INTRODUCTORY COURSE

Introduction to Fiber Optics

Presented by Peter Tarquinio

2026 Edition

Your instructor

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Introduction to Fiber Optics

2026

Building blocks of fiber optic communication

Optical fiber with cladding

Low-loss optical fiber

A light source suited to the fiber

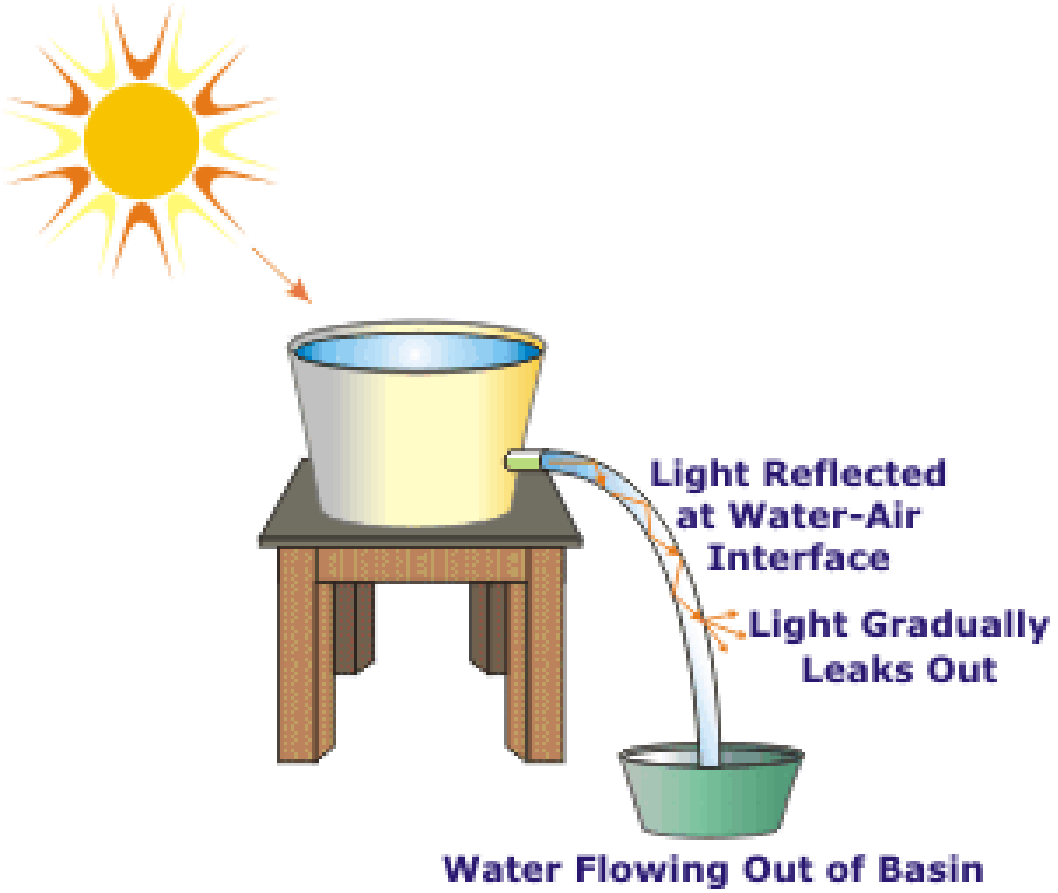
A light detector suited to the fiber

A connector system

Light guidance in the 1800s

In 1870, John Tyndall of the British Royal Society demonstrated light guidance by internal reflection.

The water-stream demonstration preceded the total internal reflection principle used in optical fiber.



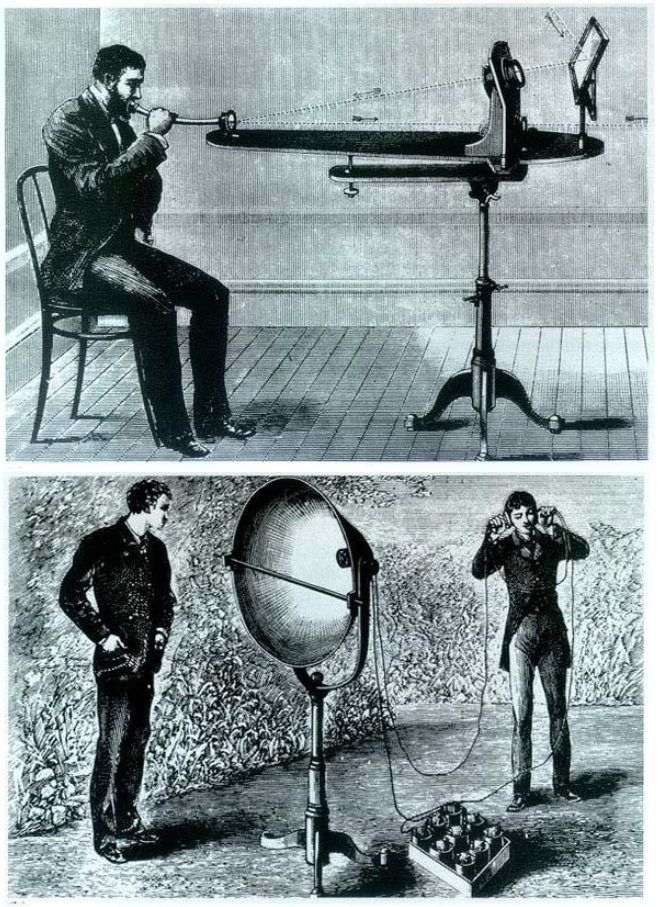
Bell’s photophone

Alexander Graham Bell developed the photophone in 1880.

Speech vibrated a diaphragm and mirror, varying the intensity of transmitted light.

A selenium detector on a parabolic reflector converted the received light into an electrical signal.

The source describes it as the first AM free-space optical link.



Early optical fibers

The pace of development accelerated through the second half of the 20th century.

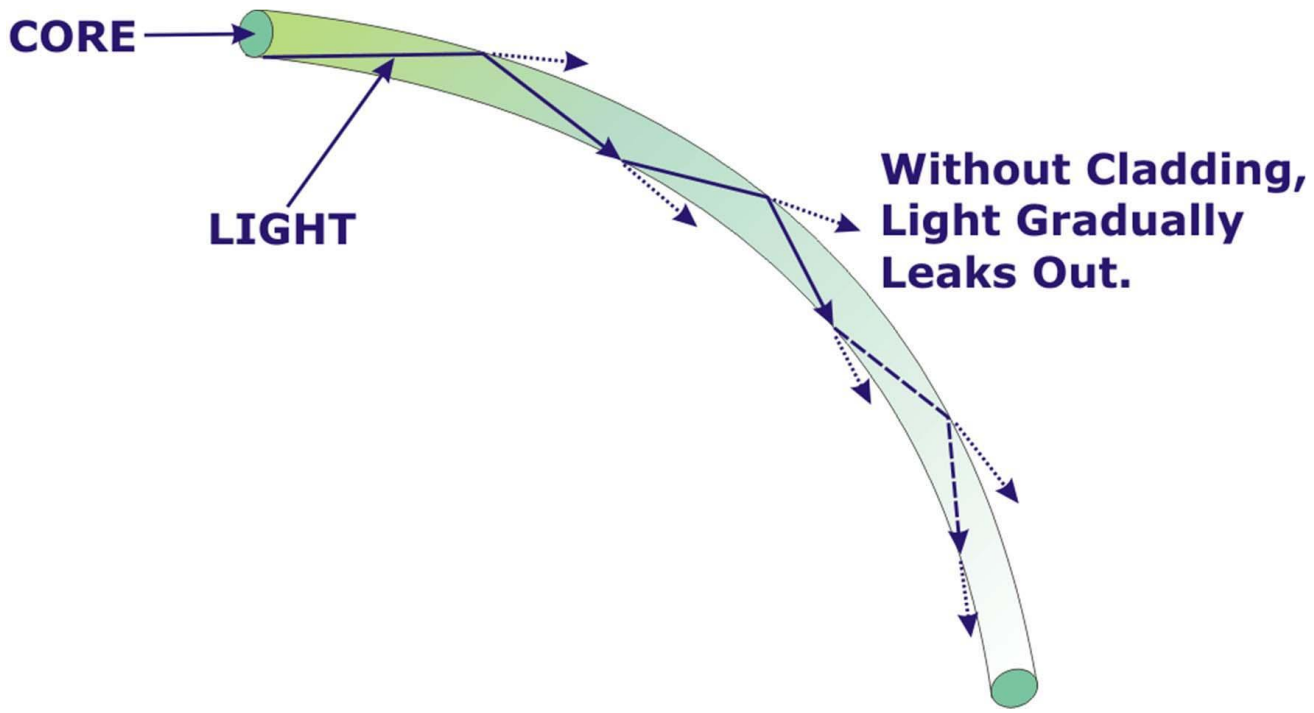
The first practical all-glass fibers appeared in the early 1950s.

In 1956, Narinder Kapany of American Optical Company coined the phrase “fiber optics.”

Early fibers lacked cladding and contained impurities, which caused excessive attenuation and limited transmission distance.

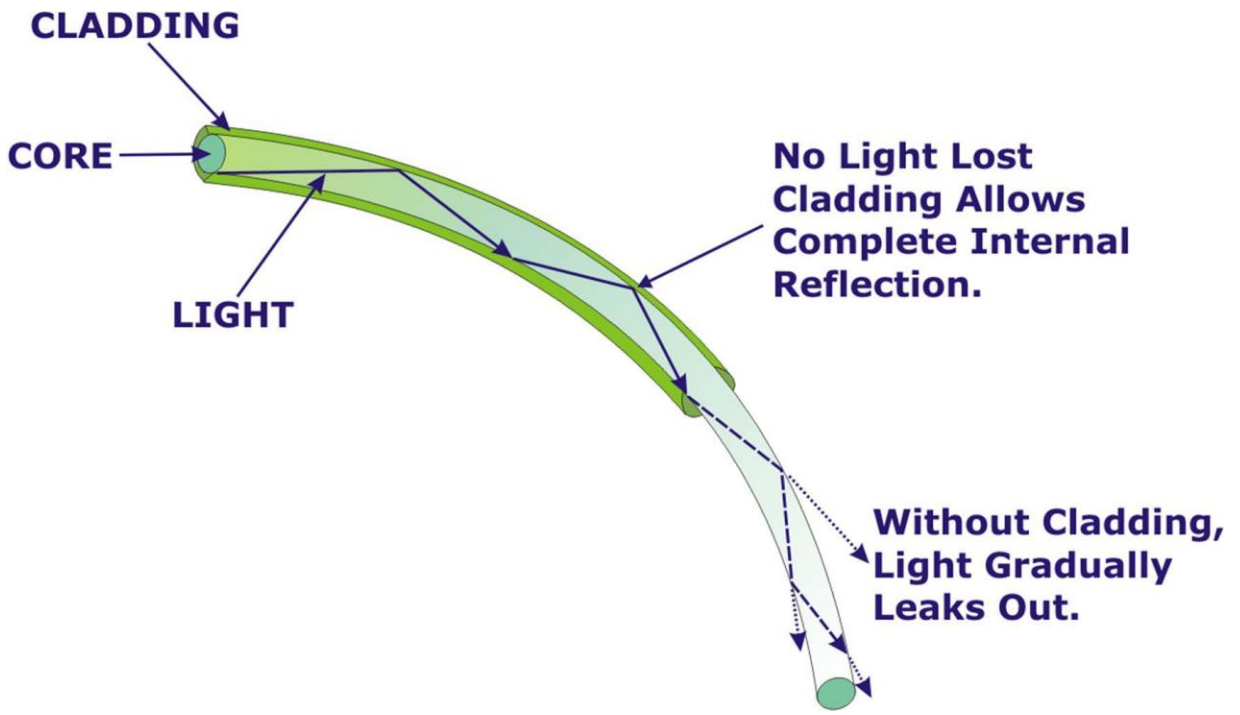
Fiber without cladding

Early glass fibers resembled small-diameter glass rods. Light traveled in the core but quickly escaped without cladding.



Fiber with cladding

Cladding confines light in the core through total internal reflection. The source diagram contrasts guided light with leakage from an unclad fiber.

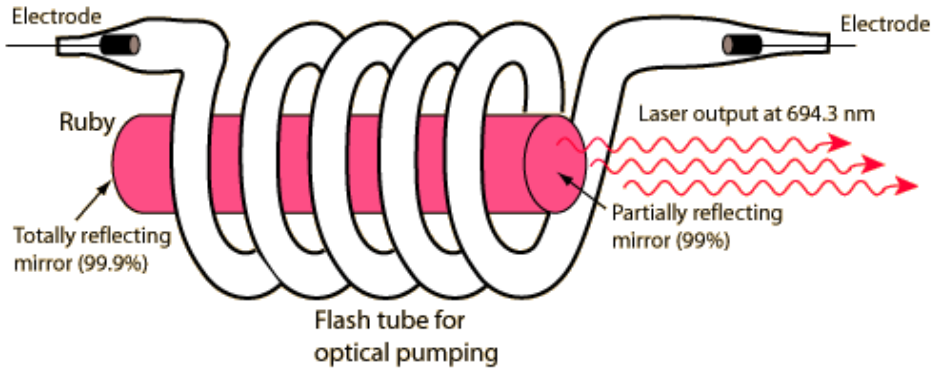


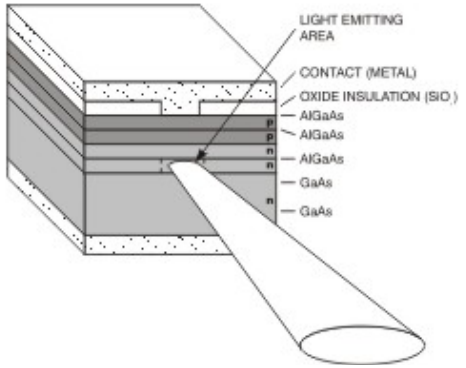
The development of lasers

In 1957, Gordon Gould and Charles Townes proposed the laser as an intense light source.

Theodore Maiman demonstrated the ruby laser in 1960.

The first semiconductor laser followed in 1962 at 850 nm. Its small emitting area, about 10 × 20 µm, suited fiber coupling.





The birth of fiber optic communications

1961: Elias Snitzer at American Optical demonstrated the first single-mode fiber.

High attenuation initially made fiber seem unsuitable for communications.

Charles Kao’s team at STL traced much of the loss to impurities rather than silica itself.

1966: Kao and George Hockham proposed long-distance single-mode transmission with loss below 20 dB/km.

1970: Corning produced fiber below that threshold. Kao received the Nobel Prize in Physics in 2009.

Why fiber optics?

Feature	Benefit
All dielectric	No emitted EM radiation Immunity to EMI, EMP, and lightning
High bandwidth	Very high data-rate capability
Low attenuation	Longer distances and better signal quality
Cost	Often lower than copper beyond a crossover distance

Metric units in fiber optics

The metric system describes fiber dimensions, distance, and wavelength.

1 meter = 39.37 inches

1 kilometer = 1,000 meters ≈ 0.62 miles

1 mile ≈ 1.61 kilometers

1 micrometer (μm) = 10^{-6} meter. Used for fiber dimensions.

1 nanometer (nm) = 10^{-9} meter. Used for optical wavelength (λ).

Metric prefixes

Prefix	Symbol	Multiplier	Power of ten
Tera	T	1,000,000,000,000	10^{12}
Giga	G	1,000,000,000	10^{9}
Mega	M	1,000,000	10^{6}
Kilo	k	1,000	10^{3}
Milli	m	0.001	10^{-3}
Micro	μ	0.000001	10^{-6}
Nano	n	0.000000001	10^{-9}

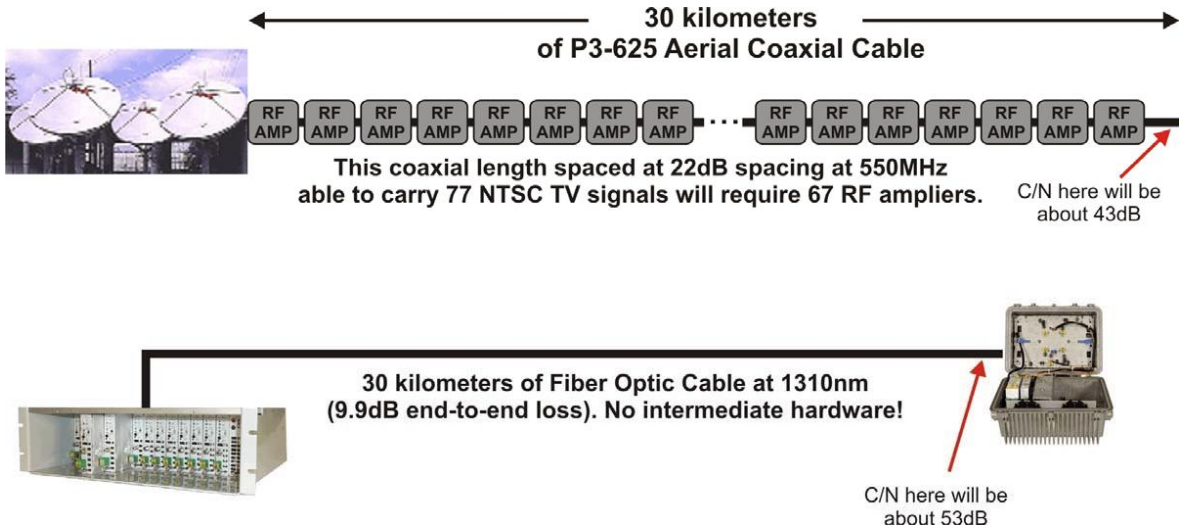
Decibel-to-power conversion

Loss dB	Power out	Power lost	Fraction
1	79%	21%	—
2	63%	37%	—
3	50%	50%	1/2
4	40%	60%	—
5	32%	68%	—
6	25%	75%	1/4
7	20%	80%	1/5
8	16%	84%	1/6
9	12%	88%	1/8
10	10%	90%	1/10
11	8.0%	92%	1/12
12	6.3%	93.7%	1/16

Loss dB	Power out	Power lost	Fraction
13	5.0%	95.0%	1/20
14	4.0%	96.0%	1/25
15	3.2%	96.8%	1/30
16	2.5%	97.5%	1/40
17	2.0%	98.0%	1/50
18	1.6%	98.4%	1/60
19	1.3%	98.7%	1/80
20	1.0%	99.0%	1/100
25	0.3%	99.7%	1/300
30	0.1%	99.9%	1/1000
40	0.01%	99.99%	1/10000
50	0.001%	99.999%	1/100000

Rounded values and fractions reproduce the course reference table.

Coaxial cable and fiber: a 30 km example



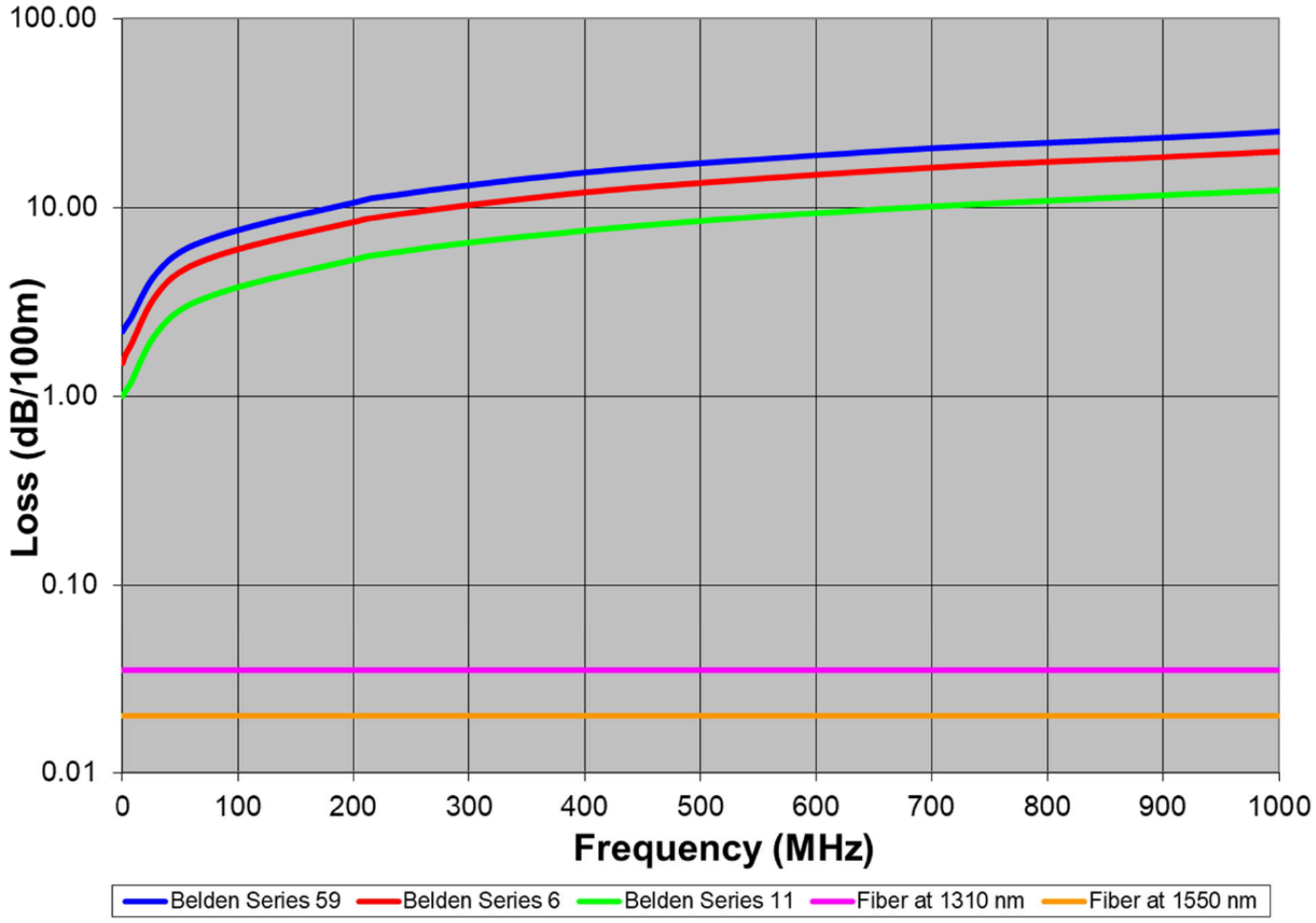
The source compares 30 km of P3-625 coaxial cable with a 1310 nm fiber link.

Coax: 67 RF amplifiers, using 22 dB spacing at 550 MHz for 77 NTSC signals. The illustrated C/N is about 43 dB.

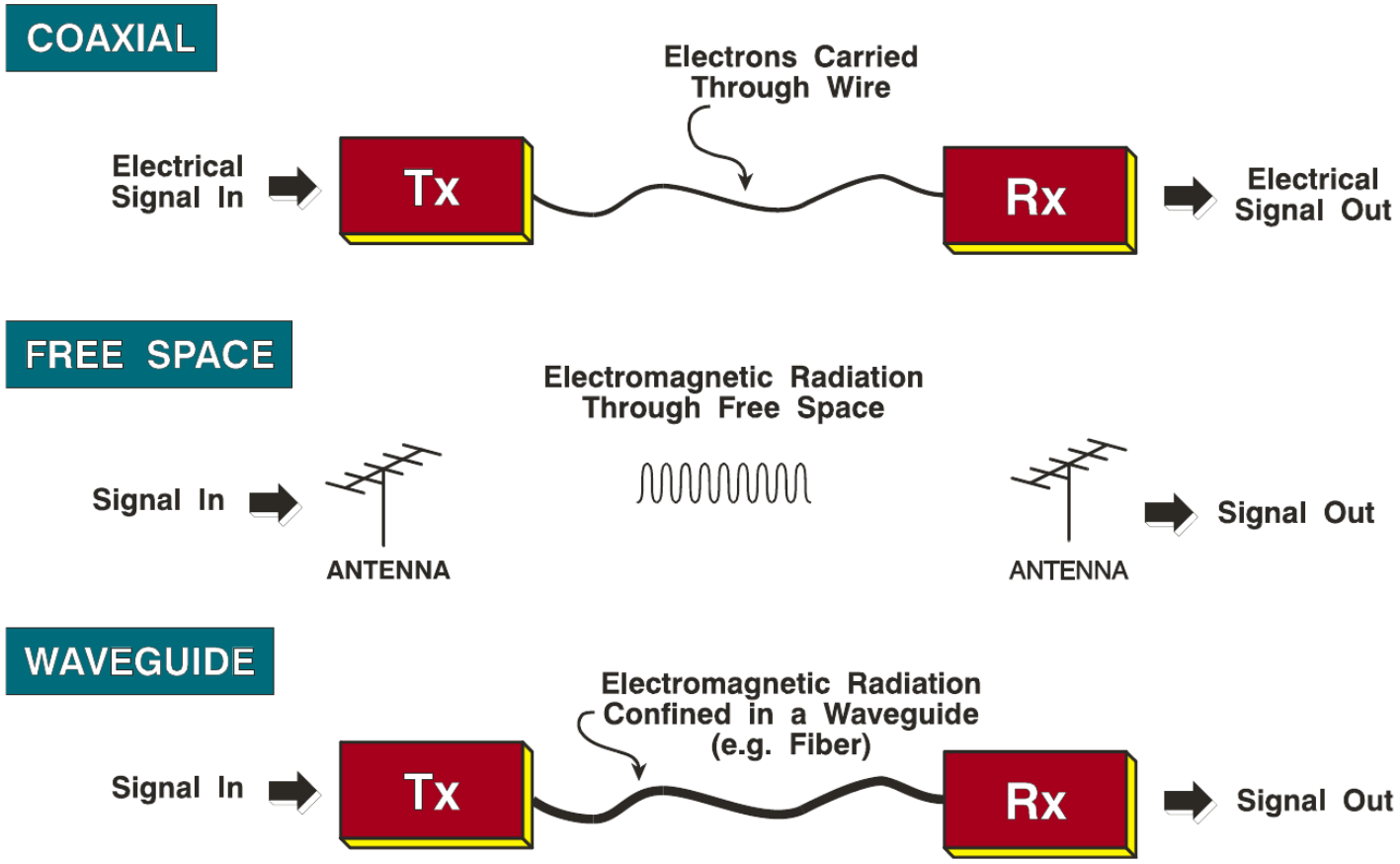
Fiber: one +12 dBm transmitter and one receiver. The illustrated C/N is about 53 dB.

The example also cites improved CTB/CSO performance and greater stability with temperature.

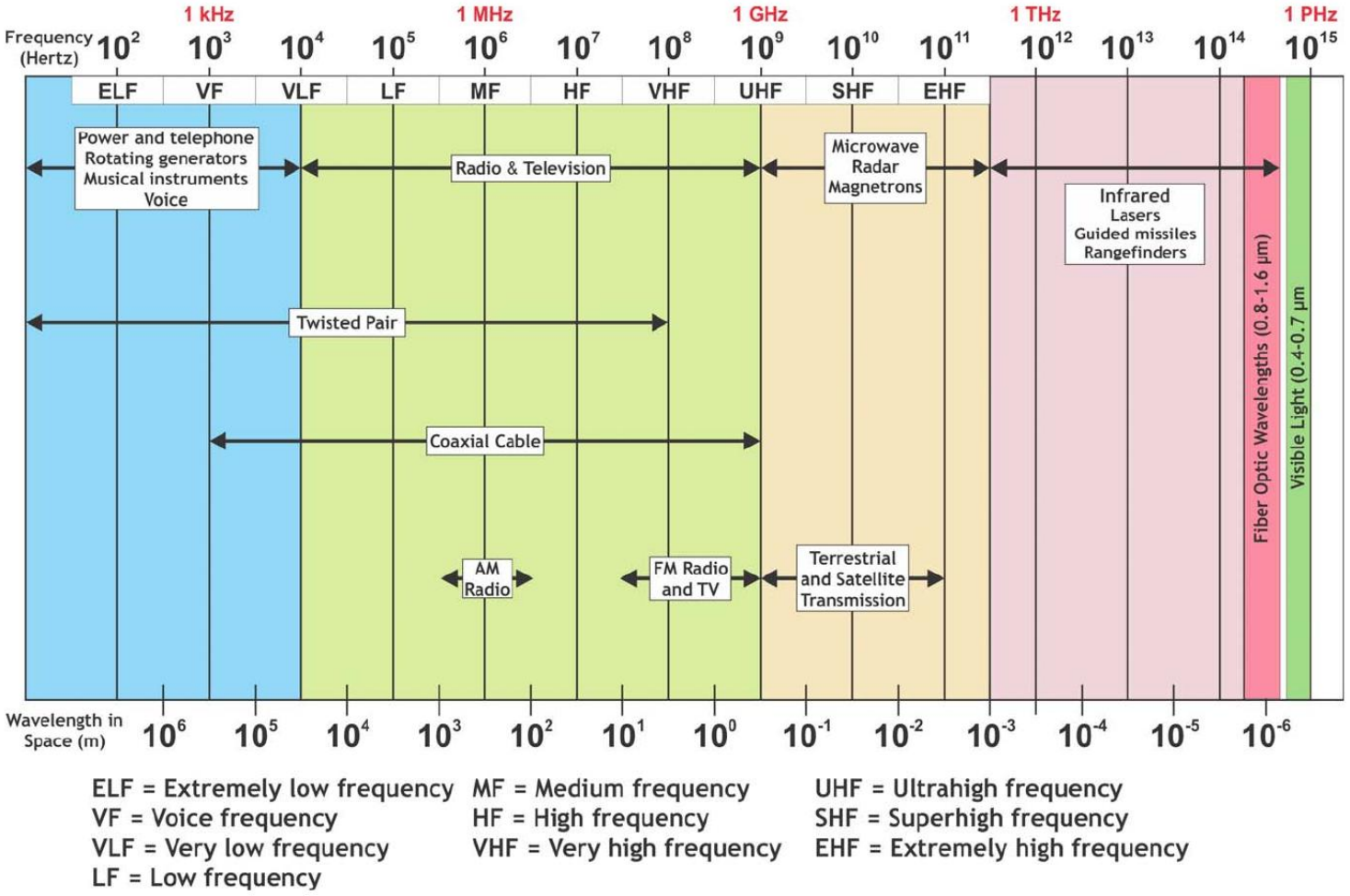
Attenuation of coaxial cable and fiber



Three transmission schemes

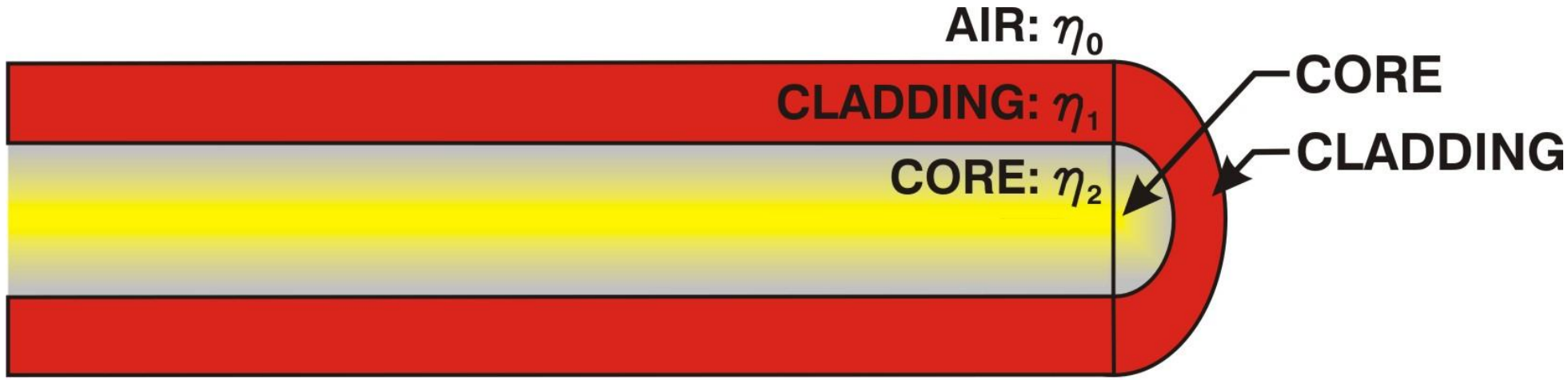


The electromagnetic spectrum



The optical fiber waveguide

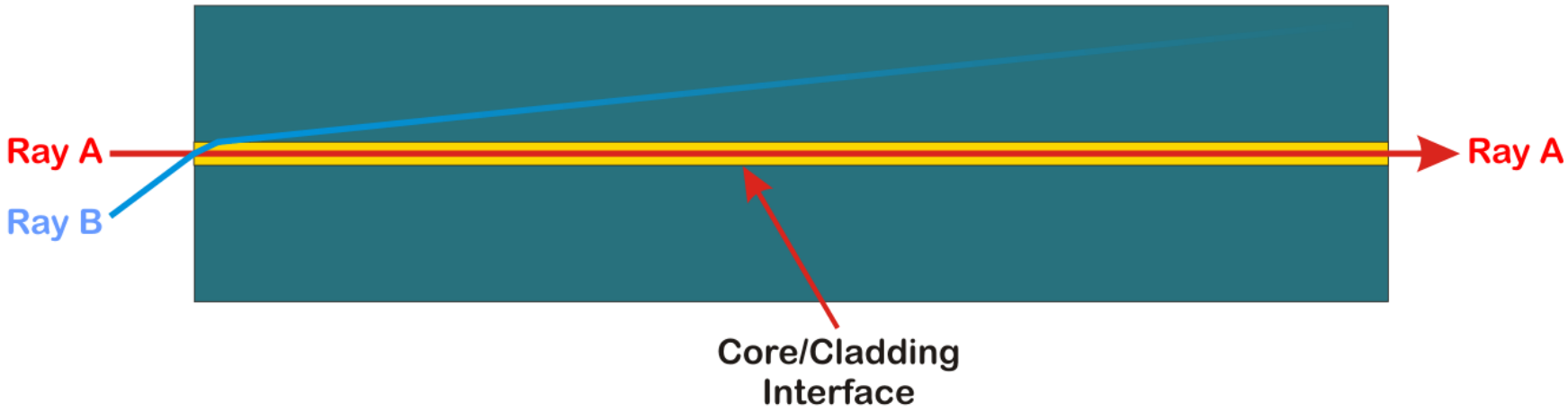
An optical fiber is a dielectric waveguide. Reflection and refraction support the propagation of optical energy.



$\eta_0 = 1.00$
$\eta_1 = 1.45$
$\eta_2 = 1.47$

η = Index of Refraction

Single-mode fiber



Core diameter is comparable to the optical wavelength, typically 8–10 μm.

Small numerical aperture, typically 0.1.

Attenuation: 0.2–0.5 dB/km. Dispersion: less than 0.2 ns/km.

Typical bandwidth: 10 GHz·km.

One mode propagates at the rated wavelength. Multiple single-mode fiber types exist.

The Corning SMF-28 family

The course describes the SMF-28 family: SMF-28, SMF-28e and XB, SMF-28e+, and SMF-28-ULL.

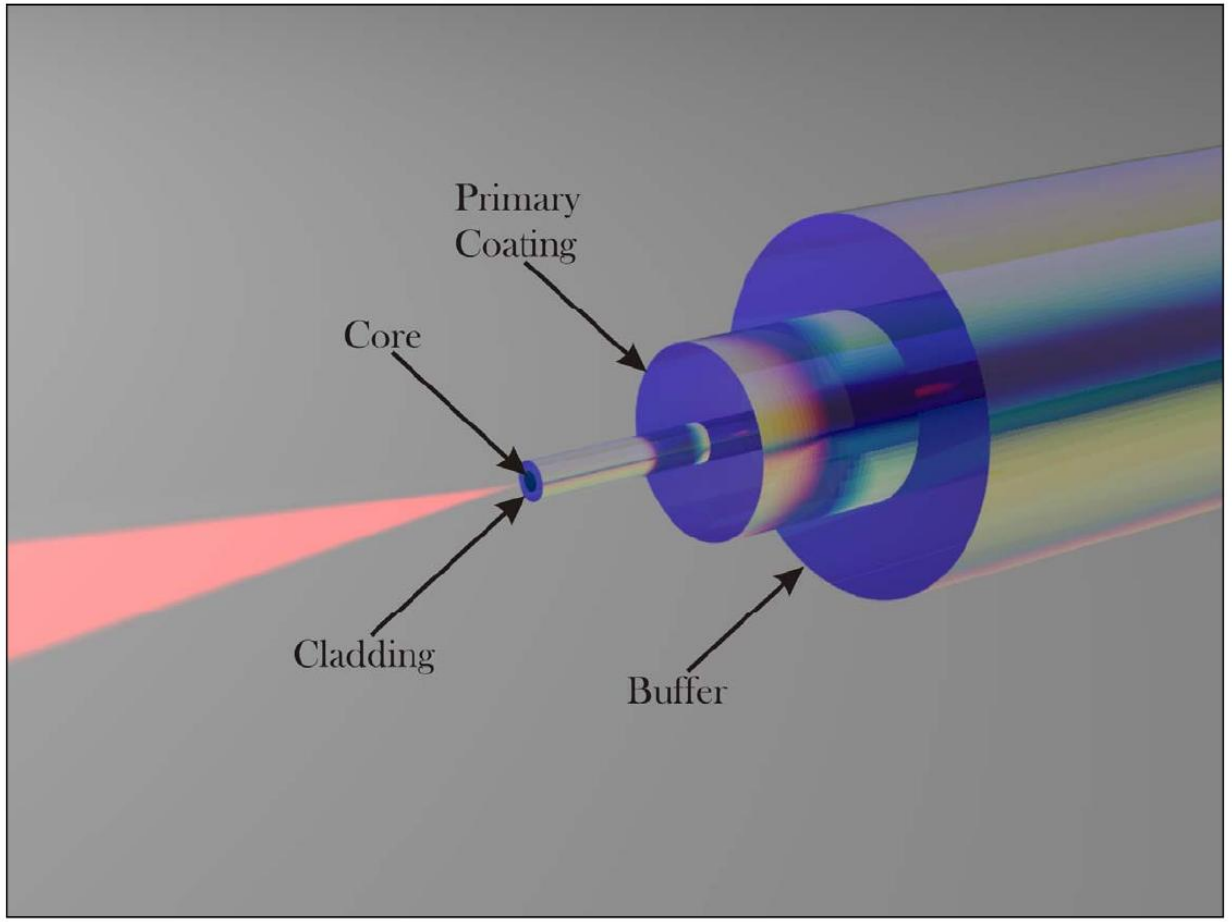
Cutoff wavelength: 1260 nm. Numerical aperture: about 0.14. Core–cladding index difference: 0.36%.

Typical dimensions: 8.3 µm core and 125 µm cladding.

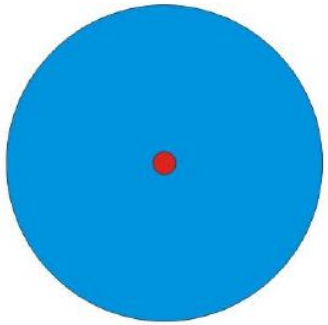
At 1550 nm: attenuation 0.17–0.30 dB/km and dispersion 17 ps/(nm·km). Zero dispersion is near 1310 nm.

The source also lists 100 kpsi proof strength, spools up to 50 km, and improved macrobending, PMD, and tolerances in later variants.

Light emerging from an optical fiber

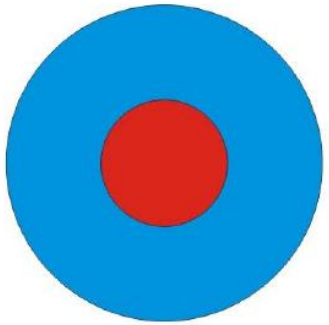


Common fiber sizes



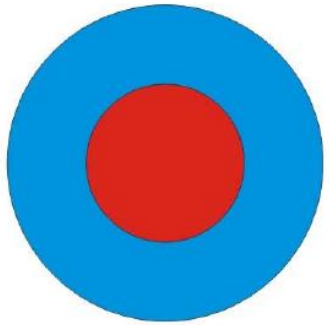
Single-mode 9/125μm

95+% of All Applications



Multimode 50/125μm

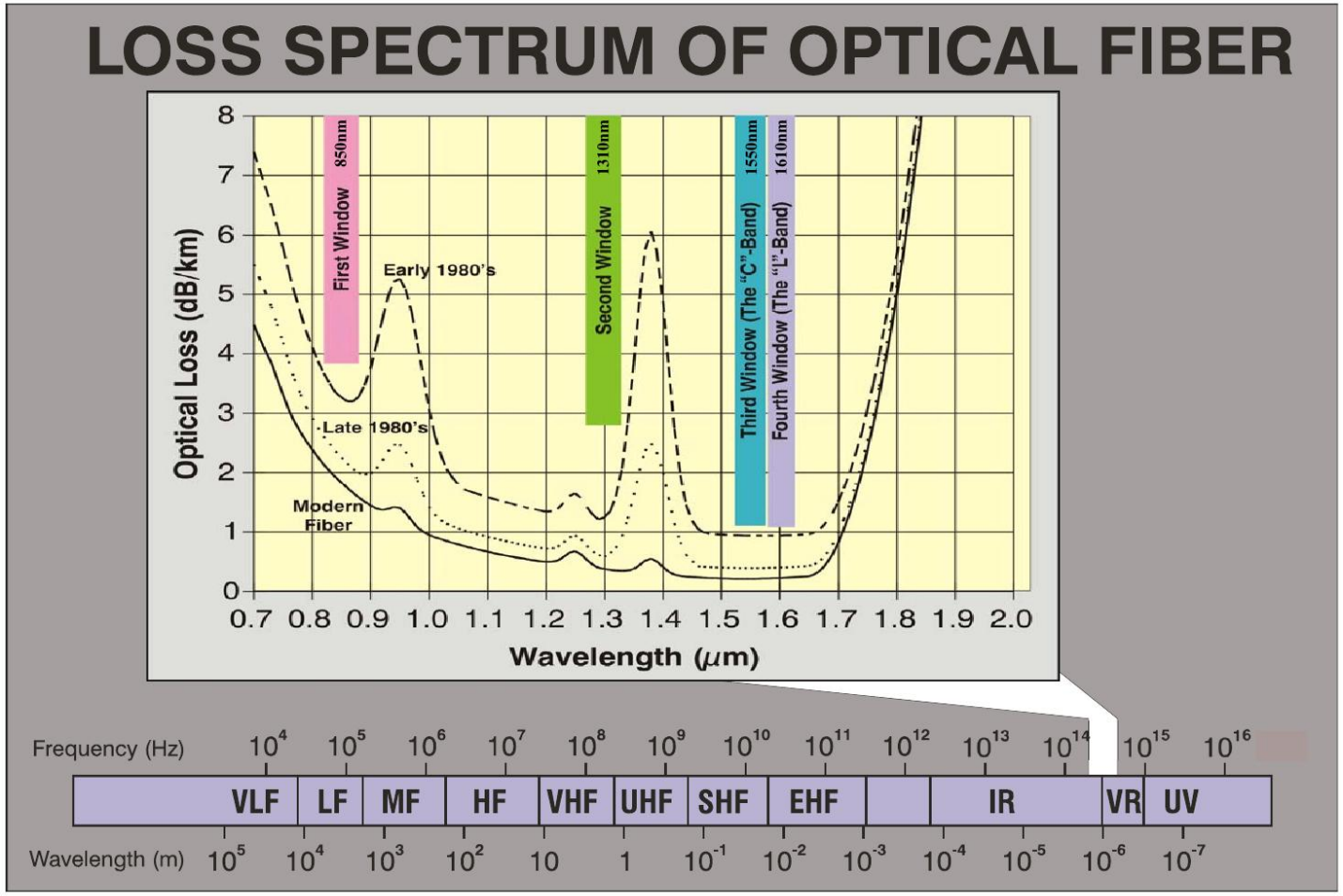
Most of the balance. *Has higher BW than 62.5/125μm fiber.*



Multimode 62.5/125μm

Very few new applications. Some legacy

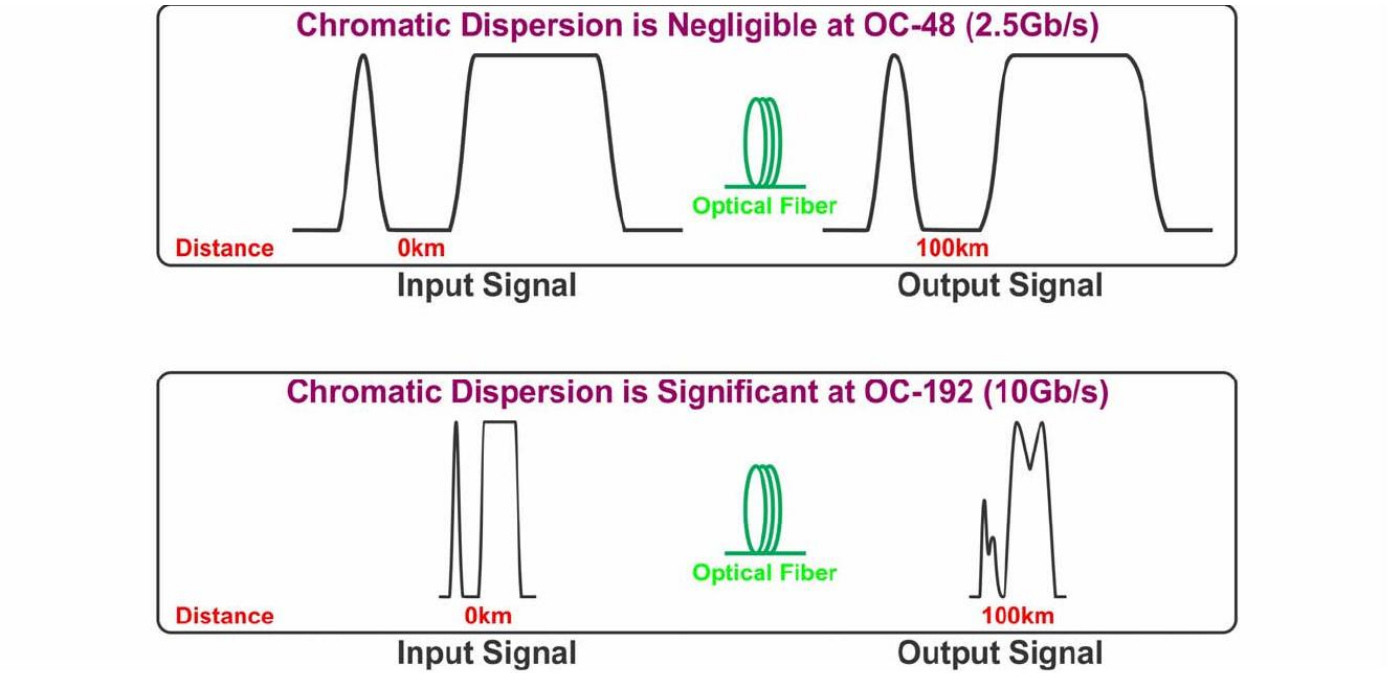
The loss spectrum of optical fiber



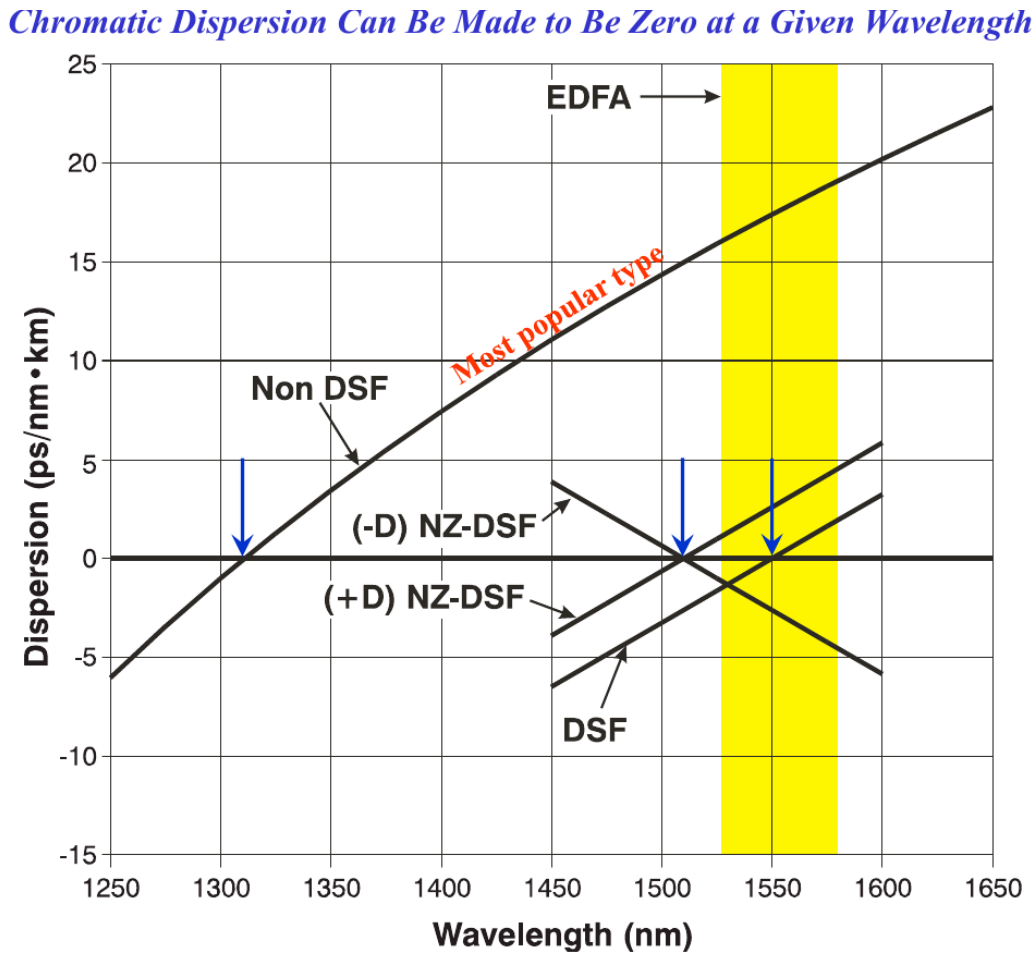
Chromatic dispersion

Chromatic dispersion broadens pulses as they travel through fiber because different wavelengths travel at different speeds.

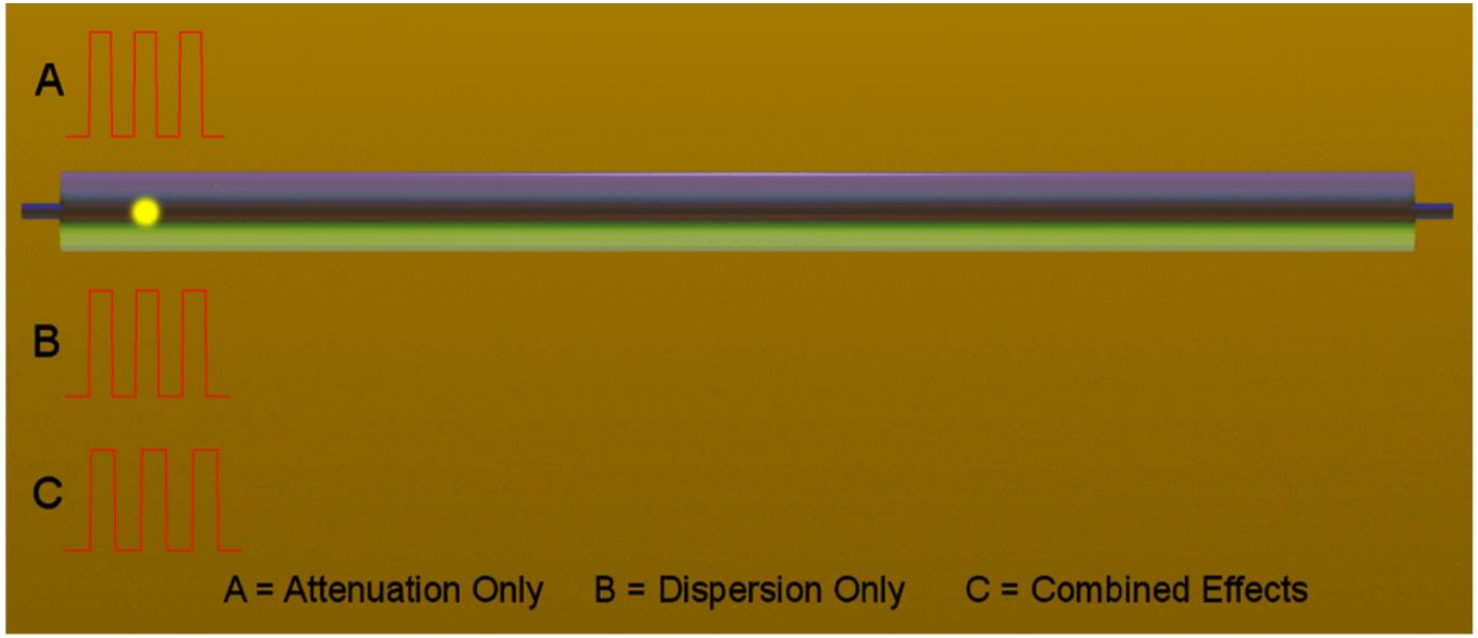
The source compares 100 km examples at OC-48 (2.5 Gb/s) and OC-192 (10 Gb/s).



Dispersion in single-mode fiber types



Attenuation and dispersion



The elements of a fiber optic link



User input

Electrical-to-optical conversion

User output

Optical-to-electrical conversion

Semiconductor laser light sources

Optical power rises approximately in proportion to current above threshold.

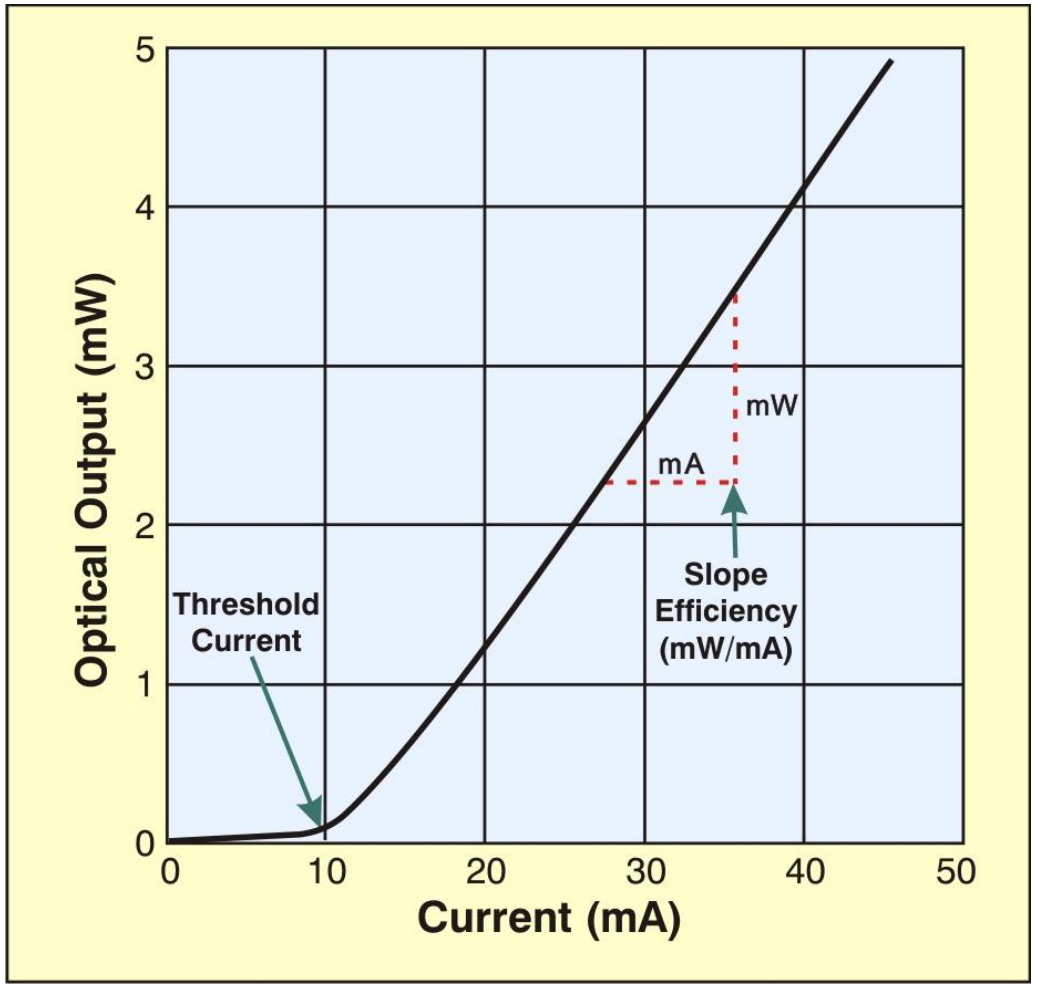
Threshold current: 5–20 mA

Coupled optical power: 1 to more than 30 mW

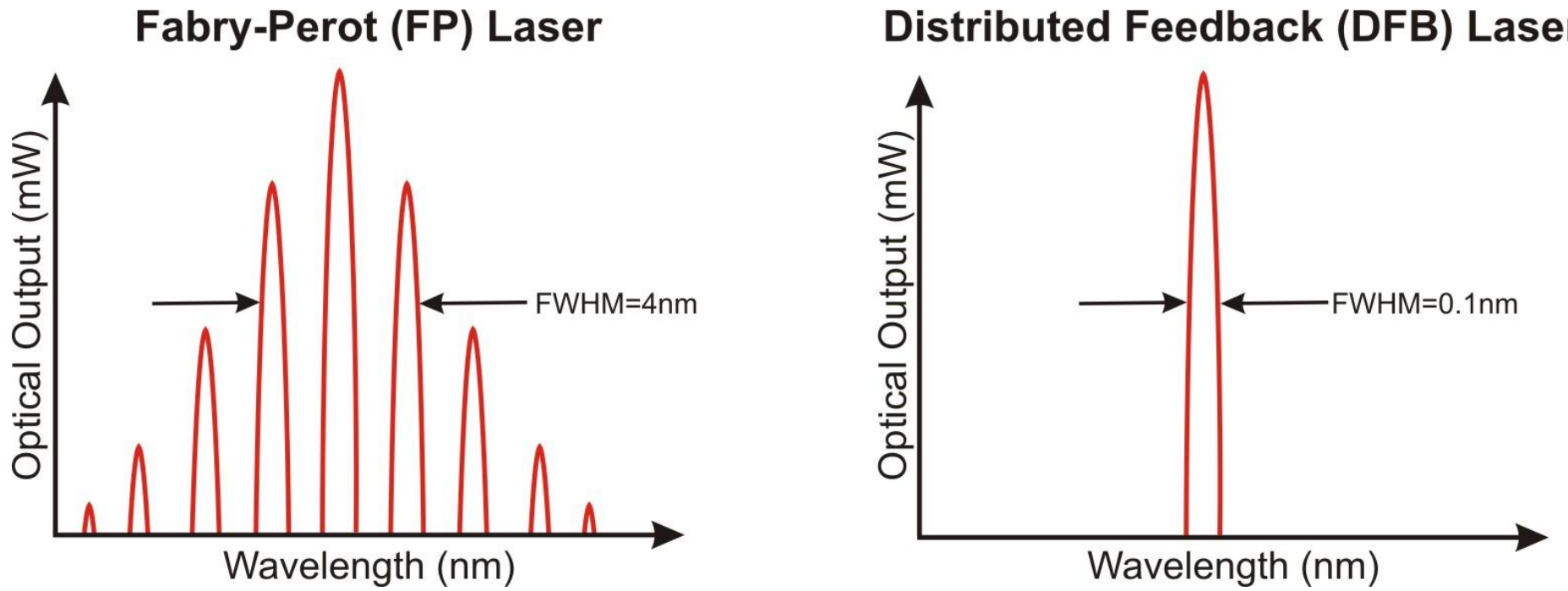
Bandwidth: 500 MHz to more than 6 GHz

Higher cost is one of the source’s stated tradeoffs.

A typical laser L–I curve



FP and DFB laser spectra



Fabry–Perot (FP): multiple evenly spaced wavelengths, with an illustrated spectral width of about 4 nm.

Distributed feedback (DFB): a tuned cavity limits output to one wavelength, with an illustrated width of about 0.1 nm.

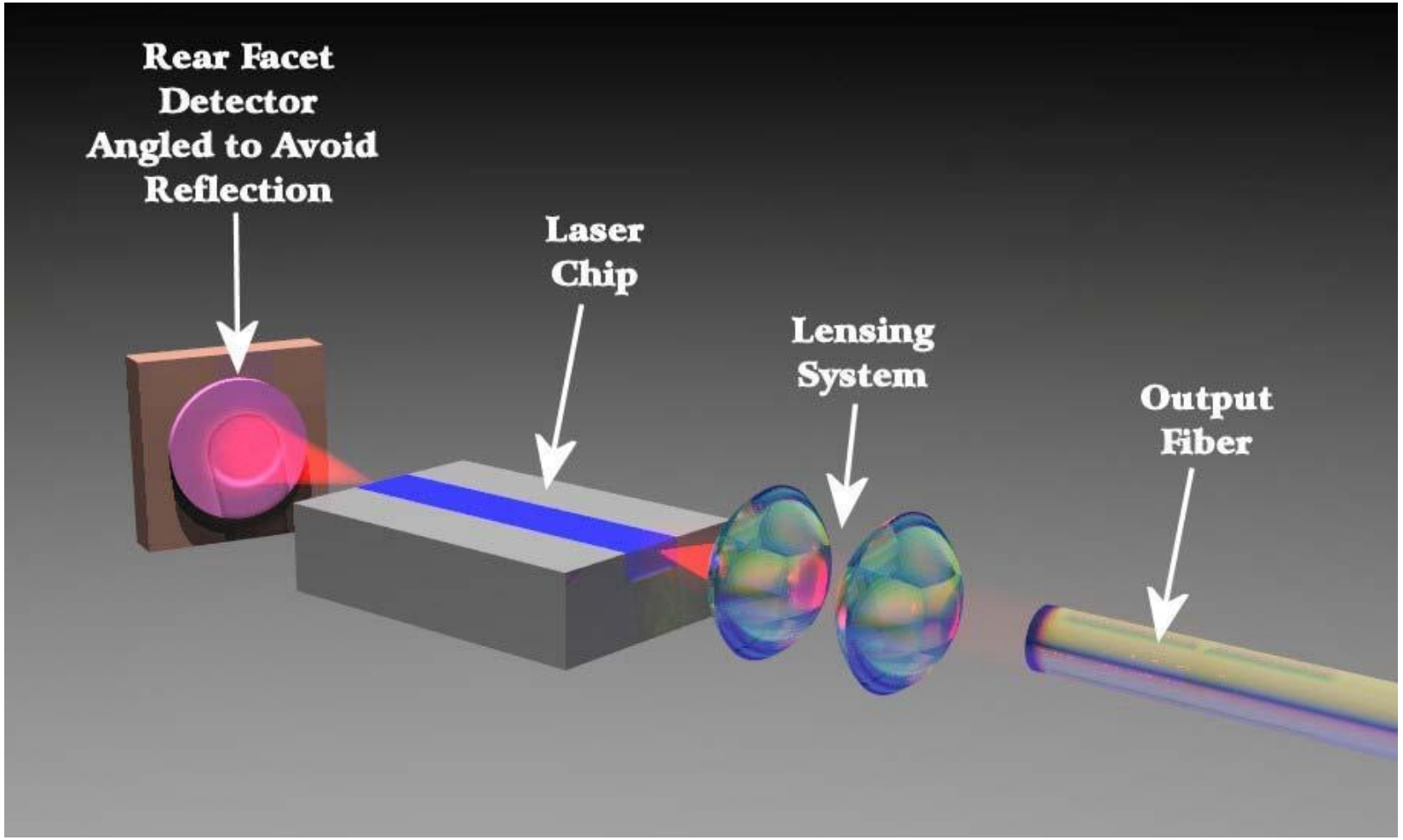
Laser type comparison

Fabry–Perot (FP): practical at 1310 nm in this course's comparison. Lowest cost, low CNR, and greater dispersion sensitivity at Gb/s rates. Not suited to WDM. Wavelength drift is about 0.5 nm/°C.

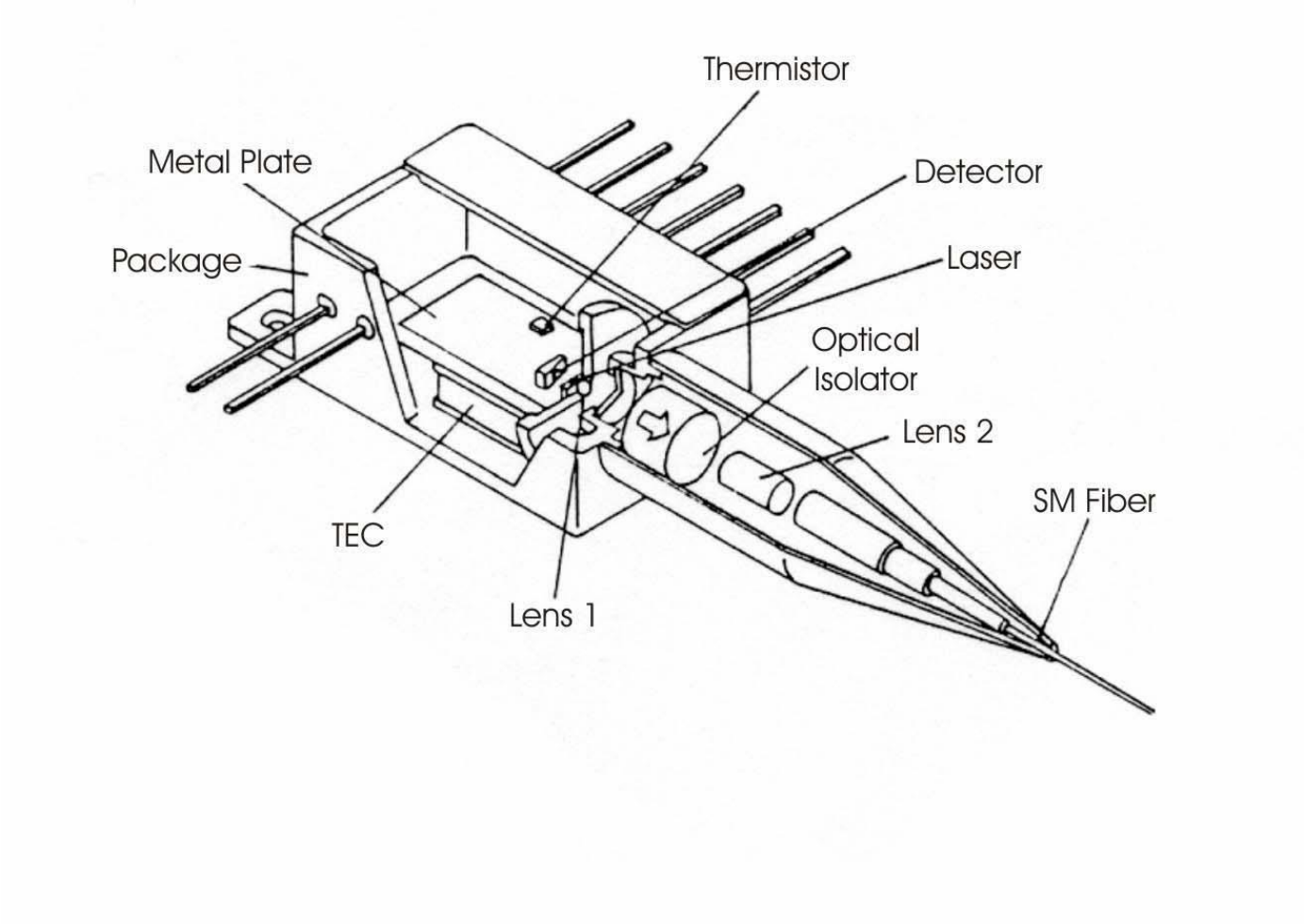
Distributed feedback (DFB): suitable for WDM and long haul, with less dispersion sensitivity and higher CNR. Wavelength drift is about 0.06 nm/°C.

VCSEL: very low cost and suited to mass production.

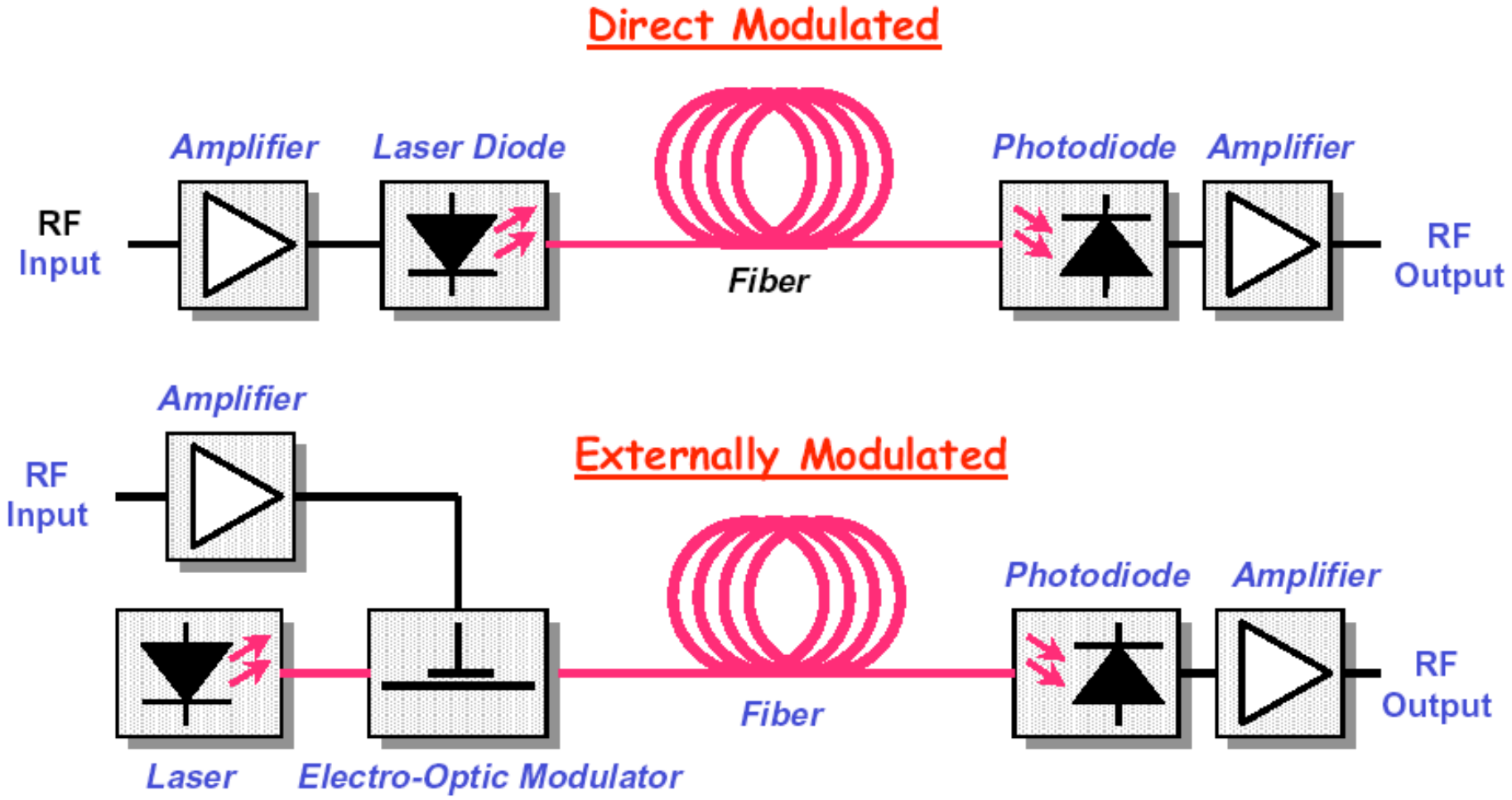
Laser diode construction



Butterfly laser construction



RF fiber optic links



Photodiode detector comparison

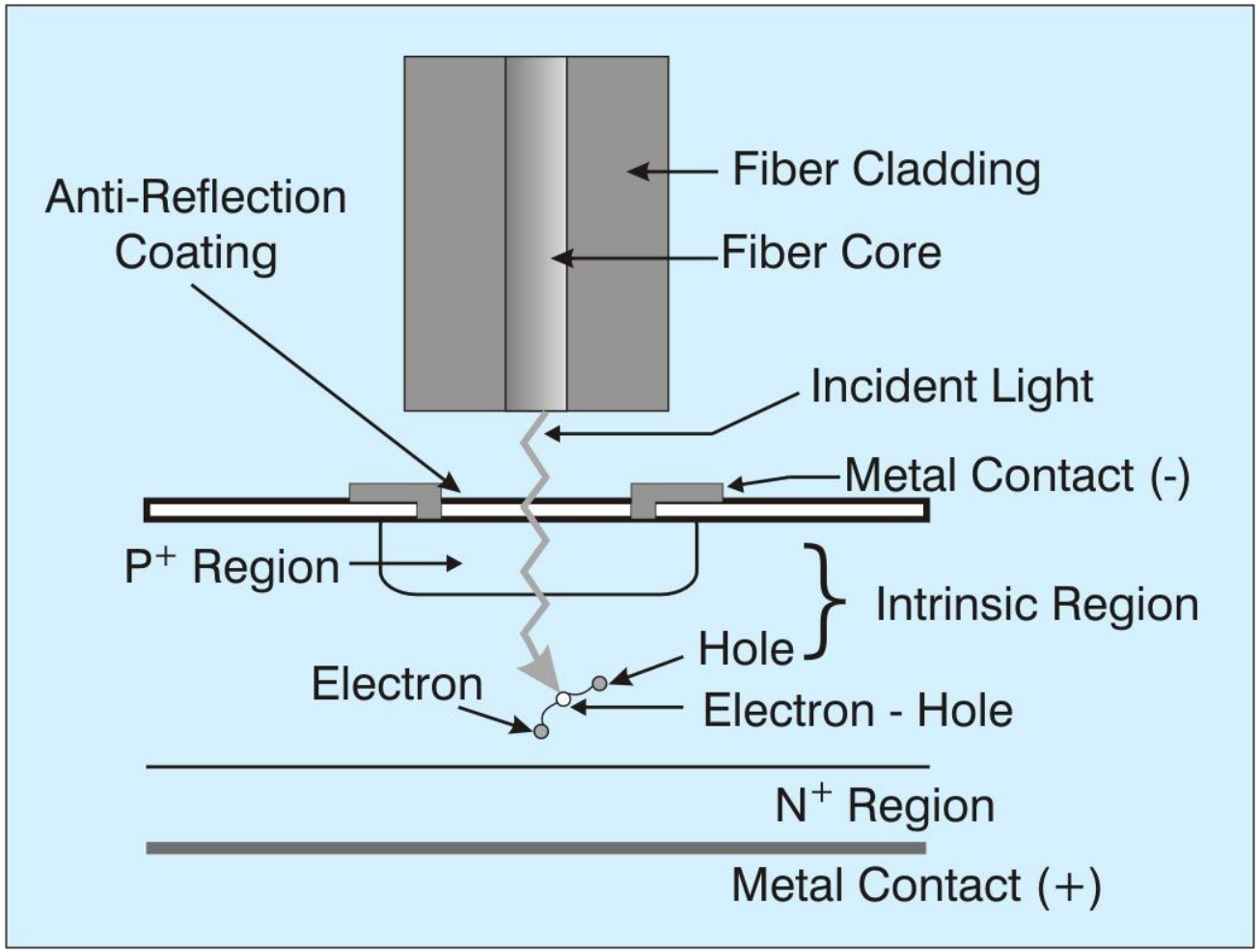
PIN photodiodes: silicon or InGaAs. The most common detector type.

PIN responsivity: 0.5–1.0 A/W. Bandwidth: 10 MHz to more than 6 GHz. Very linear and relatively inexpensive.

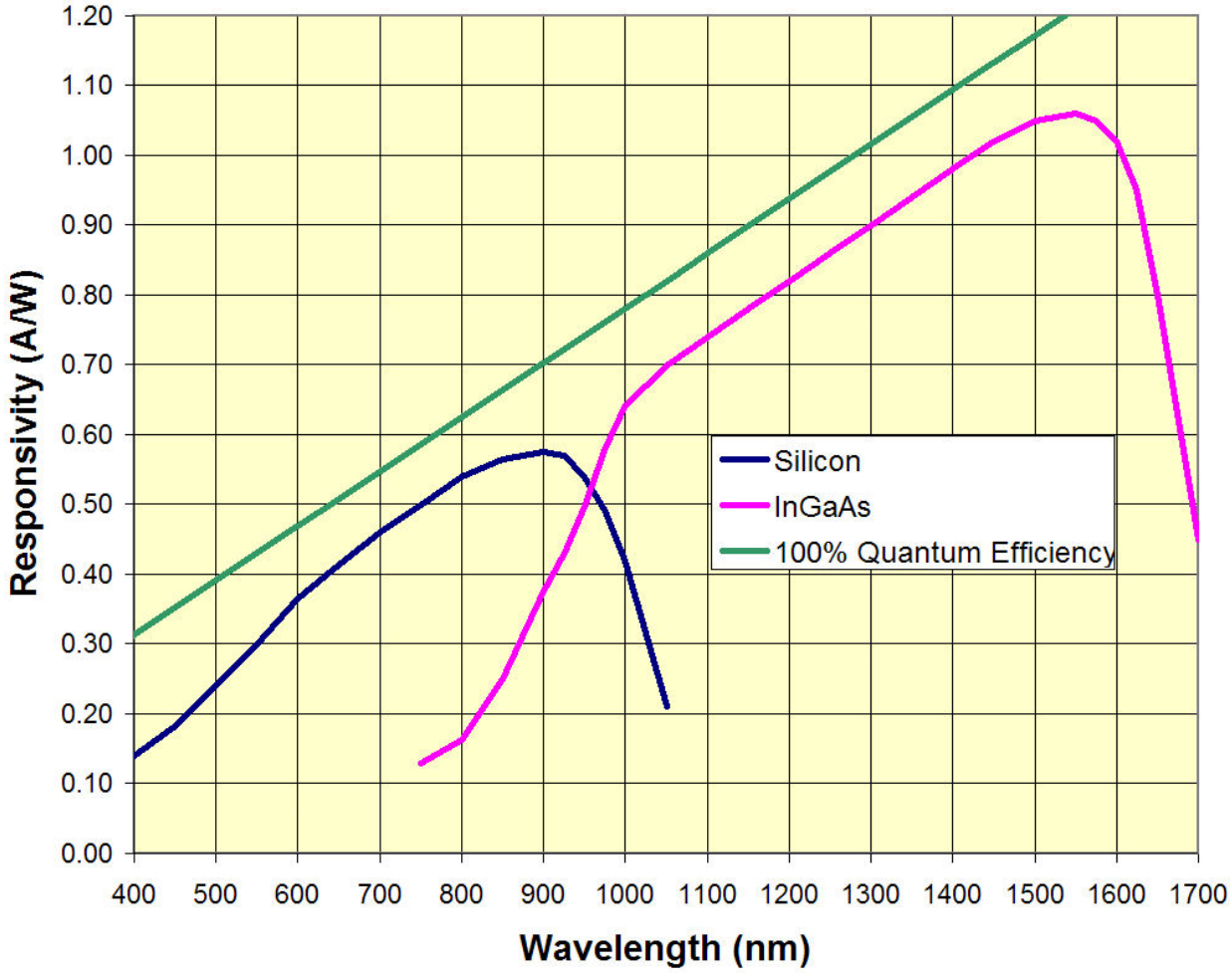
Avalanche photodiodes (APD): silicon or InGaAs, with internal gain of 10–500. Used for very long haul.

APD bandwidth: 100 MHz to more than 3 GHz. The course notes poor linearity, higher cost, extensive support circuitry, and high temperature sensitivity.

Photodiode operation



Detector spectral response

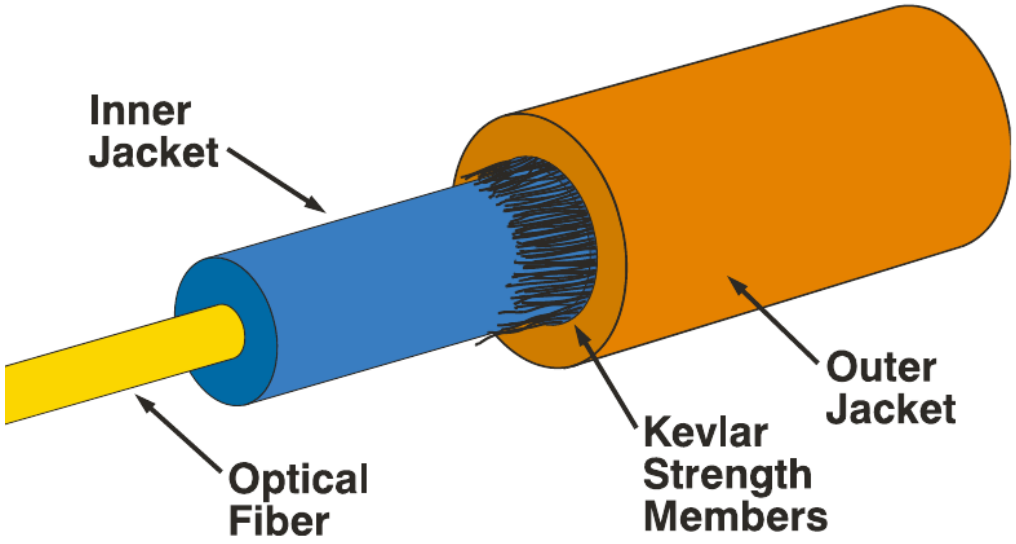


Fiber optic cable design goals

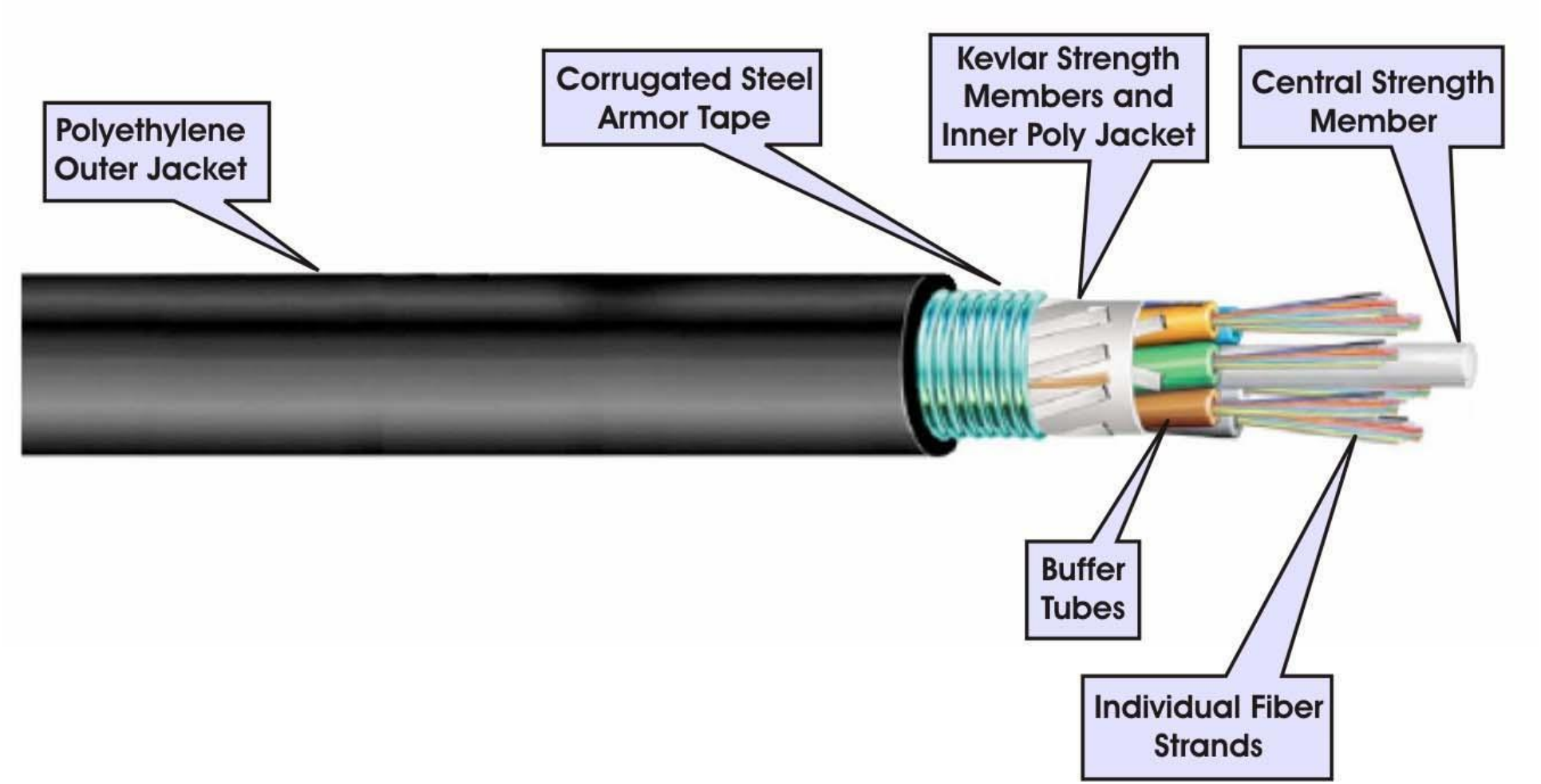
Cable design considers crush resistance, tensile strength, bend radius, and excess optical loss.

The source cross-section shows optical fiber, an inner jacket, Kevlar strength members, and an outer jacket.

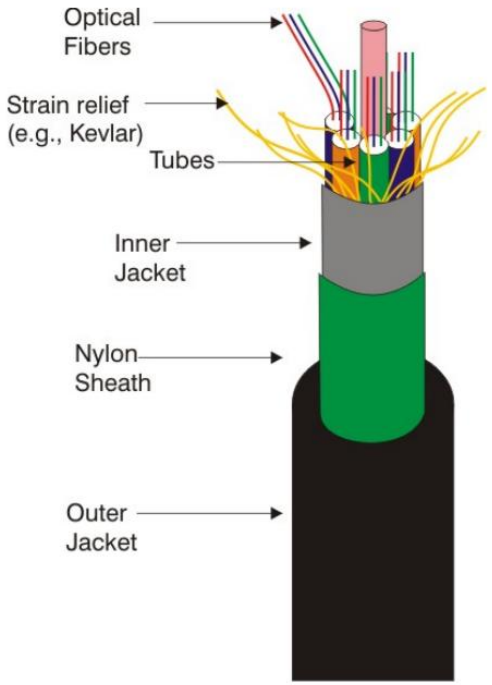
Common illustrated cable diameters: 2 mm and 3 mm.



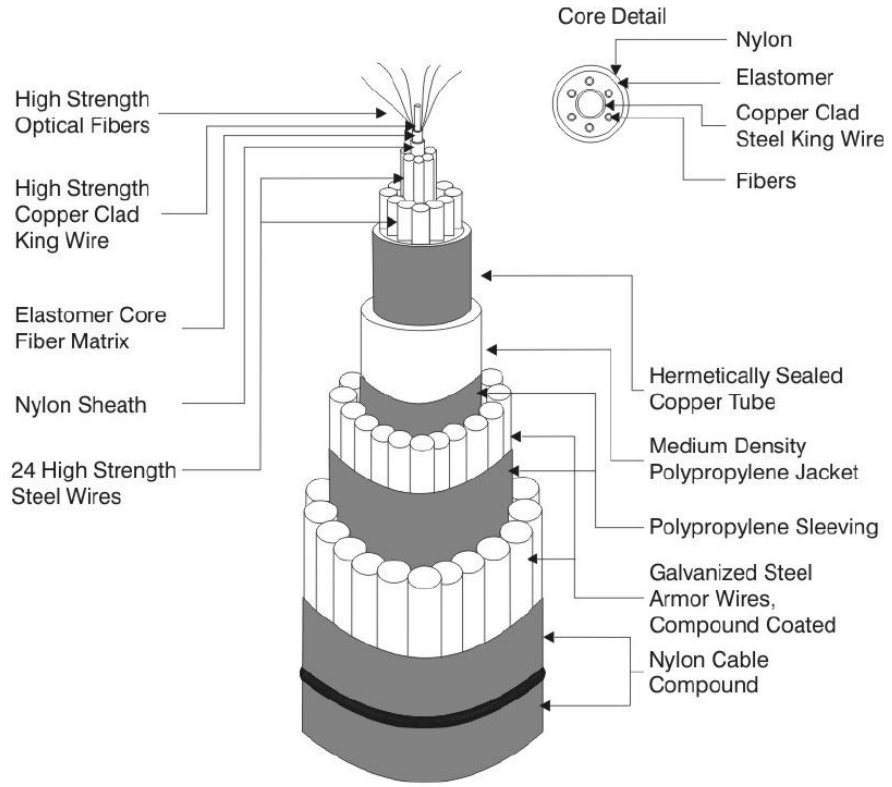
Multiple fibers in one cable



Complex fiber cables



Multipurpose Cable



Submarine Cable

Fiber optic cable color codes

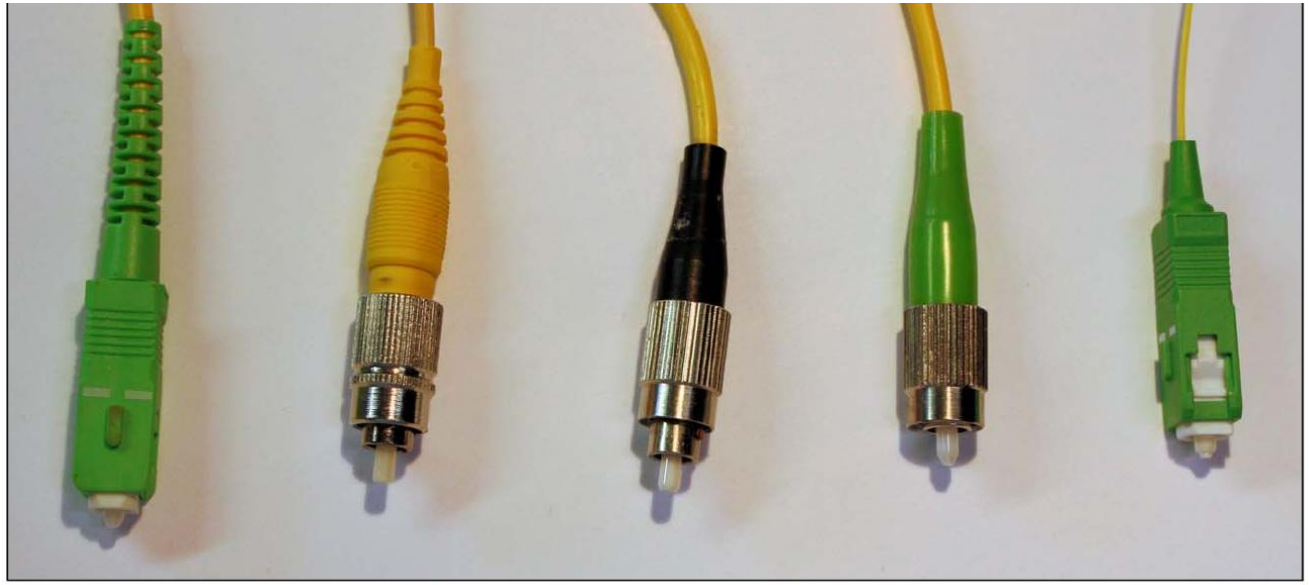
Cable and connector color references

Fiber type	Non-military	Military	Print designation
MM 50/125 µm	Orange	Orange	50/125 µm
MM 50/125 µm 850 nm laser-optimized	Aqua	Undefined	850 LO 50/125 µm
MM 62.5/125 µm	Orange	Slate	62.5/125 µm
MM 100/140 µm	Orange	Green	100/140 µm
SM 9/125 µm	Yellow	Yellow	SM/NZDS, SM
Polarization-maintaining SM 9/125 µm	Blue	Undefined	Undefined

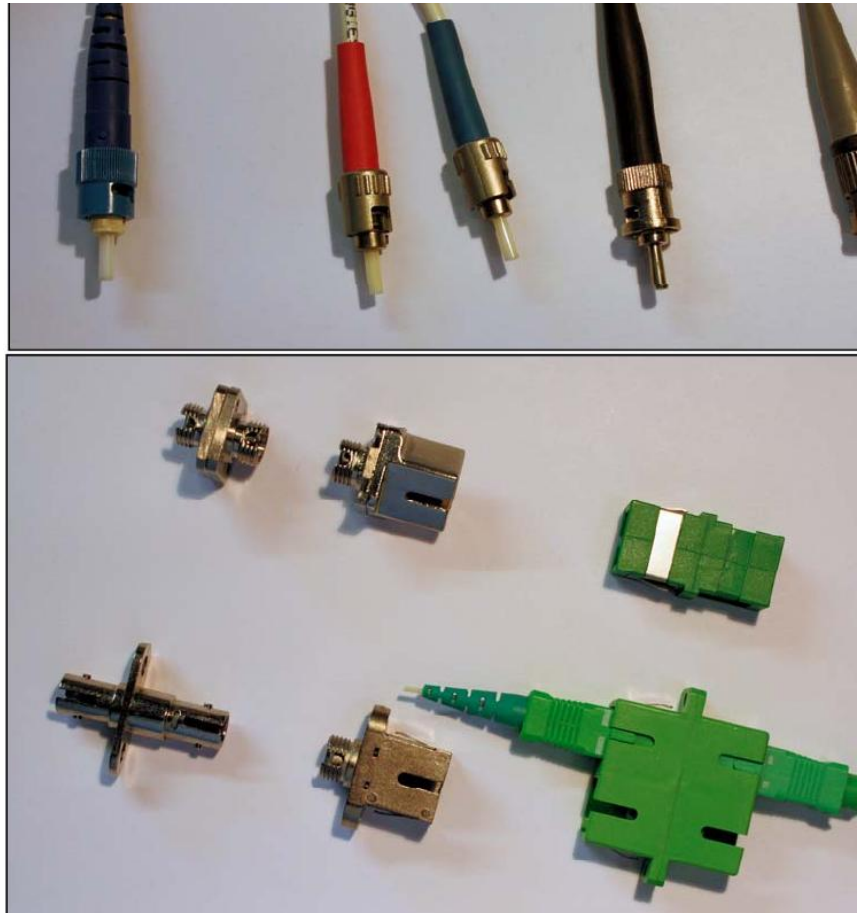
Connector colors: beige for MM, blue for SM, green for angled APC.

SC and FC connectors

The course associates SC with “Subscriber Connector” and FC with “Ferrule Connector.”



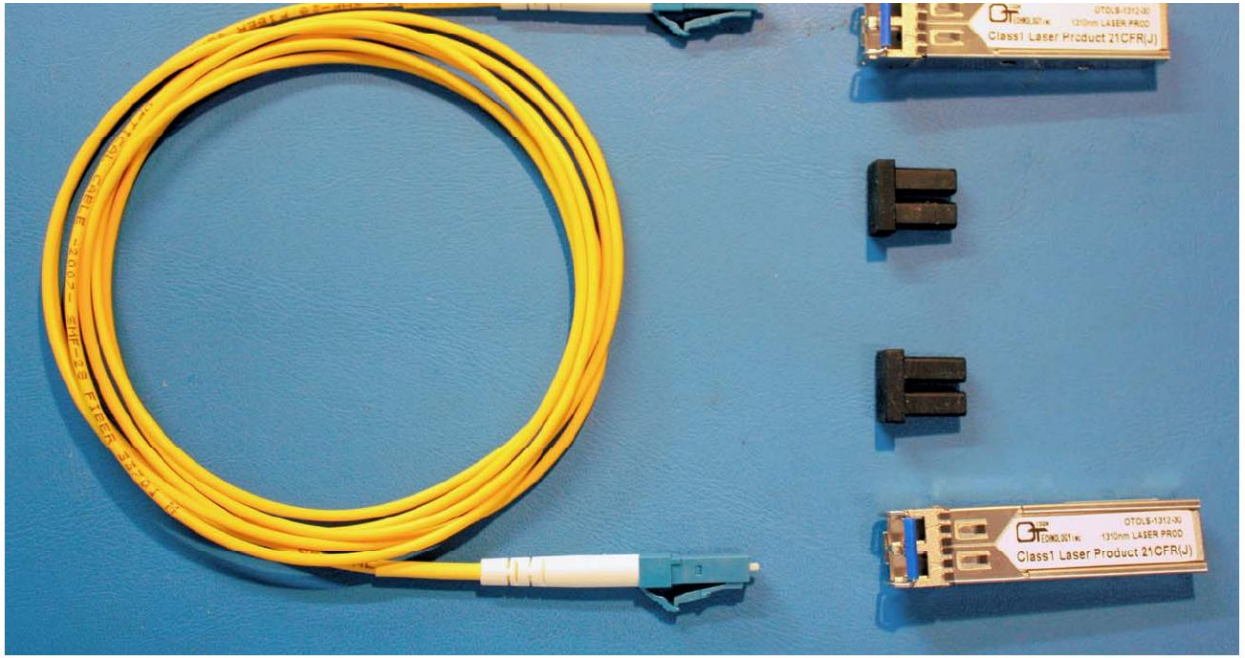
ST connectors and adapters



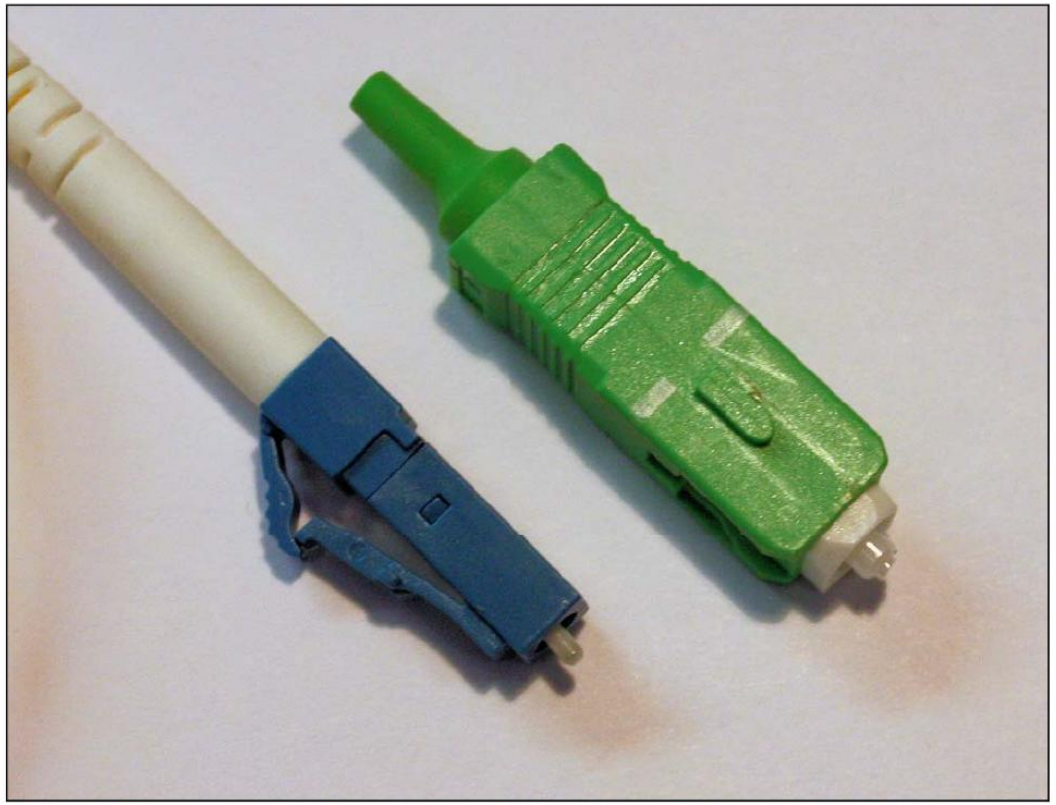
The course associates ST with “Straight Tip.” The photographs show connector and adapter examples.

LC connectors

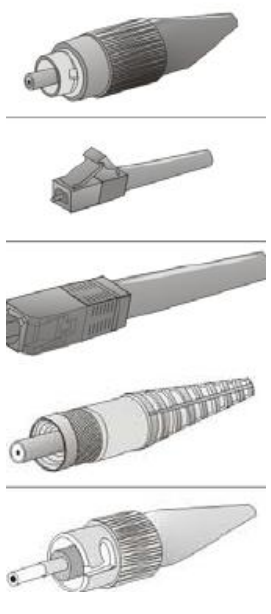
The course associates LC with “Lucent Connector.”



LC and SC connectors



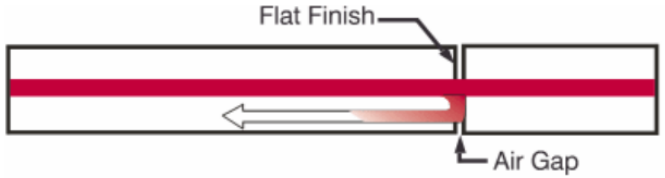
Connector types and performance



Connector	Insertion loss	Repeatability	Fiber	Applications
FC/PC	0.50–1.00 dB	0.20 dB	SM, MM	Datacom / telecom
LC	0.25 dB SM 0.20 dB MM	0.20 dB	SM, MM	High-density interconnects
SC	0.20–0.45 dB	0.10 dB	SM, MM	Telecom
SMA	0.40–0.80 dB	0.30 dB	MM	Military
ST	0.40 dB SM 0.50 dB MM	0.40 dB SM 0.20 dB MM	SM, MM	Inter/intra-building, security, Navy

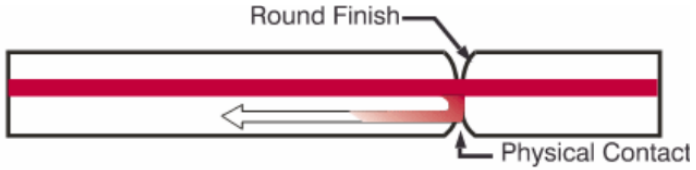
Typical source values. Hardware performance depends on the component.

Fiber end finishes



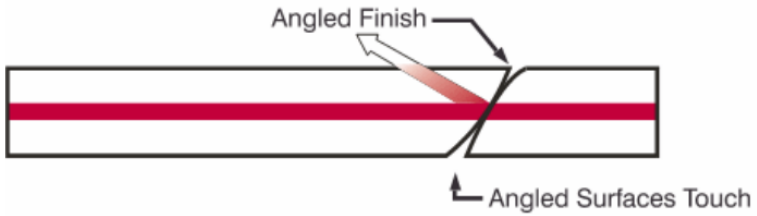
Flat finish causes light to be reflected back into the fiber due to a step in the refractive index caused by the glass-air-glass interface.

Backreflection as high as -14dB



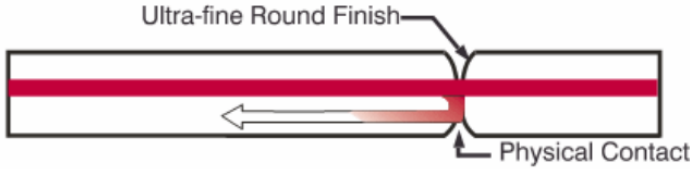
Physical Contact (PC) finish minimizes backreflection due to the very small refractive index discontinuity.

Backreflection about -40dB



Angle polish connectors cause the reflection to exit the core and dissipate in the cladding.

Backreflection less than -60dB



Ultra polish connector finish uses several grades of polishing film to achieve an ultra-smooth surface.

Backreflection around -40 to -50dB

APC and UPC connectors

APC: angle-polished, 8–9° finish, typically green. The source specifies return loss above 55 dB and calls for APC in RF video.



UPC: ultra-polished, typically blue. The source specifies return loss above 40 dB.

APC and UPC end faces must not be mixed.

Why connector cleanliness matters

A single-mode core is only about 8–9 µm in diameter, roughly one-eighth the diameter of a human hair.

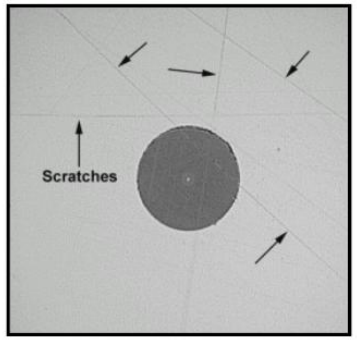
Dust can be 20 µm or larger. Particles smaller than 1 µm can remain airborne, while a 1 µm particle on the core can add up to 1 dB of loss.

A particle about 9 µm or larger can obscure the core. Clean connectors every time they mate.

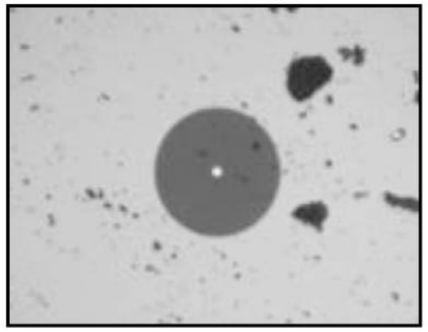
Keep unused connectors covered to prevent damage and contamination.

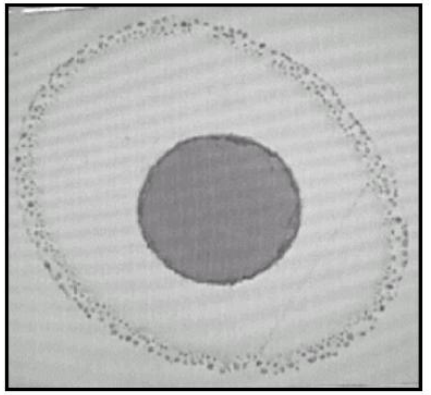
Protective boots can leave residue that combines with dust. The source describes contaminated ferrules sticking in adapters and breaking during removal.

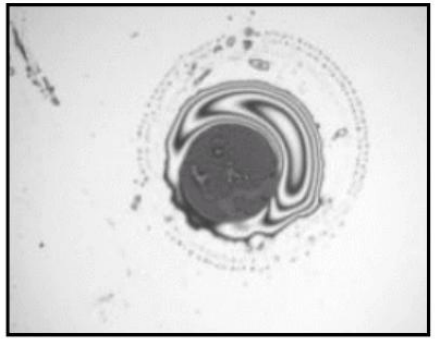
Dirty connector examples



Connector with Scratches


Connector with Dust


Connector with Dry Residue


Connector with Liquid Contamination

Fiber cleaning products



Cletop™ Cartridge



2.5mm Swabs



Wet/Dry Packaged Kit

Connector cleaning

Cleaning is required at installation and whenever a connector is removed. The source attributes about half of trouble calls to contamination.

Commercial options include wipes, swabs, Chemtronics QbE / Electrowash, and Cletop products. Follow the product instructions.

Avoid alcohol containing water and compressed air containing oil.

Once a connection is properly mated, the source describes it as maintenance-free.





Fiber optic safety

Never look into a fiber optic port or connector.

Turn off transmitters before mating connections. Keep unused ports covered.

Some inspection microscopes include infrared filters. Their limits must be understood before use. Eye damage can be irreversible.

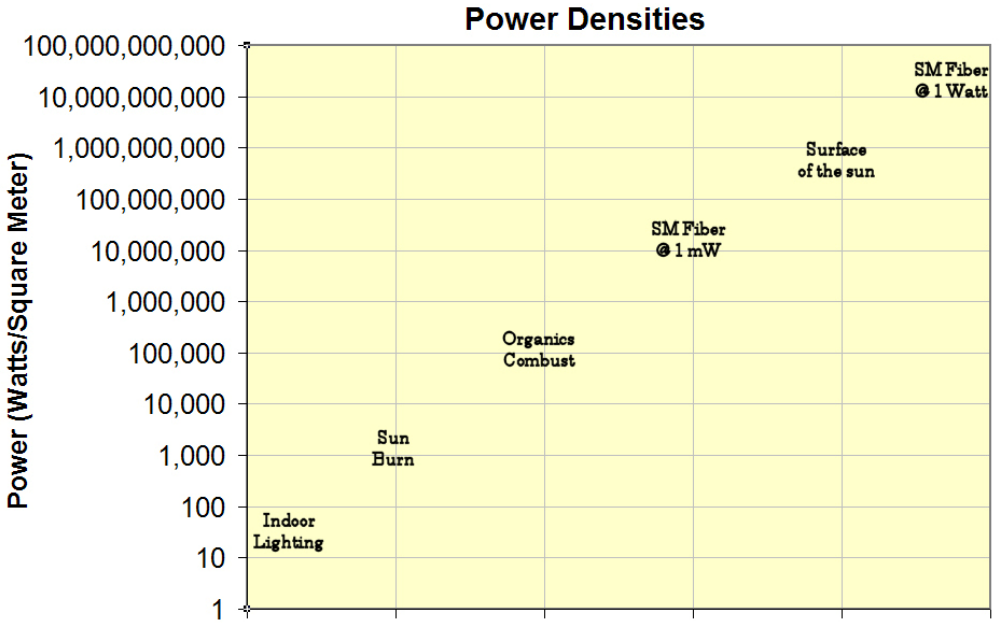
The source recommends electronic viewers for connector inspection.



Optical power density

High optical output can damage eyes and connectors. Optical power concentrates in a core only a few micrometers across.

The source compares power density in fiber with sunlight and combustion thresholds. Its example uses 1 W in a single-mode core.



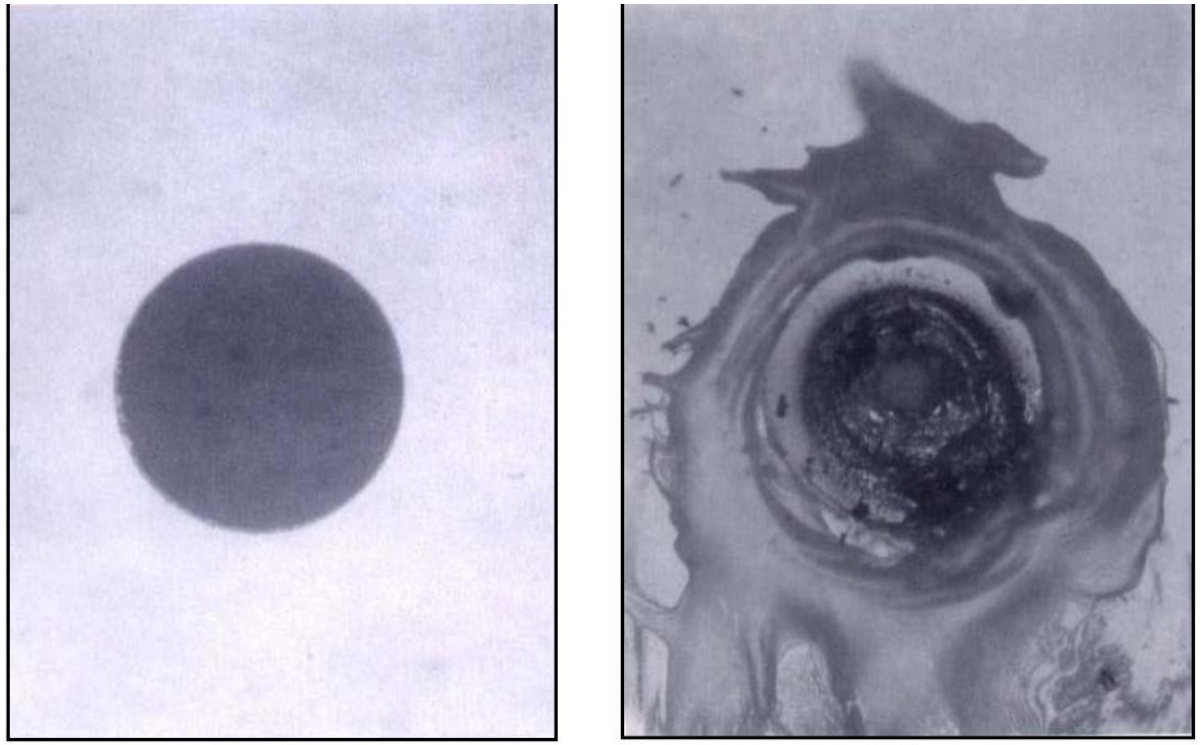
Cleaning under optical power

Never clean an optical connector while its fiber carries light.

The source warns that cleaning materials can ignite at the connector tip, including at levels below +10 dBm (10 mW).

Alcohol-saturated tissue can combust rapidly. The resulting pits and cracks can permanently increase loss or destroy the connector.

Connector damage from cleaning under power



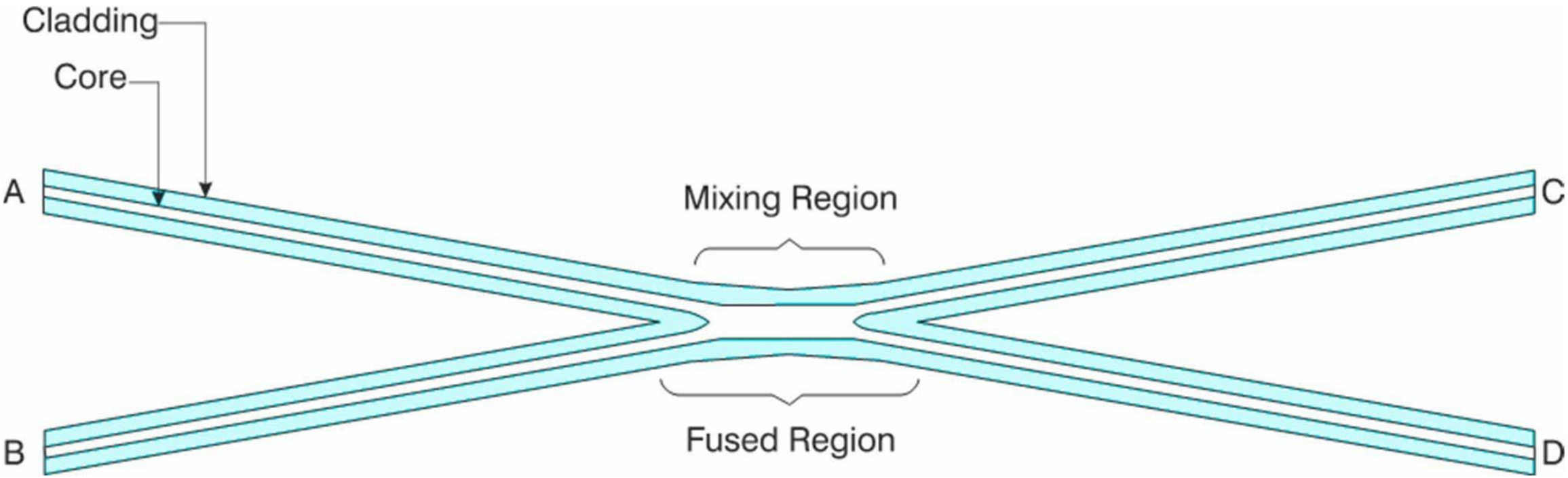
Before

After

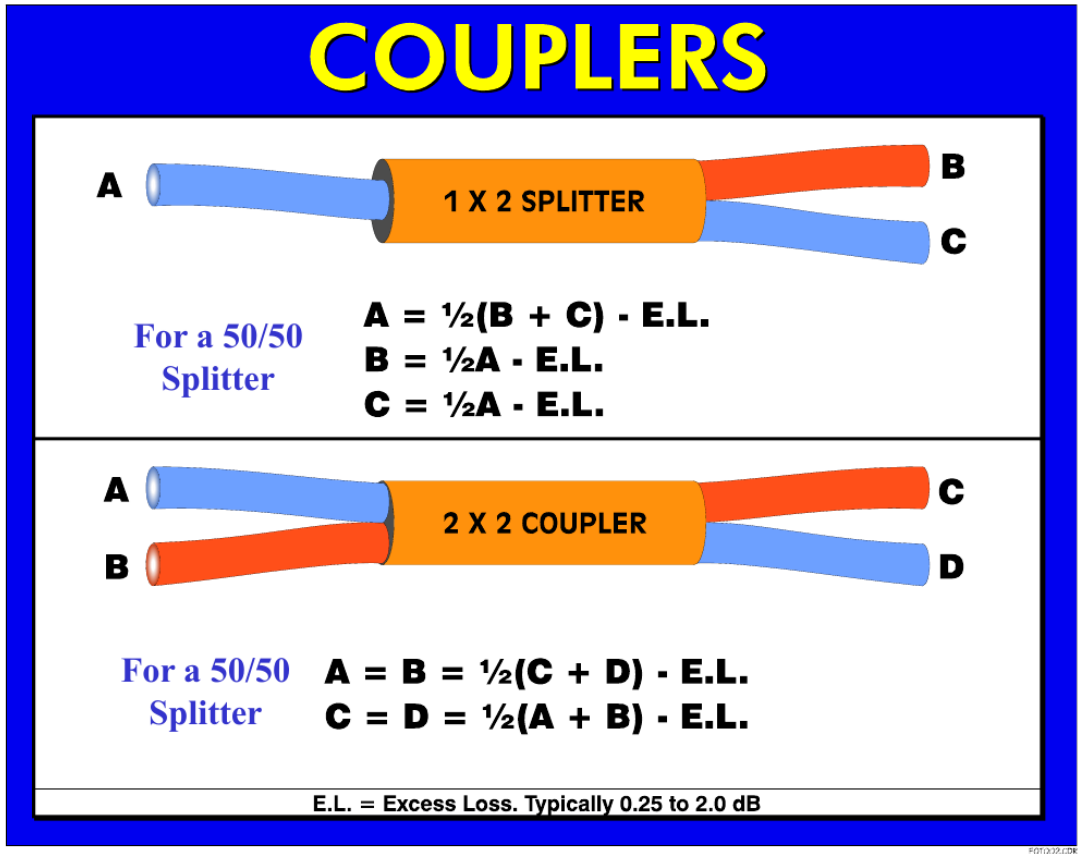
EFFECTS OF HIGHER POWER LEVELS ON OPTICAL CONNECTORS, SPLICES, AND RELATED COMPONENTS,
D.N. Ridgway, NFOEC, 2001, Page 561-572

Fused fiber couplers

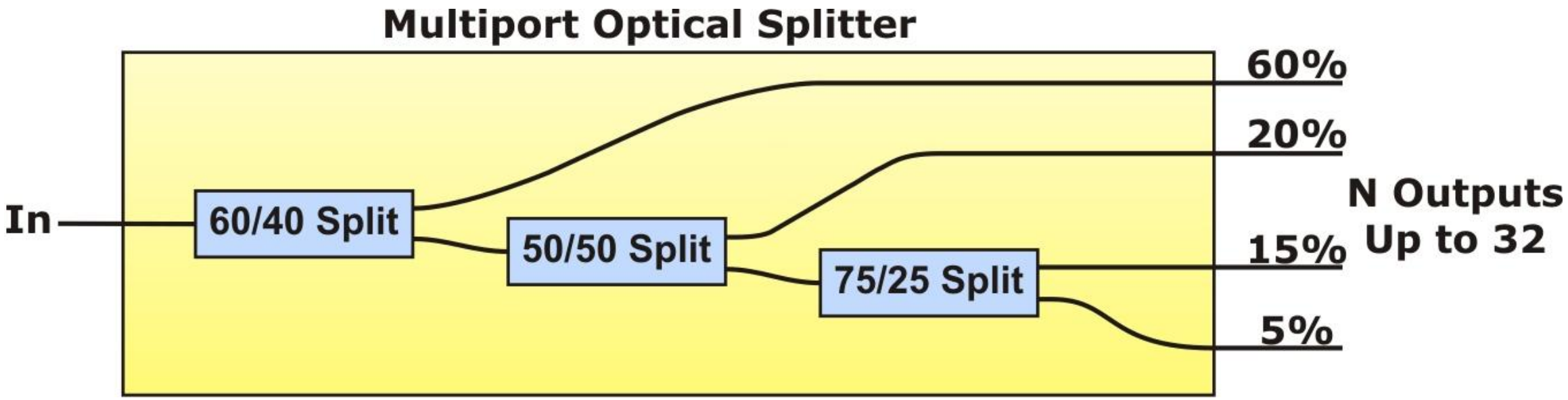
Melting two or more fibers together forms fused splitters and couplers. Wavelength multiplexers can use the same principle.



Splitters and couplers



Multiport optical splitters



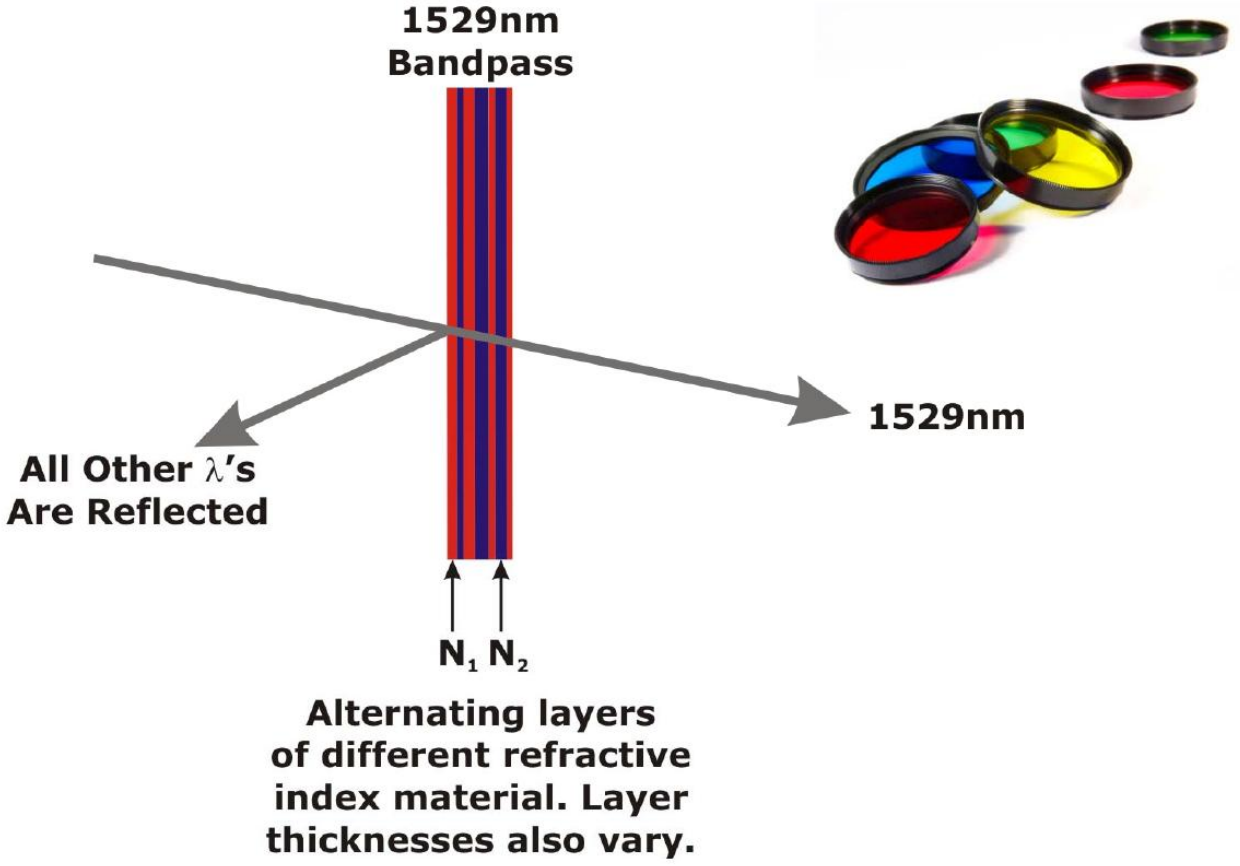
Optical multiplexing

WDM: commonly two wavelengths on one fiber, often 1310 nm and 1550 nm.

CWDM: 20 nm wavelength spacing. The source describes up to 18 wavelengths, with older water-peak fibers often limiting the useful selection.

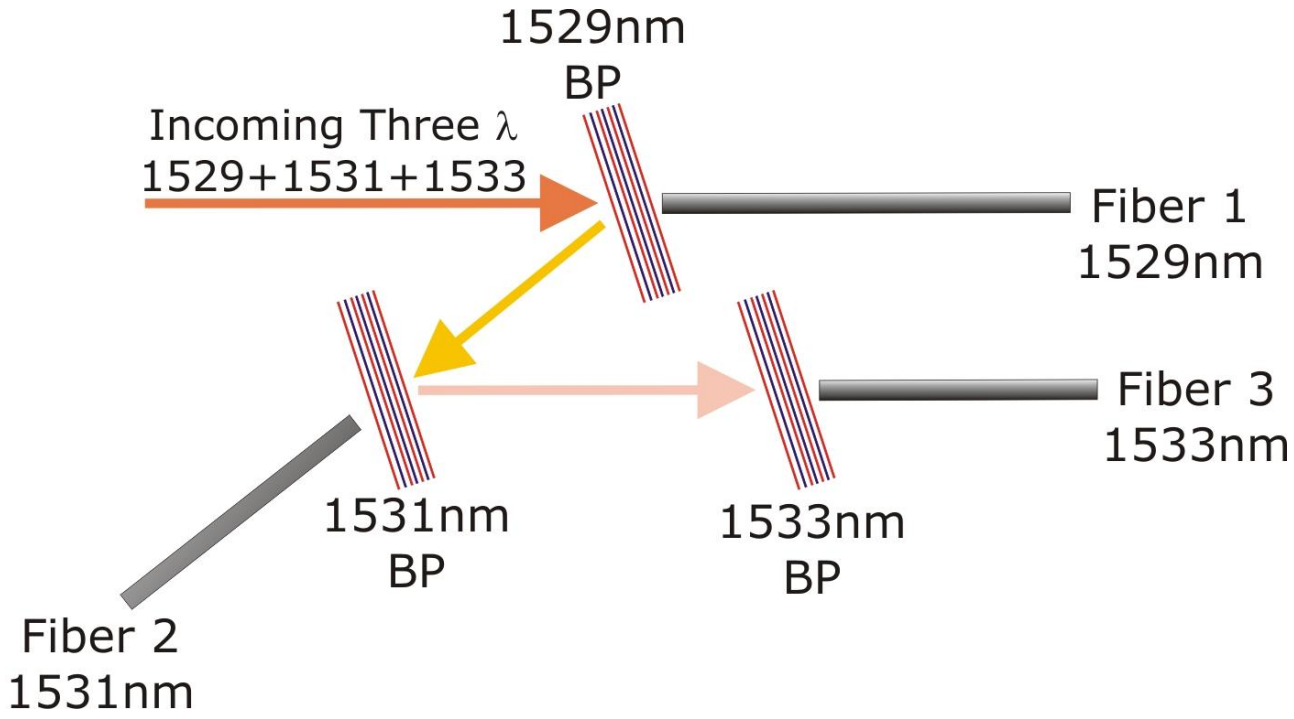
DWDM: wavelength spacing of 1.6 nm or less. The source describes up to 160 wavelengths with 25 GHz spacing.

Dichroic filters



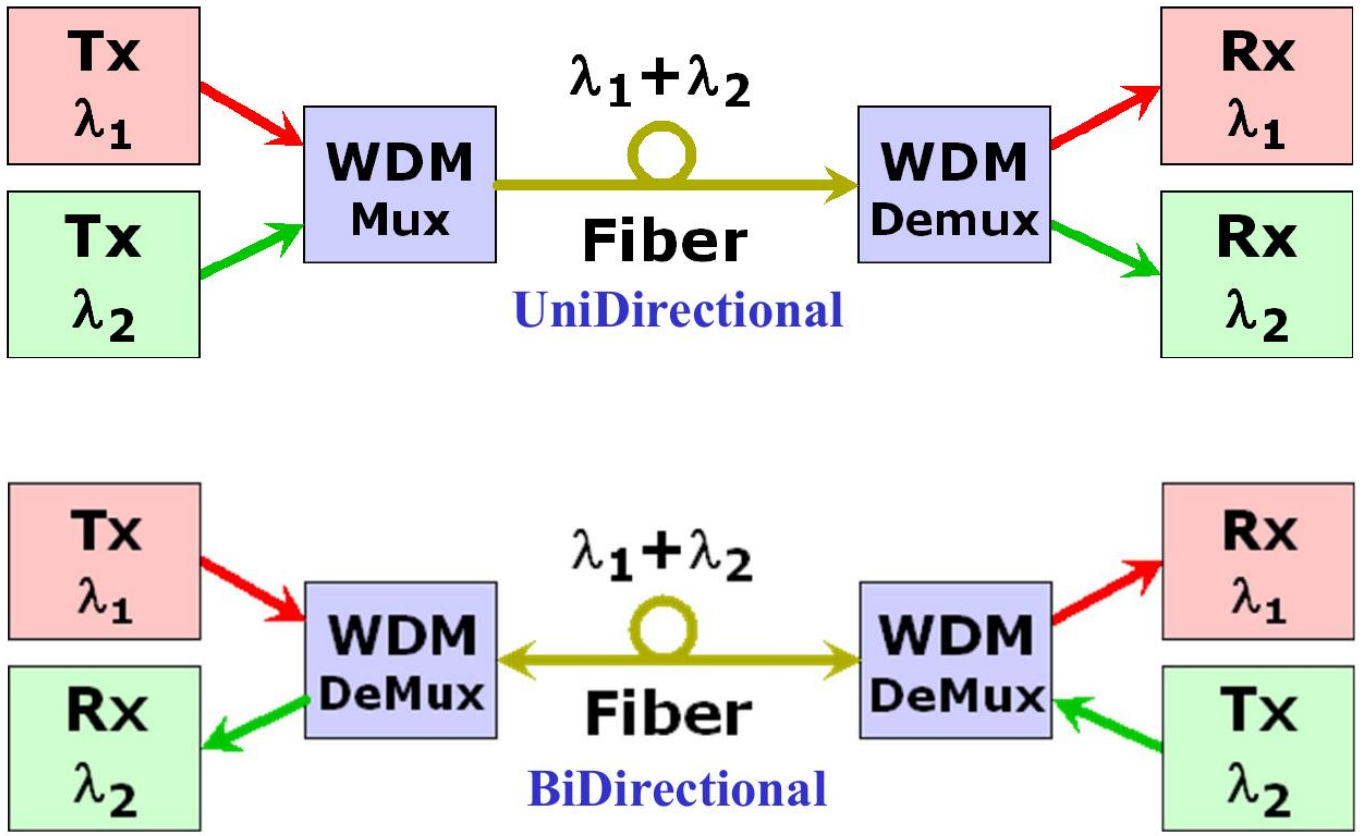
Wavelength selection uses constructive and destructive interference.

A three-wavelength WDM multiplexer

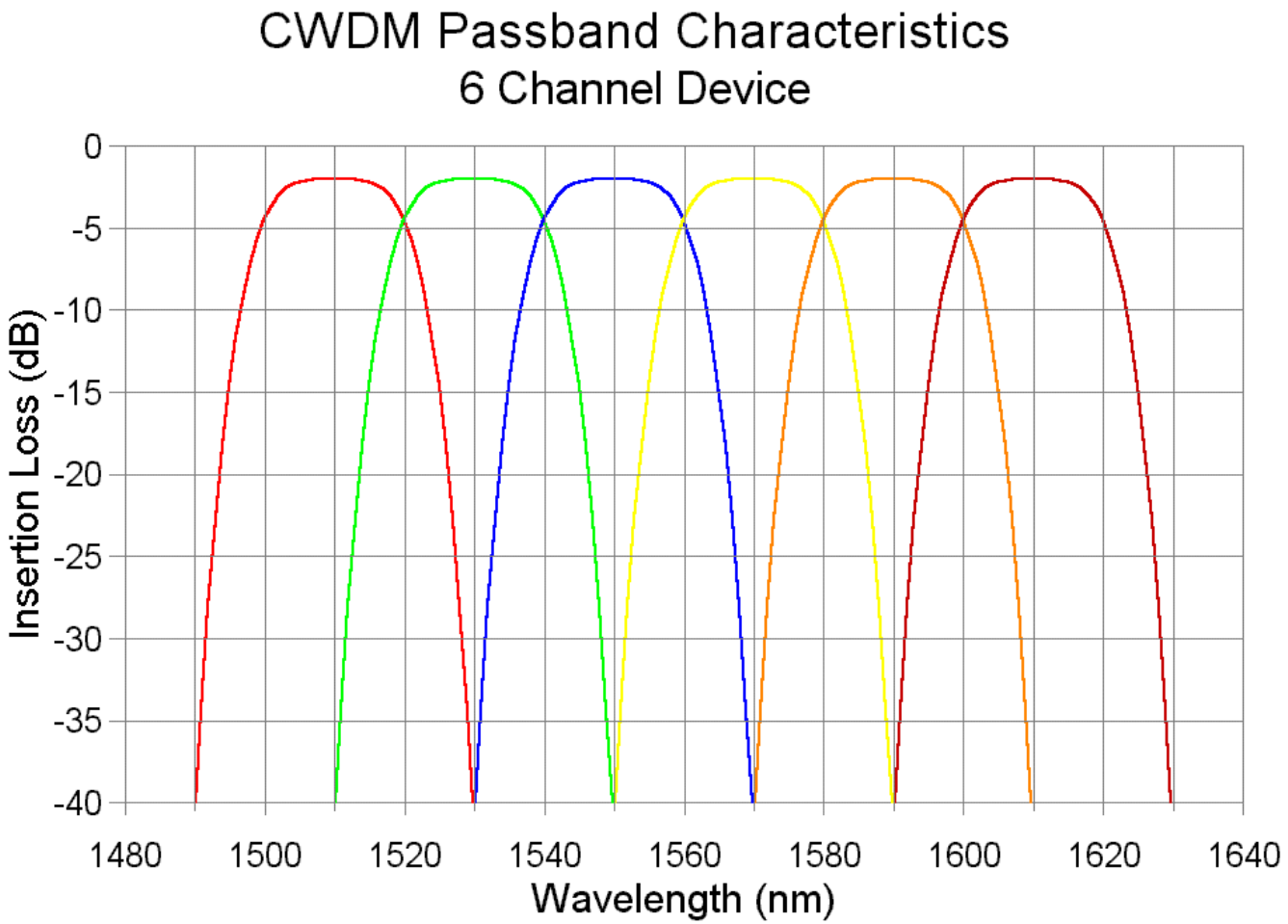


A demultiplexer runs light in the opposite direction. The filter order typically reverses so that all channels experience equal optical loss.

Wavelength division multiplexing



CWDM passband characteristics



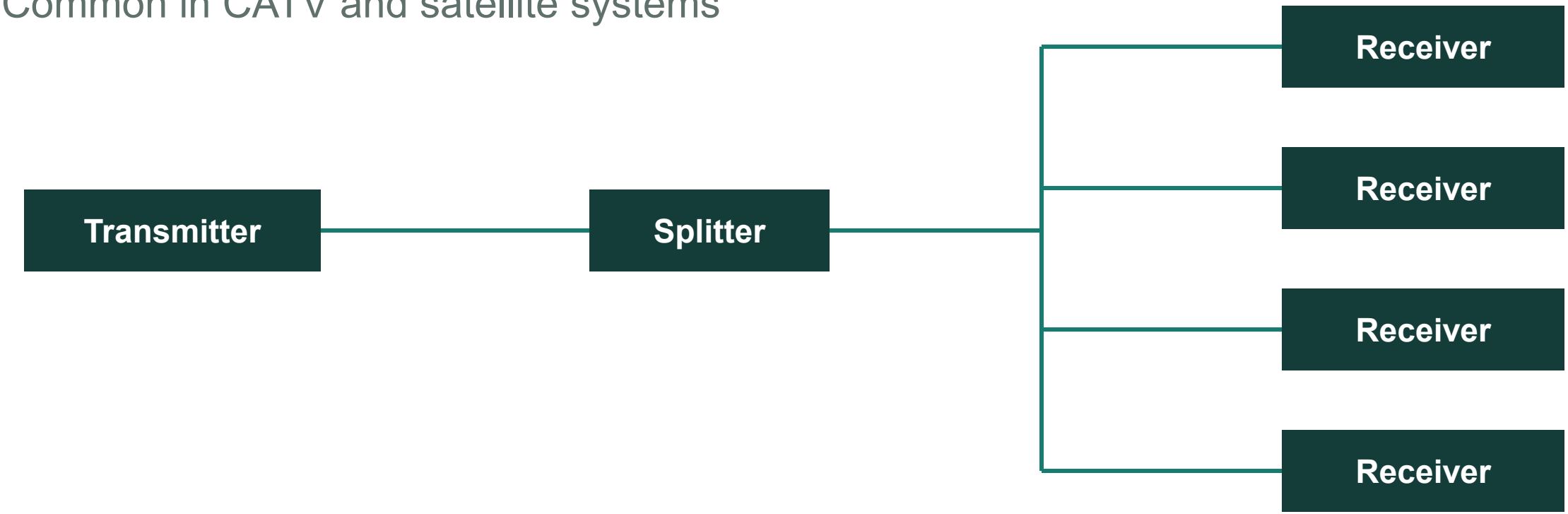
Point-to-point architecture

Simple and widely used



Star architecture

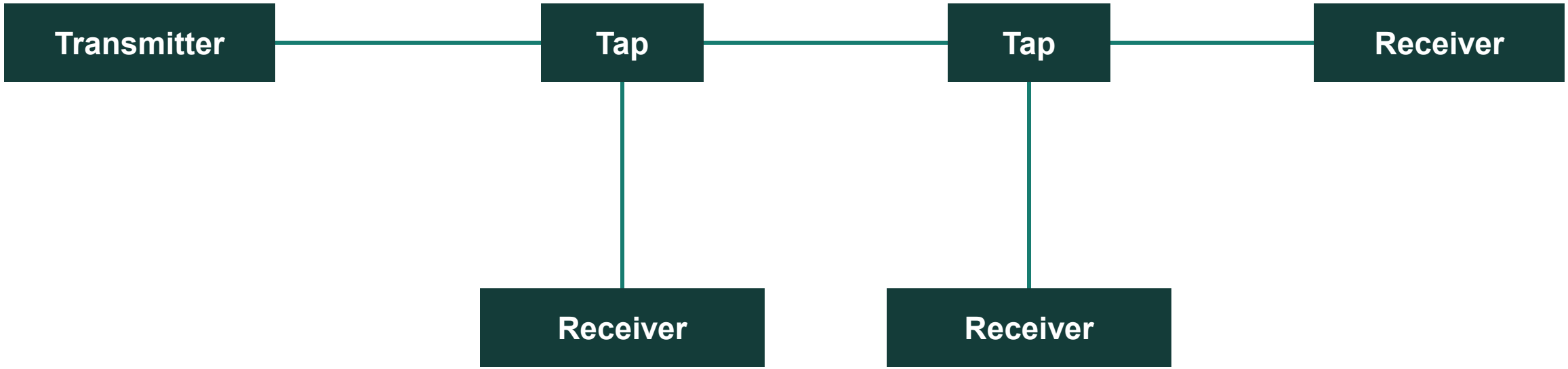
Common in CATV and satellite systems



An EDFA may precede the splitter.

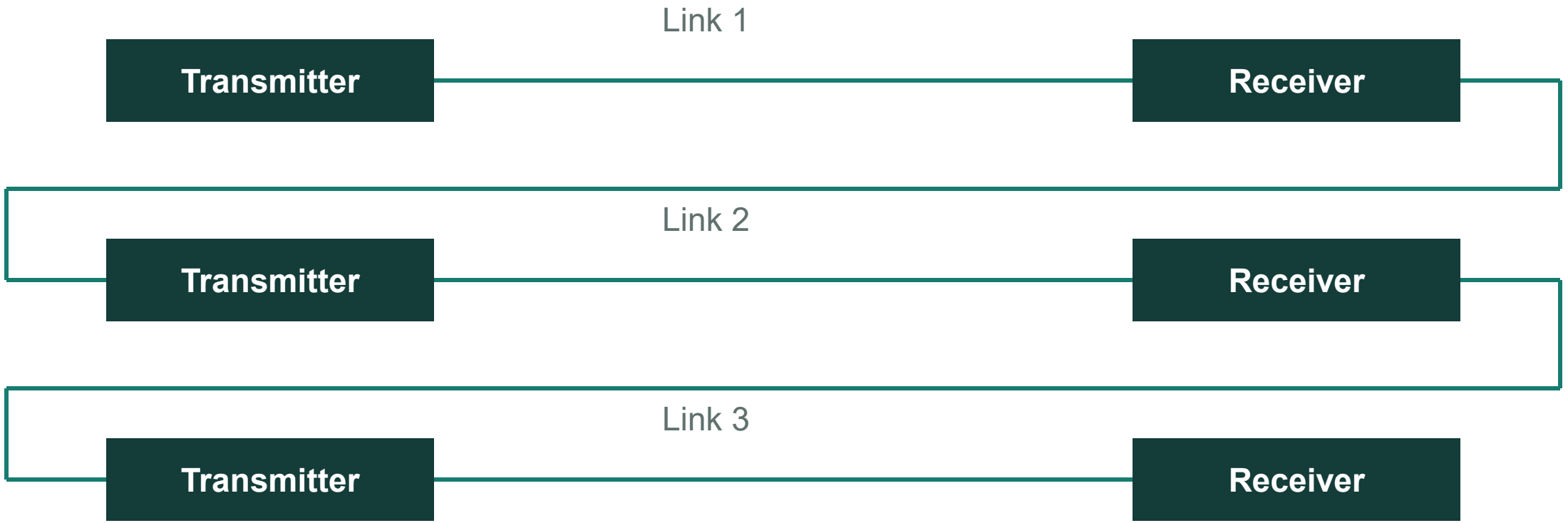
Tap architecture

Common in CATV and satellite systems



Cascade architecture

Repeated analog links accumulate noise and distortion.



Transmitter datasheet: overview



OLSON TECHNOLOGY INC.

24926 Highway 108
Sierra Village, CA 95346
Phone: (800) 545-1022
Fax: (209) 586-1026
E-Mail: sales @olsontech.com

LaserLite Model OTOT-1000-X Standalone or 1RU 19" EIA Rackmount 1310nm Optical Transmitter

Features / Benefits

Rugged and compact CATV fiber optic transmitter.

Available enhanced RF bandwidth of 48-1000MHz supports most analog and QAM digital broadcast transport applications.

Wide range of 2mW to 31mW DFB laser options for Tx launch powers from 3dBm to 15dBm.

Unsurpassed noise and distortion performance at all optical powers.

External RF and optical test points facilitate optical circuit set-up and maintenance.

Field-configurable front or rear panel SC/APC optical output connector. (FC/APC optional)

Self-contained, low profile, rugged flange mount package.

Optional 19" EIA rackmount kit for up to three (3) transmitters on a 1RU chassis panel.

Low power consumption, runs cool, integrated 90-240V_{AC} power supply. (24V_{DC} optional)

The Olson Technology, Inc. *LaserLite* Model OTOT-1000-X 1310nm 48-1000MHz CATV Broadcast Transmitter is a high quality, full-featured, cost-effective standalone or 1RU 19" EIA optical transmitter. Designed around the latest optical component technology, the OTOT-1000-X reliably delivers a full slate of multiplexed video, high speed data, and telephony services in an Hybrid Fiber Coax (HFC) broadband environment. The unit is ideally suited for the direct transmission of CATV RF signals in FTTC, FTTH, MDU, Industrial, corporate, government, educational, and other I-Net applications.

A comprehensive lineup of DFB laser offerings provides superior performance over a wide range of optical budgets (up to 21-25dBm), allowing unrepeatered spans of over 60-70km (38-45 miles) when used in conjunction with high performance, high sensitivity node receivers such as the Olson Technology Model OTPN-1000 or OTMN-II.

The rugged, self-contained OTOT-1000 provides exterior RF and optical connections and test points. The field-configurable SC/APC (or optional FC/APC) optical output connector can be mounted on the front or rear panel of the unit. The OTOT-100 cools itself with forced air via an external high MTBF fan, which is designed to be field-replaceable without interrupting operation. The stand-alone unit can be rackmounted using the Model OTLL-RMKIT to mount up to three OTOT-1000's in a 1RU (1.75") 19" space.

The *LaserLite* Model OTOT-1000 is the perfect companion to Olson Technology's *LaserLite* Models OTPN-1000 and OTOR-300 and *LaserPlus* Models OTMN-II and LP-OR optical node and return receiver product families but is also designed to work with optical transmitters and receivers from most leading manufacturers.

www.olsontech.com

Rev B All Specifications Subject to Change Without Notice Jan. 2009

Transmitter datasheet: specifications

System Specifications

RF and System Characteristics

	Min	Typ	Max	Units
Frequency Range	48		1000	MHz
Frequency Response	-1.0		+1.0	dB
Input Impedance		75		Ohms
Input Return Loss	16			dB
Input Level (+3 to +6dBm)		+18		dBmV/ch
Input Level (+8 to +15dBm)		+19		dBmV/ch
CSO	63			dBc
CTB	65			dBc
Input Adjustment Range (1)	4			dB
RF Test Point (2)		+10		dBmV/Ch

Physical Characteristics

	Min	Typ	Max	Units
Weight		1.5		lbs.
		0.68		kg
Dimensions (W x H x D)		5.5 x 1.6 x 7.5		in.
		140 x 41 x 191		mm



Electrical and Environmental Characteristics

	Min	Typ	Max	Units
Power Supply Voltage	+90		+240	V_{AC}
Power Supply Frequency	50		60	Hz
Power Consumption			10	W
Operating Temp. Range	-10		+55	°C
Humidity (RH Non Con.)	5		95	%
Cooling	Forced Air Fan			
	Field-replaceable			
Power Connector	IEC 320 w/ 5x2.0 0.5A Slo-Blo Fuse			

NOTES:
1) To +22dBmV/carrier.
2) Set for 77 analog channels, full QAM digital loading.

Transmitter Interfaces

RF Input Connector	F-type.
Optical Output Connector	SC/APC std, FC/APC opt, front or rear panel.
Optical Power Test Jack	0.1V/mW
Laser Current Test Jack	1V/50mA

Typical CNR Performance

Link Loss - Tx Power (dB)	Low Ch. Load (77 NTSC) CNR (dB)			High Ch. Load (110 NTSC) CNR (dB)		
	All Passive	Passive +3.5dB Fiber	Passive +7dB Fiber	All Passive	Passive +3.5dB Fiber	Passive +7dB Fiber
-2	56.0	55.1	54.3	55.0	54.1	53.3
-1	55.5	54.6	53.8	54.5	53.6	52.8
0	55.0	54.1	53.3	54.0	53.1	52.3
+1	54.0	53.1	52.3	53.0	52.1	51.3
+2	53.0	52.1	51.3	52.0	51.1	50.3
+3	52.0	51.1	50.3	51.0	50.1	49.3
+4	51.0	50.1	49.3	50.0	49.1	48.3

Notes
1) For example, a +8dBm transmitter through 10dB of passive optical loss would be looked up as "+2dB" in the first column (10dB - 8dB in this case) yielding 53.0dB typical CNR.
2) Loading refers to total modulated analog channels loading. Power levels are per channel peak envelope power.
3) All CNR is measured at +18dBmV/carrier.

Ordering Information

OTOT-1000-3-XX	Optical Transmitter, 1310nm, +3dBm Optical Output
OTOT-1000-6-XX	Optical Transmitter, 1310nm, +6dBm Optical Output
OTOT-1000-8-XX	Optical Transmitter, 1310nm, +8dBm Optical Output
OTOT-1000-9-XX	Optical Transmitter, 1310nm, +9dBm Optical Output
OTOT-1000-10-XX	Optical Transmitter, 1310nm, +10dBm Optical Output
OTOT-1000-12-XX	Optical Transmitter, 1310nm, +12dBm Optical Output
OTOT-1000-13-XX	Optical Transmitter, 1310nm, +13dBm Optical Output
OTOT-1000-14-XX	Optical Transmitter, 1310nm, +14dBm Optical Output
OTOT-1000-15-XX	Optical Transmitter, 1310nm, +15dBm Optical Output

Note: : The "XX" in the part numbers specifies the optical connector type. SA = SC/APC; FA = FC/APC.

www.olsontech.com

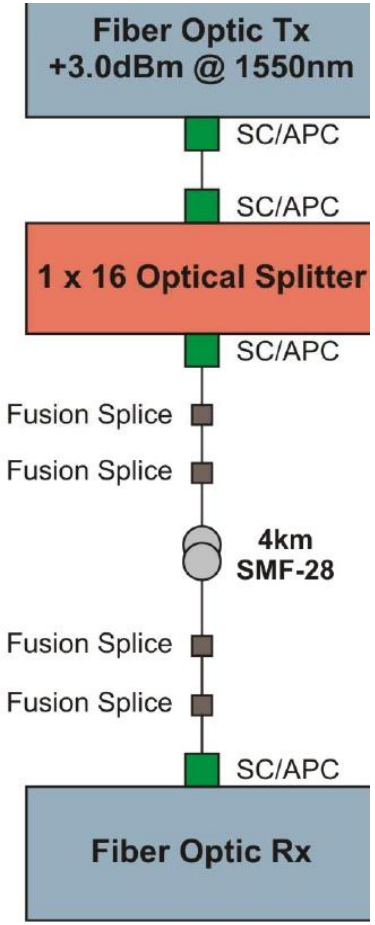
Useful equations and design constants

$dBm = 10 \times \log_{10}(\text{power in mW})$

Power in mW = 10^(dBm / 10)

Design allowance	Course value
Fiber loss at 1310 nm	0.35 dB/km ≈ 0.55 dB/mile
Fiber loss at 1550 nm	0.25 dB/km ≈ 0.4 dB/mile
Connector loss	0.25 dB
Splice loss	0.05 dB

Optical budget example

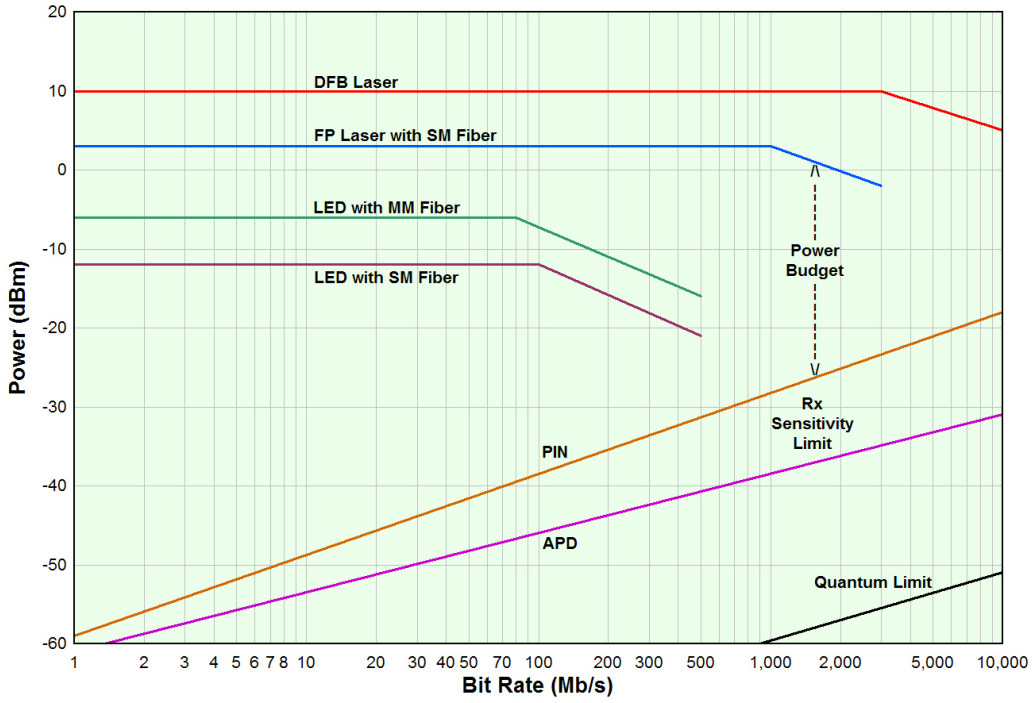


Optical loss	Value
1×16 splitter	14.4 dB
4 km SMF-28 at 1550 nm	1.0 dB
4 SC/APC connections at 0.2 dB	0.8 dB
4 fusion splices at 0.1 dB	0.4 dB
Total optical loss	16.6 dB

Receiver input = +3.0 − 16.6 = −13.6 dBm

Link power budget

The optical power budget depends on the light source, detector, fiber type, and transmission distance. The source chart compares several link technologies.



Back reflections and optical return loss

Back reflection, or optical return loss, comes from refractive-index changes at a cleaved or polished fiber end. The source gives about 4%, or −14 dB, for a glass–air interface.

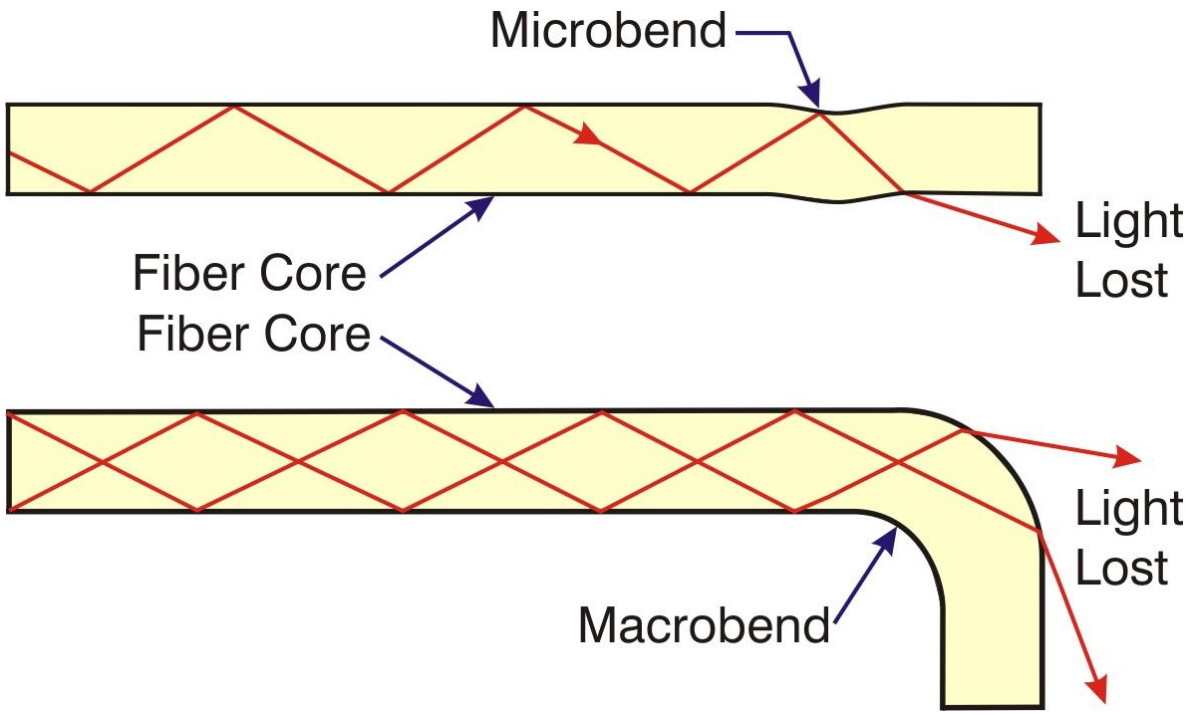
Reflections can degrade analog video and high-speed digital systems.

PC connectors use physical end-face contact. APC connectors add an 8° angle and use green identification, reducing reflected light coupled back into the core.

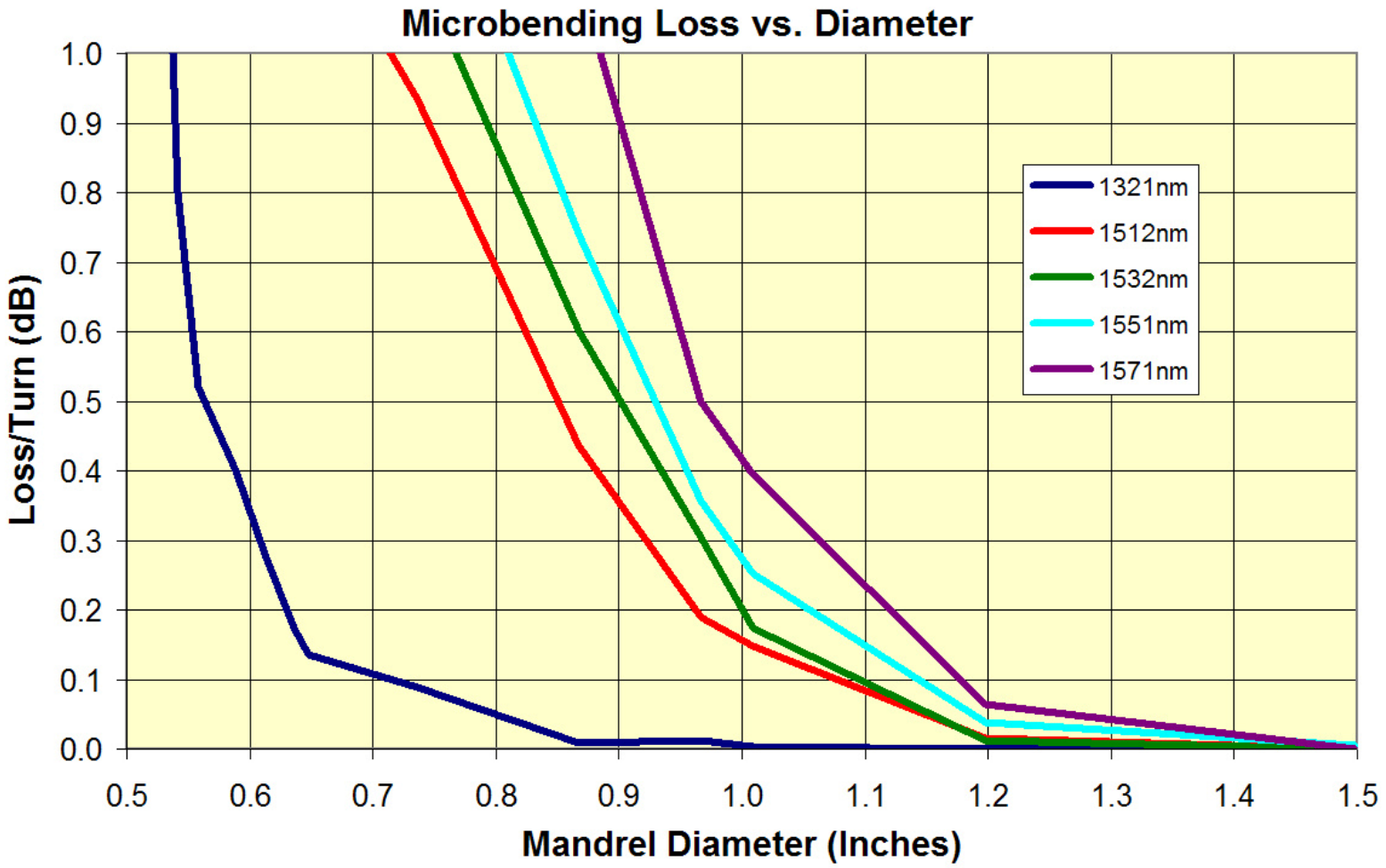
The source favors fusion splices for high-speed digital and CATV networks because they produce very low reflection.

Fiber bends and optical loss

Stress on optical fiber can cause microbending loss. Larger bends can also let light escape from the core.



Macrobending loss



Fiber strippers



The source instructor’s preferred stripper is the Jonard JIC-375.

The source also illustrates a Clauss CFS-2 stripper.

Fiber cleavers



The source illustrates an Ericsson EFC-II. A precision fiber cleaver prepares the fiber end before splicing.

Kevlar cutters



Kevlar strength members require cutters designed for that material.

Fusion splicing







A correctly made fusion splice provides very low optical loss. A precision cleaver prepares each fiber end. The fusion splicer aligns the fibers on the x, y, and z axes. An electric arc heats and welds the glass. A heat-shrink splice-protection sleeve covers the joint. The finished splice then sits in a splice tray.

Optical power meters





An optical power meter is the source instructor's first choice when only one optical test instrument is affordable.

The meter must cover the wavelengths and optical power levels in use. The source notes that some meters overload above +3 dBm.

Optical time domain reflectometry

An optical time domain reflectometer characterizes a fiber from light that scatters or reflects back toward the launch end.

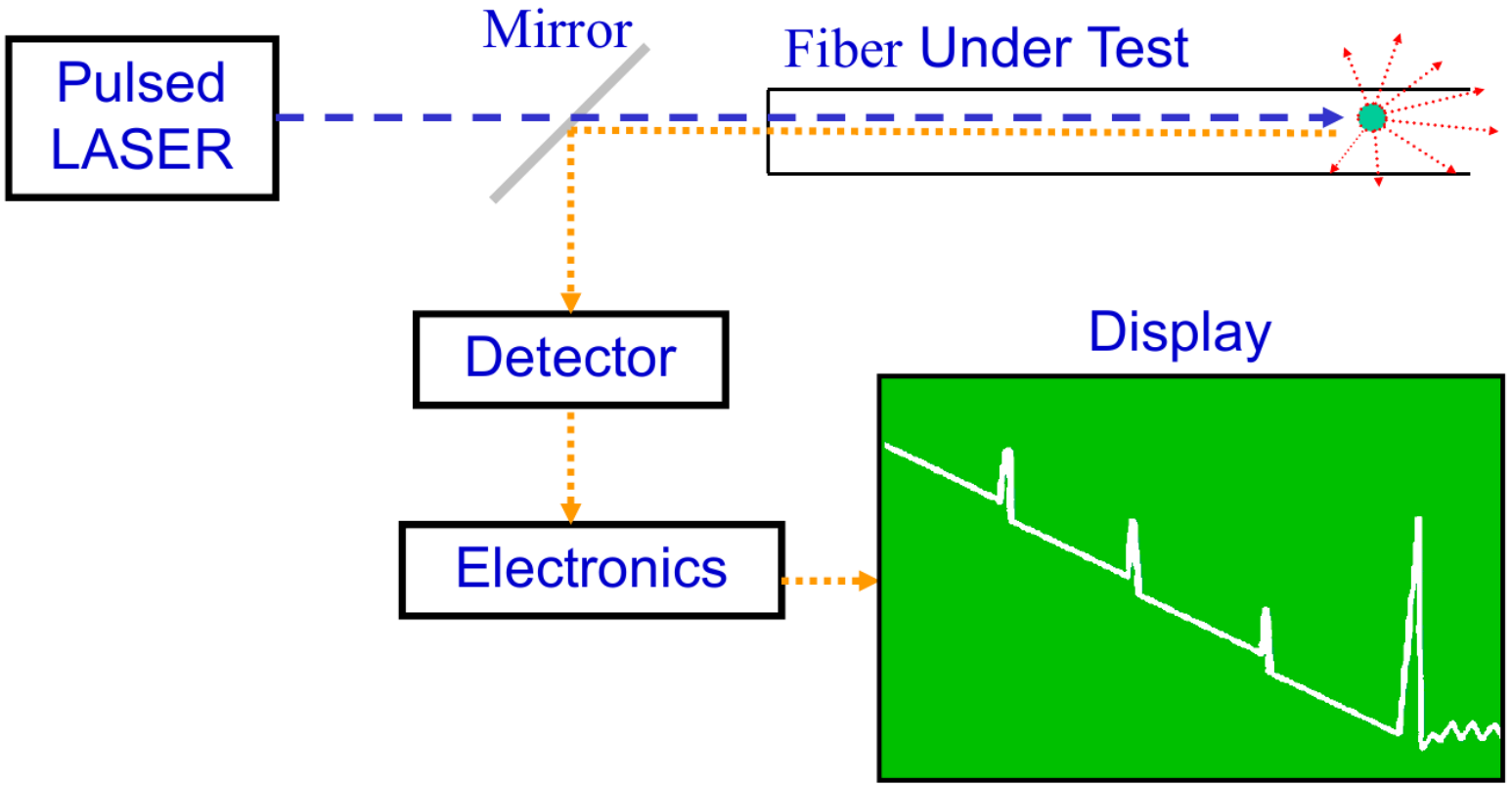
The instrument sends optical pulses, measures the returning light over time, and plots the result against distance.

An OTDR can estimate fiber length, total attenuation, splice and connector loss, and the location of faults such as breaks.

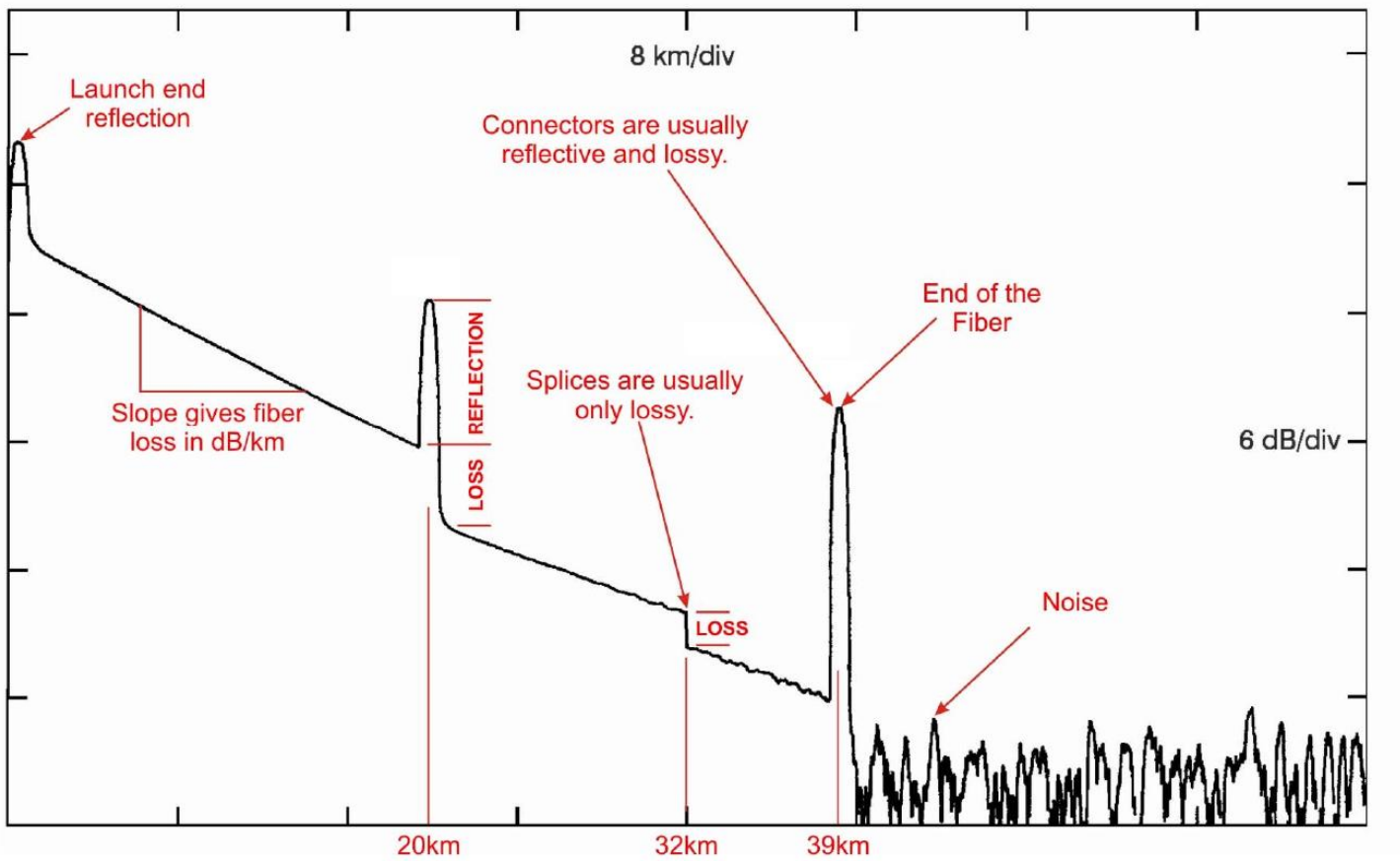
A portable OTDR and launch spool



OTDR operating principle



A typical OTDR trace

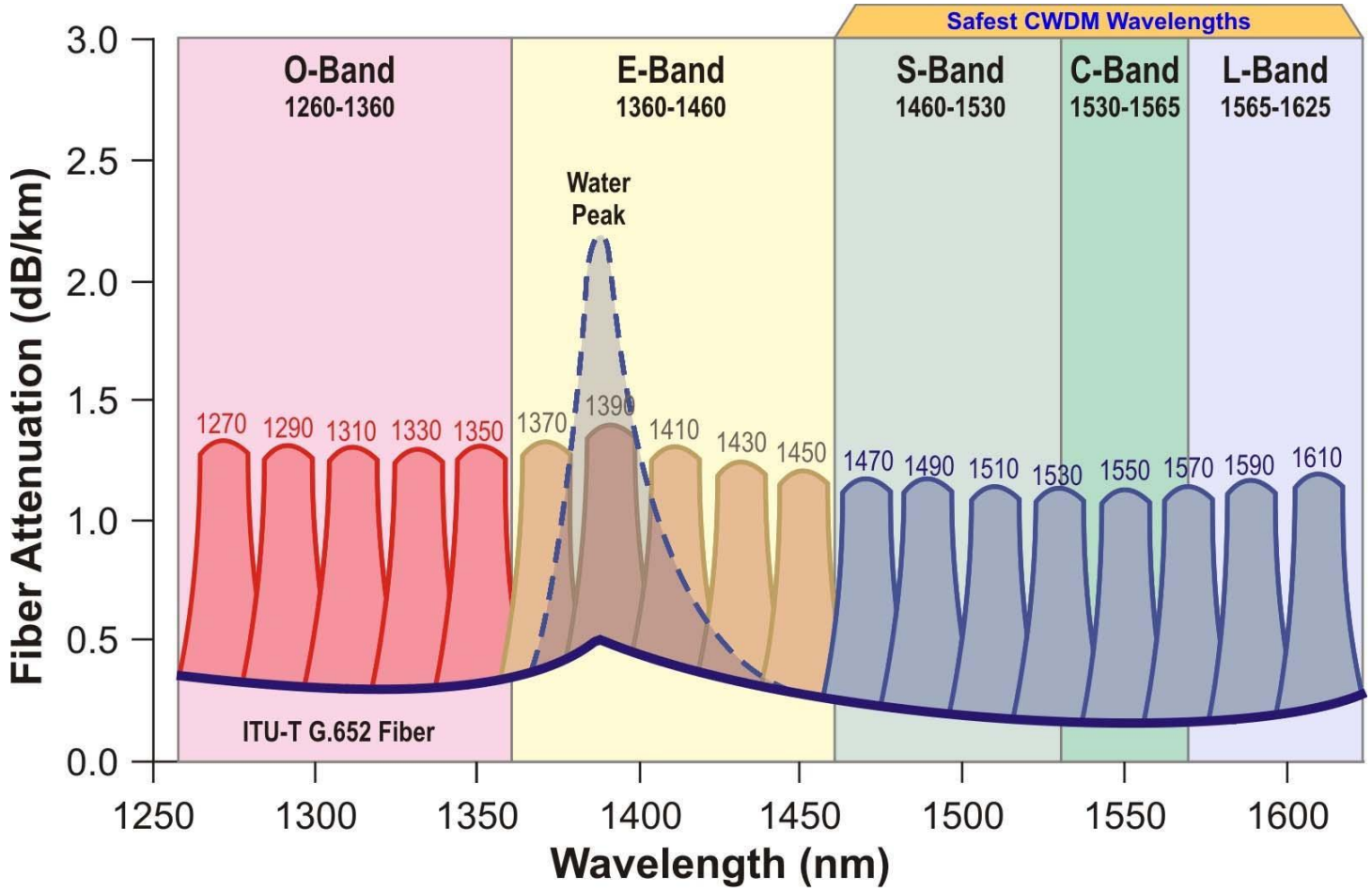


Single-mode fiber standards

ITU-T	Fiber	Attenuation	Dispersion	Zero dispersion	Use in course
G.652	Standard SMF	0.25 dB/km	17 ps/(nm·km)	1310 nm	All WDM
G.652c	Low-water-peak SMF	0.25 dB/km	17 ps/(nm·km)	1310 nm	CWDM
G.653	Dispersion-shifted (DSF)	0.25 dB/km	≈ 0 ps/(nm·km)	1550 nm	Unsuitable for WDM
G.655	Non-zero dispersion-shifted (NZDSF)	0.25 dB/km	4.5 ps/(nm·km)	1500 nm	DWDM

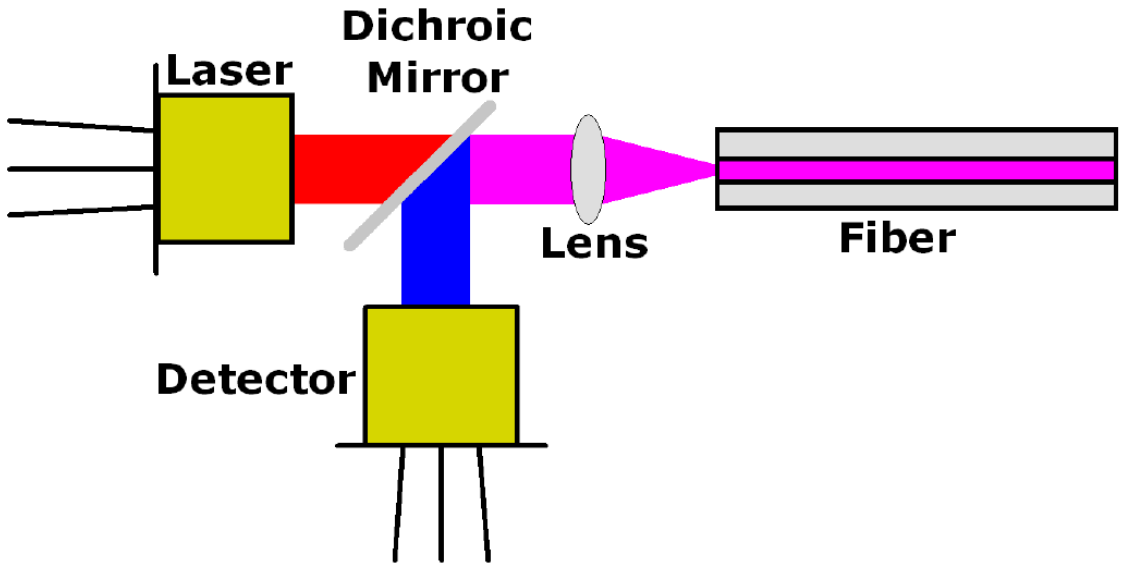
Course reference values. Attenuation and dispersion refer to the C-band.

CWDM wavelengths and bands

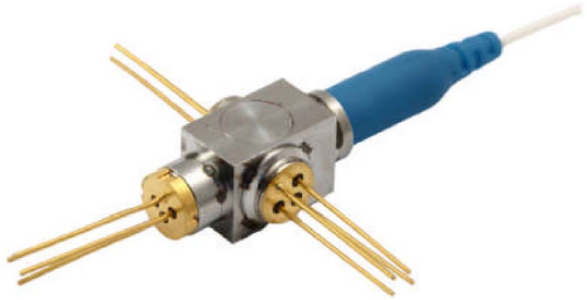


Source caution: verify fiber type before using wavelengths from 1350 to 1450 nm.

Bidirectional optical devices



A three wavelength version of this device (called a Tri-Di) is commonly used in fiber to the home applications. Wavelengths of 1310nm, 1490nm and 1550nm are commonly used for FTTH applications.



A passive device datasheet

OLSON TECHNOLOGY INC.

24926 Highway 108
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E-Mail: sales @olsontech.com

Model OT-WBSC-A-1 Dual Window SM
Wideband Star and Tree Fiber Coupler

Features / Benefits



APPLICATIONS

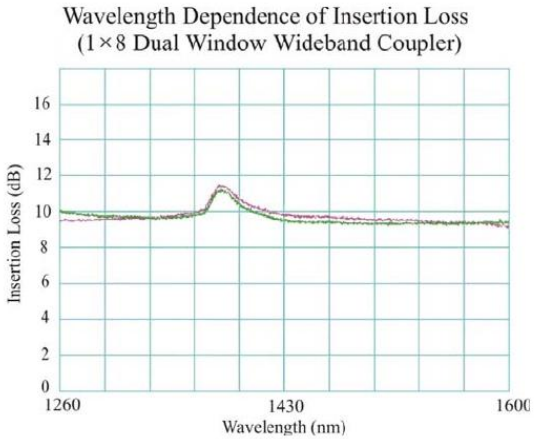
- Fiber to the Home (FTTH)
- Local Loop
- Passive Optical Networks (PON)
- Fiber Optic CATV
- Fiber Communications System
- Fiber Optic Test Equipment
- Fiber Optic Sensing
- Local Area Networks (LAN)

FEATURES

- All Fiber Construction
- High Reliability
- Outstanding Optical Performance
- Multiple Fiber Types Available

Operating Specifications

Parameter	Units	Specification			
Configuration		1 x 4	1 x 8	1 x 16	1 x 32
Center Wavelength (λ_c)	nm	1310 or 1550			
Bandwidth	nm	±40			
Typ. Insertion Loss	dB	6.3	9.5	12.6	15.8
Max. Insertion Loss	dB	7.0	10.6	14.0	17.6
Max. PDL	dB	0.30	0.45	0.60	0.75
Min. Directivity	dB	50			
Max. Uniformity	dB	1.4	2.1	2.8	3.5
Max. Flatness	dB	0.6	0.9	1.2	1.5
Max. Temp. Coefficient	dB/°C	0.004	0.006	0.008	0.010
Operating Temperature	°C	-20 to +75			
Storage Temperature	°C	-40 to +85			
Package Dimensions	mm	O: 100 x 80 x 9 P: 136 x 100 x 12 T: 19", 1RU Rack			



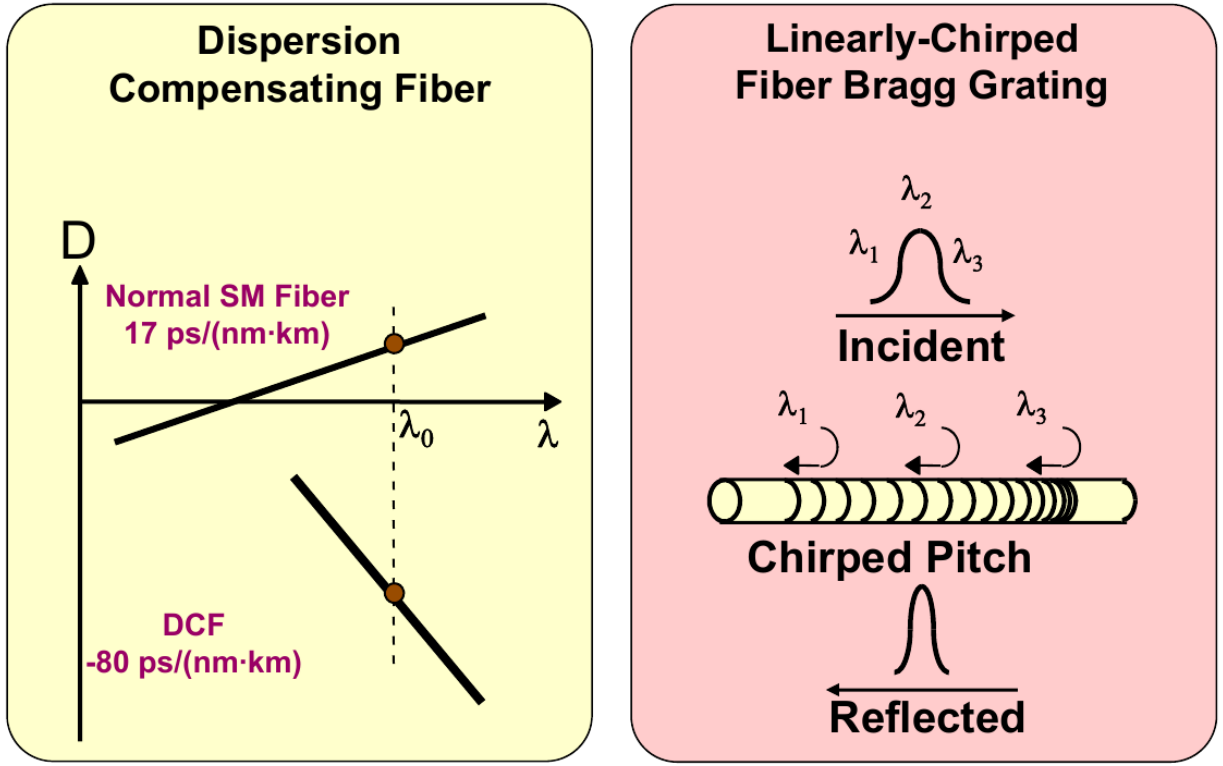
Chromatic dispersion management

Low-dispersion fiber: the source lists DSF and NZ-DSF below 5 ps/(nm·km). Cost can rise, installed fiber may be difficult to replace, and DSF nonlinearities remain a concern.

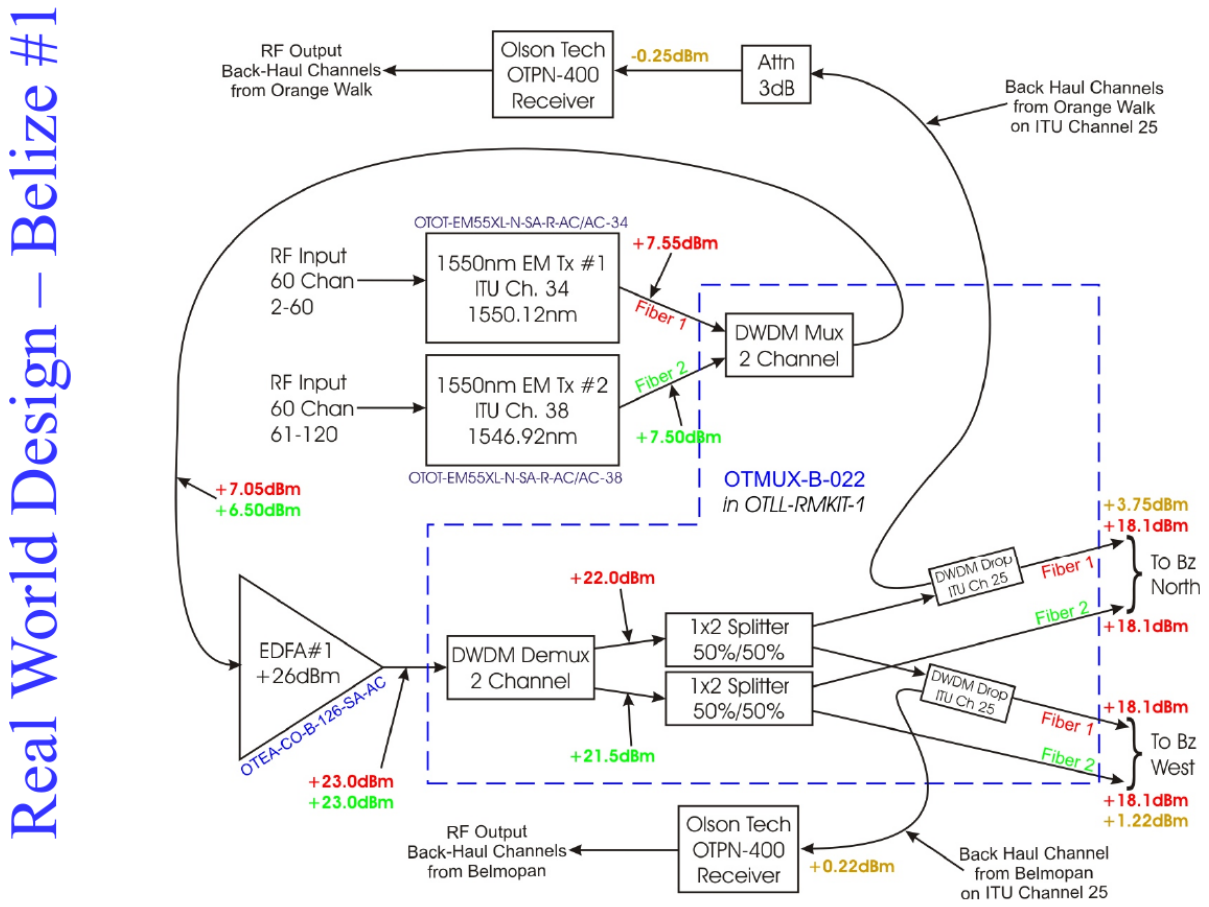
External modulation reduces transmitter chirp. The source presents it as a way to reduce chromatic-dispersion impairment.

Dispersion compensation modules (DCMs) manage dispersion on long links. The source describes fiber-based and grating-based technologies, including trans-oceanic use.

Dispersion compensation methods

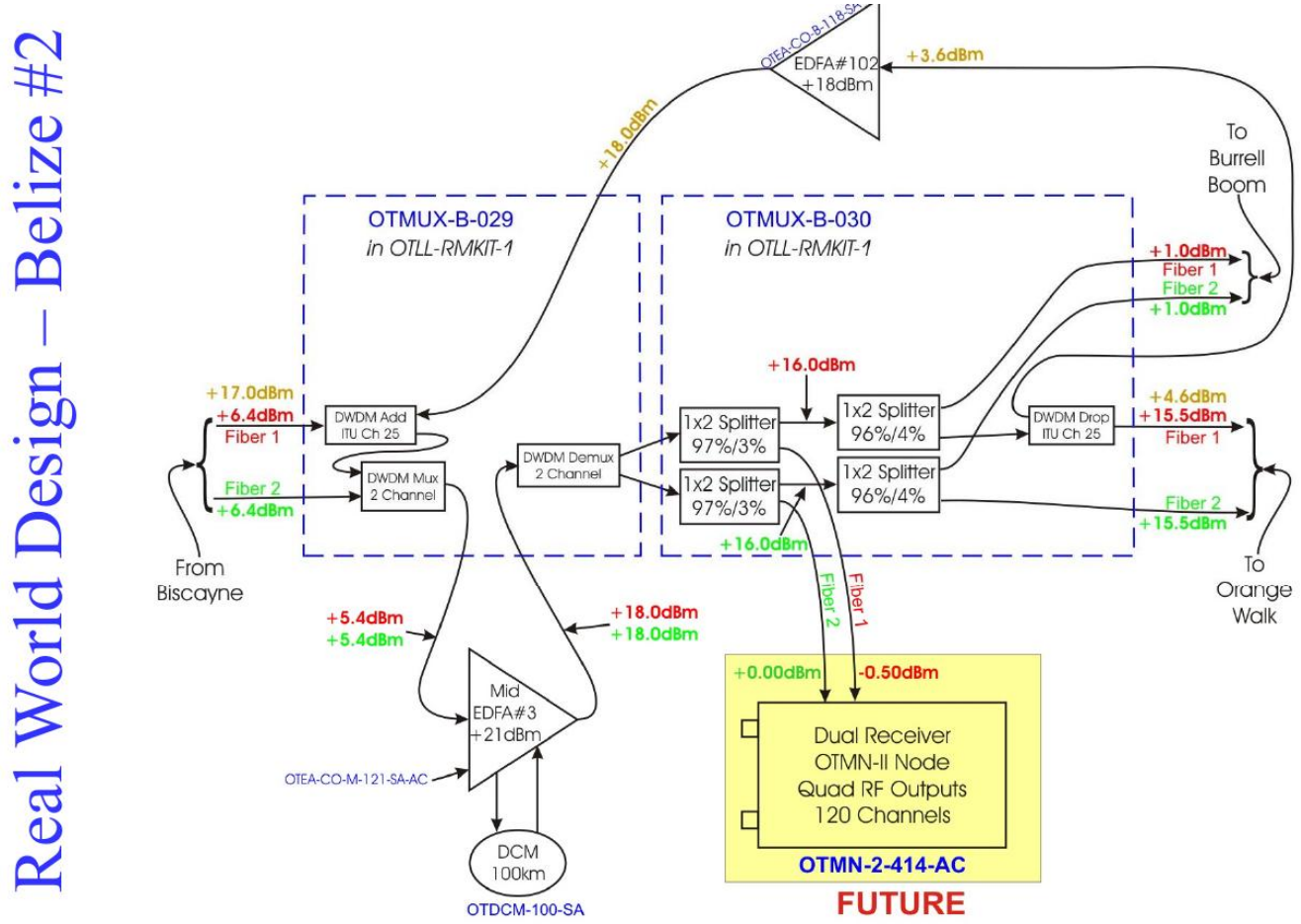


System design: Belize City

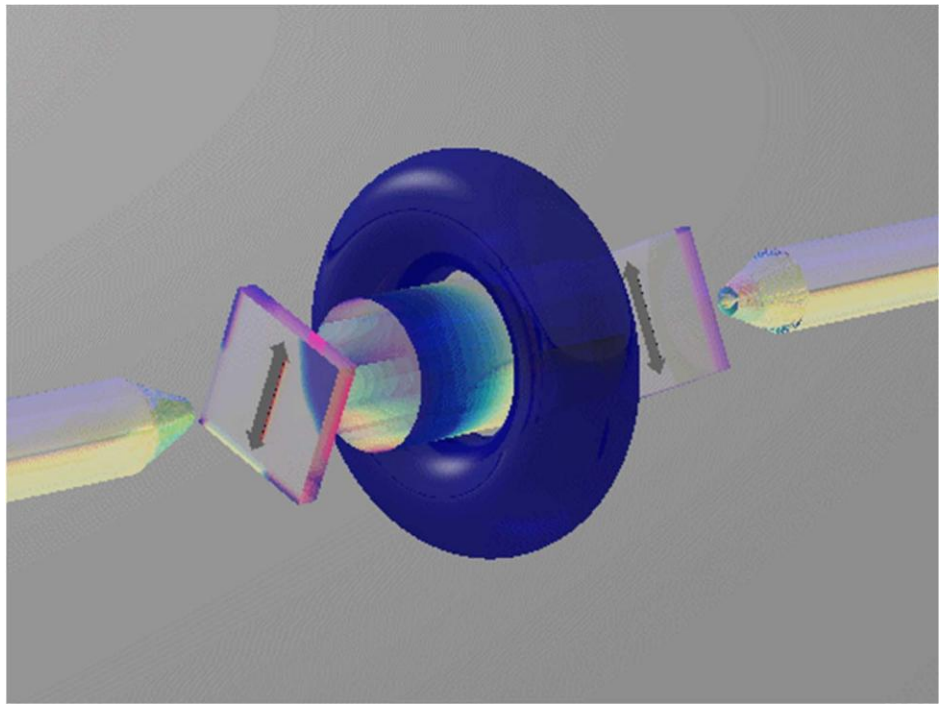


Back-haul: channel 25. Forward paths: channels 34 and 38.

System design: Crooked Tree Junction

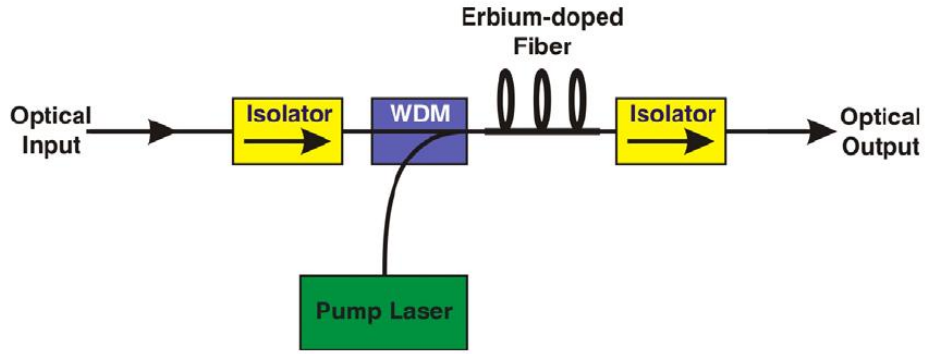


Optical isolators

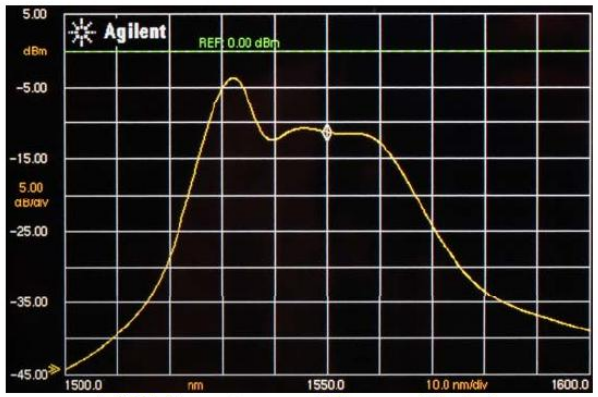


An optical isolator uses an input polarizer, a magnetically biased Faraday rotator, and an output polarizer rotated 45° relative to the input polarizer.

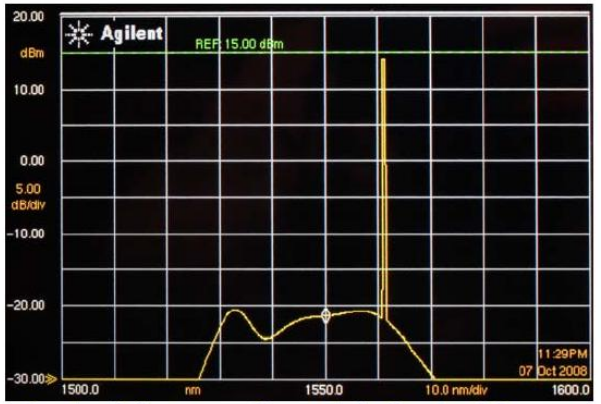
EDFA basics



Basic EDFA Block Diagram

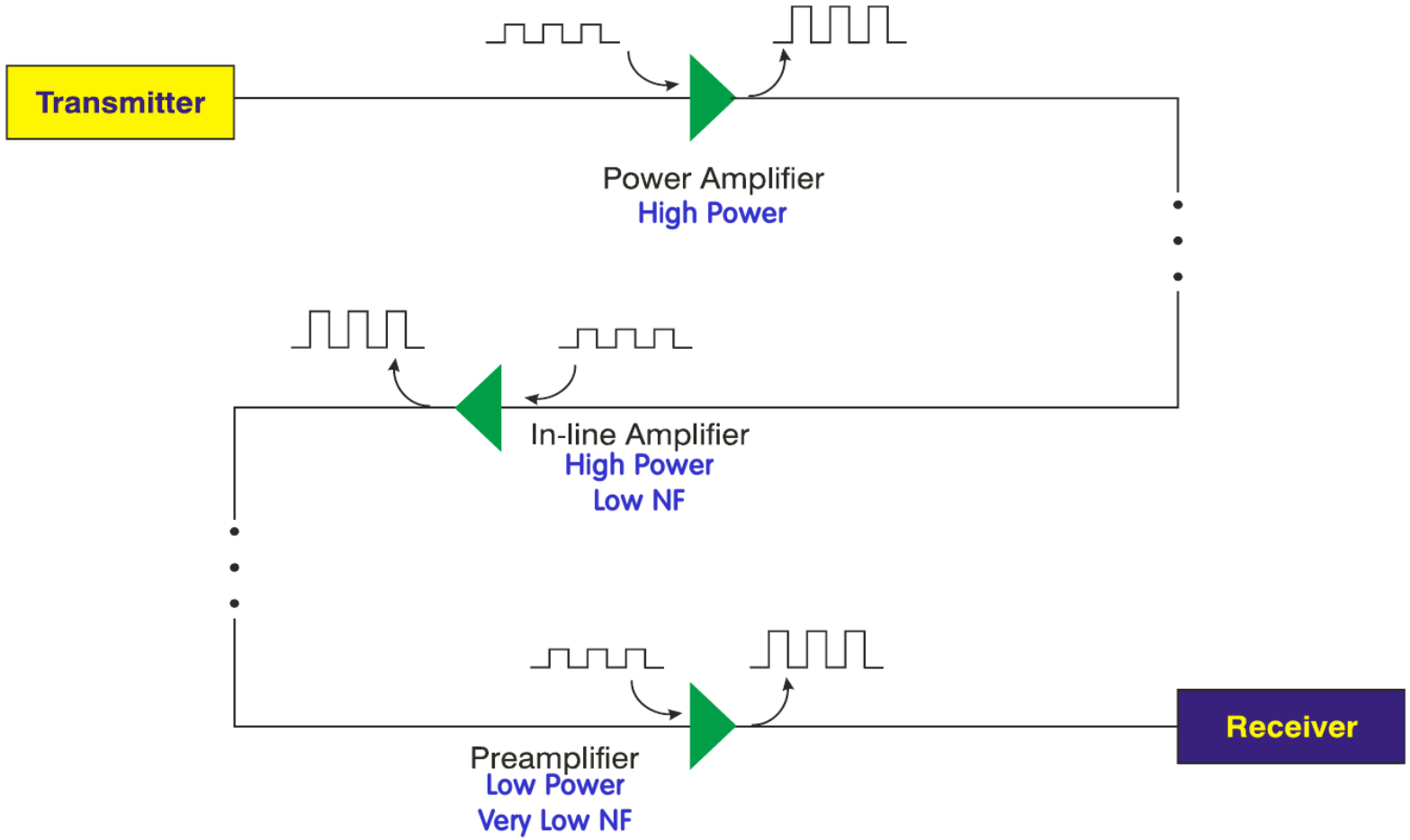


ASE Spectrum (Shows Gain)

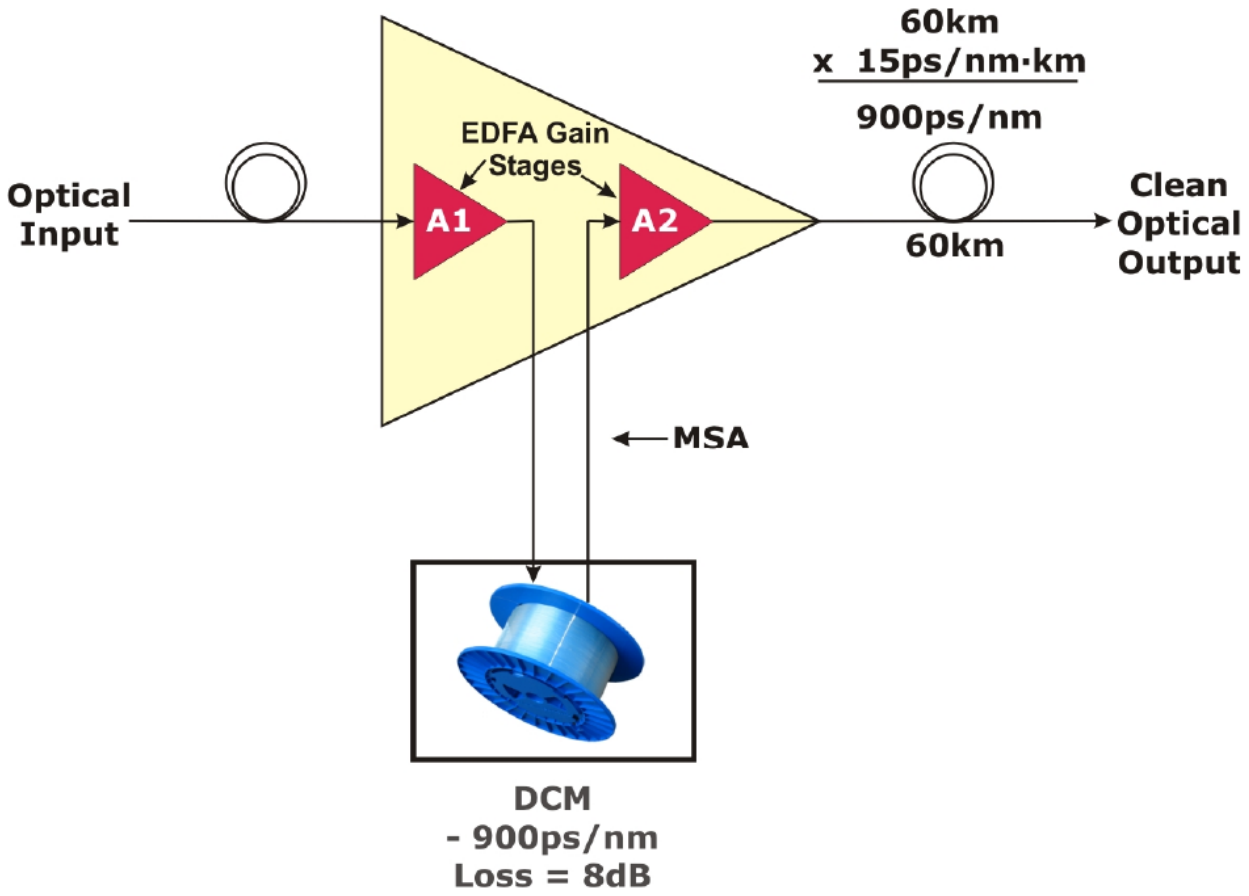


Optical Spectra Out with Optical Input

EDFA applications



EDFA mid-stage access



EDFA power across multiple wavelengths

Power per carrier = total output − $10 \times \log_{10}(N)$

Example: +17 dBm total output, approximately 50 mW

Wavelengths N	Power reduction	Power per carrier
1	0 dB	+17 dBm
2	−3 dB	+14 dBm
4	−6 dB	+11 dBm
8	−9 dB	+8 dBm
16	−12 dB	+5 dBm

With 16 equal carriers: approximately 3.13 mW, or +5.0 dBm, per carrier.

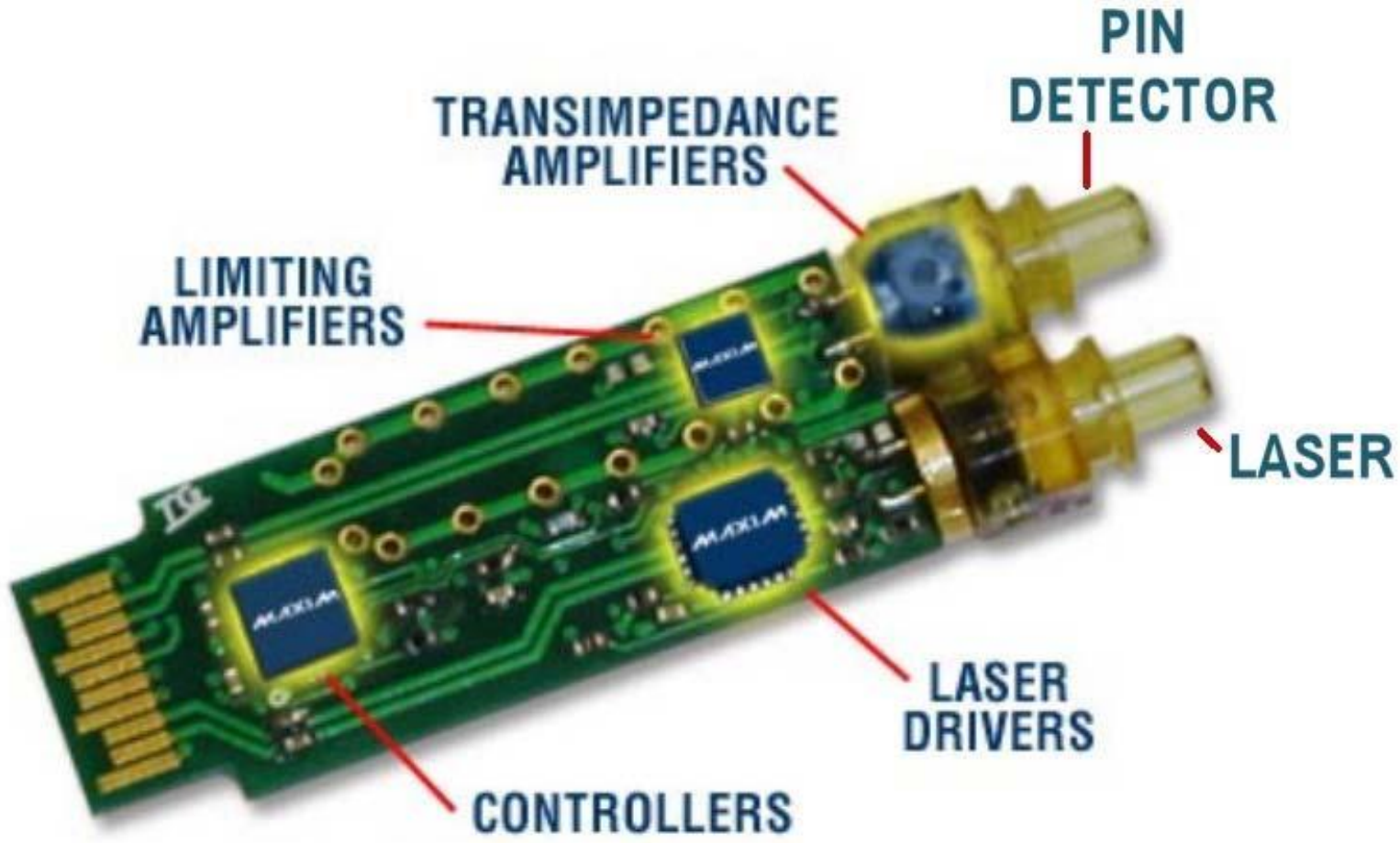
Standards-based digital modules



The source shows SFP, SFF, XFP, GBIC, and 1×9 modules.

Widespread availability of low-cost, standards-based modules reduced the cost of many digital fiber applications.

SFP module construction



Fiber optic CATV transmitter

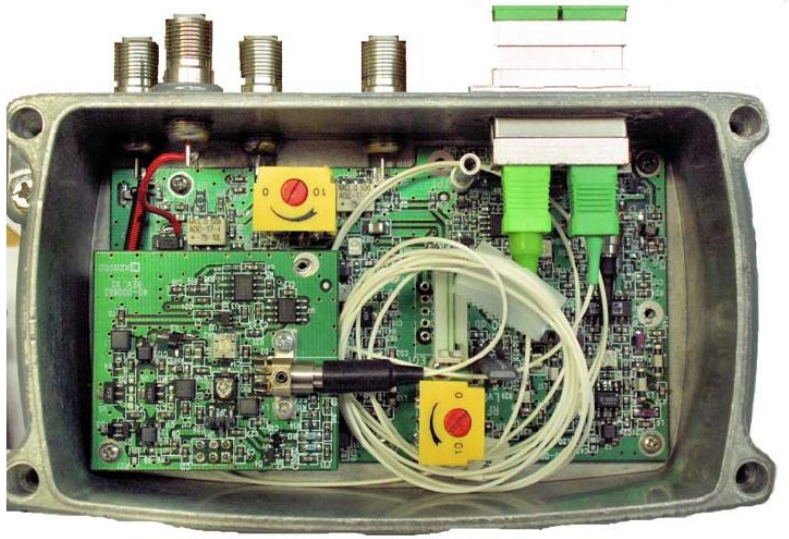






Miniature CATV node





Full-size fiber optic node

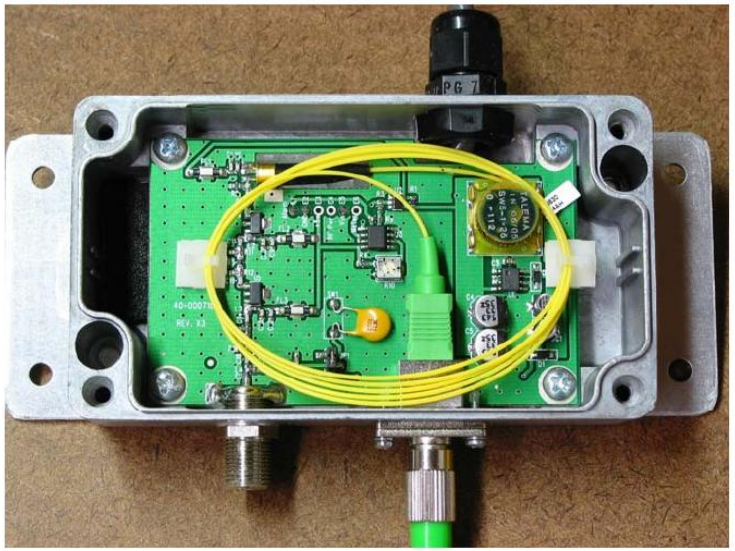


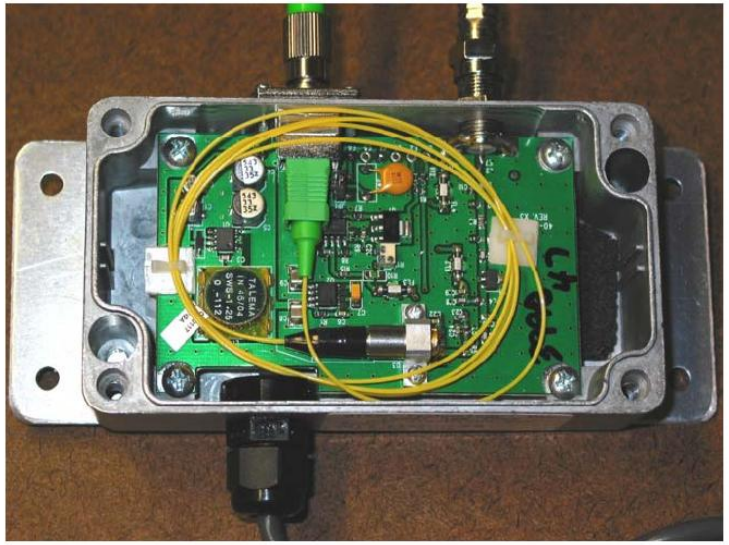
Digital video transport





L-band fiber optic link





Workbook exercises

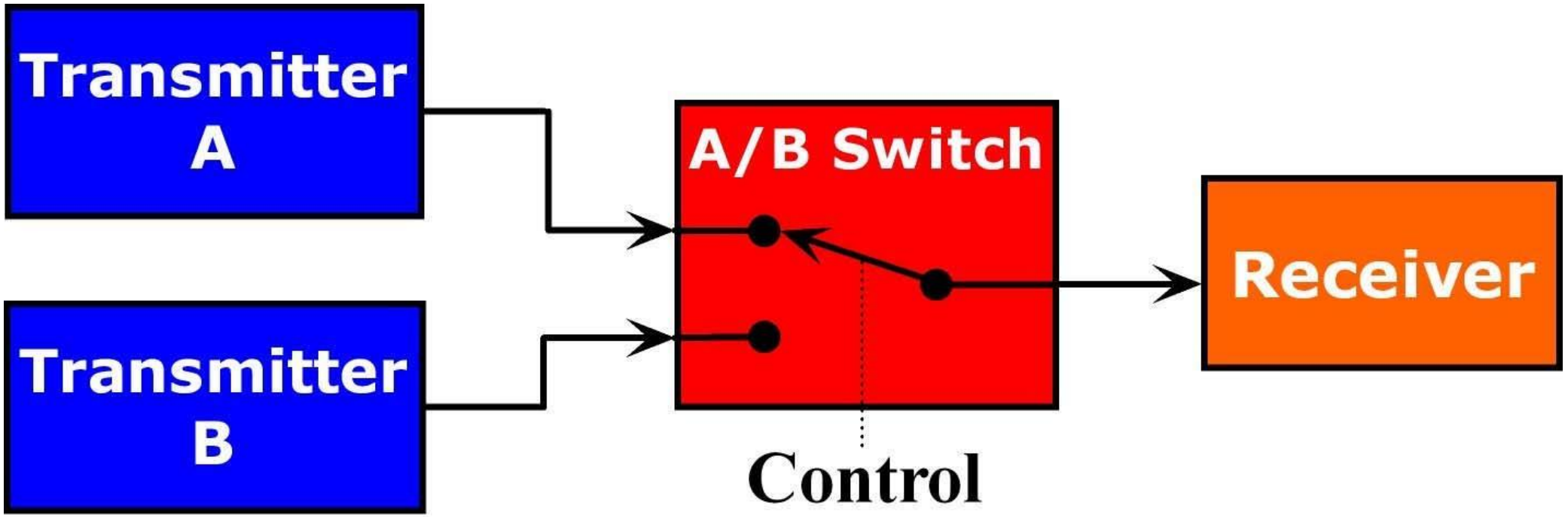
The workbook section is the last section of the course book.

The presentation resumes after the exercises.

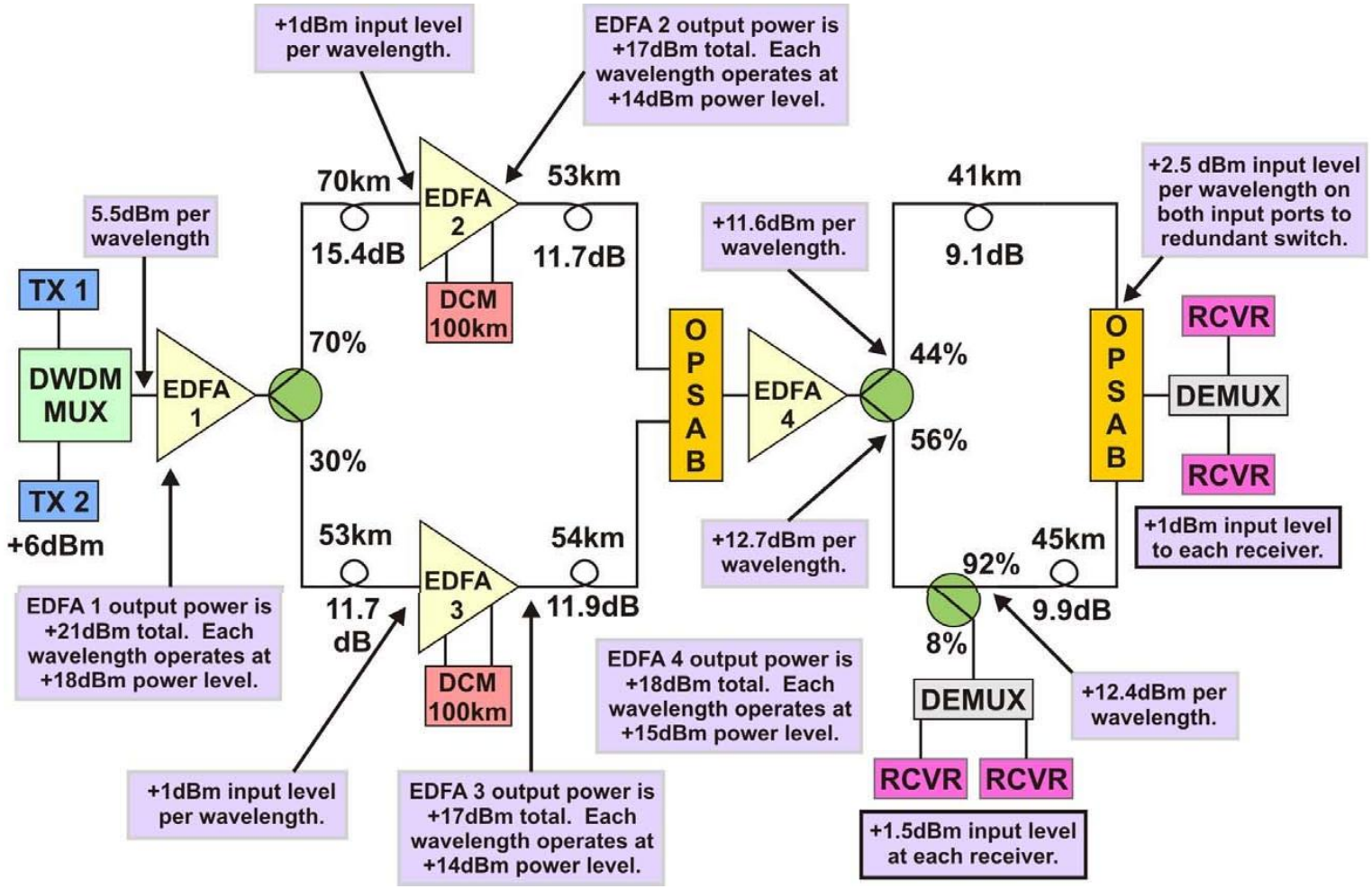
Optical A/B switching

An optical A/B switch protects against fiber breaks and transmitter failures.

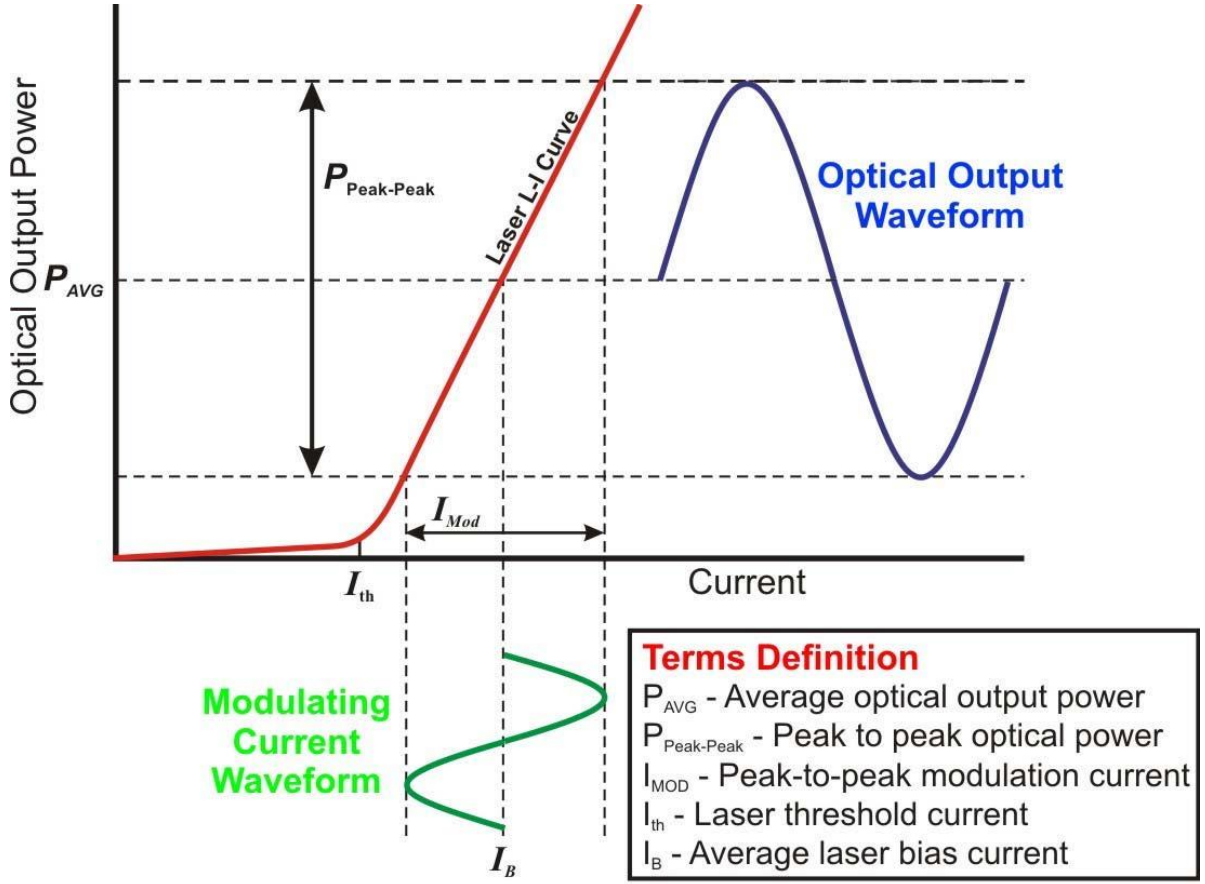
Control can select transmitter A or B. Automatic switching can use a condition such as optical input power falling below a preset level.



A complete optical system design

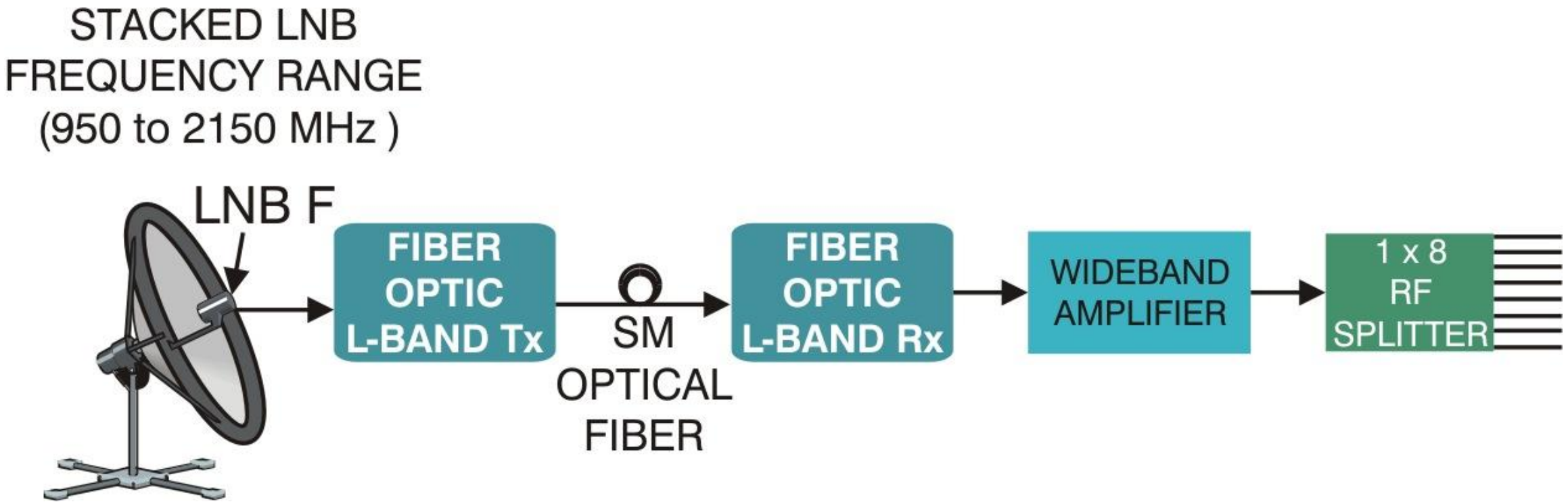


Analog laser modulation



$$\text{OMI (Optical Modulation Index)} = \frac{P_{Peak-Peak}}{2*P_{AVG}}$$

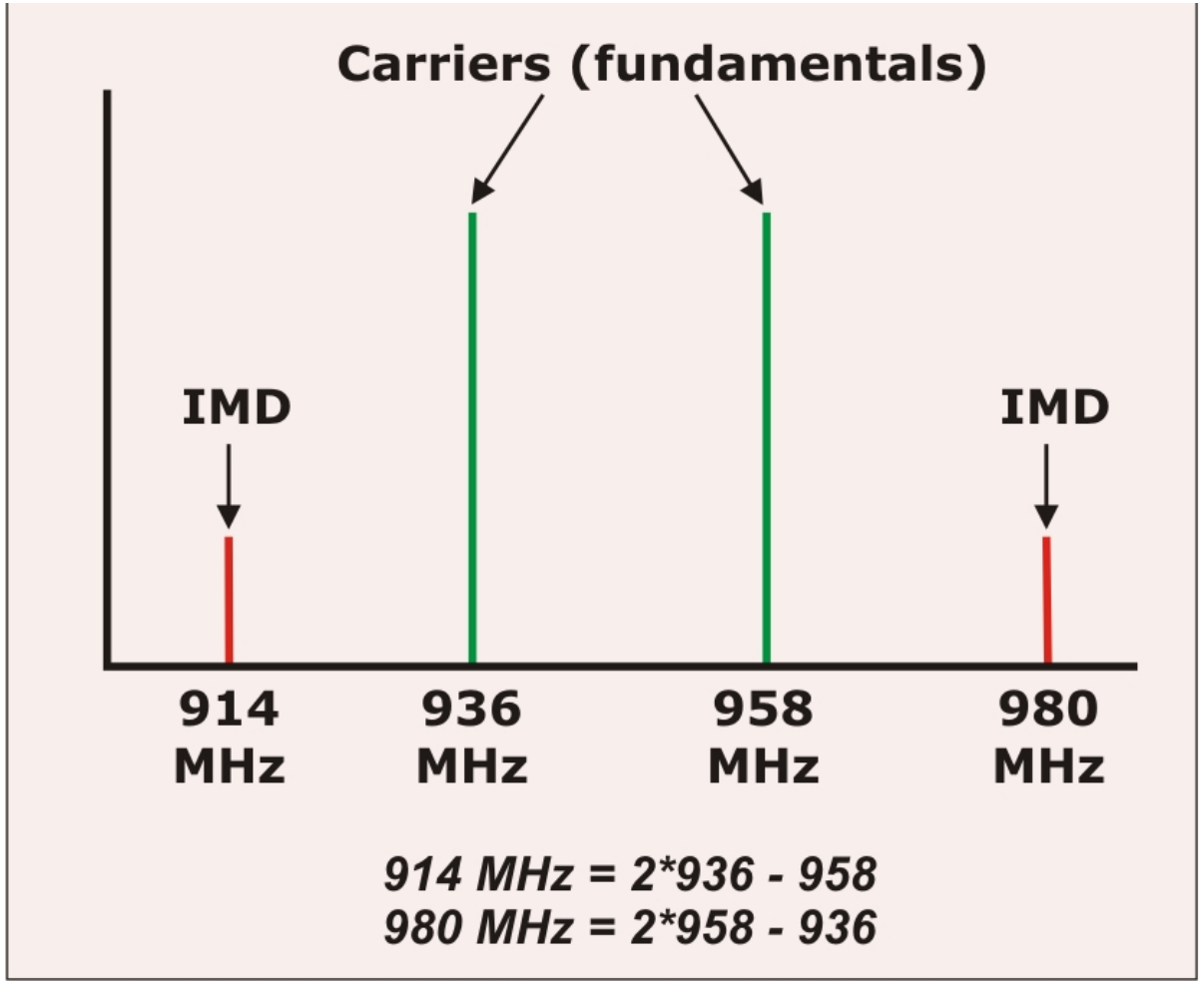
L-band satellite signal distribution



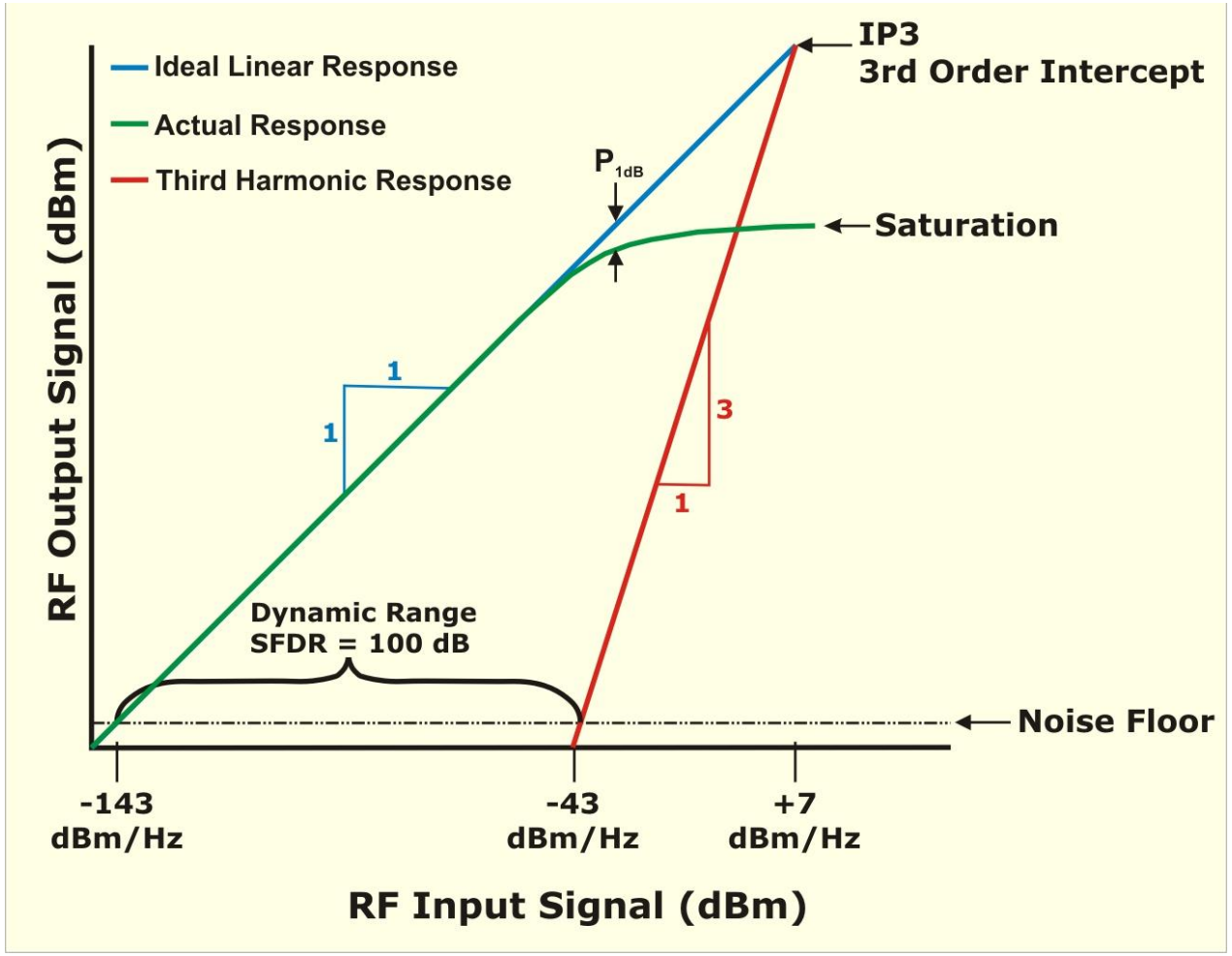
Satellite link terminology

Term	Meaning	Preferred direction
NF	Noise figure	Lower
SFDR	Spurious-free dynamic range	Higher
P1dB	1 dB compression point	Higher
IP3	Third-order intercept	Higher
IMD	Intermodulation distortion	Lower

L-band intermodulation



L-band link response and dynamic range

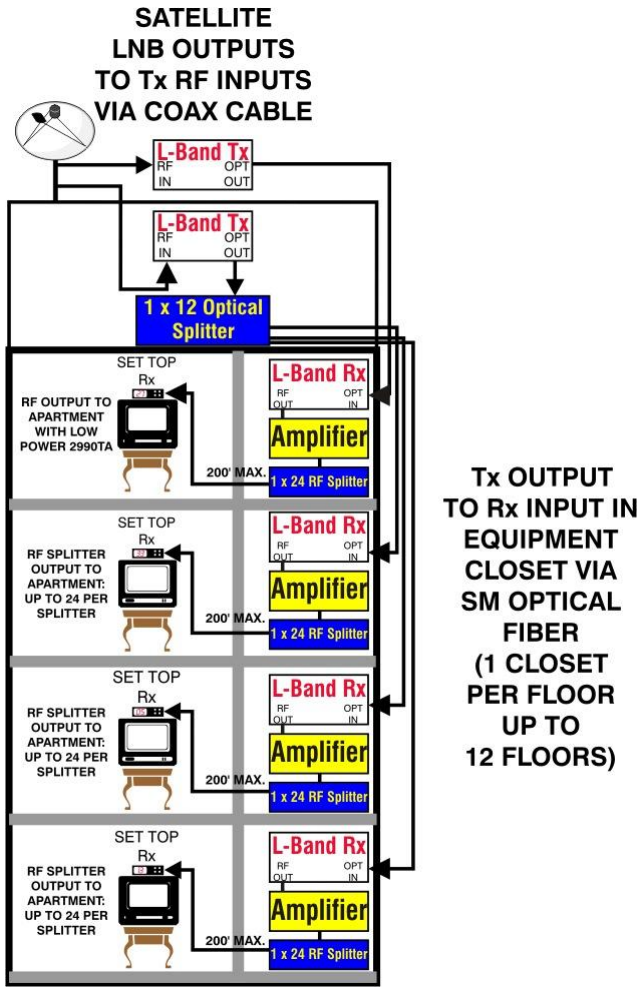


CATV and satellite terminology

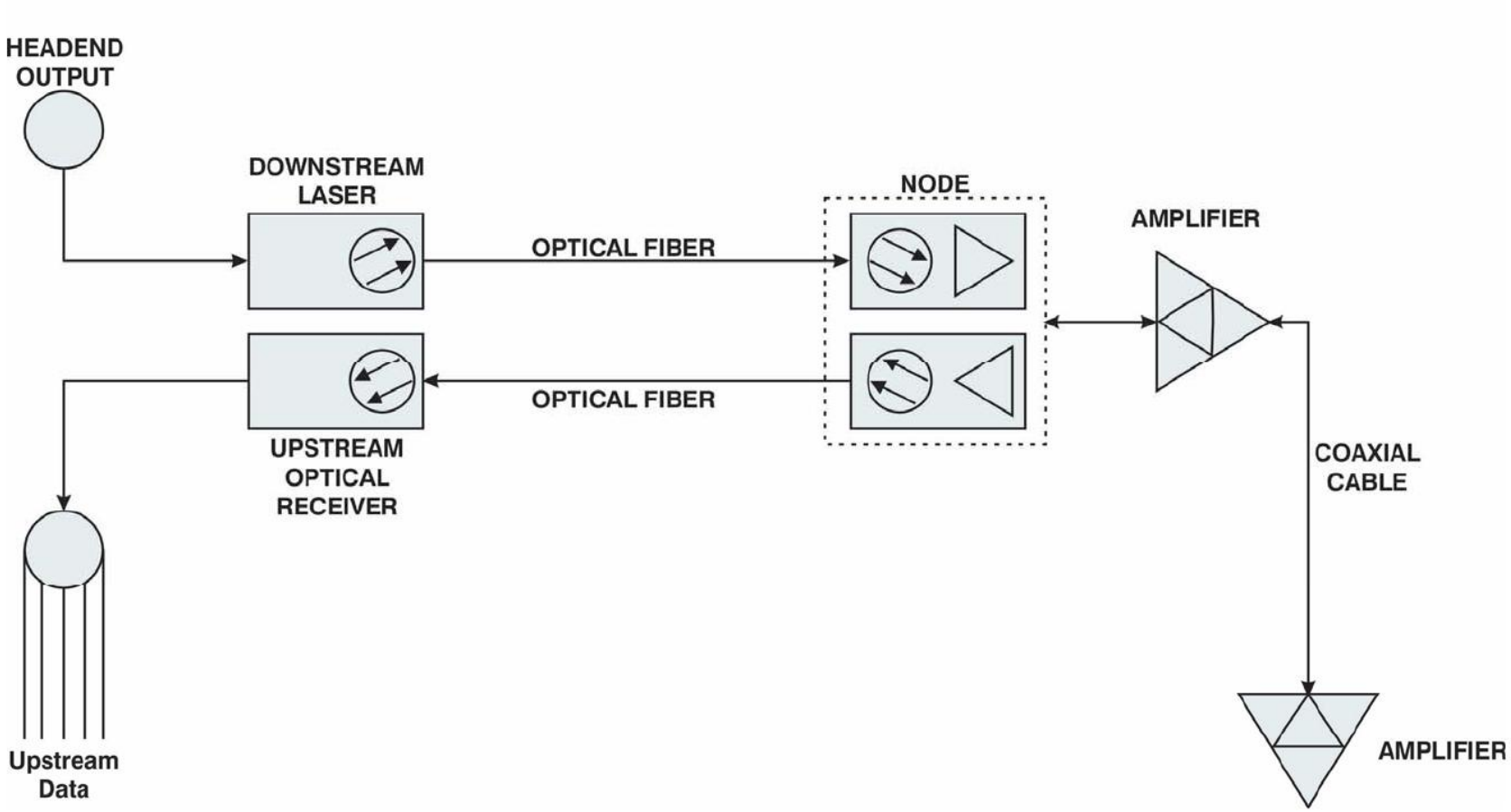
Parameter	CATV	Satellite
Signal quality	CNR	CNR or noise figure
Distortion	CSO and CTB	IMD2 and IMD3
Frequency range	40–1,000 MHz	950–2,150 MHz
Channel count	110+ channels	12 channels

System examples and terminology from the original course.

Satellite distribution in an MDU



A two-way HFC CATV system



An FTTH passive optical network

Video and data share the same fiber through WDM or CWDM, with multiplexing at the headend and demultiplexing at the home.

The source example uses 1490 nm downstream data, 1310 nm upstream data, and a 1550 nm RF video overlay.

The PON data architecture determines the split. The example uses a 1×32 optical split.

Data may use E-PON, G-PON, or a similar system. The RF video overlay operates independently of the data.

System-level precautions

Never clean connectors while any transmitter or EDFA is powered.

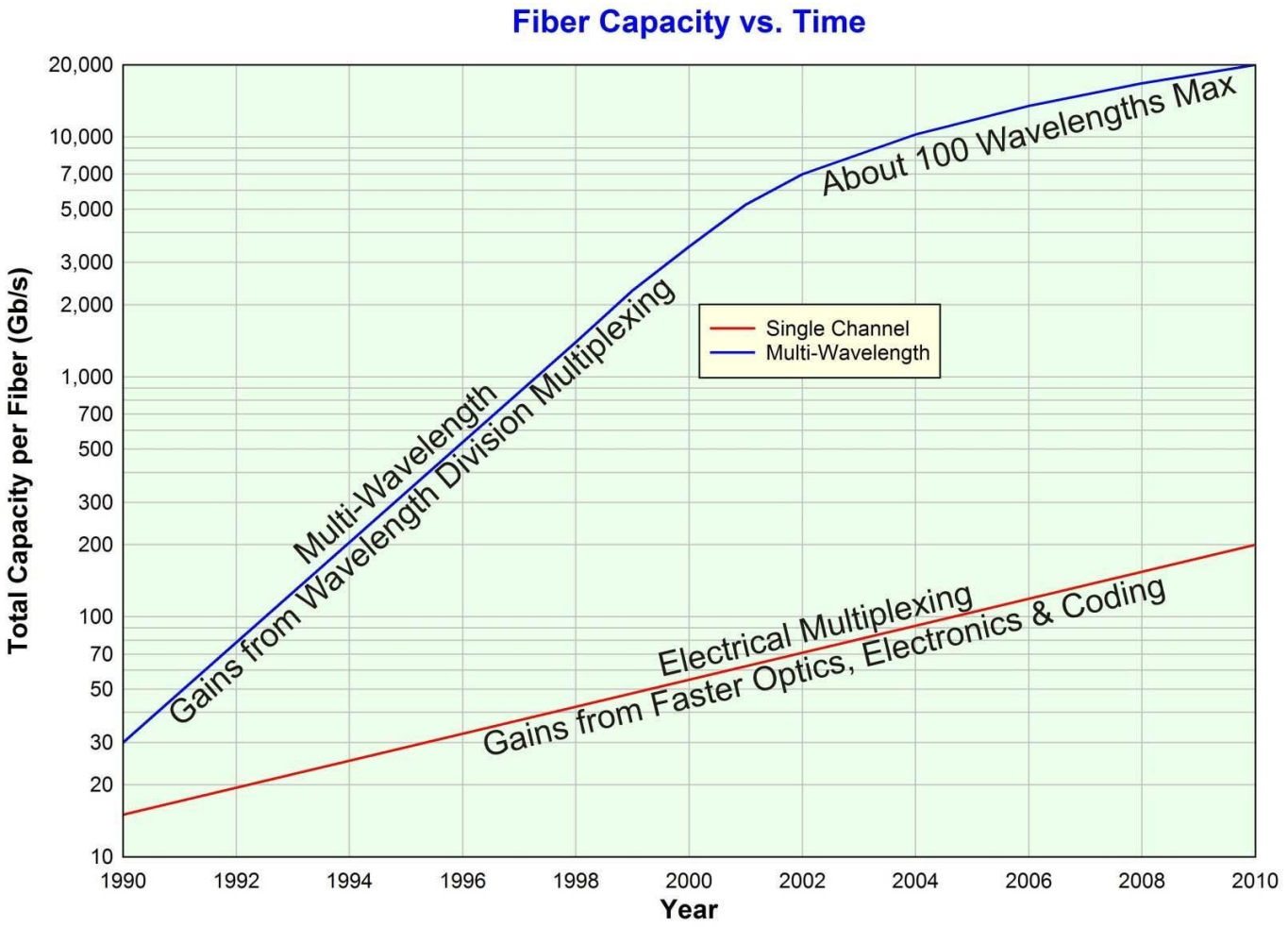
Never look into a connector that may emit light. Check with a power meter if there is any doubt.

Mate all connectors before turning on transmitters.

For the EDFA equipment discussed in the course, apply optical input before power-up. The source warns that optical input surges can damage the amplifier.

Avoid bends and stress points that add optical loss. The source gives a one-inch minimum bend-radius rule for its examples.

Fiber capacity over time



Connector cleanliness

One parting word of wisdom

Clean the connectors.