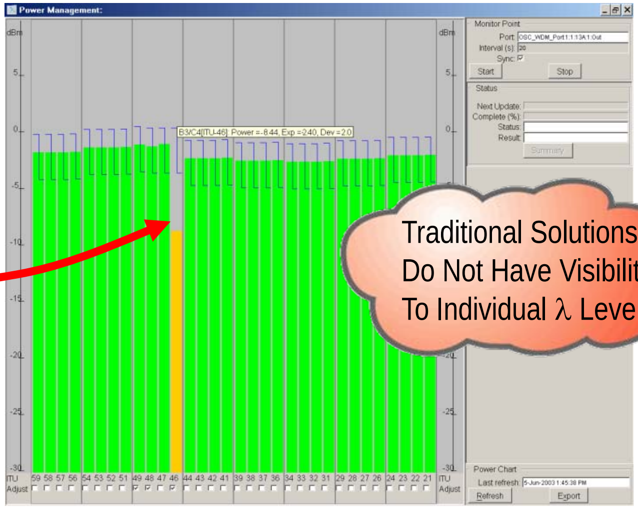
Service-aware Optical Layer Management

Problem Resolution

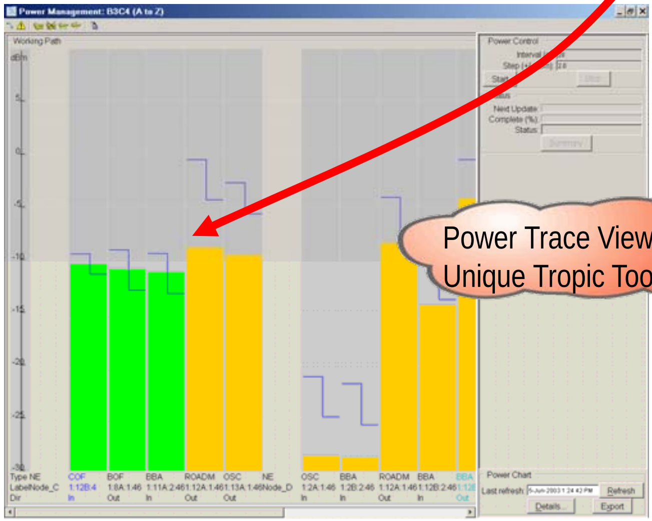
Remotely Monitors, Controls & Alarms at Component Level



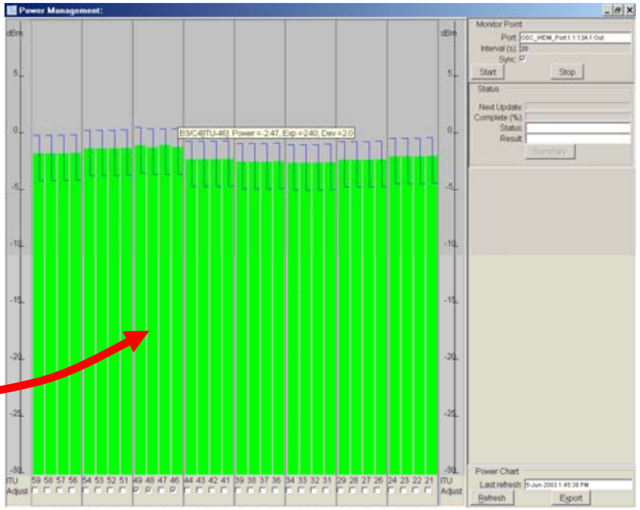
1. **Fault location identified at Node E on EMS.**
2. **Power alarm raised for λ2**
3. **Right-click takes you to the affected card or service(s)**
4. **Wavelength Tracker™ traces power along path of service to isolate spectral equalization problem at site C to single λ**
5. **Faulty power management module uniquely identified as root cause at site C**
6. **Eliminate BER's and restore service on λ2**



Traditional Solutions Do Not Have Visibility To Individual λ Level



Power Trace View is a Unique Tropic Tool



Wavelength Tracker™ Locates the Exact Location of the Problem

Thank you

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Tropic™ Networks