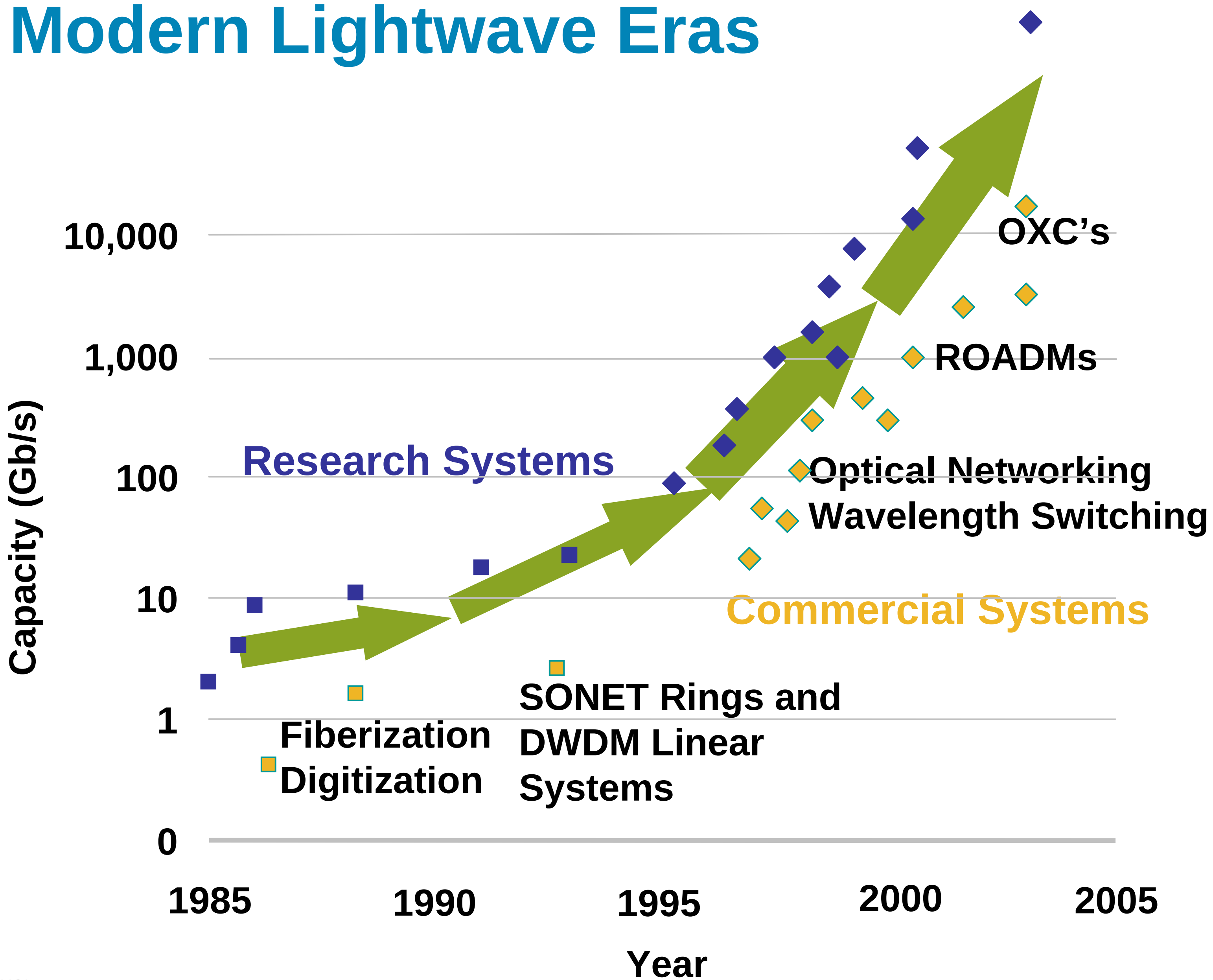
Optical DWDM Fundamentals

Agenda

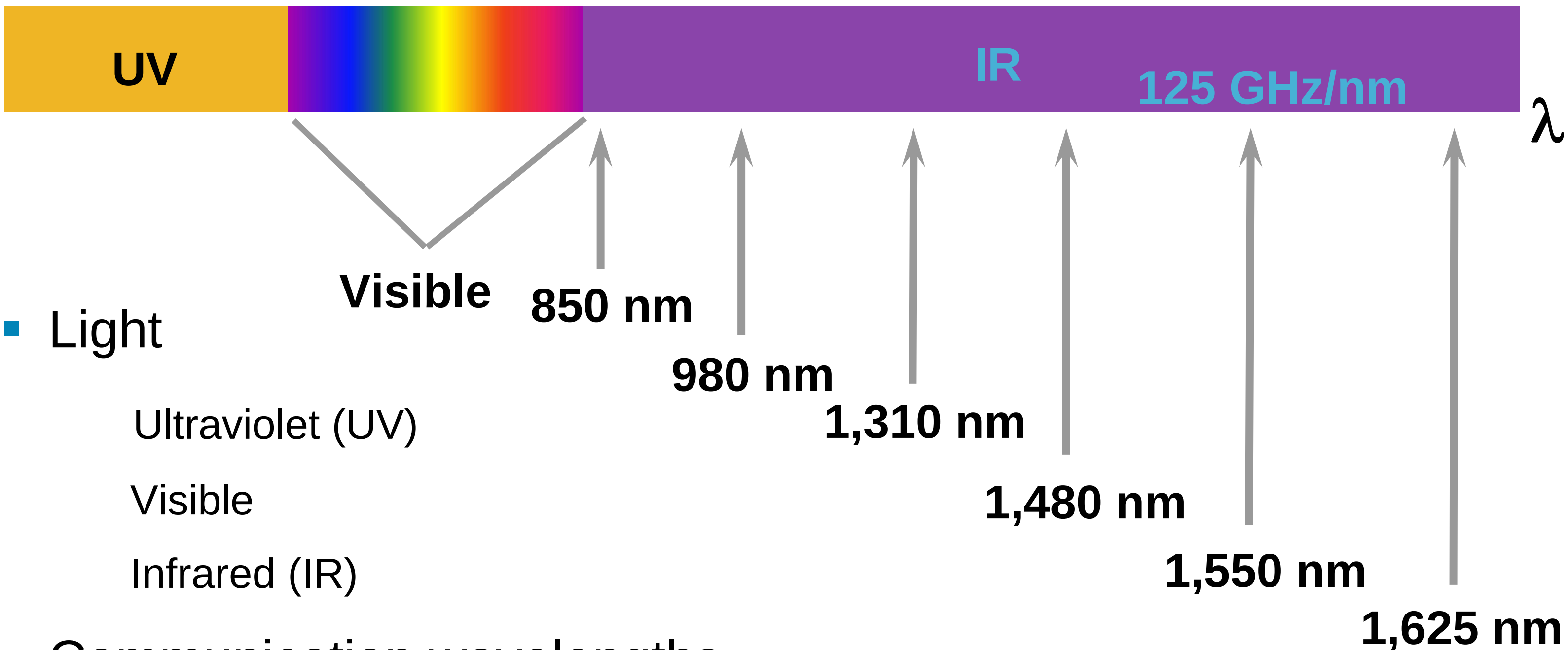
- Introduction and Terminology
- Optical Propagation and Fiber Characteristics
- Attenuation and Compensation
- Dispersion and Dispersion Compensation
- Non Linearity
- SM Optical Fiber Types
- Simple SPAN Design
- DWDM Transmission
- ROADM: Operational Benefits
- Cisco ONS 15454 MSPP/MSTP Functionality

Introduction

Modern Lightwave Eras



Optical Spectrum



- Light
  - Ultraviolet (UV)
  - Visible
  - Infrared (IR)
- Communication wavelengths
  - 850, 1310, 1550 nm
  - Low-loss wavelengths
- Specialty wavelengths
  - 980, 1480, 1625 nm

$C = f \times \lambda$

Wavelength: λ (Nanometers)

Frequency: f (Nerahertz)

Terminology

- Decibels (dB): unit of level (relative measure) –X dB is $10^{-X/10}$
- Decibels-milliwatt (dBm): decibel referenced to a milliwatt

  dBm used for output power and receive sensitivity (absolute value)

  dB used for power gain or loss (relative value)

  X mW is $10\mathrm{x}\log_{10}(X)$ in dBm, Y dBm is $10^{Y/10}$ in mW

- Wavelength (Lambda): length of a wave in a particular medium; common unit: nanometers, $\mathbf{10^{-9}m}$ (nm)
- Frequency (ν): the number of times that a wave is produced within a particular time period

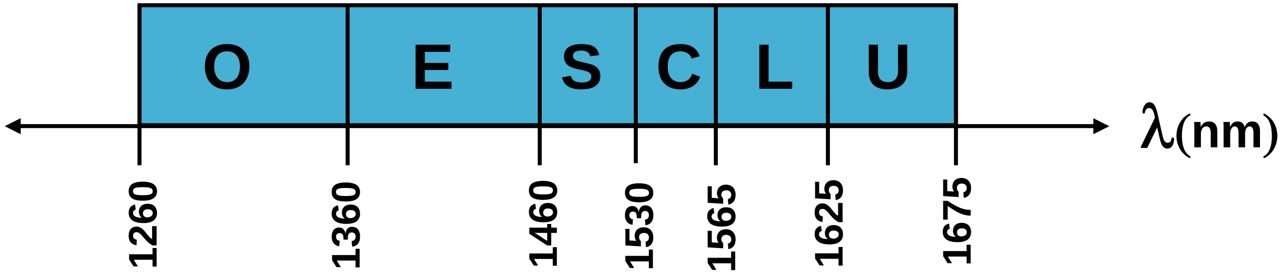
Wavelength x frequency = speed of light ⇒ $\lambda \times \nu = C$

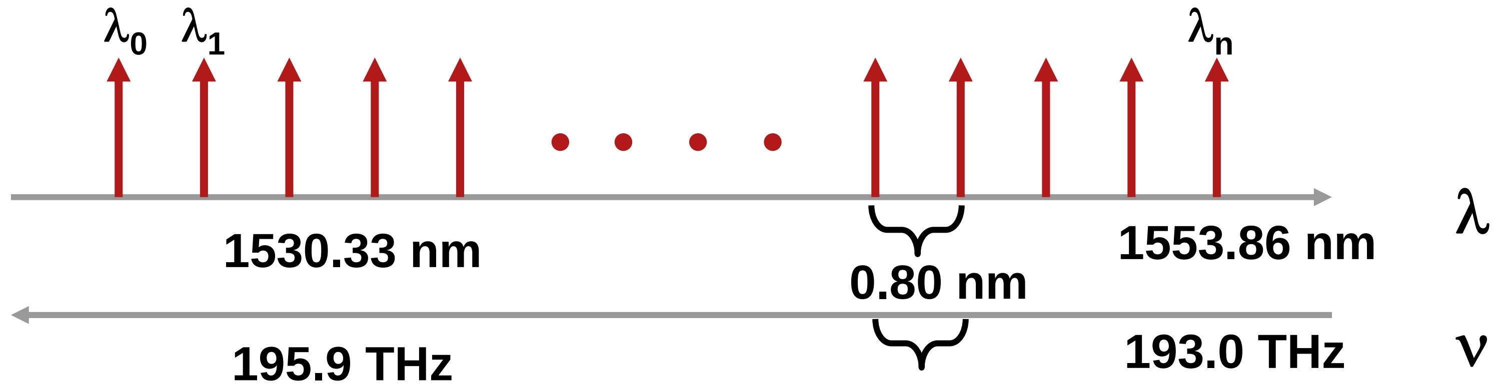
Terminology—Fiber Impairments

- Attenuation = Loss of power in dB/km
- Chromatic Dispersion = Spread of light pulse in ps/nm-km
- Optical Signal-to-Noise Ratio (OSNR) = Ratio of optical signal power to noise power for the receiver

ITU Wavelength Grid

- The International Telecommunications Union (ITU) has divided the telecom wavelengths into a grid; the grid is divided into bands; the C and L bands are typically used for DWDM
- ITU Bands



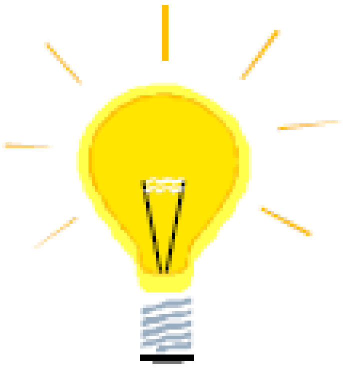


Channel Spacing = 100 GHz

Bit Error Rate (BER)

- BER is a key objective of the optical system design
- Goal is to get from Tx to Rx with a BER < BER threshold of the Rx
- BER thresholds are on data sheets
- Typical minimum acceptable rate is 10^{-12}

Optical Power



Definition:

Optical Power Is the Rate at Which Power Is Delivered in an Optical Beam

Optical Power Measurements:

- Power is measured in watts; however, a convenient way to measure optical power is in units of decibels (dB)
- The power measured on a particular signal is measured in dBm
- The gain/loss measured between two points on a fiber is in dB

  Power loss is expressed as negative dB

  Power gain is expressed as positive dB

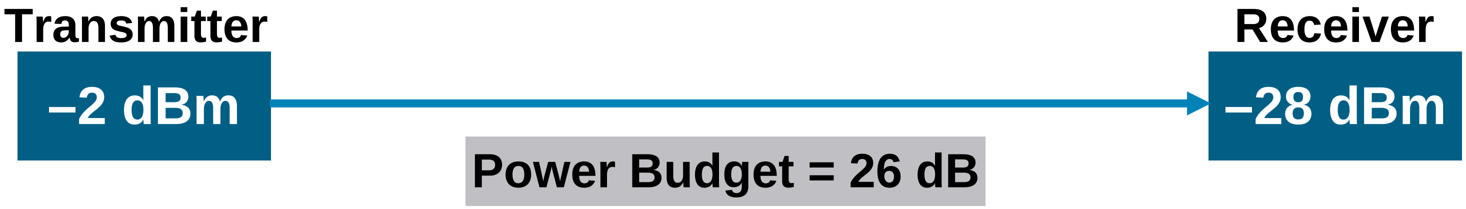
Optical Power Budget

The Optical Power Budget is:
Optical Power Budget = Power Sent – Receiver Sensitivity

- Calculate using minimum transmitter power and minimum receiver sensitivity
- Attenuation/loss in the link, greater than the power budget, causes bit errors (dB)
- Design networks with power budgets, not distances

Optical Power Budget—Example

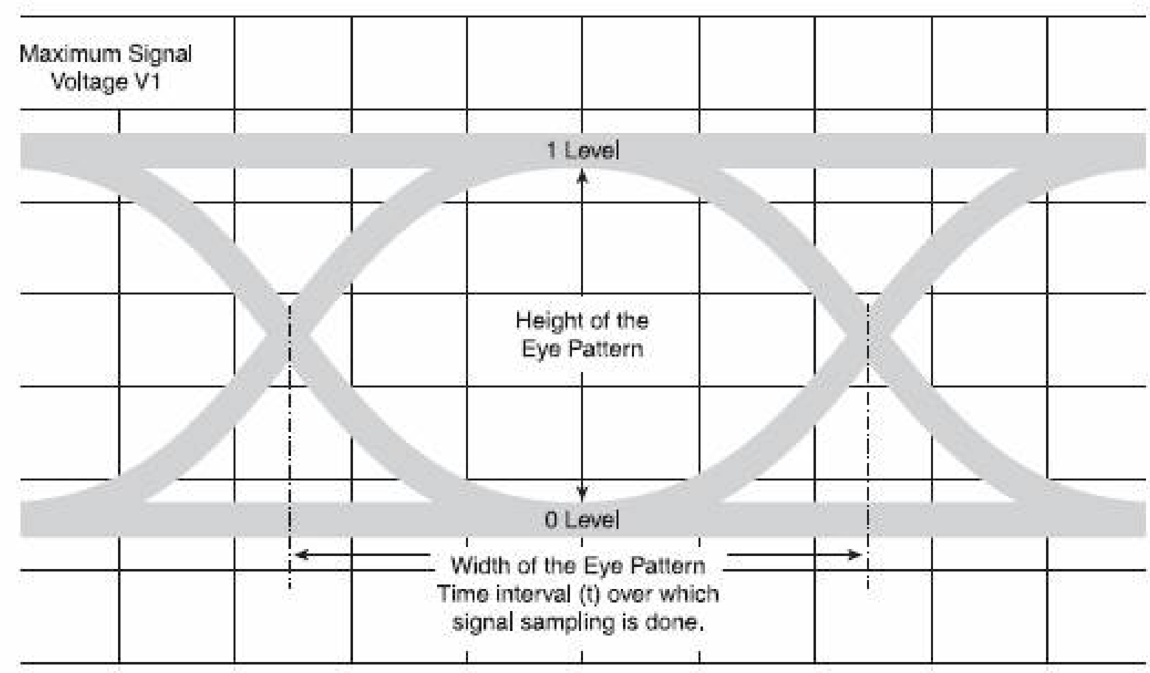
- Transmitter maximum power = –2 dBm
- Receiver sensitivity = –28 dBm



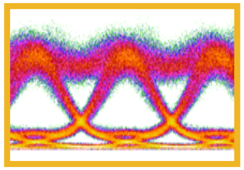
Calculate Power Budget = ??	
Short Reach (SR)	6 dB (75% Power Loss)
Intermediate Reach (IR)	13 dB (95% Power Loss
Long Reach (LR)	26 dB (99.75% Power Loss)

Key: Every 3dB is loss of half of signal

Eye Diagram

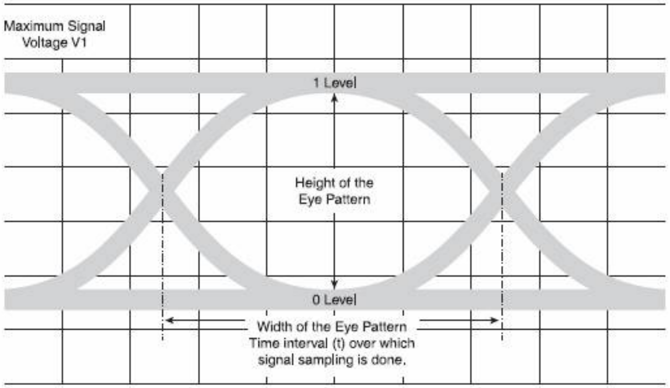


- The vertical eye opening shows the ability to distinguish between a 1 and a 0 bit
- The horizontal opening gives the time period over which the signal can be sampled without errors



Eye Diagram

- For a good transmission system, the eye opening should be as wide and open as possible
- Eye diagram also displays information such as maximum signal voltage, rise and decay time of pulse, etc.
- Extinction ratio (ratio of a 1 signal to a 0 signal) is also calculated from eye diagram



A Few Words on Optical Safety

- Think optical safety at all times
- Wear specified optical eye protection
- Optical power is invisible to the human eye
- Never stare at an optical connector
- Keep optical connectors pointed away from yourself and others
- Glass (fiber cable) can cut and puncture
- Fiber splinters are extremely difficult to see
- Damage is usually **permanent!**

Laser Classifications/Safety Icons

Class 1

Lasers that are incapable of causing damage when the beam is directed into the eye under normal operating conditions. These include helium-neon lasers operating at less than a few microwatts of radiant power.

Class 2 ← SR and IR Optics, Some LR

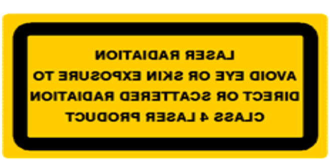
Lasers that can cause harm if viewed directly for ¼ second or longer. This includes helium-neon lasers with an output up to 1 mW (milliwatt).

Class 3A ← Many LR Optics, CWDM GBICS

Lasers that have outputs less than 5 mW. These lasers can cause injury when the eye is exposed to either the beam or its reflections from mirrors or other shiny surfaces. As an example, laser pointers typically fall into this class.

Class 3B ← Some LR Optics, Amplifier Outputs

Lasers that have outputs of 5 to 500 mW. The argon lasers typically used in laser light shows are of this class. Higher power diode lasers (above 5 mW) from optical drives and high performance laser printers also fall into this class.



Class 4

Lasers that have outputs exceeding 500 mW. These devices produce a beam that is hazardous directly or from reflection and can produce skin burn. Many ruby, carbon dioxide, and neodymium-glass lasers are class 4.

Protective Eyewear Available

- Protective goggles or glasses should be worn for all routine use of Class 3B and Class 4 lasers
- Remember: eyewear is wavelength specific, a pair of goggles that effectively blocks red laser light affords no protection for green laser light

Laser Safety Equipment Can Be Investigated in Greater Detail at the Following Link:
http://www.lasersafety.co.uk/frhome.html

Optical Propagation in Fibers

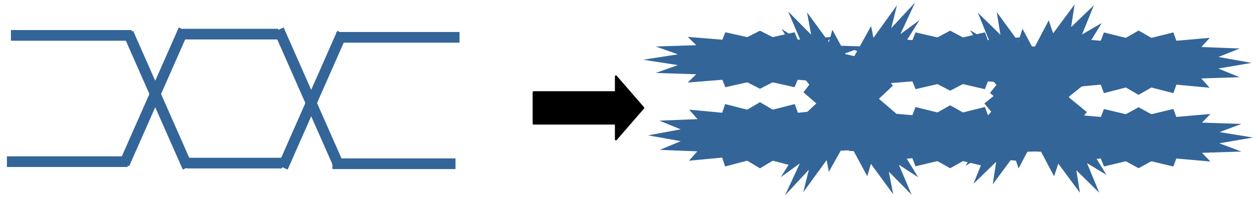
Analog Transmission Effects

- Attenuation:

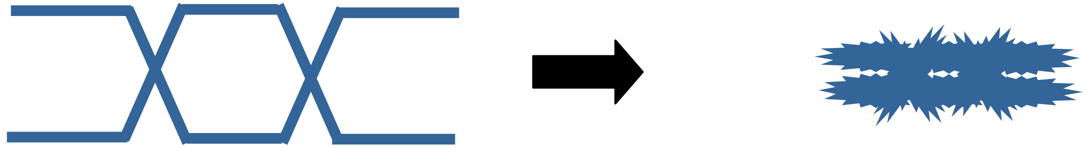
  Reduces power level with distance

- Dispersion and nonlinearities:

  Erodes clarity with distance and speed



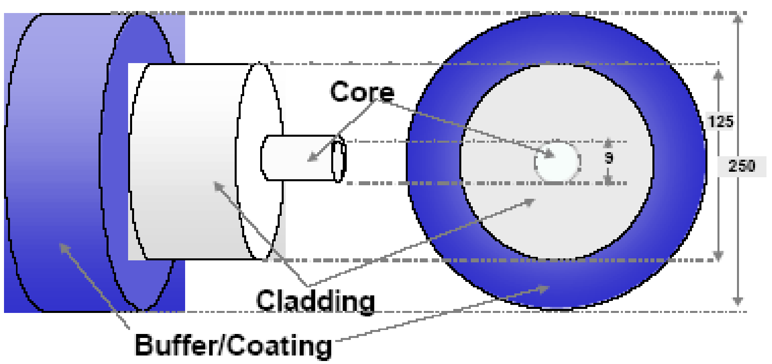
- Signal detection and recovery is an analog problem

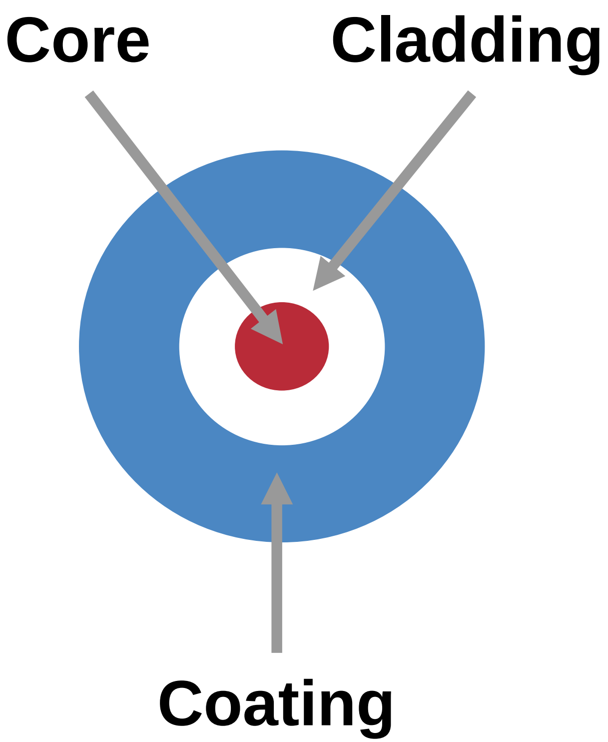


Fiber Geometry

An Optical Fiber Is Made of Three Sections:

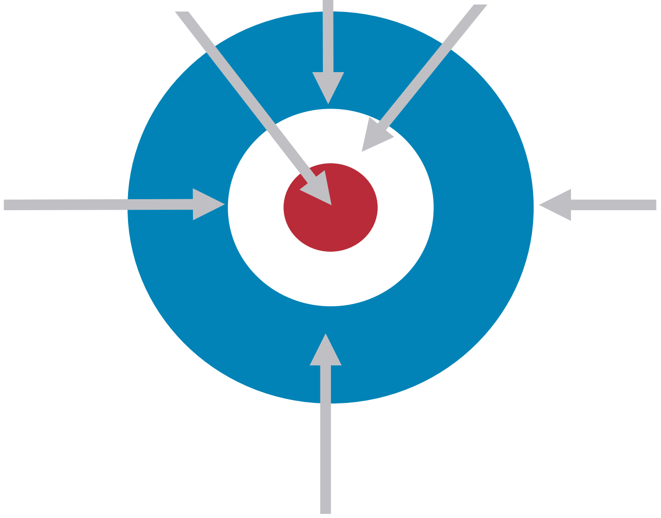
- The core carries the light signals
- The cladding keeps the light in the core
- The coating protects the glass





Fiber Dimensions

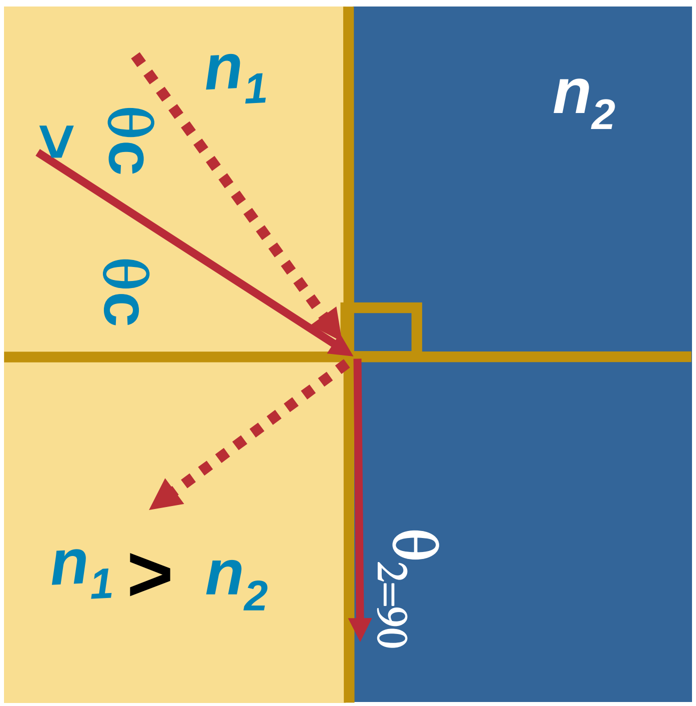
- Fiber dimensions are measured in µm
  - 1 µm = 0.000001 meters (10-6)
  - 1 human hair ~ 50 µm
- Refractive Index (n)
  - n = c/v
  - n ~ 1.46
  - n (core) > n (cladding)

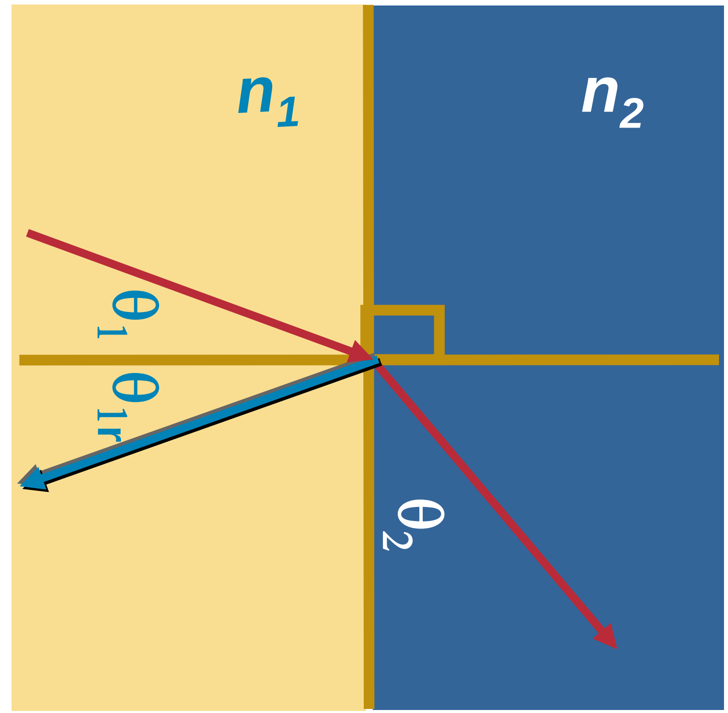


Geometrical Optics

Light Is Reflected/Refracted at an Interface

- θ_1 = Angle of incidence
- θ_{1r} = Angle of reflection
- θ_2 = Angle of refraction

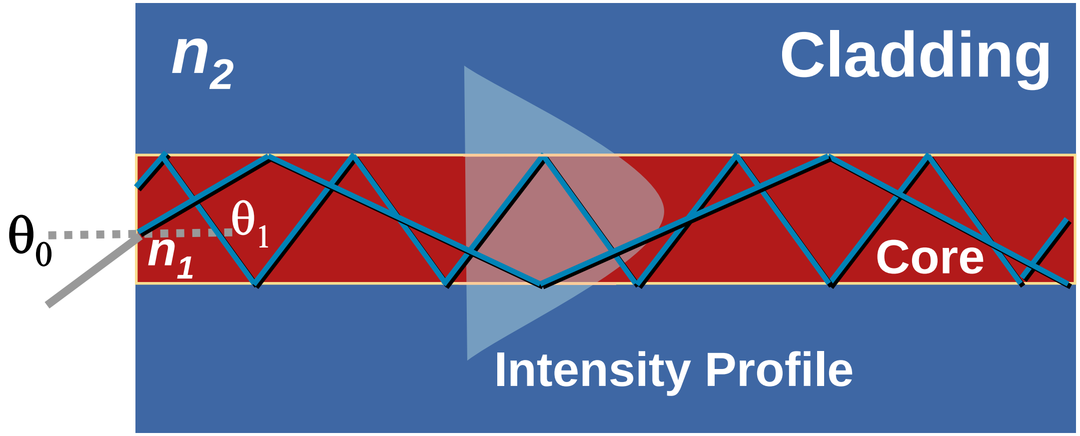




θc—Is the Critical Angle

If Angle of Incidence Is Greater Than Critical Angle, All the Light Will Reflect (Instead of Refract); This Is Called Total Internal Reflection

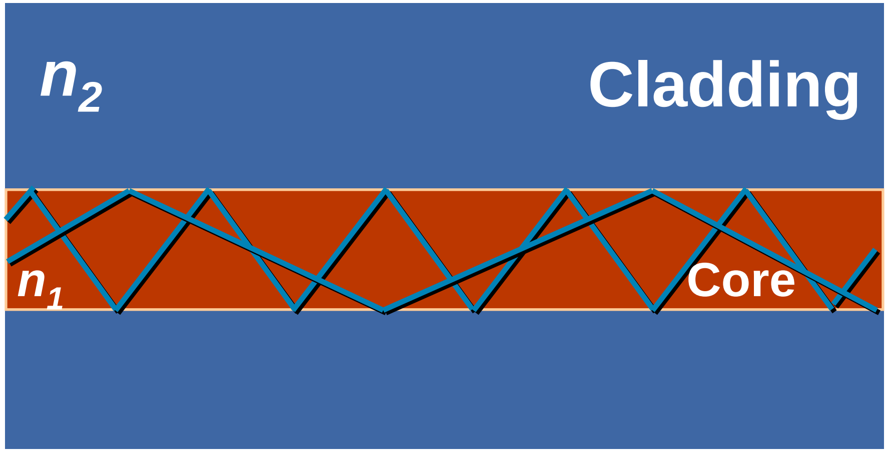
Wavelength Propagation in Fiber

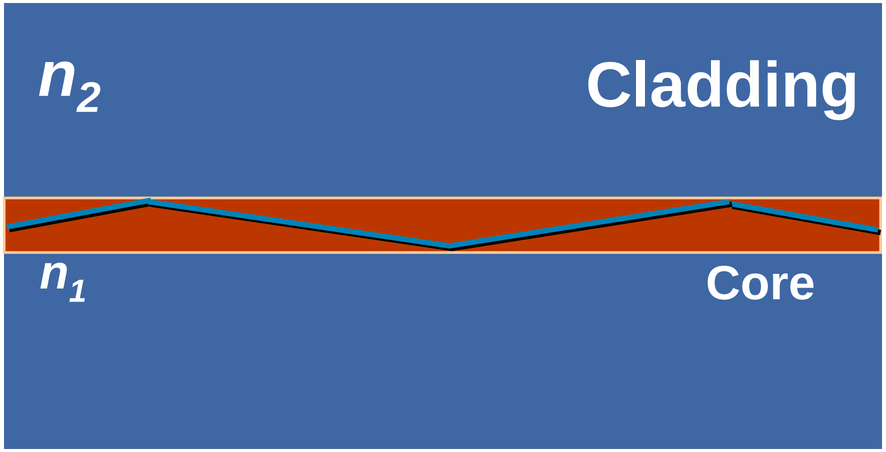


- Light propagates by total internal reflections at the core-cladding interface
- Total internal reflections are lossless
- Each allowed ray is a mode

Different Types of Fiber

- Multimode fiber
  - Core diameter varies
    - 50 µm for step index
    - 62.5 µm for graded index
  - Bit rate-distance product > 500 MHz-km
  - Distance limited
- Single-mode fiber
  - Core diameter is about 9 µm
  - Bit rate-distance product > 100 THz-km

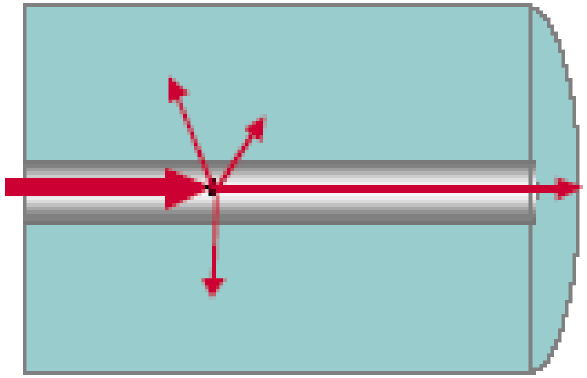




Attenuation

Attenuation in Fiber

- Light loss in fiber is caused by two things
  - Absorption by the fiber material
  - Scattering of the light from the fiber
- Light loss causes signal attenuation

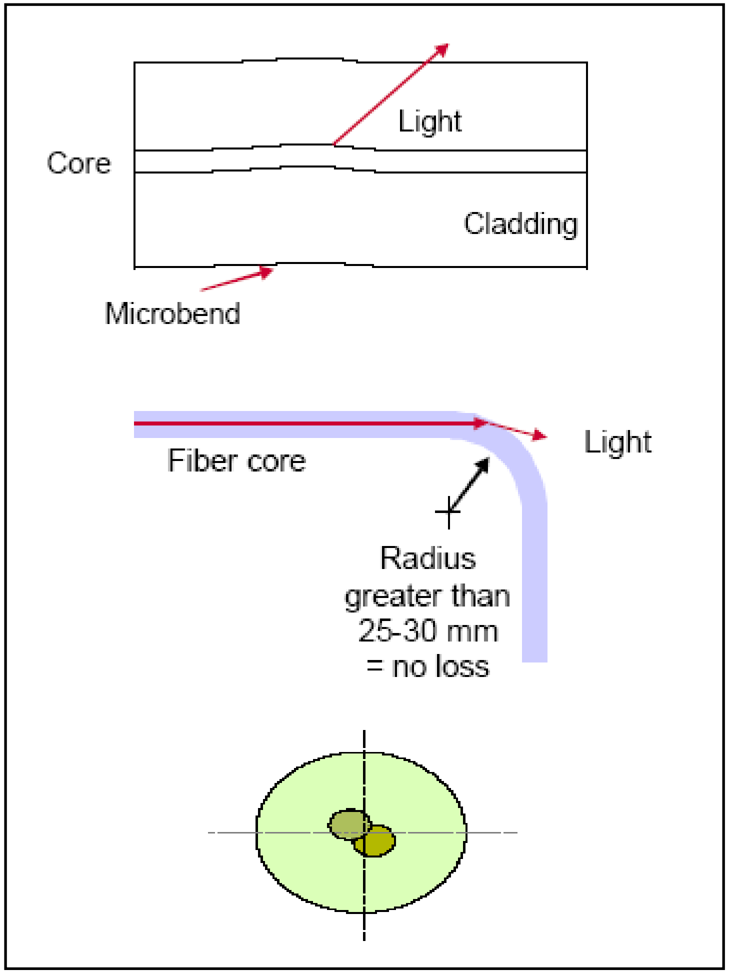


Rayleigh Scattering

	Scattering
850 nm	Highest
1310 nm	Lower
1550 nm	Lowest

Other Causes of Attenuation in Fiber

- Microbends—Caused by small distortions of the fiber in manufacturing
- Macrobends—Caused by wrapping fiber around a corner with too small a bending radius
- Back reflections—Caused by reflections at fiber ends, like connectors
- Fiber splices—Caused by poor alignment or dirt
- Mechanical connections—Physical gaps between fibers

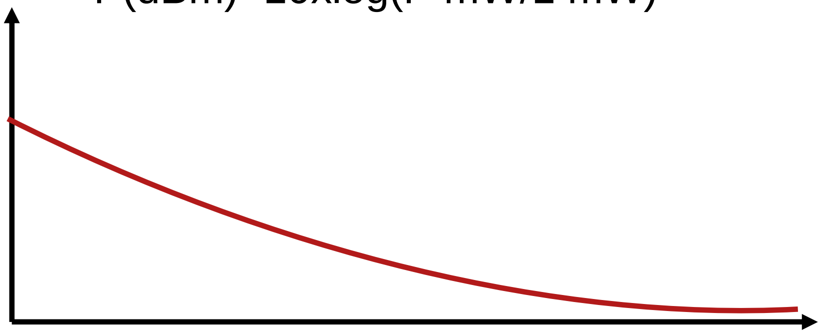


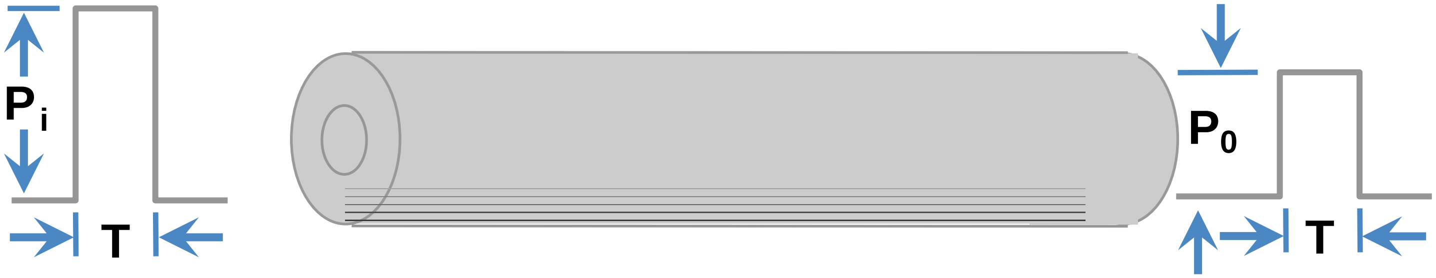
Optical Attenuation

- Pulse amplitude reduction limits "how far" (distance)
- Attenuation in dB=10xLog(Pi/Po)
- Power is measured in dBm:

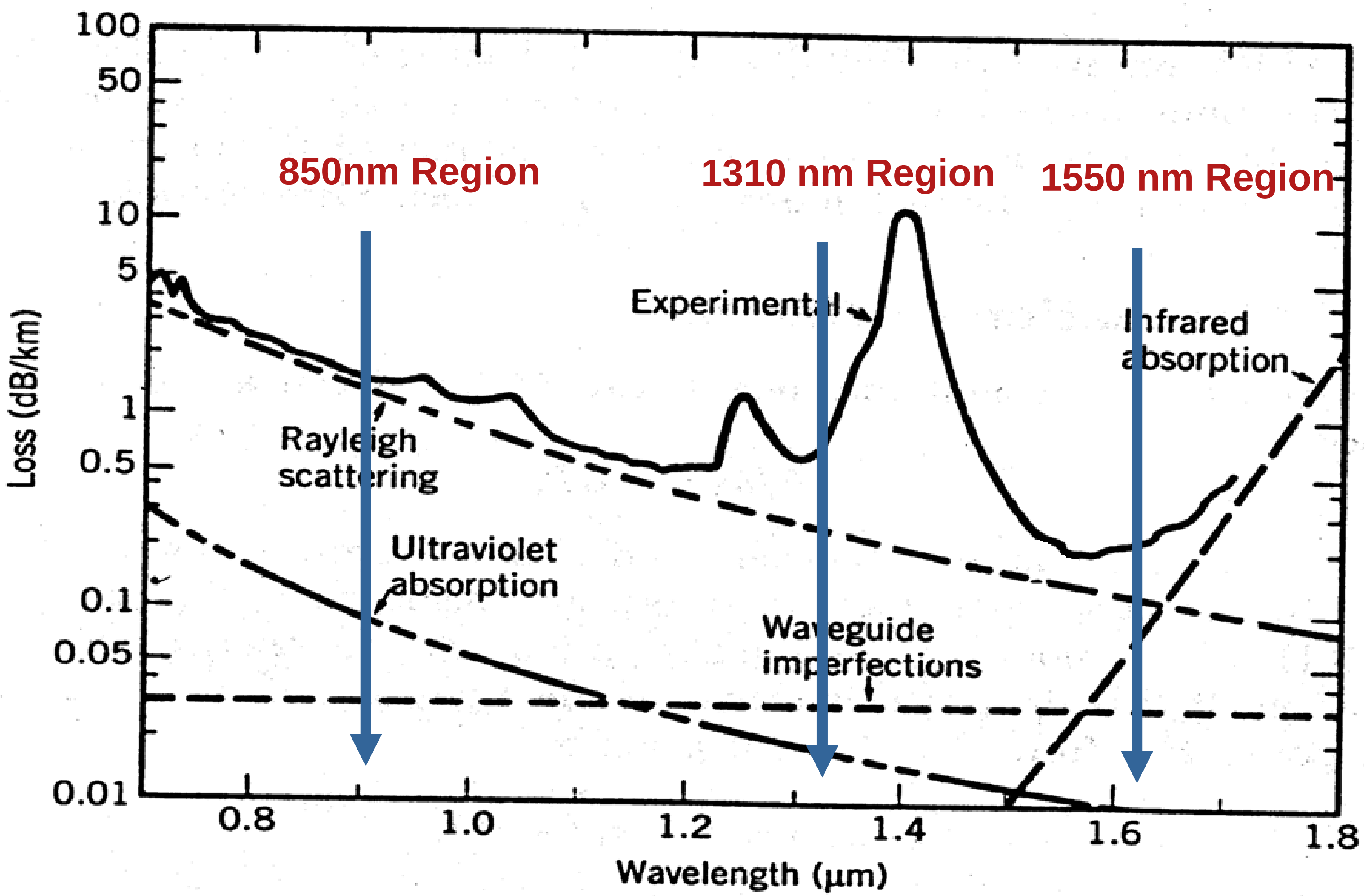
P(dBm)=10xlog(P mW/1 mW)

Examples	
10 dBm	10 mW
0 dBM	1 mW
–3 dBm	500 uW
–10 dBm	100 uW
–30 dBm	1 uW



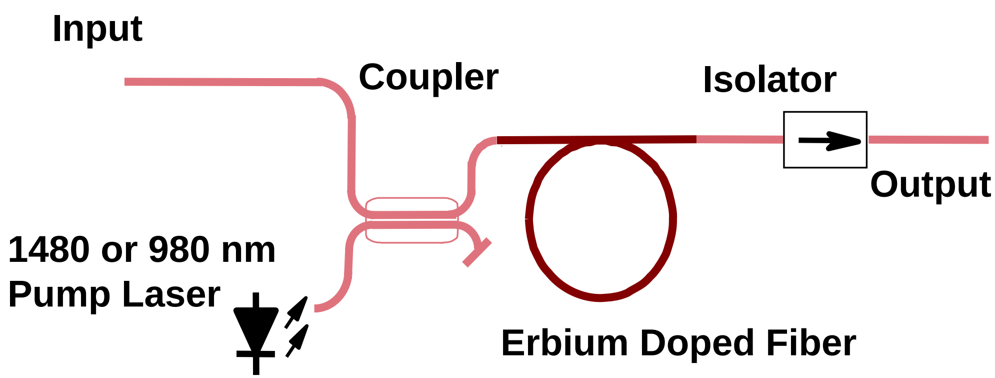


Attenuation Response at Different Wavelengths



Attenuation: Compensated by Optical Amplifiers

- Erbium-doped fiber amplifiers (EDFA) are the most commonly deployed optical amplifiers
  - Commercially available since the early 1990s
  - Works best in the range 1530 to 1565 nm
  - Gain up to 30 dB (1000 photons out per one photon in)
- Optically transparent
  - Wavelength transparent
  - Bit rate transparent



Dispersion

Types of Dispersion

Chromatic Dispersion

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

Polarization Mode Dispersion (PMD)

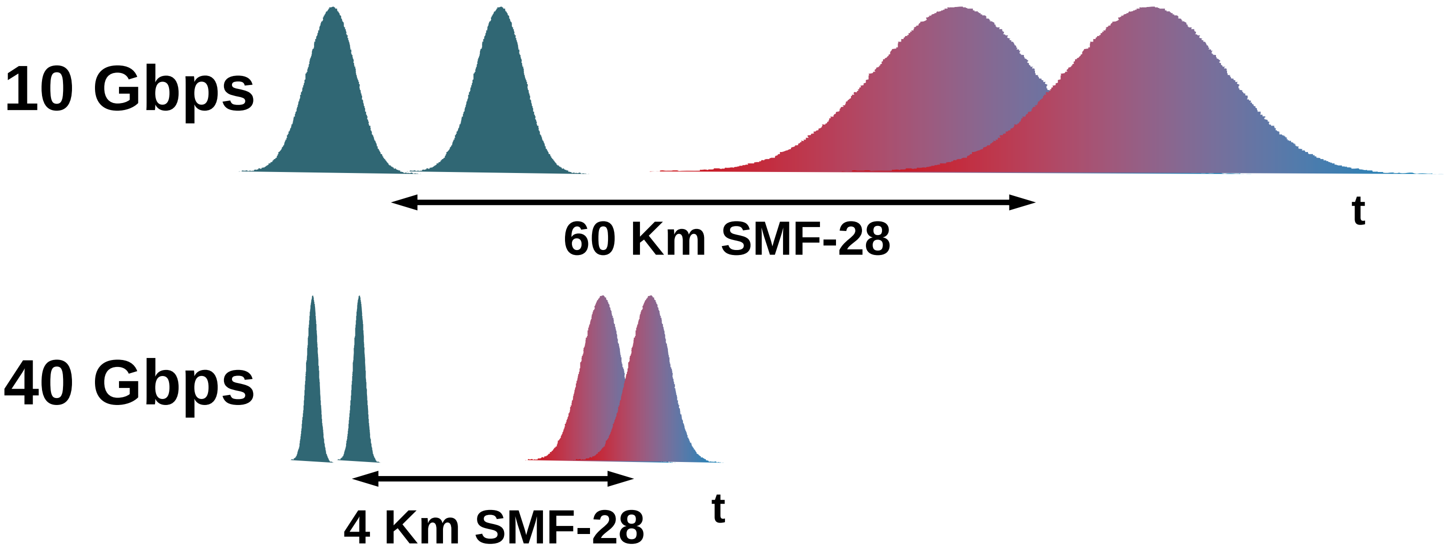
- **Single-mode fiber supports two polarization states**
- **Fast and slow axes have different group velocities**
- **Causes spreading of the light pulse**

A Snapshot on Chromatic Dispersion

- Affects single channel and DWDM systems
- A pulse spreads as it travels down the fiber
- Inter-symbol Interference (ISI) leads to performance impairments
- Degradation depends on:
  - Laser used (spectral width)
  - Bit-rate (temporal pulse separation)
  - Different SM types

Limitations from Chromatic Dispersion

- Dispersion causes pulse distortion, pulse “smearing” effects
- Higher bit-rates and shorter pulses are less robust to Chromatic Dispersion
- Limits “how fast” and “how far”



Combating Chromatic Dispersion

- Specialized fibers: DSF and NZDSF fibers

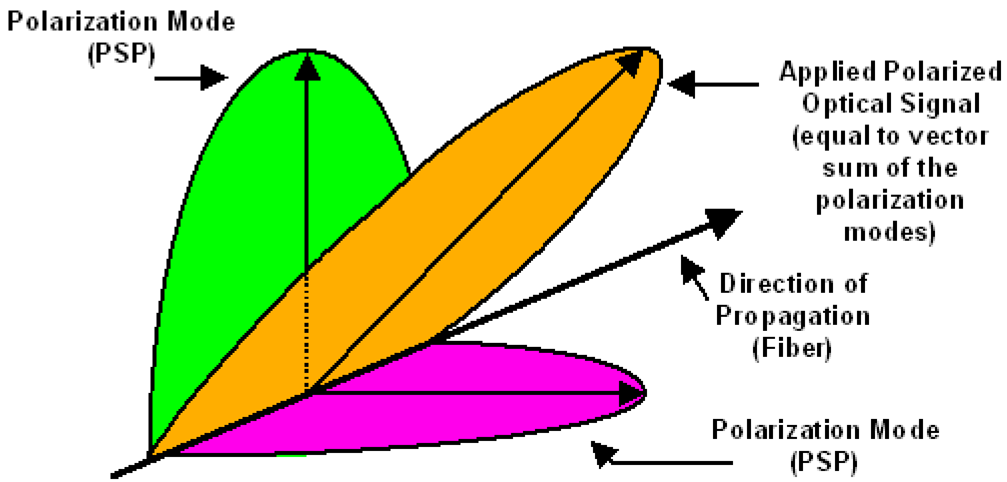
  (G.653 and G.655)

  Dispersion compensating fiber

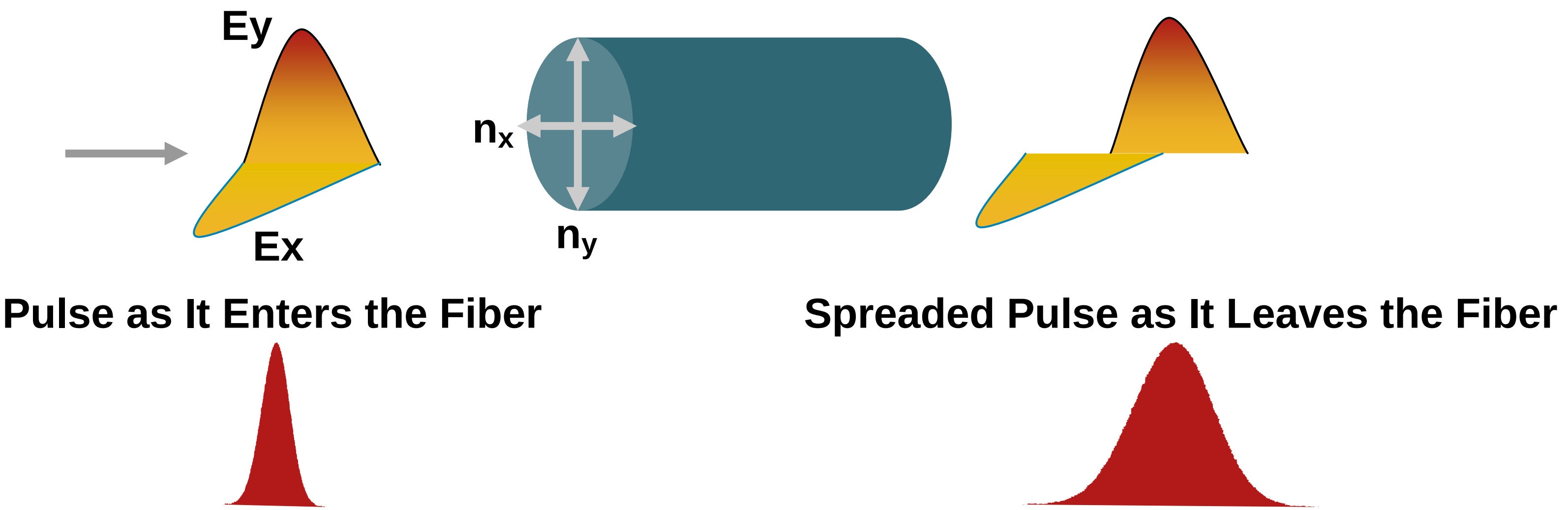
- Transmitters with narrow spectral width
- Regenerate pulse (O-E-O)

Polarization Mode Dispersion

- Caused by ovality of core due to:
  - Manufacturing process
  - Internal stress (cabling)
  - External stress (trucks)
- Only discovered in the 90s
- Most older fiber not characterized for PMD



Polarization Mode Dispersion (PMD)



- The optical pulse tends to broaden as it travels down the fiber; this is a much weaker phenomenon than chromatic dispersion and it is of some relevance at bit rates of 10Gb/s or more

Combating Polarization Mode Dispersion

- Factors contributing to PMD
  - Bit rate
  - Fiber core symmetry
  - Environmental factors
  - Bends/stress in fiber
  - Imperfections in fiber
- Solutions for PMD
  - Improved fibers
  - Regeneration
  - Follow manufacturer's recommended installation techniques for the fiber cable
- PMD does not need compensation up to 10G in systems up to about 1600km optical transmission, while compensation is required for longer systems or 40G

How Far Can I Go Without Dispersion Issues?

$$\text{Distance (Km)} = \frac{\text{Specification of Transponder (ps/nm)}}{\text{Coefficient of Dispersion of Fiber (ps/nm*km)}}$$

A Laser Signal with Dispersion Tolerance of 3400 ps/nm Is Sent Across a Standard SM Fiber, Which Has a Coefficient of Dispersion of 17 ps/nm*km

It Will Reach 200 Km at Maximum Bandwidth

Note That Lower Speeds Will Travel Farther

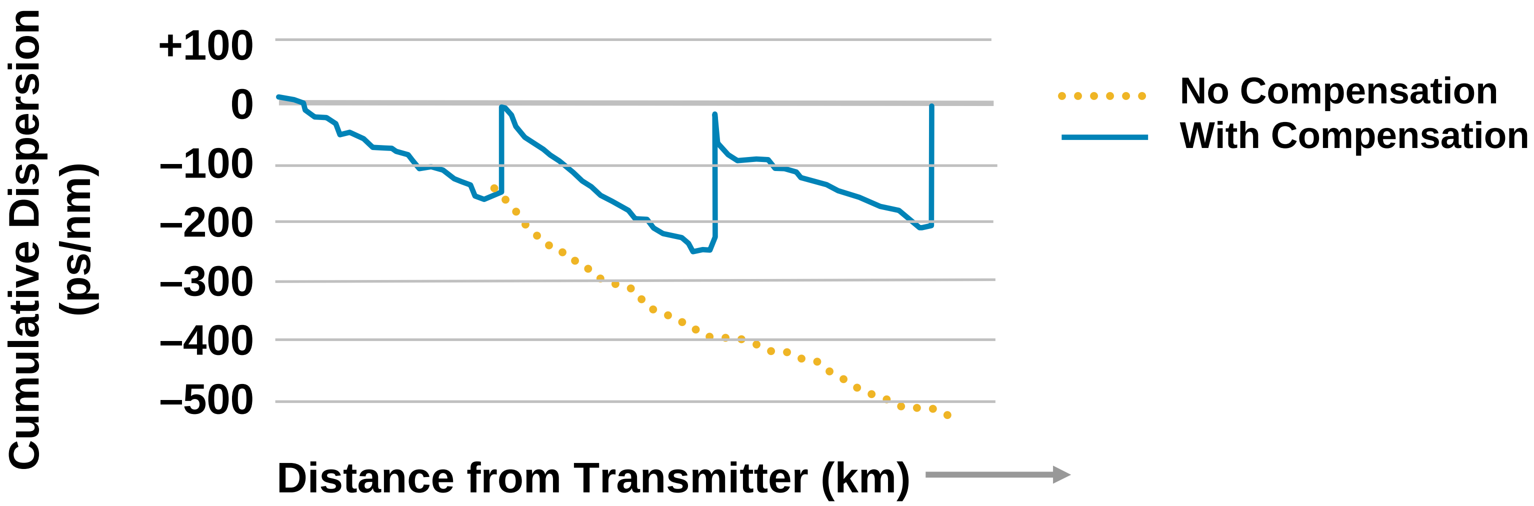
Transmission Over SM Fiber—Without Compensation

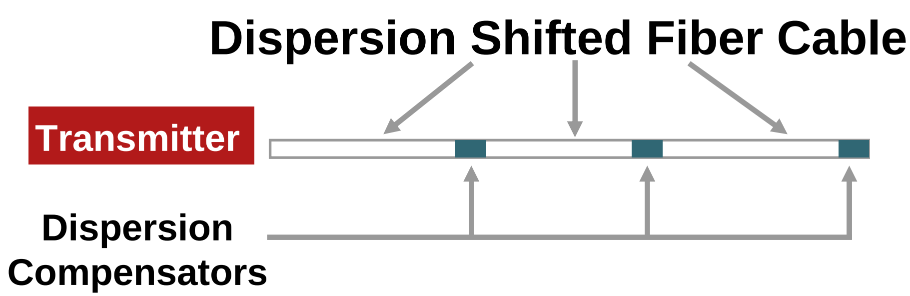
Transmission Rate	Distance
2.5 Gb/s	980 km
10 Gb/s	60 km
40 Gb/s	4 km

Industry Standard—Not Cisco Specific

Dispersion Compensation

Total Dispersion Controlled





Nonlinearity

From Linear to Non-Linear Propagation

- As long as optical power within an optical fiber is small, the fiber can be treated as a linear medium

    Loss and refractive index are independent of the signal power

- When optical power levels gets fairly high, the fiber becomes a nonlinear medium

    Loss and refractive index depend on the optical power

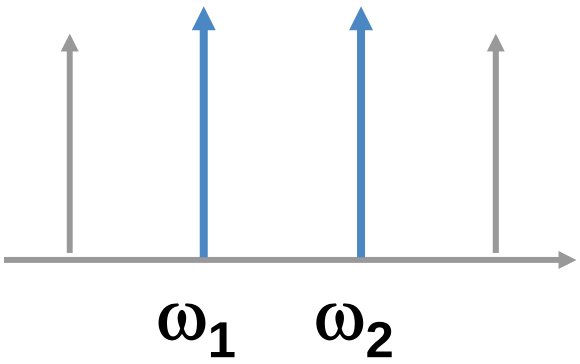
Effects of Nonlinearity

Self-Phased Modulation (SPM) and Cross Phase Modulation (XPM)

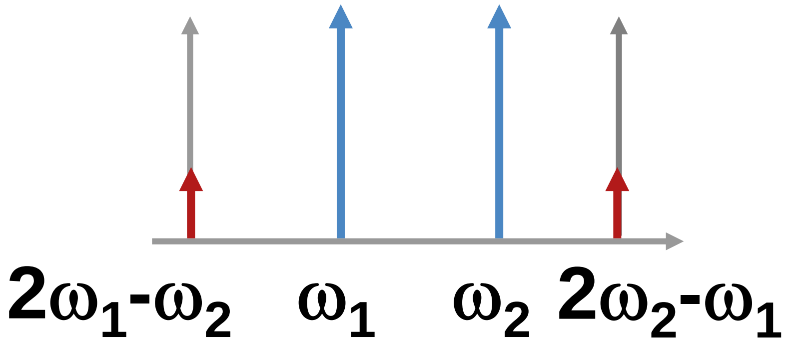
A Single Channel's Pulses Are Self-Distorted as They Travel (SPM)

Multiple Channels Interact as They Travel (XPM)

Four-Wave Mixing (FWM)



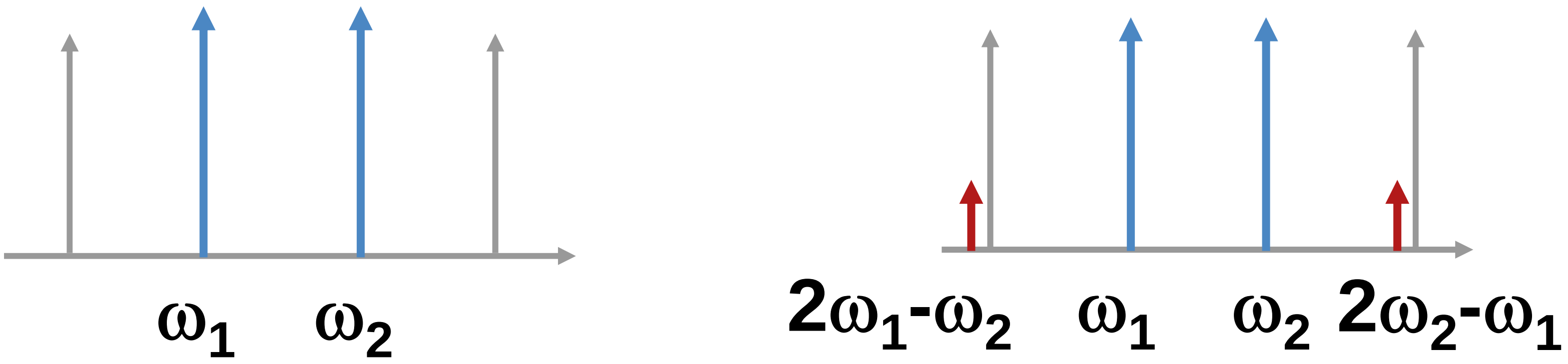
Into Fiber



Out of Fiber

- Channels beat against each other to form intermodulation products
- Creates in-band crosstalk that cannot be filtered (optically or electrically)

Four-Wave Mixing (FWM)

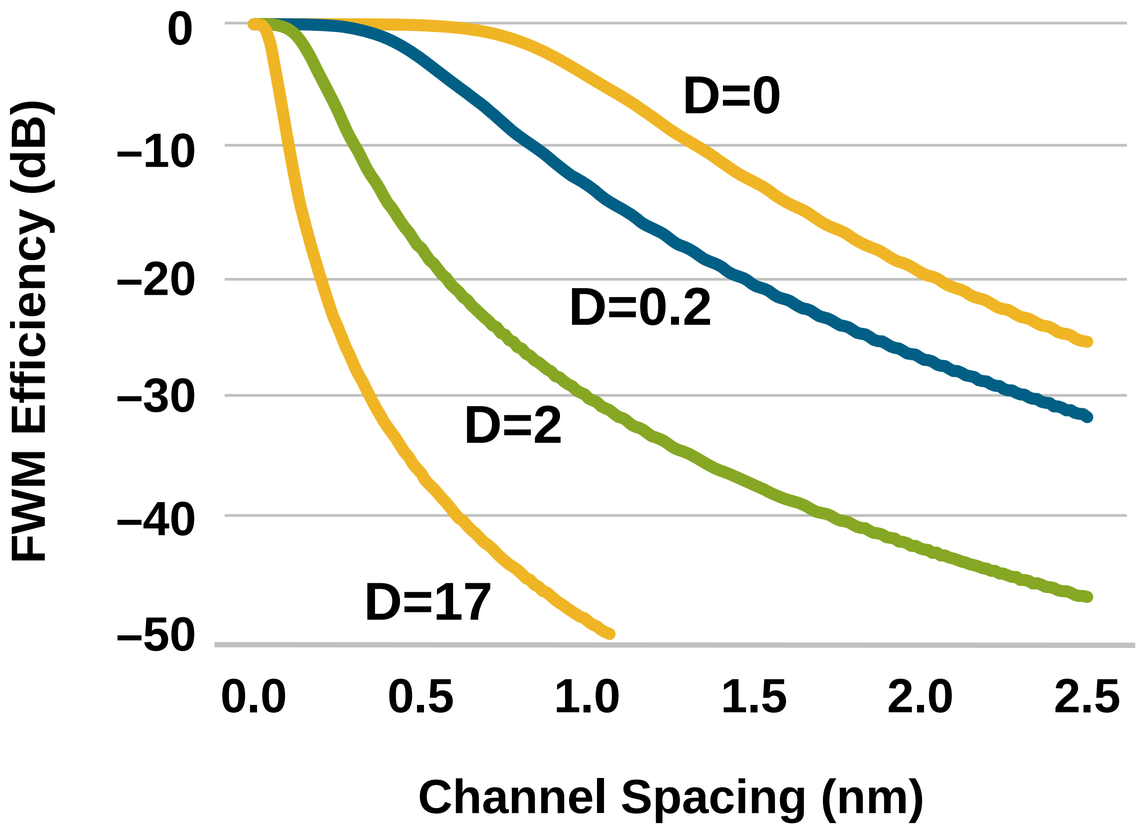


Into Fiber   Out of Fiber

- If you have dispersion the beat signal will not fall on a real signal
  - Therefore, some dispersion can be good in preventing FWM in an optical network

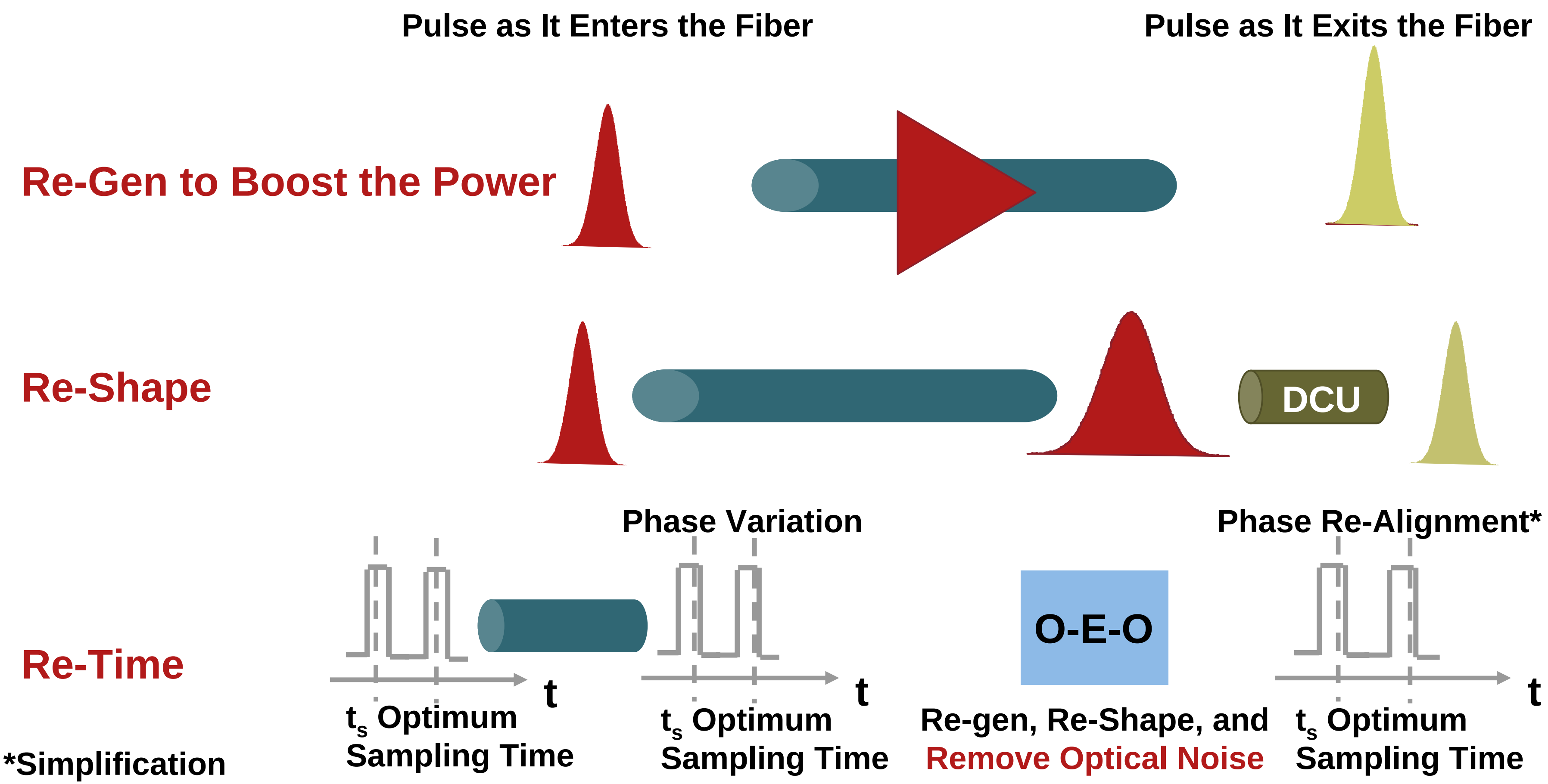
FWM and Dispersion

Dispersion Washes out FWM Effects



The Three “R”s of Optical Networking

The Options to Recover the Signal from Attenuation/Dispersion/Jitter Degradation Are:



*Simplification

SM Optical Fiber Types

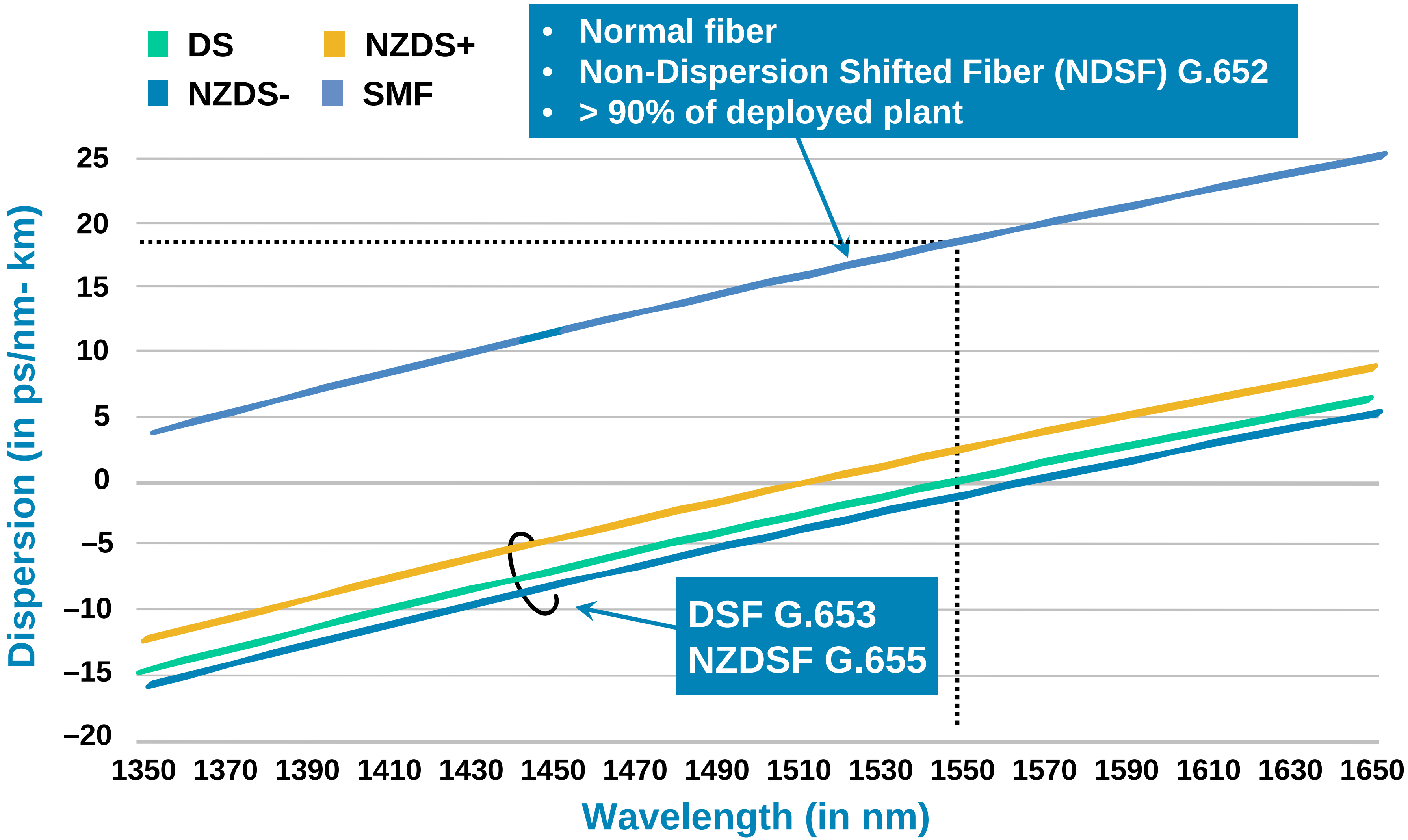
Types of Single-Mode Fiber

- SMF (standard, 1310 nm optimized, G.65)
  - Most widely deployed so far, introduced in 1986, cheapest
- DSF (Dispersion Shifted, G.653)
  - Intended for single channel operation at 1550 nm
- NZDSF (Non-Zero Dispersion Shifted, G.655)
  - For WDM operation in the 1550 nm region only
  - TrueWave™, FreeLight™, LEAF, TeraLight™, etc.
    - Latest generation fibers developed in mid 90s
    - For better performance with high capacity DWDM systems
  - MetroCor™, WideLight™
  - Low PMD ultra long haul fibers

TrueWave Is a Trademark of Lucent; TeraLight Is a Trademark of Alcatel;

FreeLight and WideLight Are Trademarks of Pirelli; MetroCor Is a Trademark of Corning

Fiber Dispersion Characteristics



Different Solutions for Different Fiber Types

SMF (G.652)	▪ Good for TDM at 1310 nm ▪ OK for TDM at 1550 ▪ OK for DWDM (with Dispersion Mgmt)
DSF (G.653)	▪ OK for TDM at 1310 nm ▪ Good for TDM at 1550 nm ▪ Bad for DWDM (C-Band)
NZDSF (G.655)	▪ OK for TDM at 1310 nm ▪ Good for TDM at 1550 nm ▪ Good for DWDM (C + L Bands)
Extended Band (G.652.C) (Suppressed Attenuation in the Traditional Water Peak Region)	▪ Good for TDM at 1310 nm ▪ OK for TDM at 1550 nm ▪ OK for DWDM (with Dispersion Mgmt ▪ Good for CWDM (> Eight wavelengths)

The Primary Difference Is in the Chromatic Dispersion Characteristics

Span Design

Span Design Limits Attenuation

- Source and receiver characteristics

    Tx: 0dBm

    Rx sensitivity: –28dBm

    Dispersion tolerance: 1600ps/nm

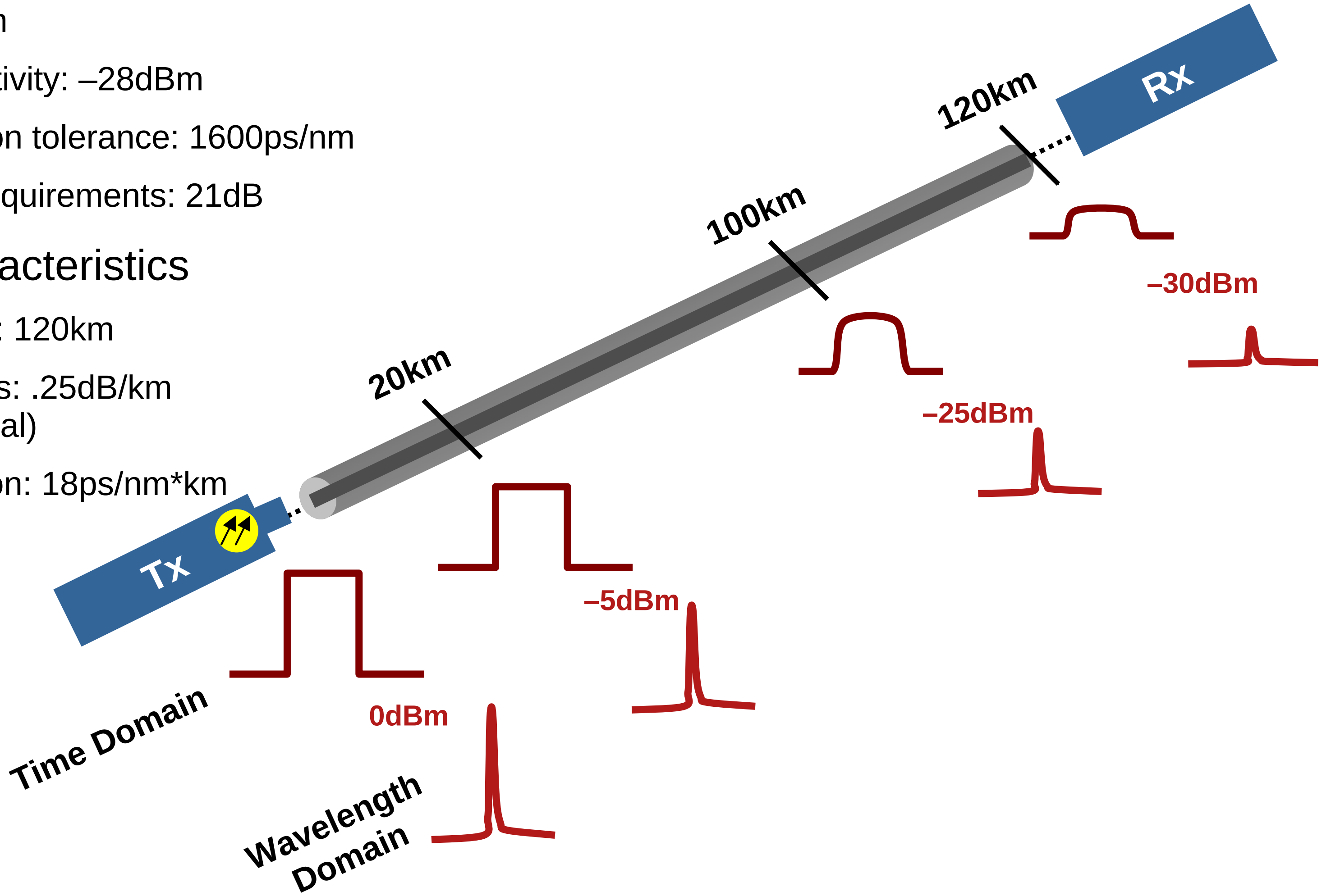
    OSNR requirements: 21dB

- Span characteristics

    Distance: 120km

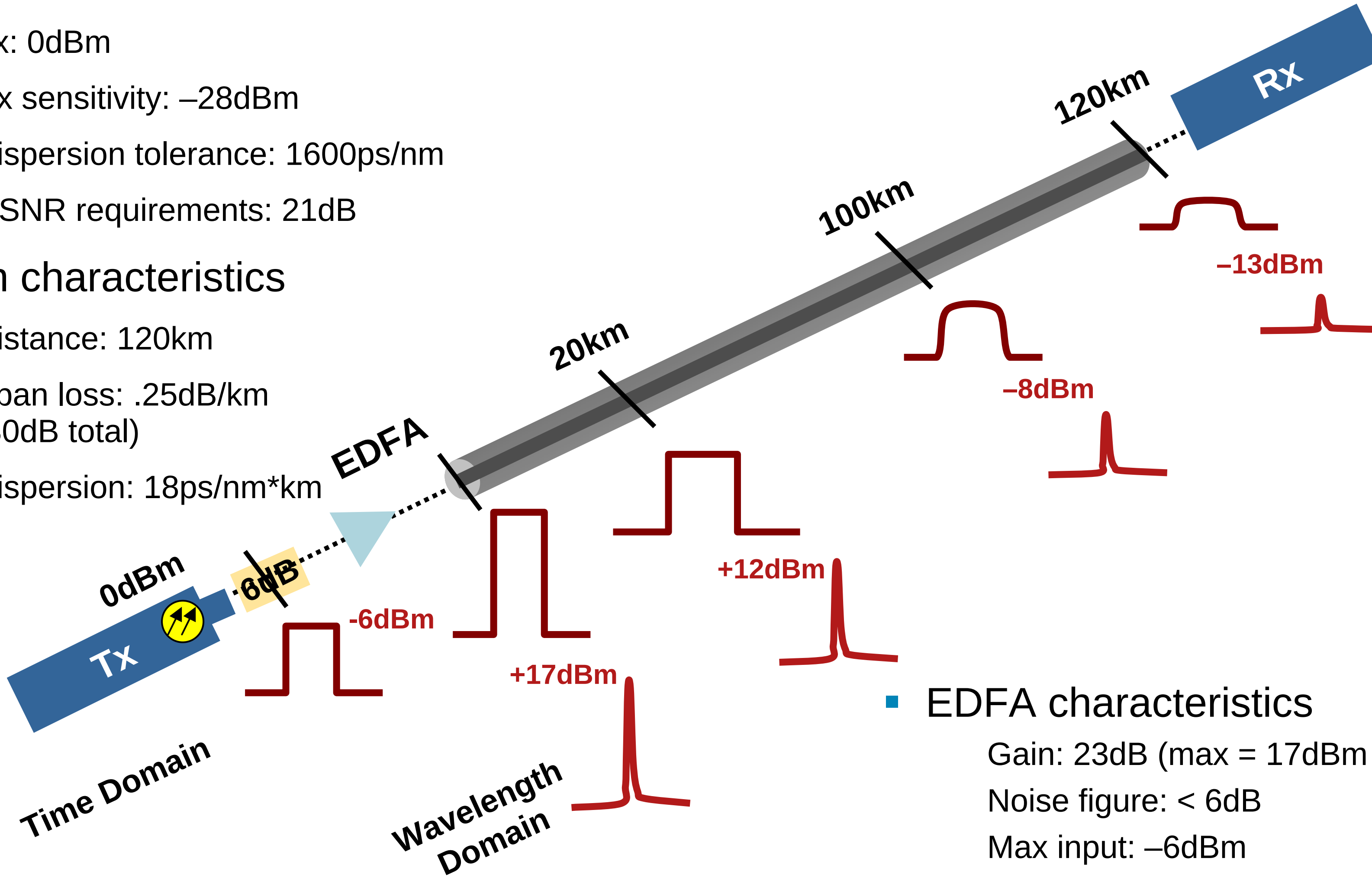
    Span loss: .25dB/km
    (30dB total)

    Dispersion: 18ps/nm*km



Span Design Limits Amplification

- Source and receiver characteristics
  - Tx: 0dBm
  - Rx sensitivity: –28dBm
  - Dispersion tolerance: 1600ps/nm
  - OSNR requirements: 21dB
- Span characteristics
  - Distance: 120km
  - Span loss: .25dB/km (30dB total)
  - Dispersion: 18ps/nm*km



- EDFA characteristics
  - Gain: 23dB (max = 17dBm
  - Noise figure: < 6dB
  - Max input: –6dBm

Span Design Limits
Dispersion

- Source and receiver characteristics

  Tx: 0dBm

  Rx sensitivity: –28dBm

  Dispersion tolerance: 1600ps/nm

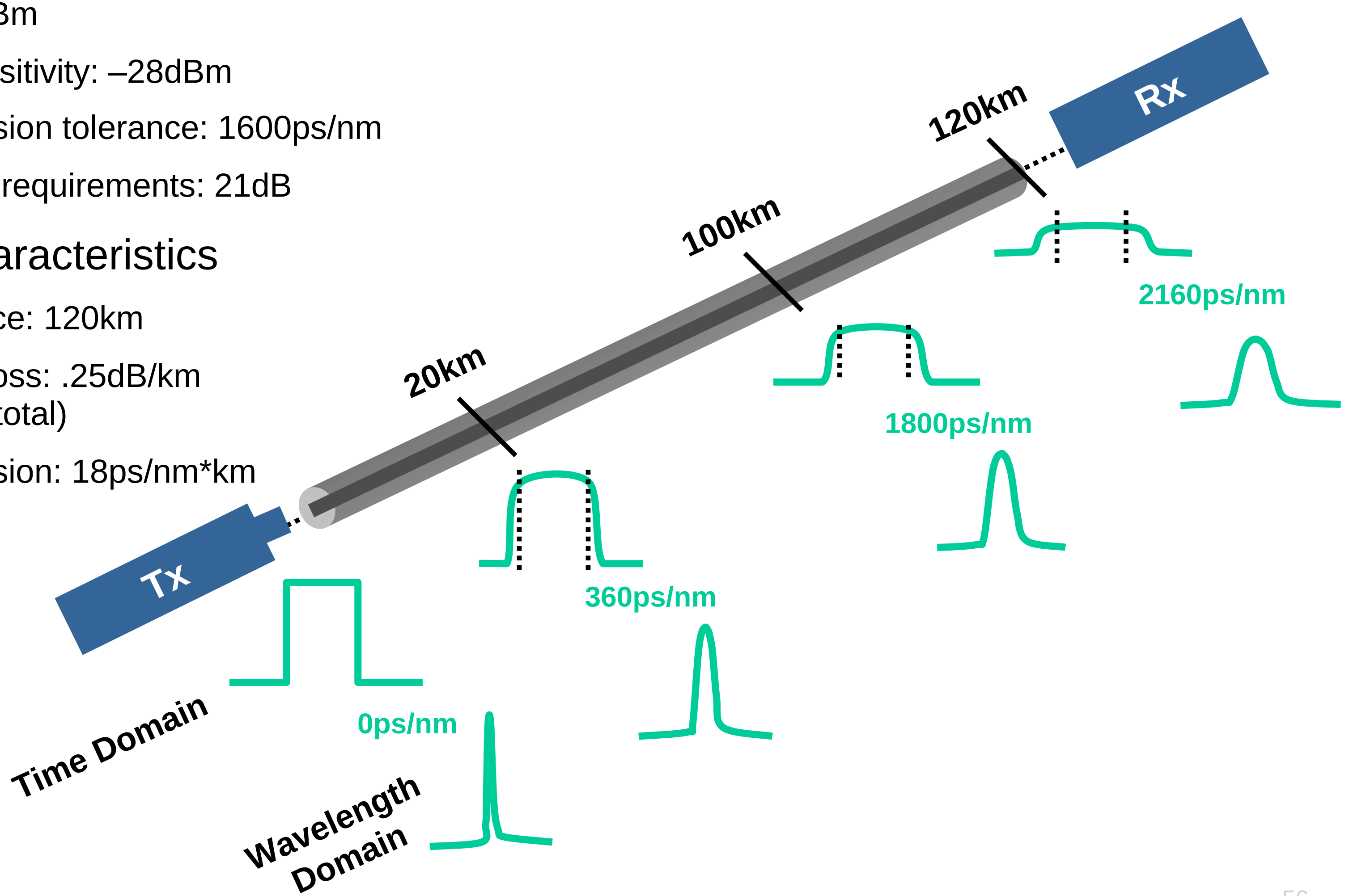
  OSNR requirements: 21dB

- Span characteristics

  Distance: 120km

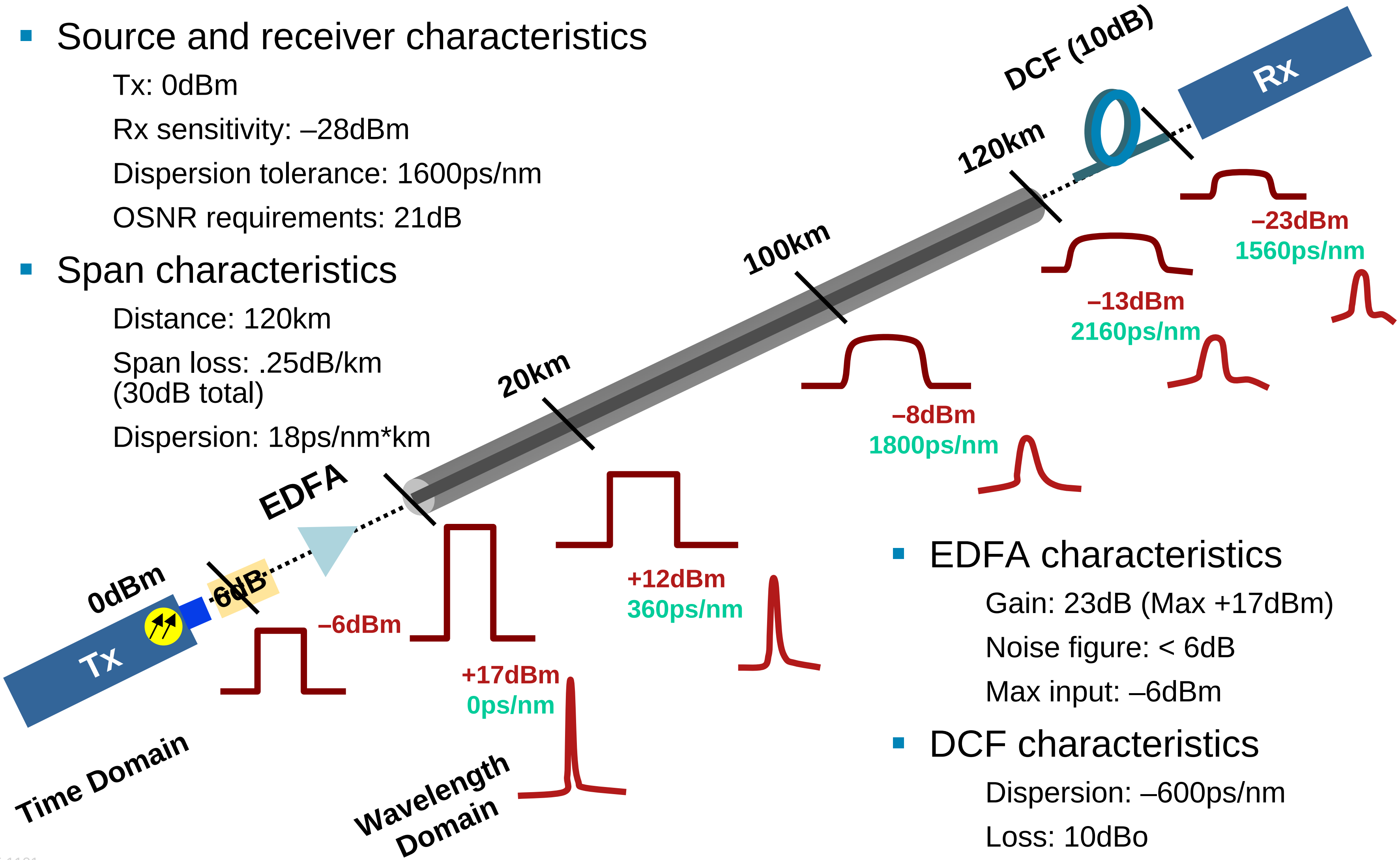
  Span loss: .25dB/km
  (30dB total)

  Dispersion: 18ps/nm*km



Span Design Limits
Dispersion Compensation

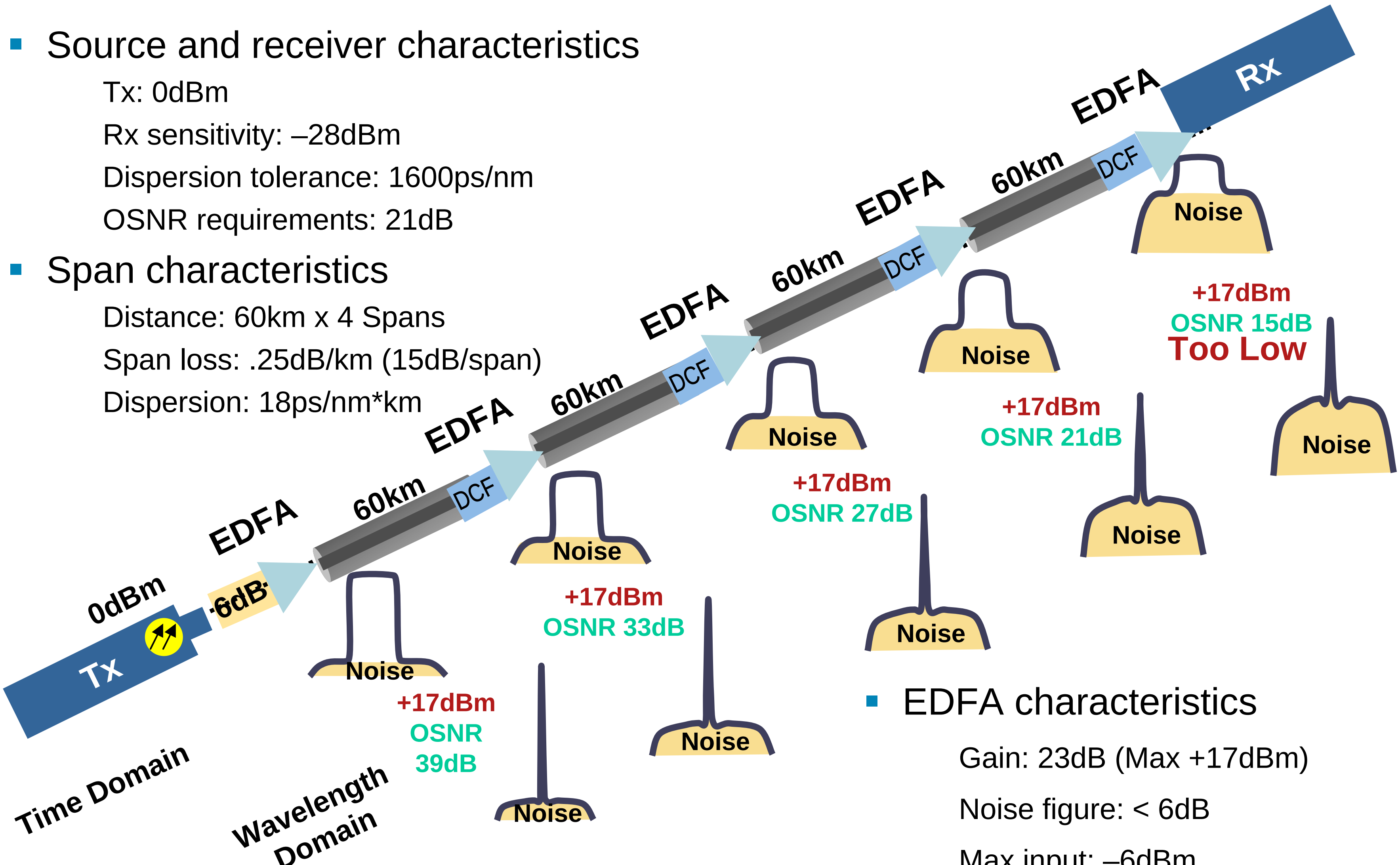
- Source and receiver characteristics
  - Tx: 0dBm
  - Rx sensitivity: –28dBm
  - Dispersion tolerance: 1600ps/nm
  - OSNR requirements: 21dB
- Span characteristics
  - Distance: 120km
  - Span loss: .25dB/km (30dB total)
  - Dispersion: 18ps/nm*km



- EDFA characteristics
  - Gain: 23dB (Max +17dBm)
  - Noise figure: < 6dB
  - Max input: –6dBm
- DCF characteristics
  - Dispersion: –600ps/nm
  - Loss: 10dBo

Span Design
Limits of Amplification (OSNR)

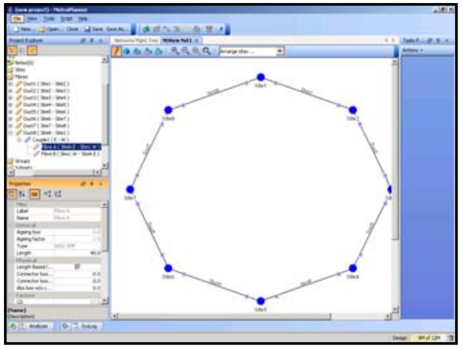
- Source and receiver characteristics
  - Tx: 0dBm
  - Rx sensitivity: –28dBm
  - Dispersion tolerance: 1600ps/nm
  - OSNR requirements: 21dB
- Span characteristics
  - Distance: 60km x 4 Spans
  - Span loss: .25dB/km (15dB/span)
  - Dispersion: 18ps/nm*km

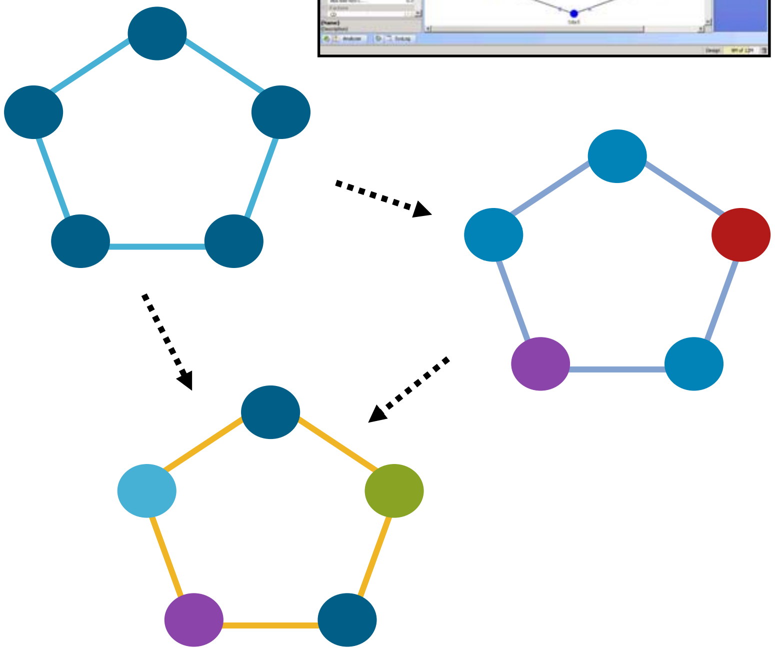


- EDFA characteristics
  - Gain: 23dB (Max +17dBm)
  - Noise figure: < 6dB
  - Max input: –6dBm

Real Network Design Challenges

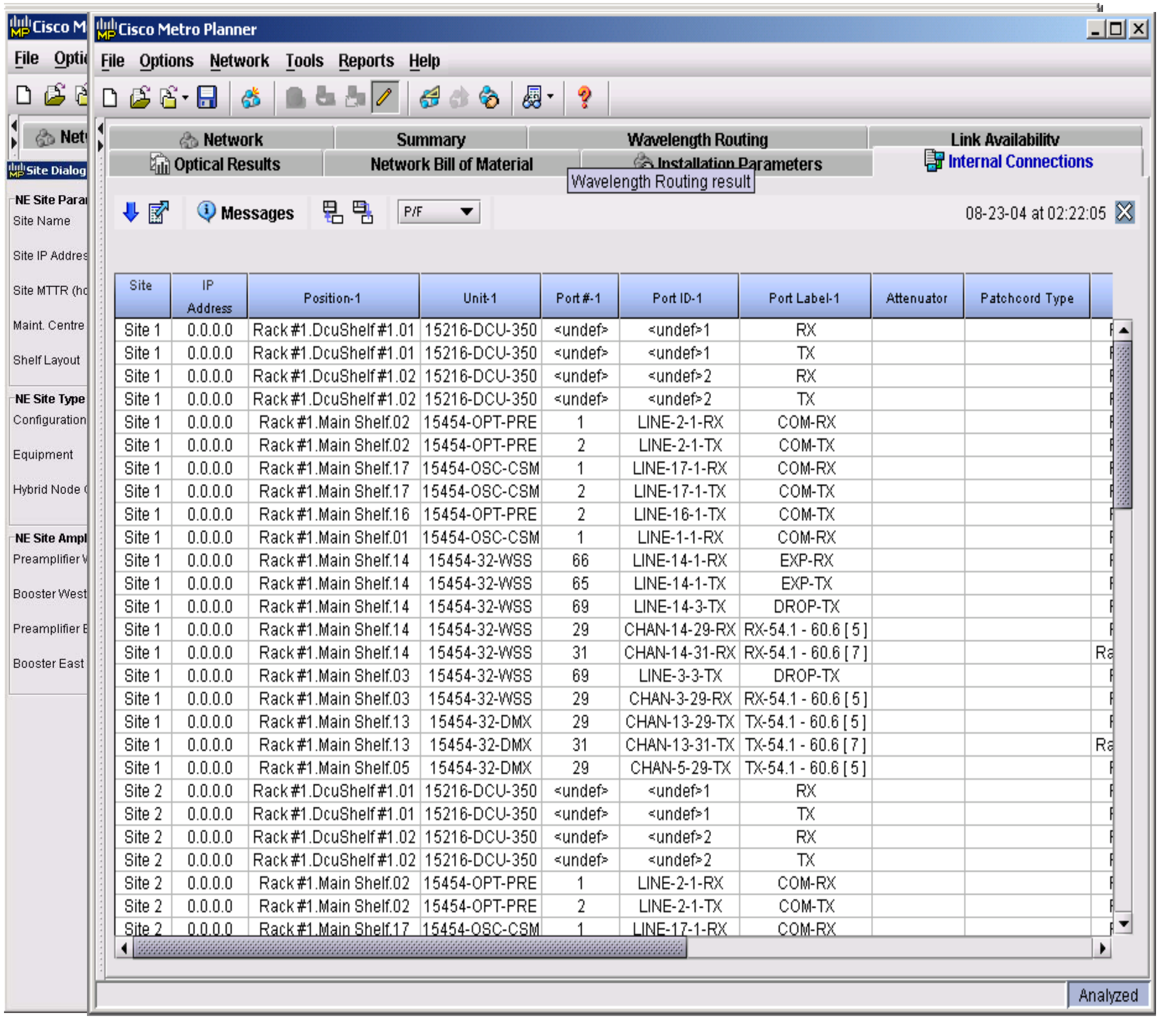
- Complicated multi-ring designs
- Multiple wavelengths
- Any to any demand
- Nonlinearities
- Advanced modulation





Simulation and Network Design Software Is Used to Simplify Design

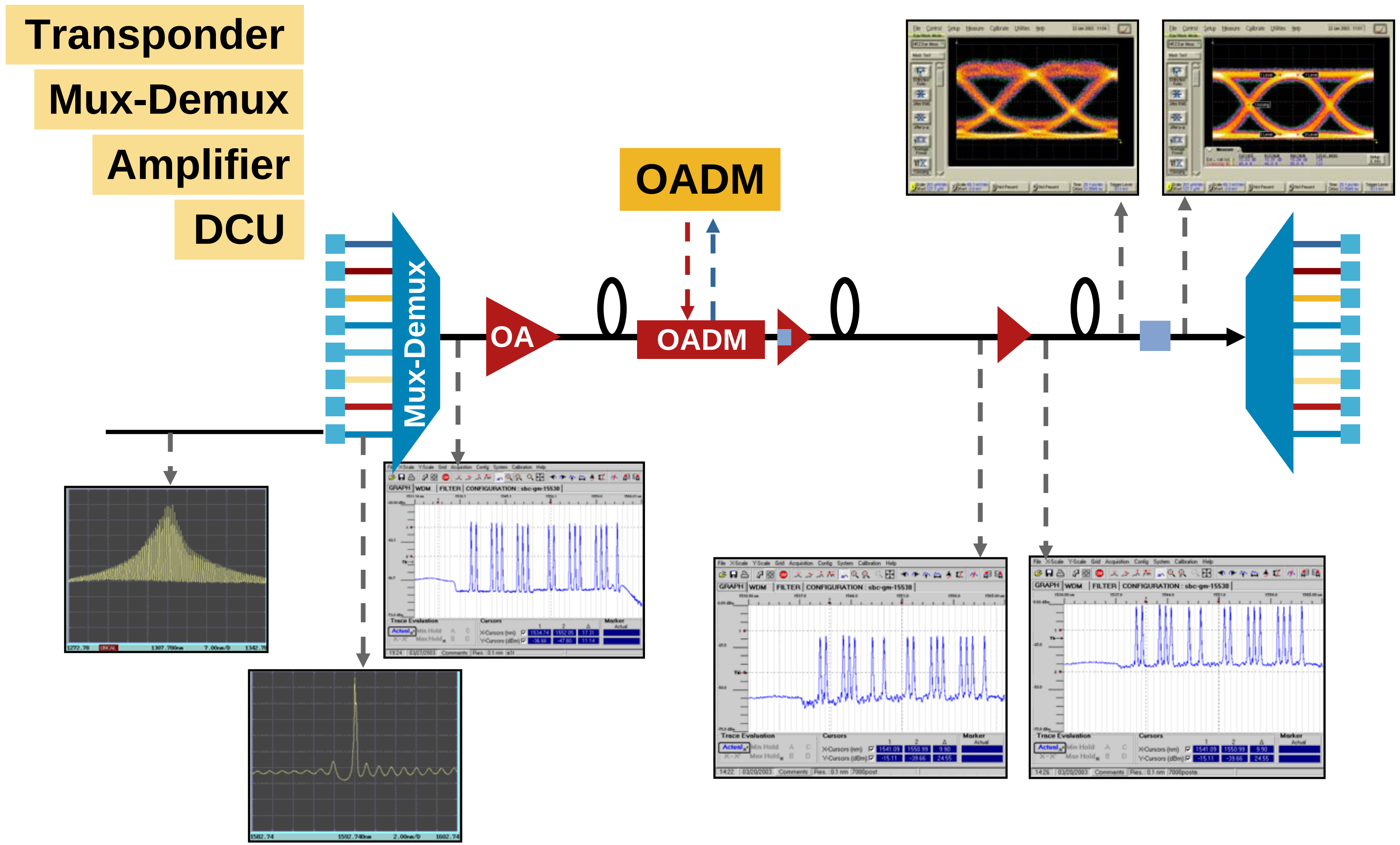
Network Design Tools? Concept to Creation Easier



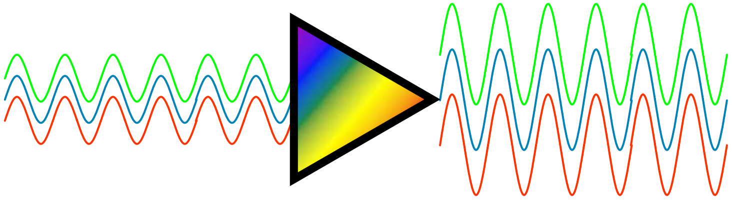
- GUI-based network design entry
- Any-to-any demand
- Comprehensive analysis = first-time success
- Smooth transition from design to implementation
- Bill of materials
- Rack diagrams
- Step-by-step interconnect

DWDM Transmission

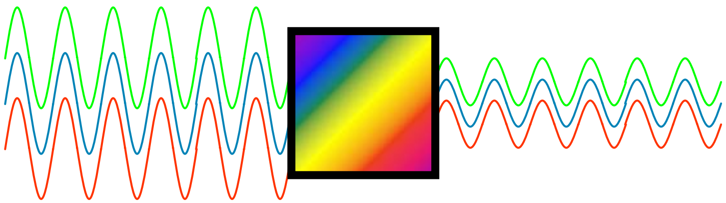
DWDM Systems



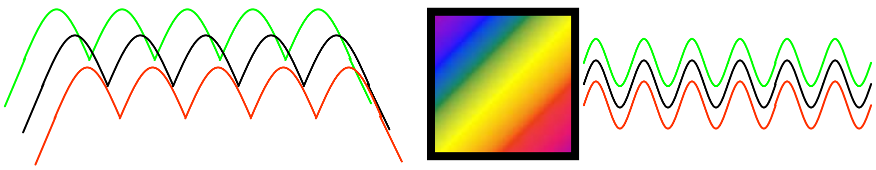
More DWDM Components



Optical Amplifier
(EDFA)

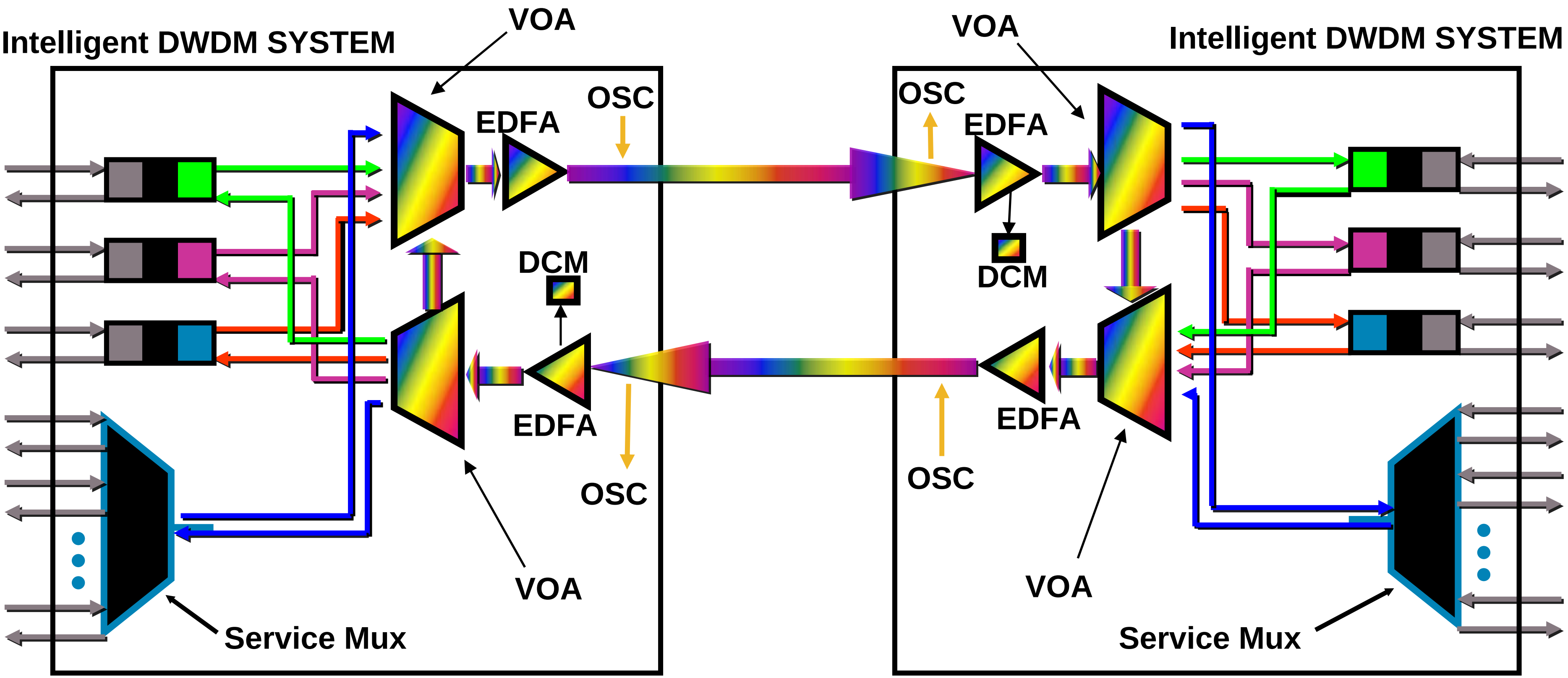


Optical Attenuator
Variable Optical Attenuator



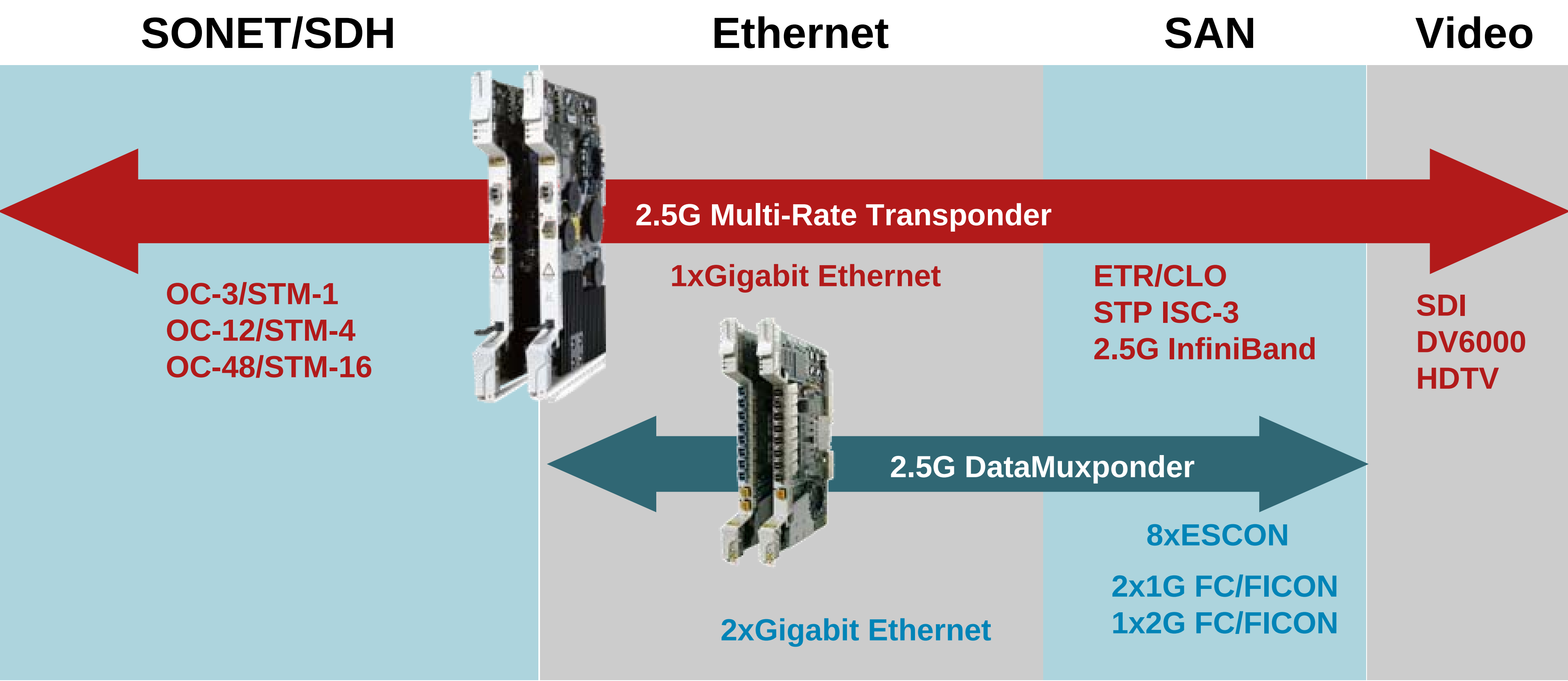
Dispersion Compensator (DCM / DCU)

Intelligent DWDM Network Architecture

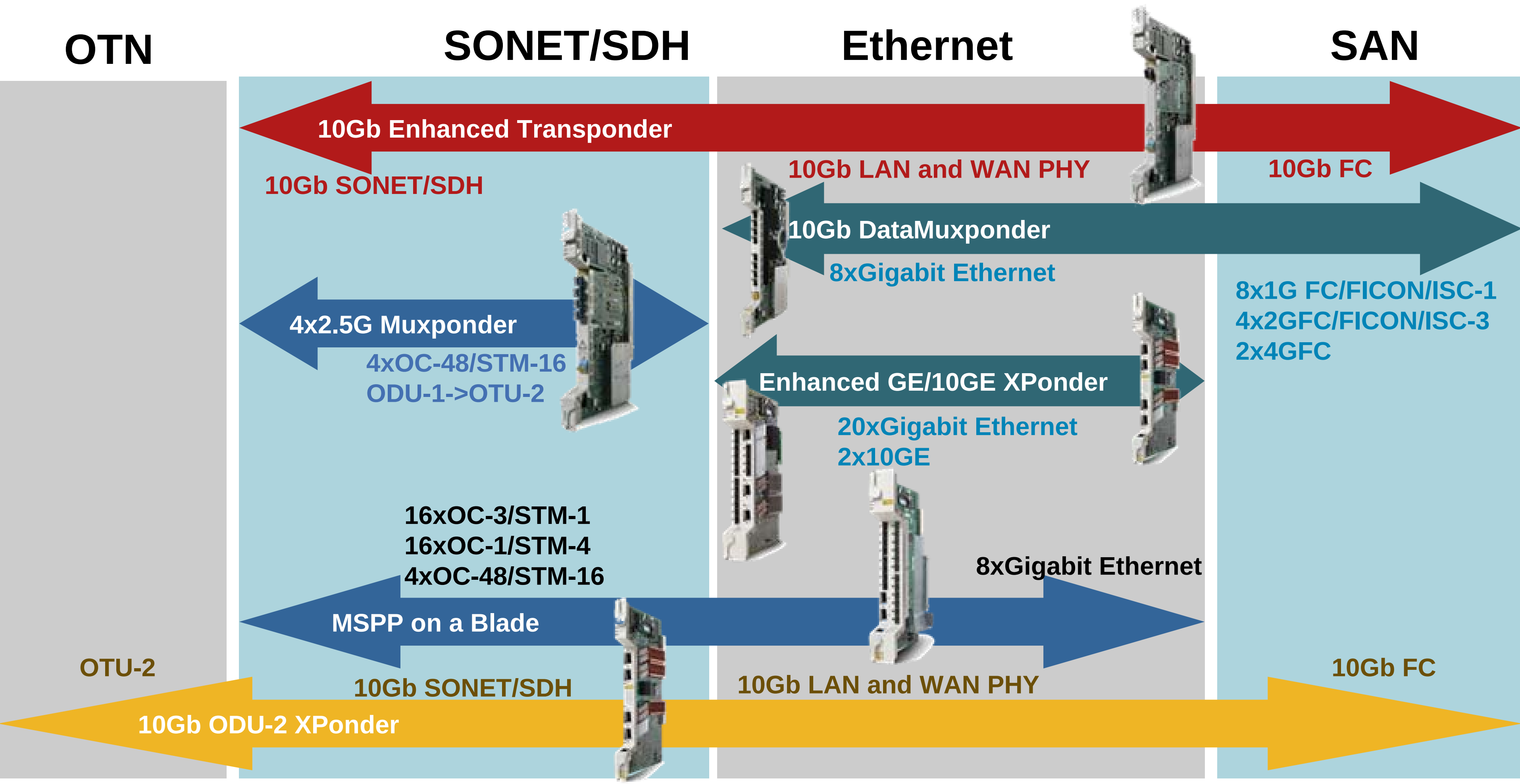


Integrated system architecture

2.5Gb Service Cards



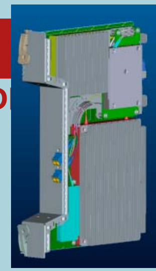
10Gb Service Cards



40Gb Service Cards

OTN | **SONET/SDH** | **Ethernet** | **SAN**

40Gb Transponder

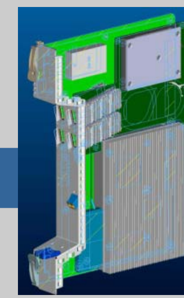


40Gb OTU-3

40Gb SONET/SD

40Gb LAN

40Gb Muxponder



4x10Gb OTU-2
4x10Gb OTU-2e

4x10Gb SONET/SDH

4x10Gb LAN

4x10Gb FC
4x8Gb FC

- BENEFIT: All 40G applications covered by 1 transponder
- BENEFIT: Aggregation cards reduce the cost of service delivery and allow for “pay as you grow” using XFP

Optical Amplifiers and Filters

EDFA

- 17dBm Variable Gain Pre-Amplifier with DCU Access
- 17dBm Variable Gain Booster
- 21dBm Variable Gain Booster
- 17 dBm Fix Gain Booster
- 21dBm Variable Gain Regional Amplifier with DCU Access
- L-Band 17dB Variable Gain Booster
- L-Band 20 dB Variable Gain Pre-Amplifier with DCU Access

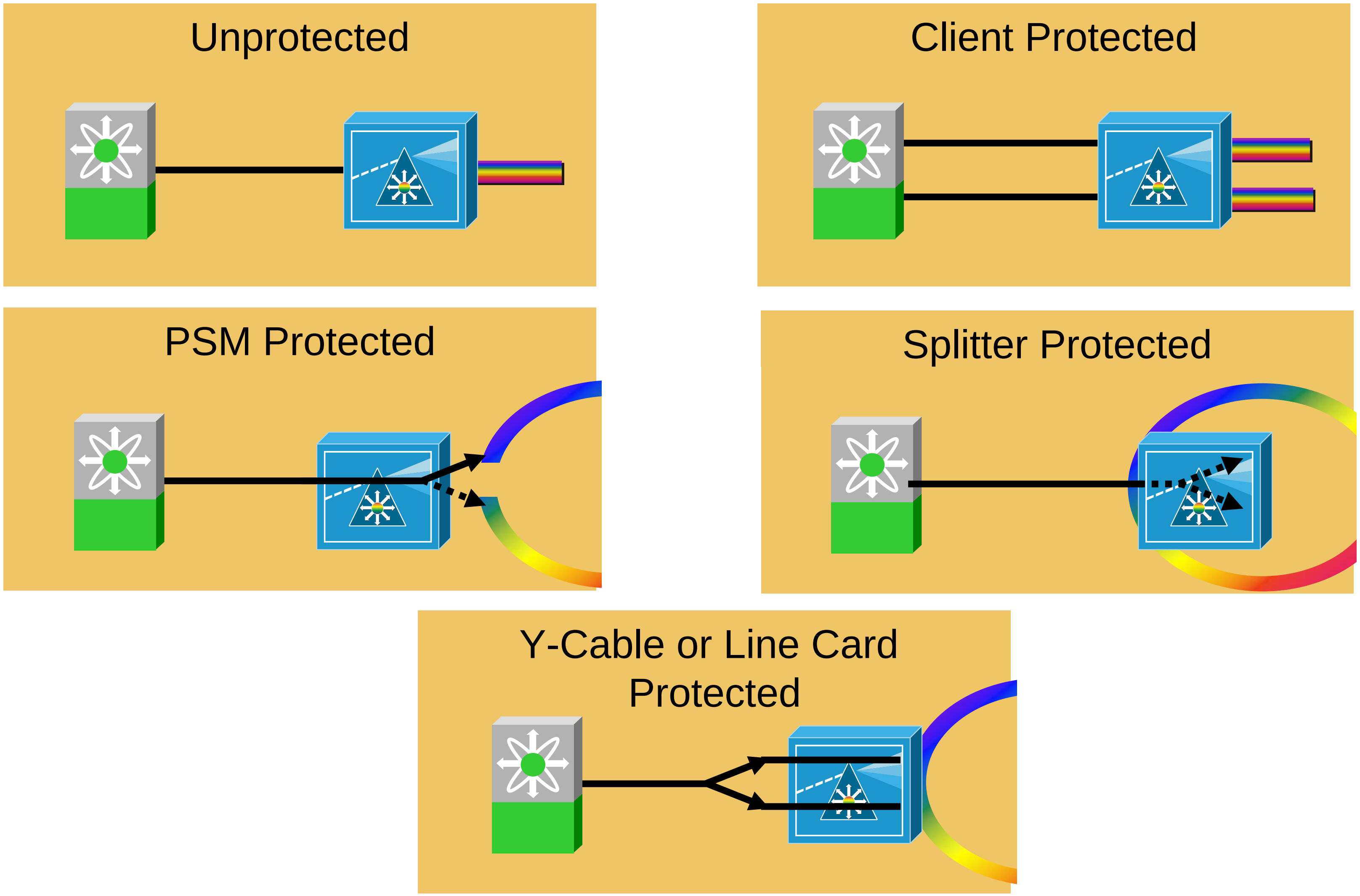
RAMAN

- 500mW RAMAN
- w/ integrated 7dBm
- Variable Gain Pre-Amplifier

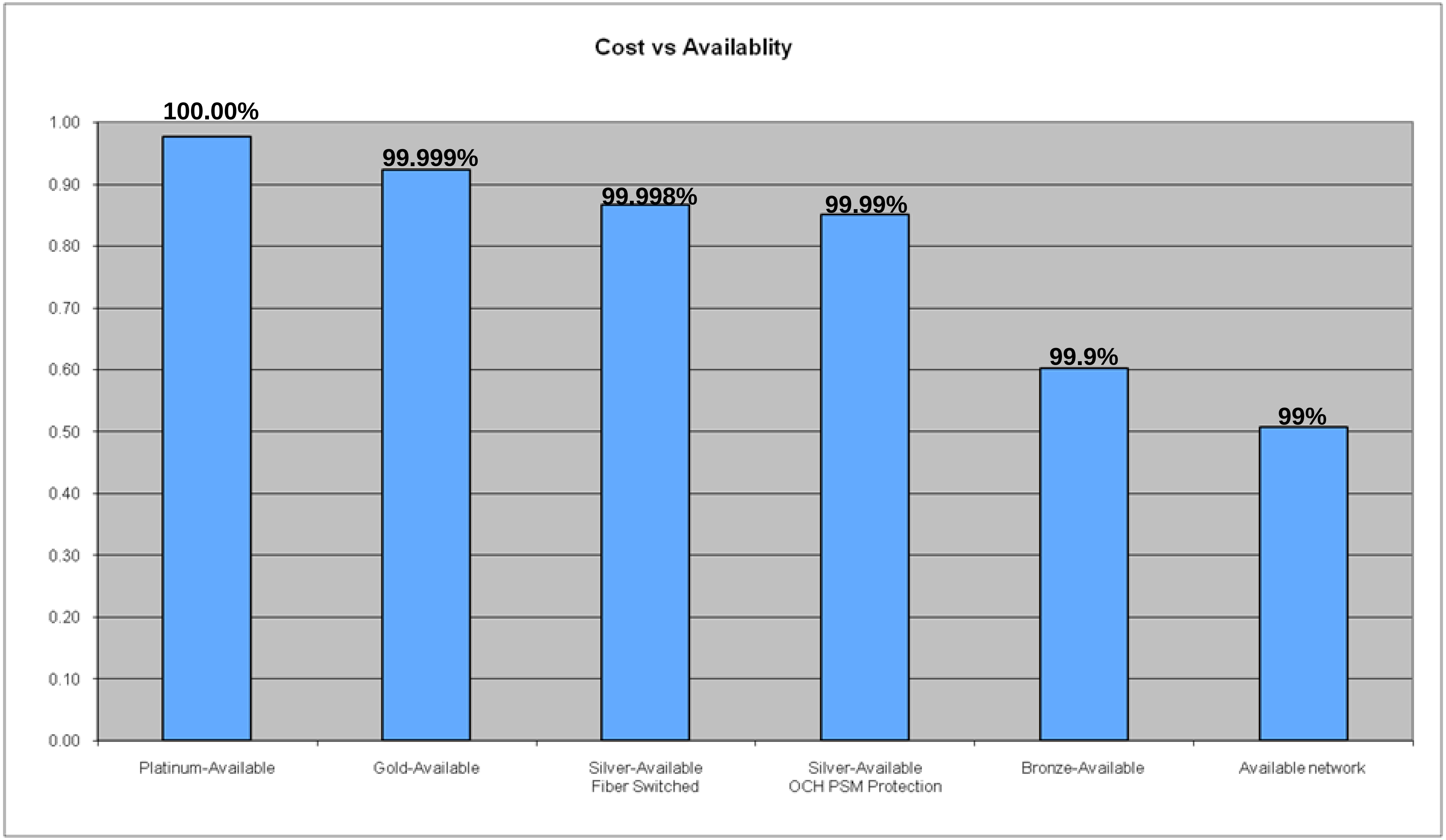
Filters

- 40ch/80ch 2^0 WSS ROADM
- 40ch 8^0 WXC ROADM
- 40ch/80ch Mux/Demux

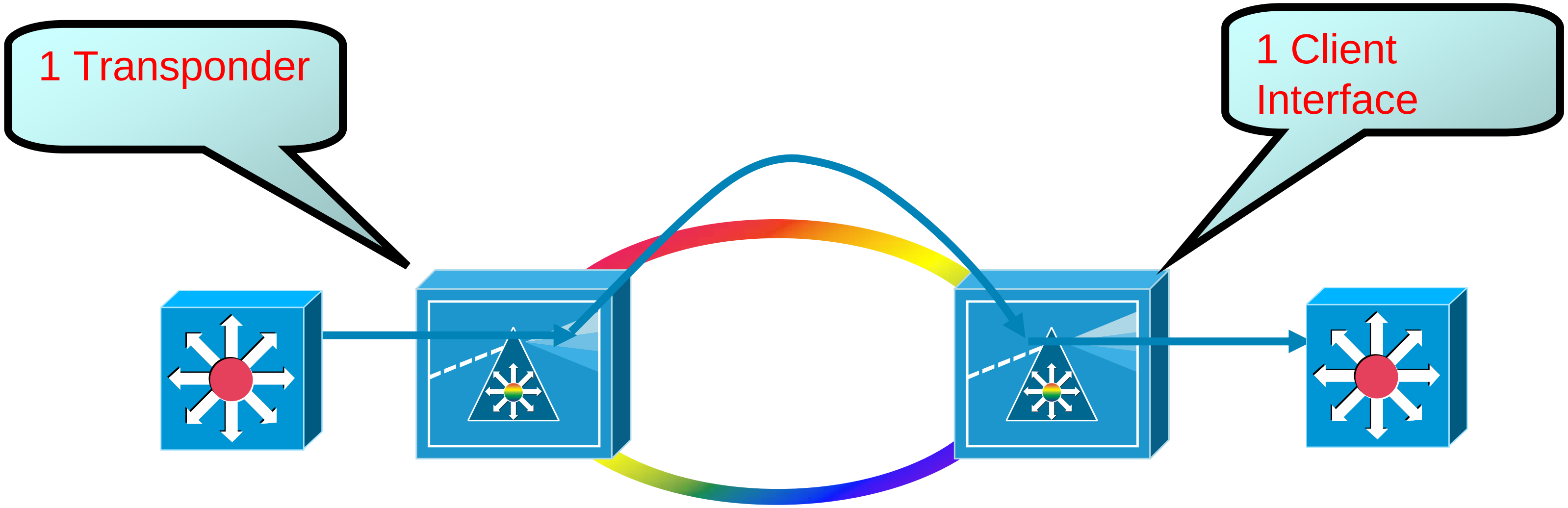
Optical Protection Schemes



Availability Solutions Comparison

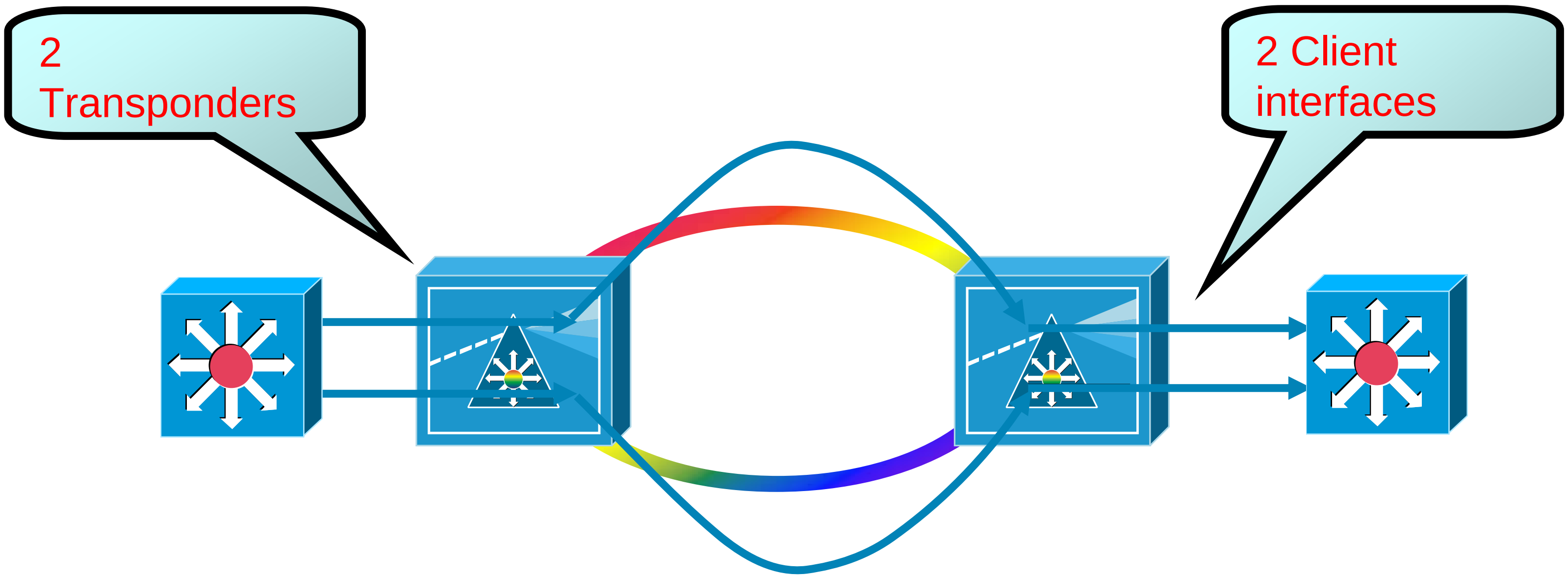


Unprotected



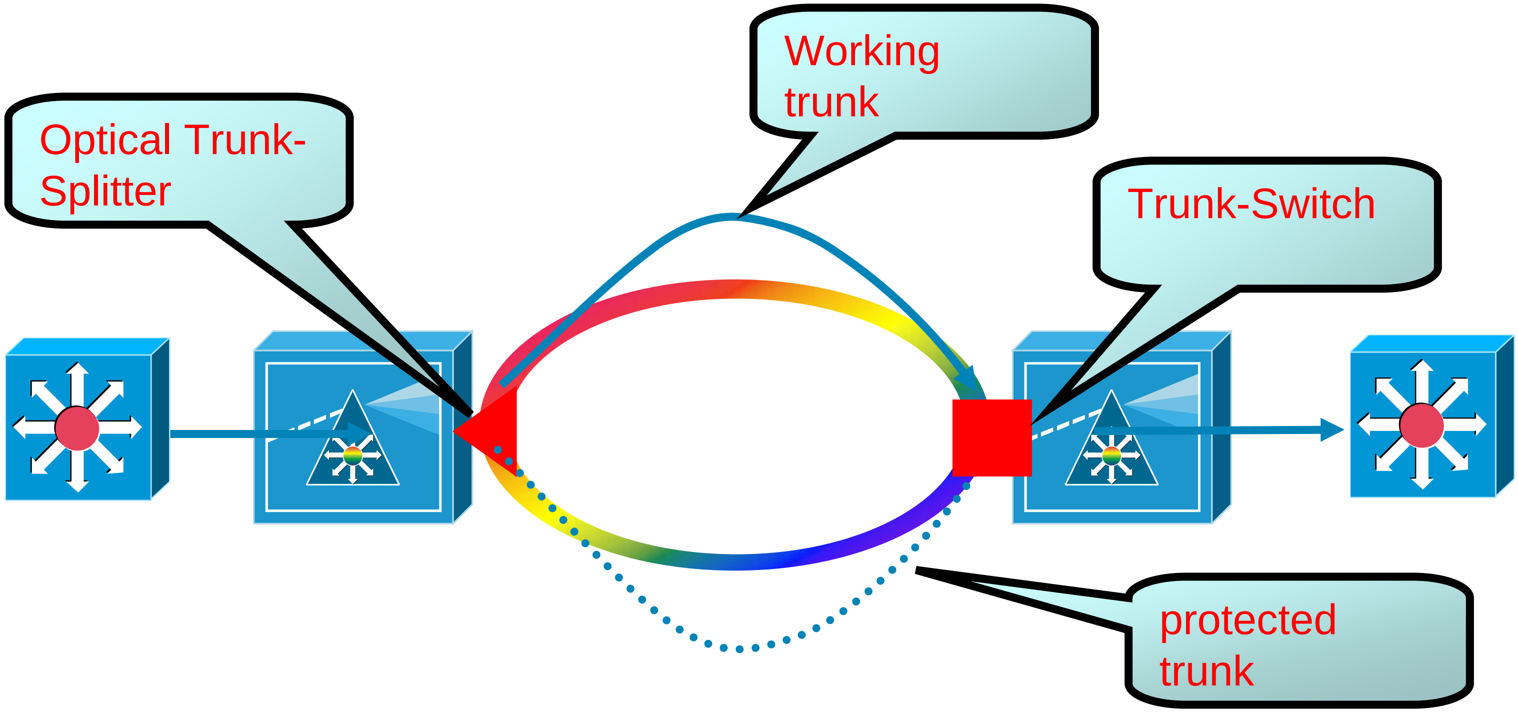
- 1 client & 1 trunk laser (one transponder) needed, only 1 path available
- No protection in case of fiber cut, transponder failure, client failure, etc..

Client Protected Mode



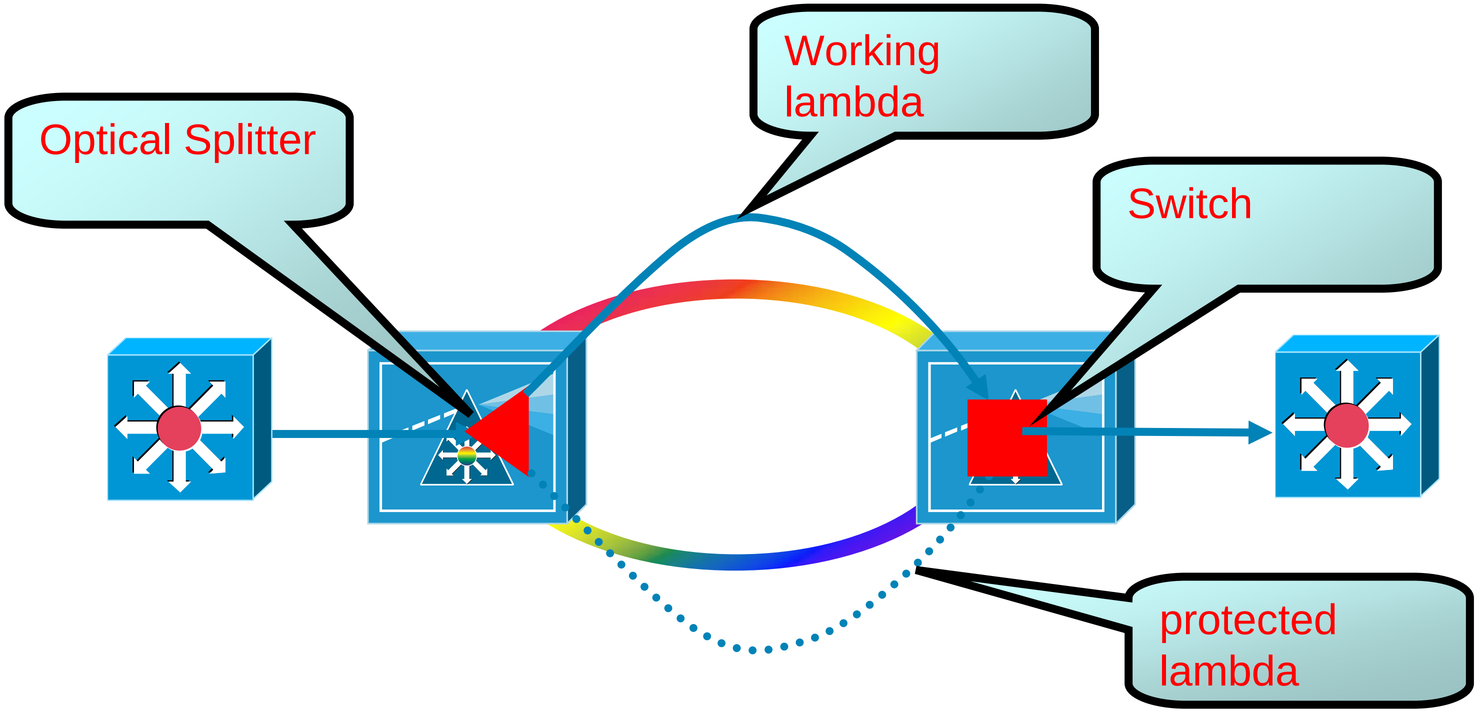
- 2 client & 2 trunk lasers (two transponders) needed, two optically unprotected paths
- Protection via higher layer protocol

Optical Trunk Protection



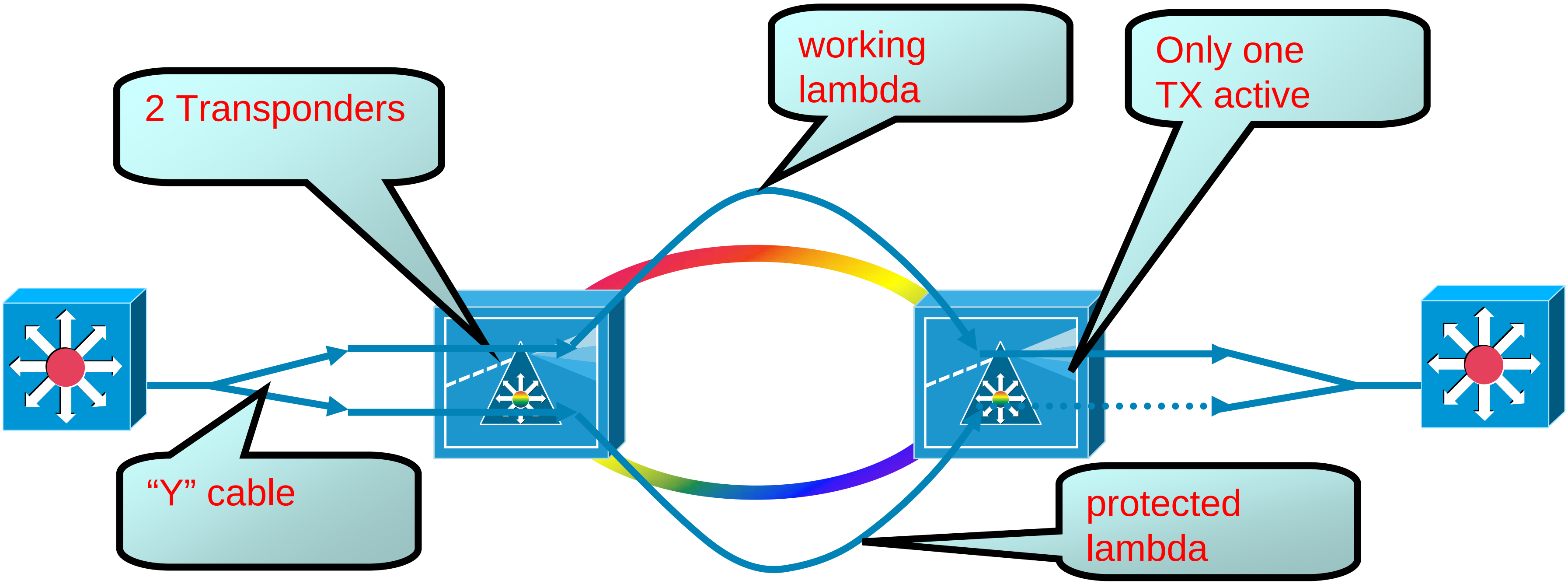
- Only valid in Point 2 Point topologies
- Protects against Fiber Breaks

Optical Splitter Protection



- Only 1 client & 1 trunk laser (single transponder) needed
- Protects against Fiber Breaks

Line Card / Y- Cable Protection



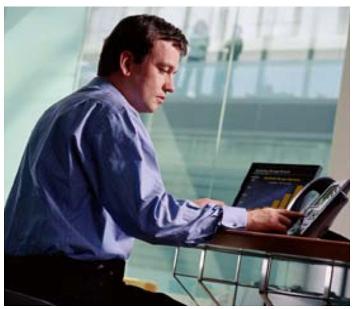
- 2 client & 2 trunk lasers (two transponders) needed
- Increased cost & availability

ROADM:
Operational Benefits

Manual DWDM Network Life-Cycle: Present Mode of Operation (PMO)

Manual provisioning of optical design parameters

Manual provisioning of equipment & topology into EMS/NMS



Complicated Network Planning

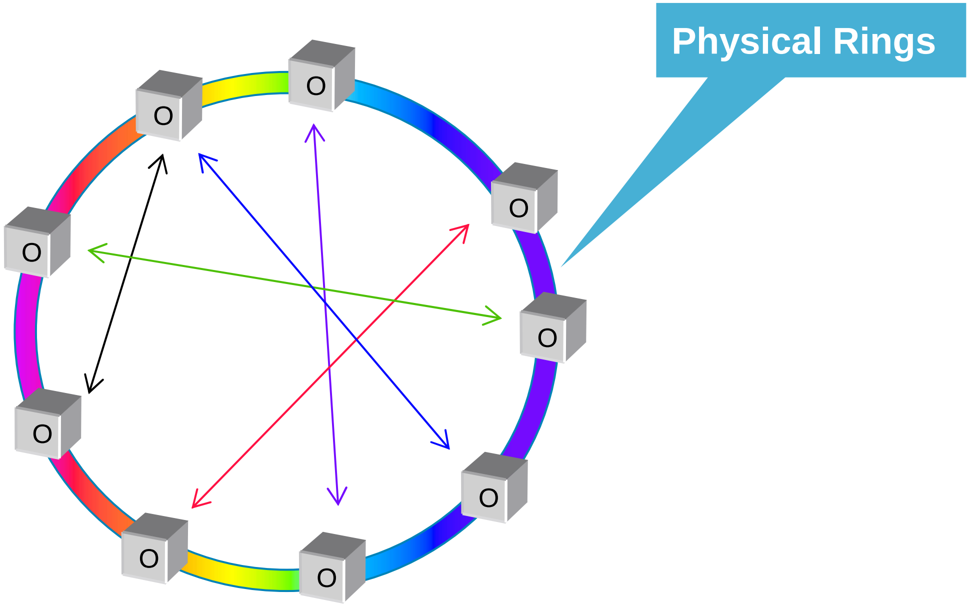
Manual installation, manual power measurements and VOA tweaking at every site for every l

Labor-intensive operation

Manual DWDM processes: labor intensive and error prone
Result: high OpEx costs

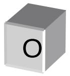
ROADM Based DWDM Networks

Simplify Opex, Simplify Network Architecture, Simplify Network Planning



OADM Based Architecture

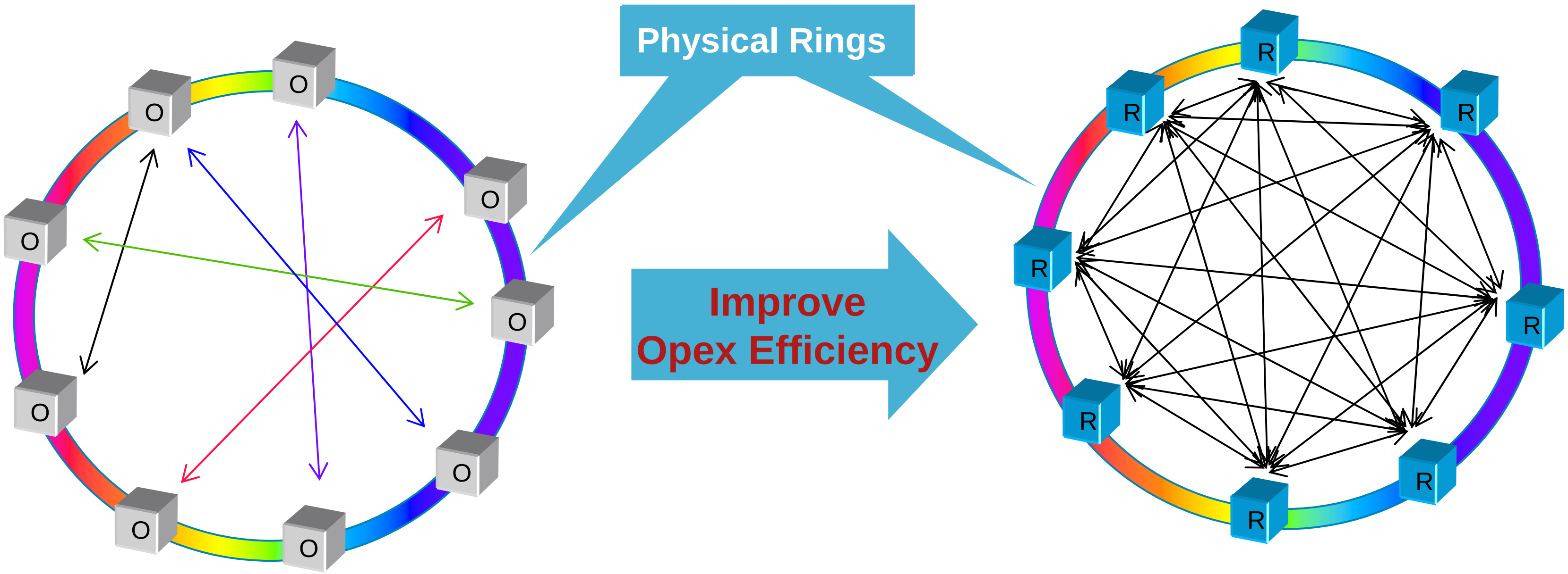
- Re-plan network every time a new services is added
- Certain sites can only communicate with certain other sites
- Extensive man hours to retune the network
- Need to brake entire ring to prevent lasing



1-8ch OADM

ROADM Based DWDM Networks

Simplify Opex, Simplify Network Architecture, Simplify Network Planning



OADM Based Architecture

- Re-plan network every time a new services is added
- Certain sites can only communicate with certain other sites
- Extensive man hours to retune the network
- Need to brake entire ring to prevent lasing

ROADM Based Architecture

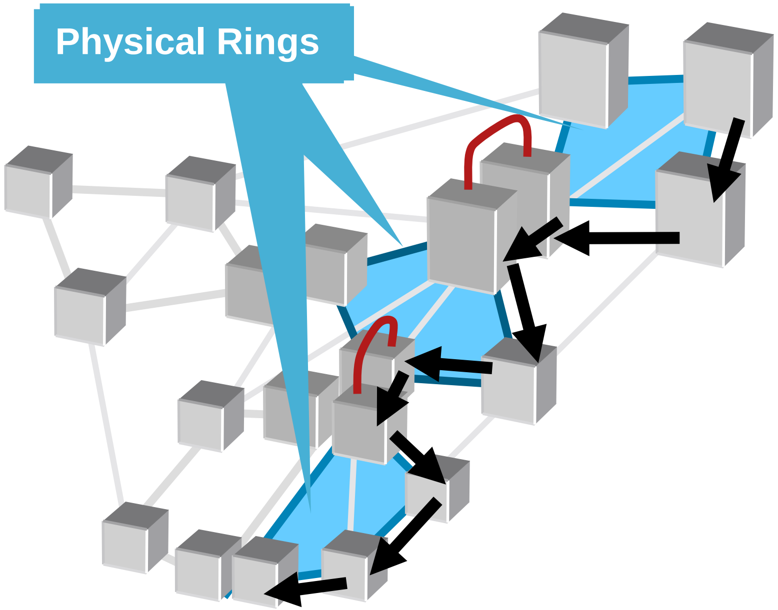
- Plan network once
- All nodes can talk to all nodes day one
- The network Automatically Tunes itself
- Improved network performance with DGE at every site

O 1-8ch OADM

R 2˚ ROADM

DWDM Mesh Benefits

Capacity Increase, Efficient Fiber Usage, Increased Availability



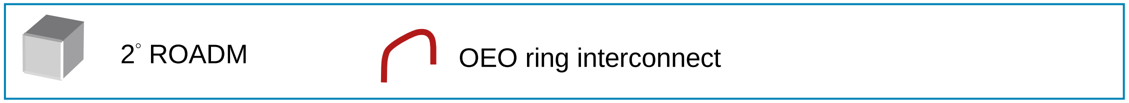
Ring-Based Architecture

Traffic must follow ring topology, constricted

Inefficient traffic routing increase regeneration

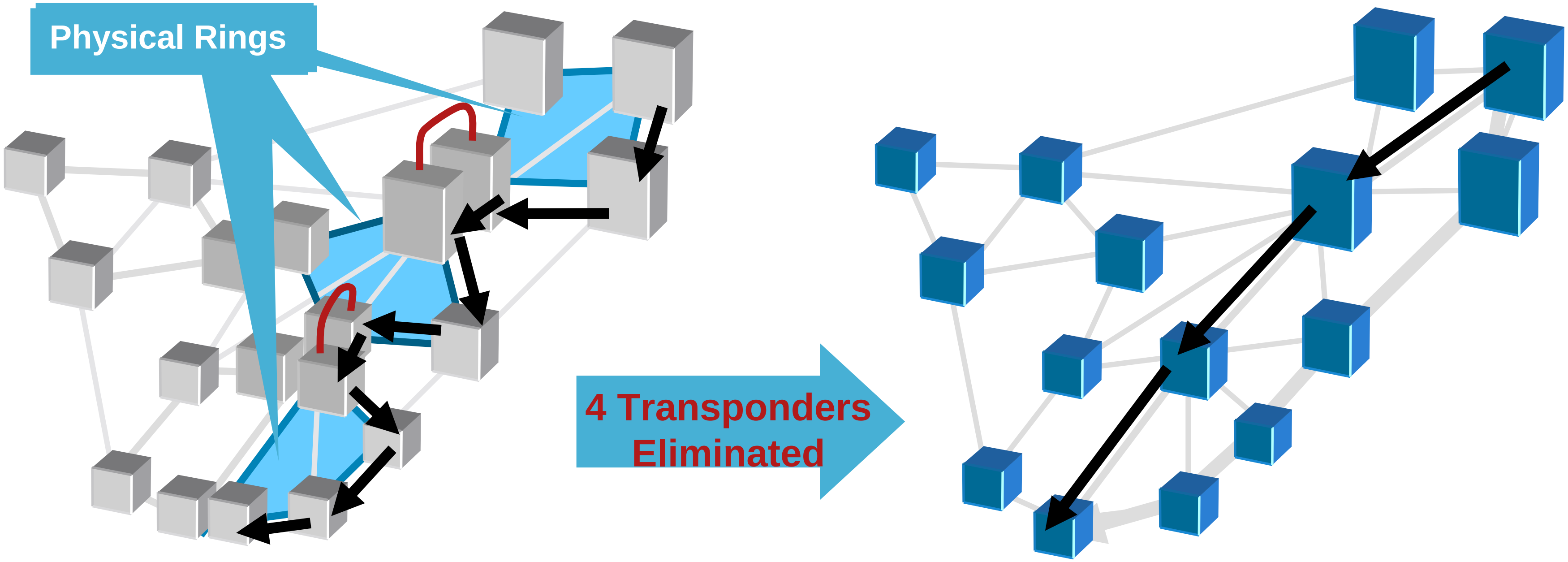
Costly transponders for OEO ring interconnects

Single choice for service path & protect path



DWDM Mesh Benefits

Capacity Increase, Efficient Fiber Usage, Increased Availability



Ring-Based Architecture

- Traffic must follow ring topology, constricted
- Inefficient traffic routing increase regeneration
- Costly transponders for OEO ring interconnects
- Single choice for service path & protect path

Mesh Architecture

- A–Z provisioning—data follows fiber topology
  - more efficient use of fiber
  - Better load balancing increases capacity
  - Shorter distance = less regeneration
- Eliminate transponders
- More options for service & protect paths

Automated DWDM Network Life-Cycle: Next-Generation Cisco ONS 15454 MSTP

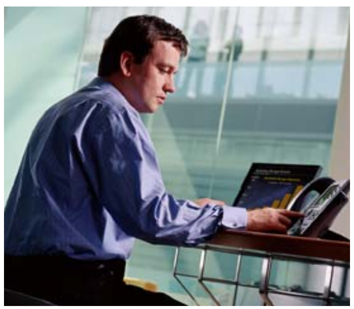
Automated provisioning of all parameters

Easy planning with Cisco MetroPlanner

Automated DWDM Network Life-Cycle: Next-Generation Cisco ONS 15454 MSTP

Automated provisioning of all parameters

Easy design changes based on actual fiber plant

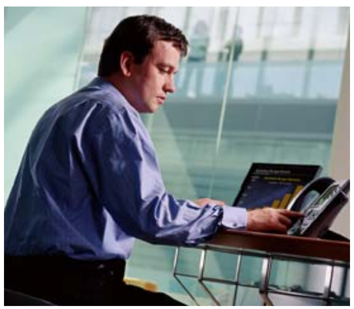


Easy planning with Cisco MetroPlanner

Automated DWDM Network Life-Cycle: Next-Generation Cisco ONS 15454 MSTP

Automated provisioning of all parameters

Easy design changes based on actual fiber plant



Easy planning with Cisco MetroPlanner

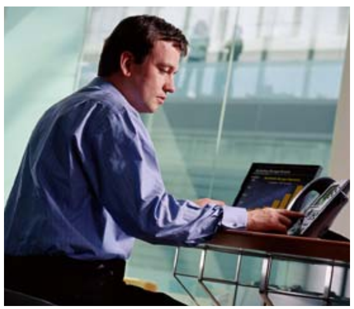
Automated optical layer for end-to-end connection setup; Manual patching of client at end-points only

Automated DWDM Network Life-Cycle: Next-Generation Cisco ONS 15454 MSTP

Automated provisioning of all parameters

Easy design changes based on actual fiber plant

CTM learns everything from the network and stays in sync



Easy planning with Cisco MetroPlanner

Automated optical layer for end-to-end connection setup; Manual patching of client at end-points only

Simplified, graphical A-Z provisioning & trouble shooting via CTM

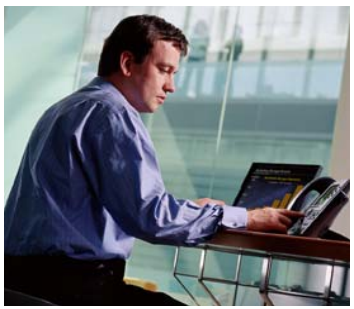
Automated DWDM Network Life-Cycle: Next-Generation Cisco ONS 15454 MSTP

Automated provisioning of all parameters

Easy design changes based on actual fiber plant

CTM learns everything from the network and stays in sync

Automated end-to-end setup



Easy planning with Cisco MetroPlanner

Automated optical layer for end-to-end connection setup; Manual patching of client at end-points only

Simplified, graphical A-Z provisioning & trouble shooting via CTM

Automated DWDM Processes: simplified, SONET-like operation
Result: Reduces OpEx, facilitates wide deployment

Cisco ONS 15454 MSPP/MSTP Functionality

Cisco Vision: Flexible and Intelligent Optical Network

Traditional Vendors	Cisco Optical
Inflexible • Preplanning • Rigid configurations • Limited application support • No linkage with service delivery/enables	**Flexible** • ROADM: Fully flexible design rules • ROADM: Any wavelength anywhere • Wide variety of applications • Integrated TDM / Layer2 functionalities + Direct interconnection with L2 / L3
Difficult to Manage	**Intelligent Software Enables Automated Network Set-Up and Management Along Network Life**

Cisco IP NGN Transport Network Innovation– Investment Protection

Multiservice Provisioning Platform

Over 75,000 Deployed

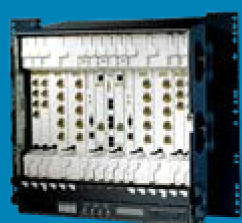
ONS 15454
SONET and SDH

Multiservice Provisioning Platform

MSPP Introduction: SONET/SDH + Ethernet (EoS)

Multiservice Transport Platform

ONS 15454
SONET and SDH



Multiservice Transport Platform

Intelligent DWDM: Consolidating MSPP and DWDM Functionality onto a Single Platform

Reconfigurable Add/Drop Multiplexer (ROADM)

ONS 15454
SONET and SDH

Multiservice Transport Platform

ROADM Solution

2-Degree ROADM: Industry-Leading ROADM Technology Drives Deployable Wavelength Services into the Metro

IP over DWDM

CRS-1

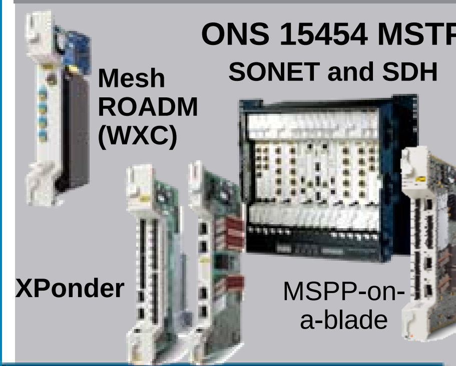
ONS 15454
SONET and SDH

Multiservice Transport Platform

Efficient Core Transport: Integrated Intelligent DWDM and Core Routing Solution: SW Management and Tunable ITU Optics on CRS-1

Mesh ROADM, Ethernet-Enabled DWDM

ONS 15454 MSTP
SONET and SDH



Mesh ROADM (WXC)

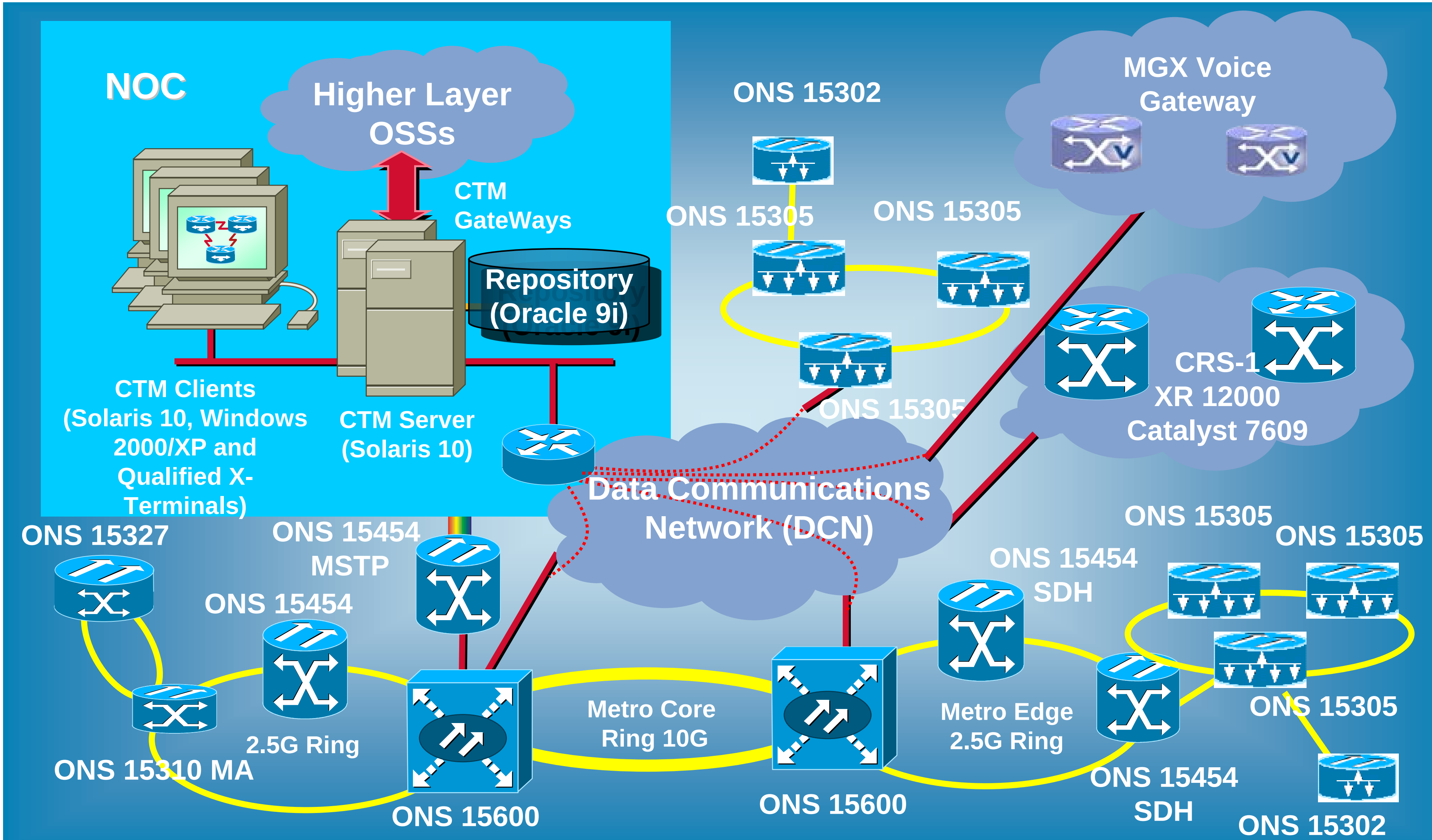
XPonder

MSPP-on-a-blade

Cisco IP NGN: Optical Vision

Operationalize, Packetize and Deliver Connected Life Experiences

Compatible to Existing Management System (CTM)



Summary

Summary

- Introduction on terminology
- Optical Propagation
- Attenuation and Compensation
    - Chromatic
    - PMD
- Non-Linearity
- Fiber types
- Basic span design
- DWDM System/ROADM
- ONS 15454 MSPP/MSTP Functionality

Q and A