Optical

Lecture 4

- Ethernet physical
  - Copper… 10Base5,2,T, 100/1000/10G
  - Optical
- Optical transmission
- Frequency response
- WDM

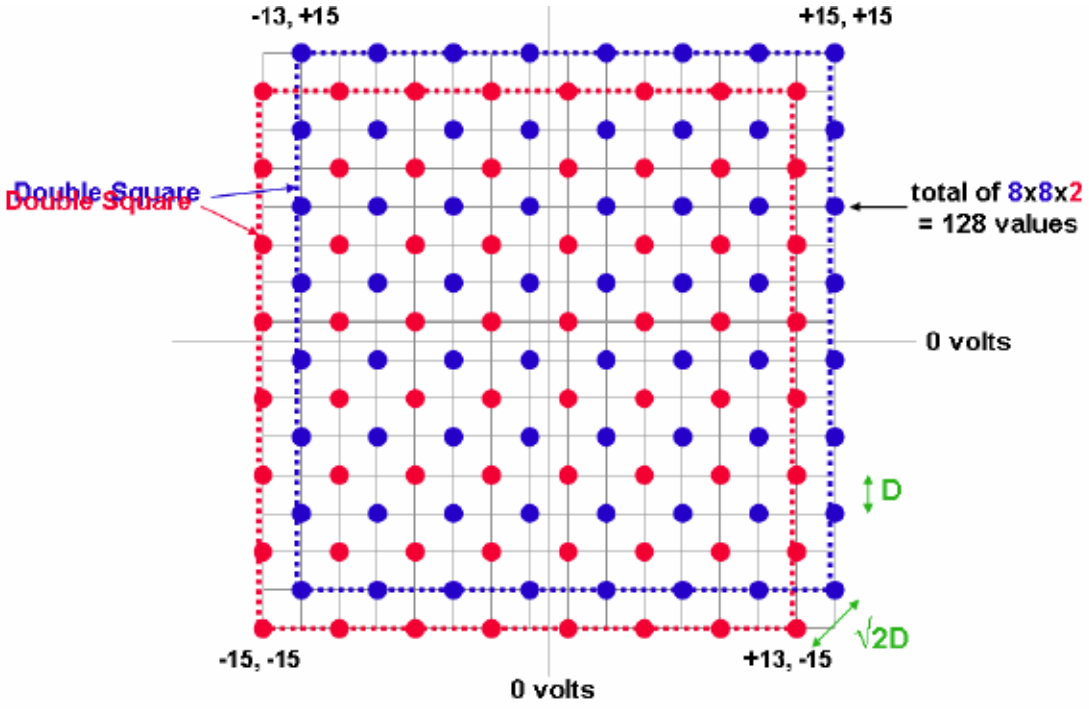
Ethernet Physical

- 10Base5 – Vampire taps
- 10Base2 – “Thinwire” BNC
- 10BaseT – Twisted pair (500m)

All above Manchester encoding..

- 100BaseT – see TX, T4, T2 (100m), 4b5b
- 1000BaseT – use 2 pairs, “PAM5” encoding

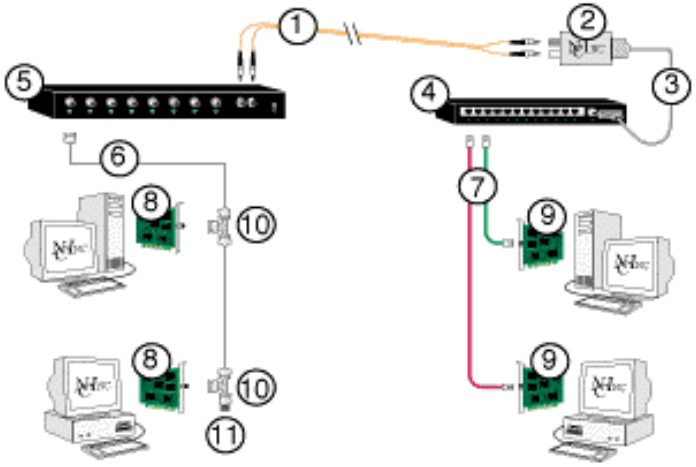
10GBase-T



- “PAM16” - DSQ128

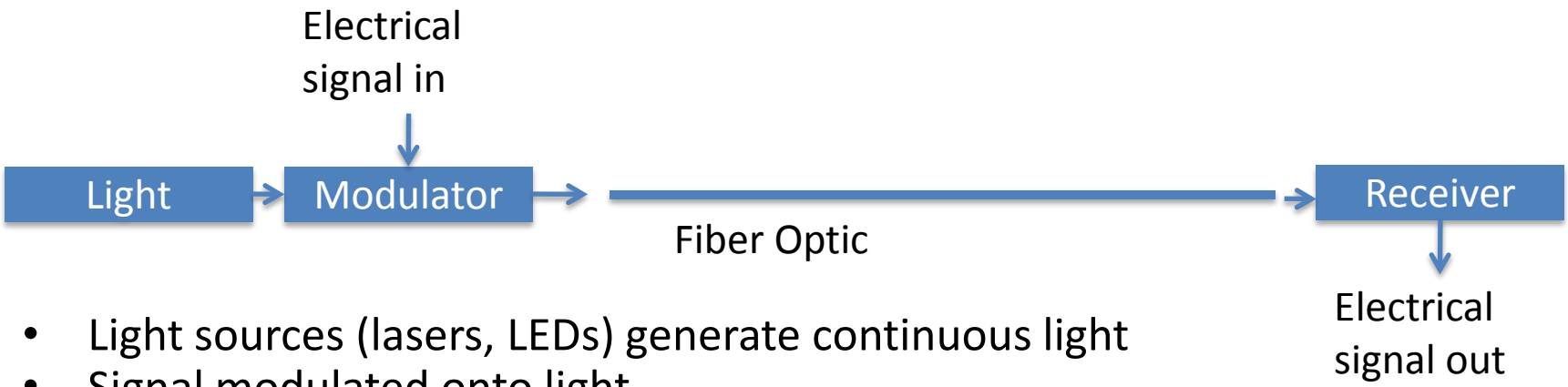
Ethernet Optical

- 10BaseFL
  - 850nm 2km
- 100Base…
  - FX – 1300nm 2km
  - SX – 850nm cheaper
  - LX – 1300nm 10/20/40km – “si…
- 1000Base
  - even more variants
- 10G
  - and even more…



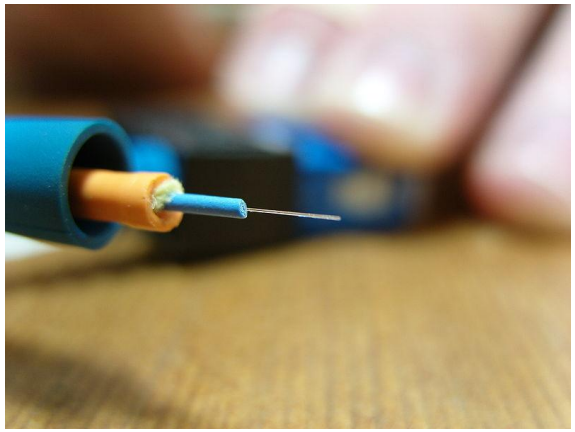
Why??

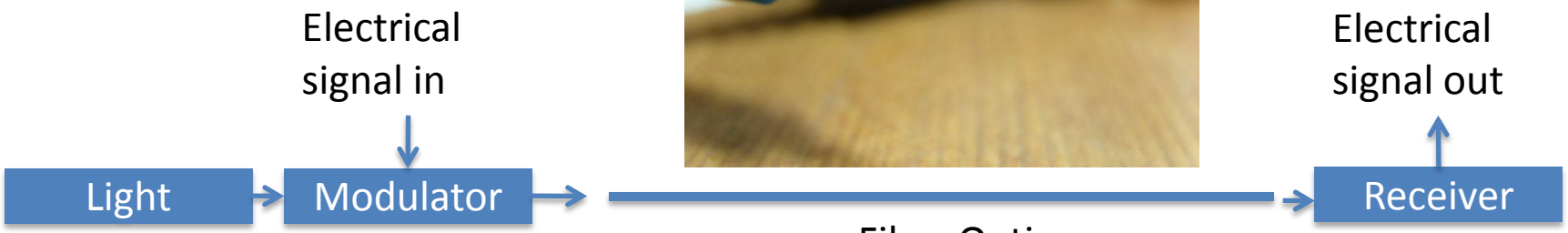
Optical Fiber



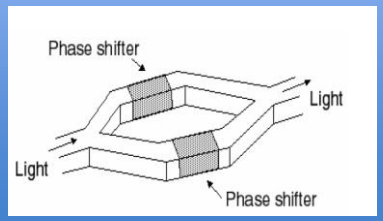
- Light sources (lasers, LEDs) generate continuous light
- Signal modulated onto light
- Transmission over various distances….
- Received by photdetector
  - Very long distances (>1000 km)
  - Very high speeds (>40 Gbps/wavelength)
  - Nearly error-free (BER of 10^{-15})
- Profound influence on network architecture
  - Dominates long distance transmission
  - Distance less of a cost factor in communications
  - Plentiful bandwidth for new services

Optical Fiber





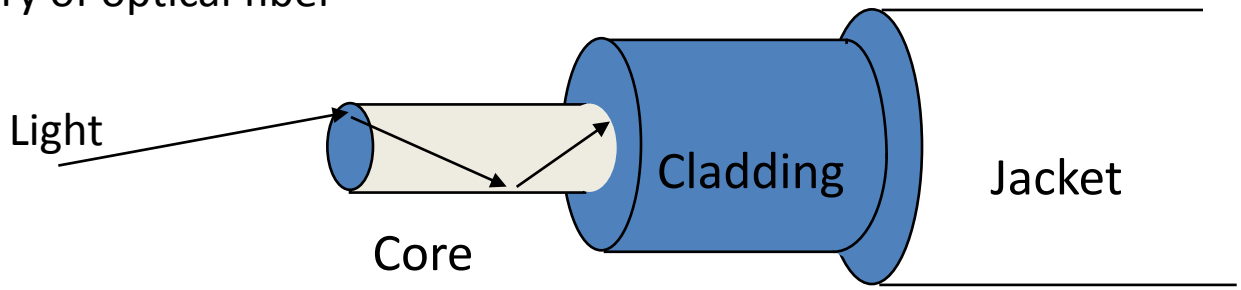
e.g. Mach-Zender uses interference to modulate signal



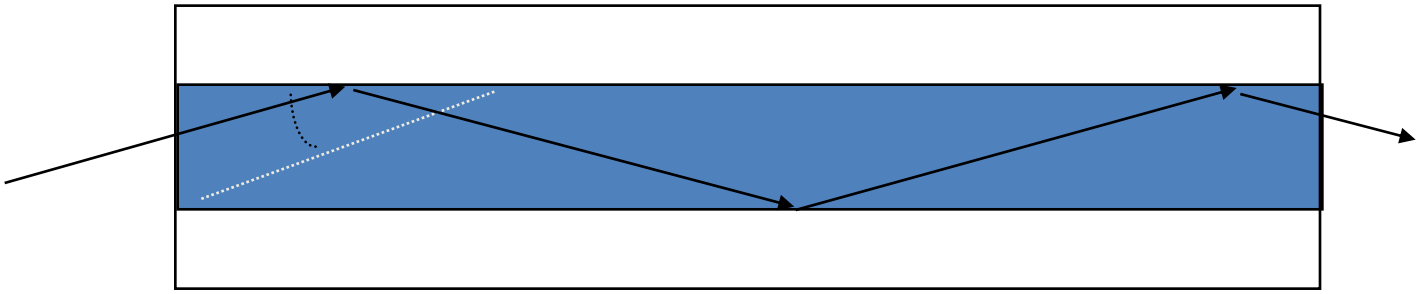
- Light sources (lasers, LEDs) pass to…
- Modulator
- Injected into fibre and..
- Received by photodetector

Transmission in Optical Fiber

Geometry of optical fiber



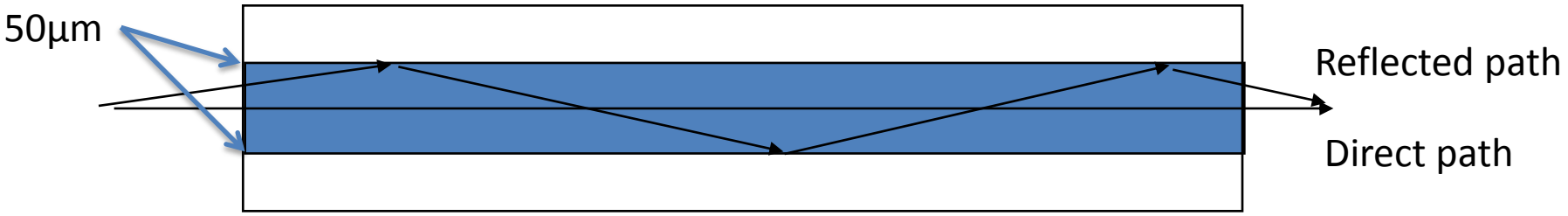
Total Internal Reflection in optical fiber



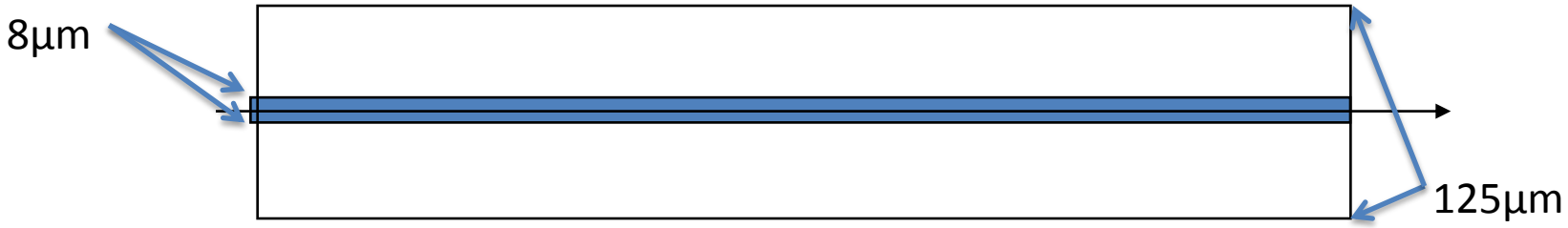
- Glass core surrounded by layer of cladding
- Core has higher index of refraction than cladding
- Light rays undergo “total internal reflection”
  - That’s the simple form of the explanation….

Multimode & Single-mode Fiber

Multimode fiber: multiple rays follow different paths



Single-mode fiber: only direct path propagates in fiber



- Multimode: 50µm in 125µm
  - Rays on different paths interfere causing dispersion
  - LEDs and Lasers as source
- Single mode: 8µm in a cladding of 125µm
  - Lasers

Optical Fiber Properties

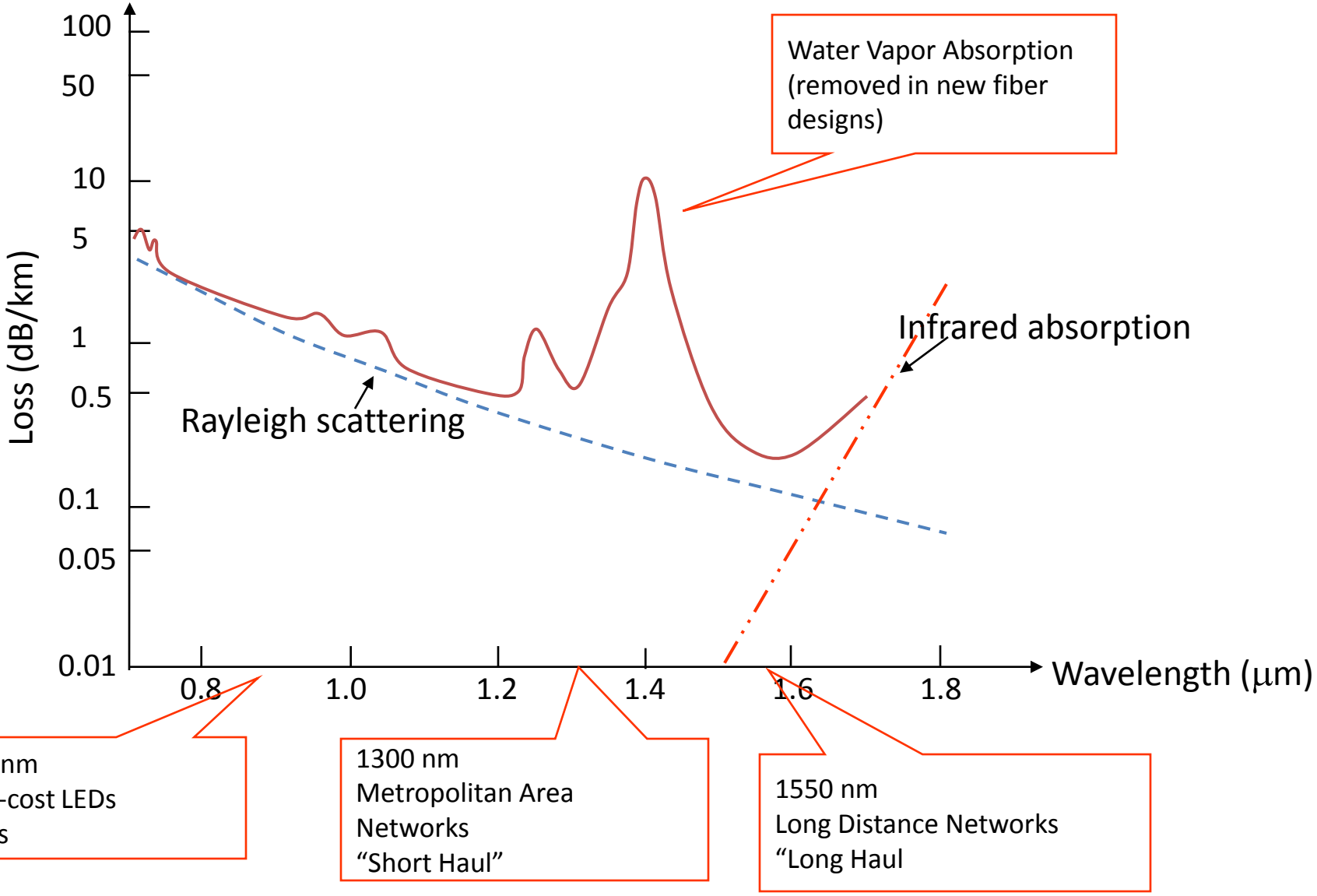
Advantages

- Very low attenuation
- Noise immunity
- Extremely high bandwidth
- No corrosion
- More compact & lighter than copper wire
- Long distances (>1000 km)
- High speeds (>40 Gbps/wavelength)
- Nearly error-free (BER of 10^{-15})

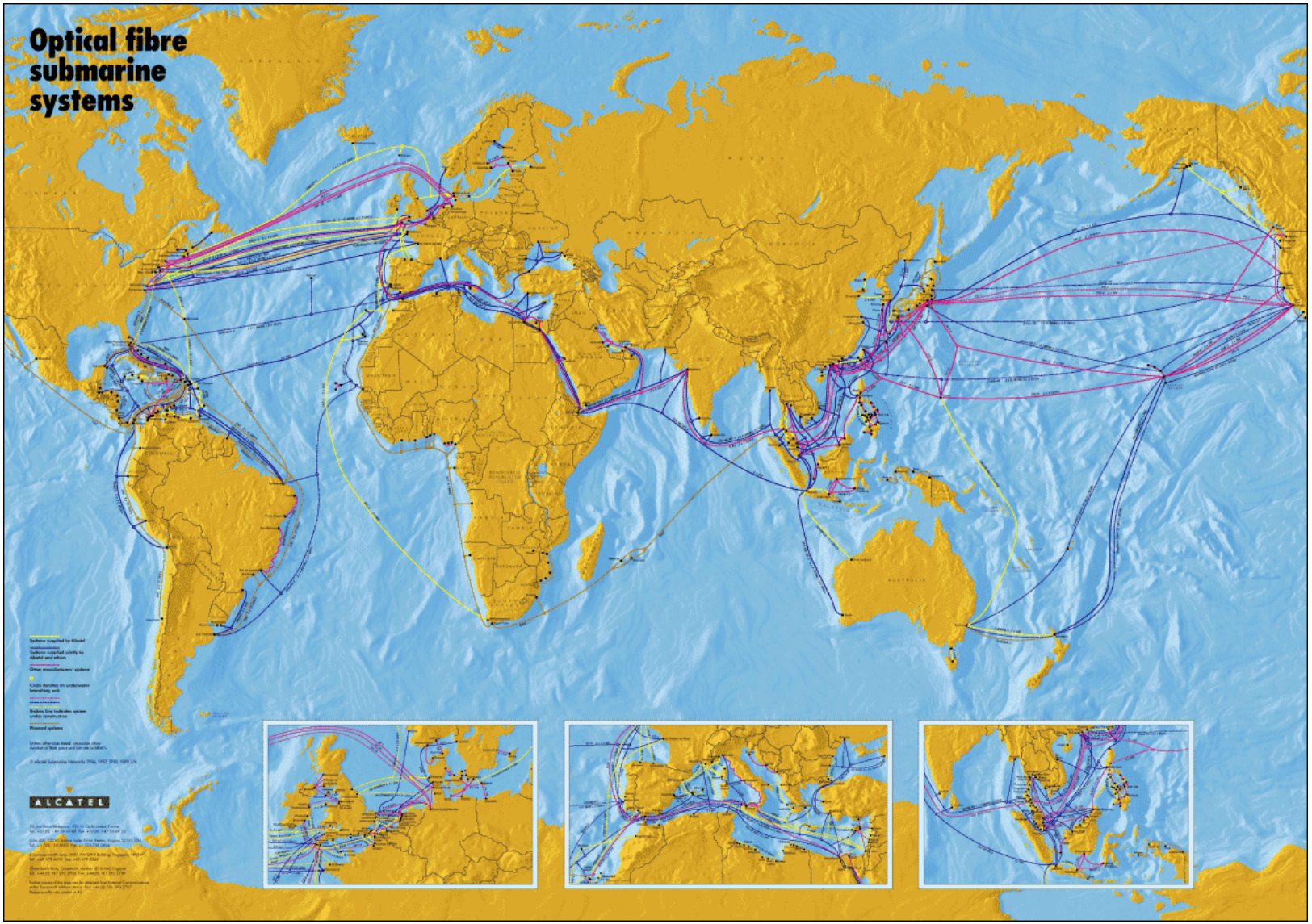
Disadvantages

- New types of optical signal impairments & dispersion
  - Polarization dependence
  - Wavelength dependence
- Limited bend radius
  - If physical arc of cable too high, light lost or won't reflect
  - Will break
- Difficult to splice
- Mechanical vibration becomes signal noise

Very Low Attenuation

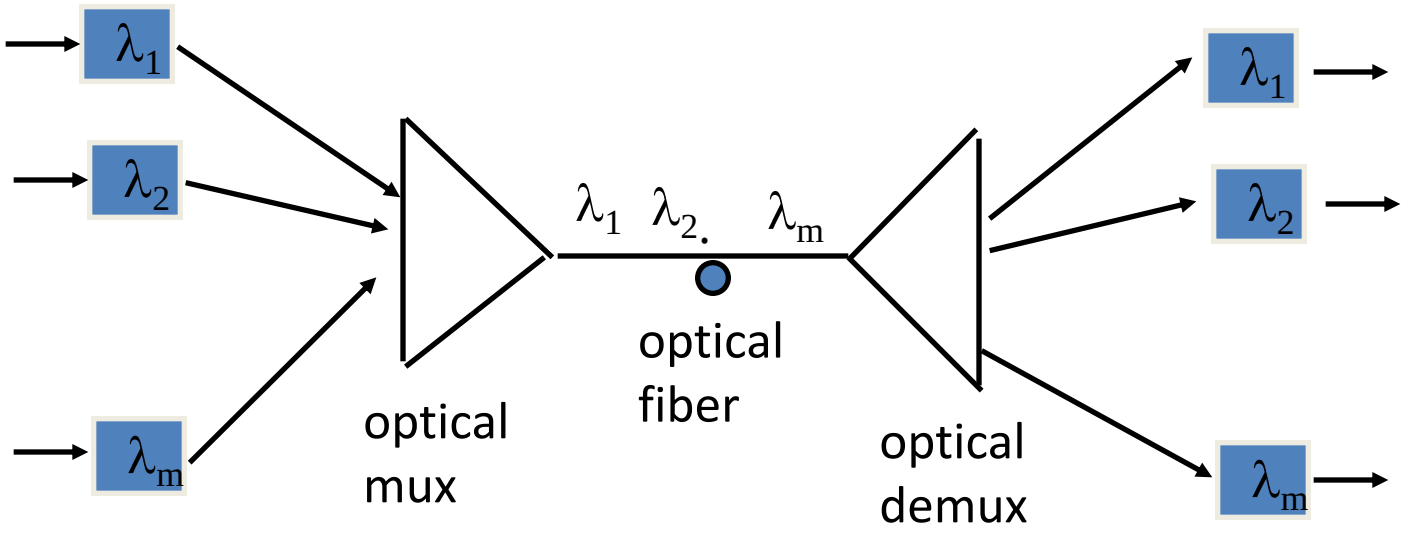


Global Undersea Fiber systems



Wavelength-Division Multiplexing

- Different wavelengths carry separate signals
- Multiplex into shared optical fiber
- A single fiber can carry 160 wavelengths, 10 Gbps per wavelength: 1.6 Tbps



Regenerators & Optical Amplifiers

- The maximum span of an optical signal is determined by the available power & the attenuation:
  - Ex. If 30 dB power available,
  - then at 1550 nm, optical signal attenuates at 0.25 dB/km,
  - so max span = 30 dB/0.25 km/dB = 120 km
- Optical amplifiers amplify optical signal (no equalization, no regeneration)
- Impairments in optical amplification limit maximum number of optical amplifiers in a path
- Optical signal must be regenerated when this limit is reached
  - Requires optical-to-electrical (O-to-E) signal conversion, equalization, detection and retransmission (E-to-O)
  - Expensive
- Severe problem with WDM systems

Optical Fiber Attenuation and Fiber Amplifier Gain