Optical

G54ACC

Lecture 6

richard.mortier@nottingham.ac.uk

Content

- Optical Fibres
- Transmission
- Properties

Content

- Optical Fibres
  - Ethernet
  - Impact
- Transmission
- Properties

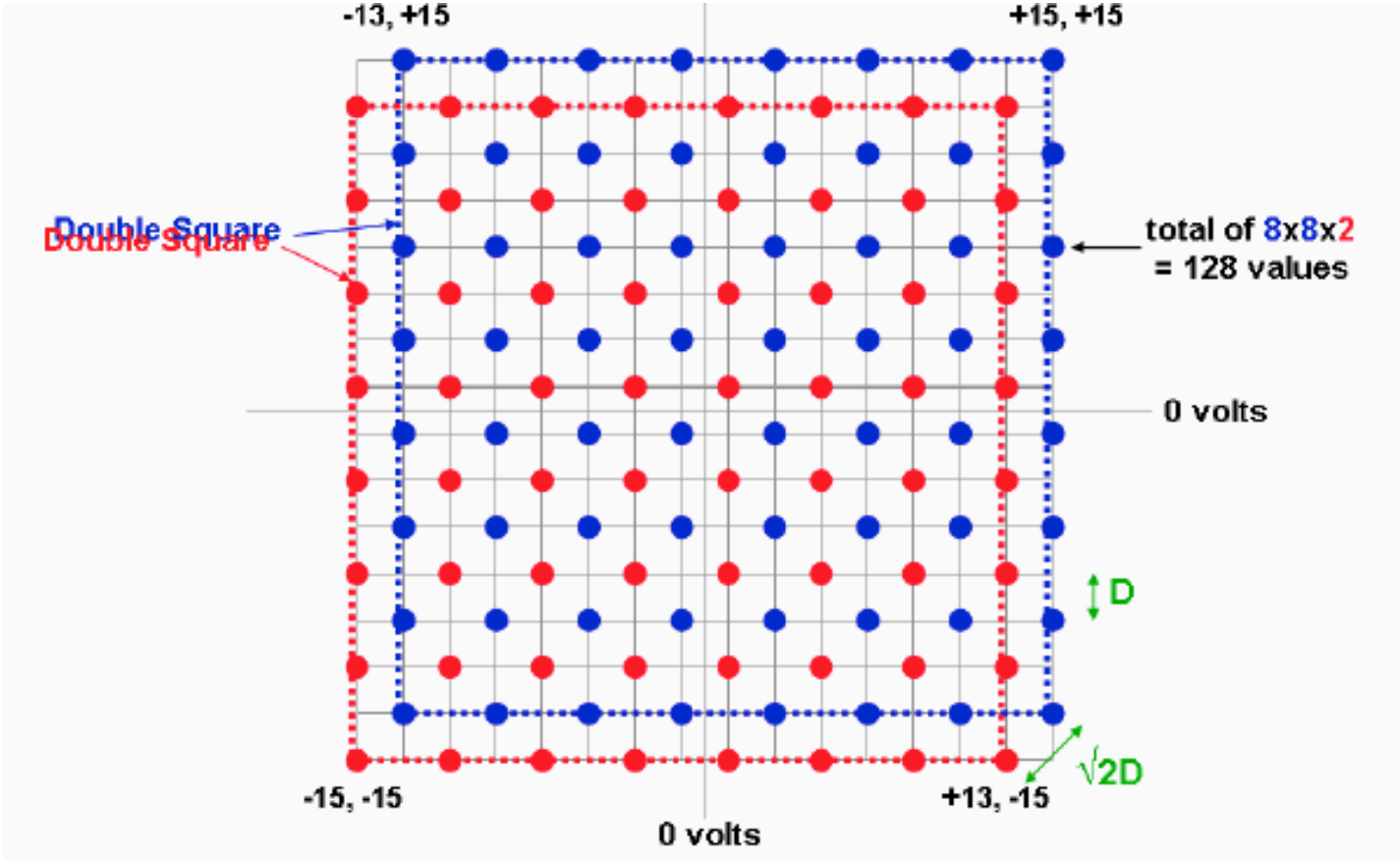
Ethernet Physical

- 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

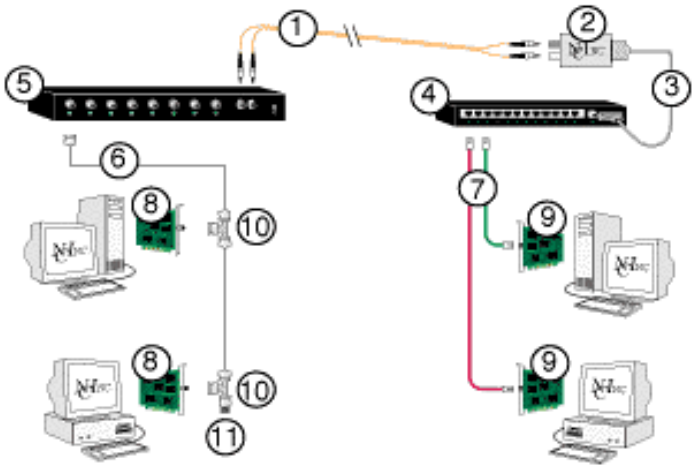
10GBase-T



- "PAM16" – DSQ128

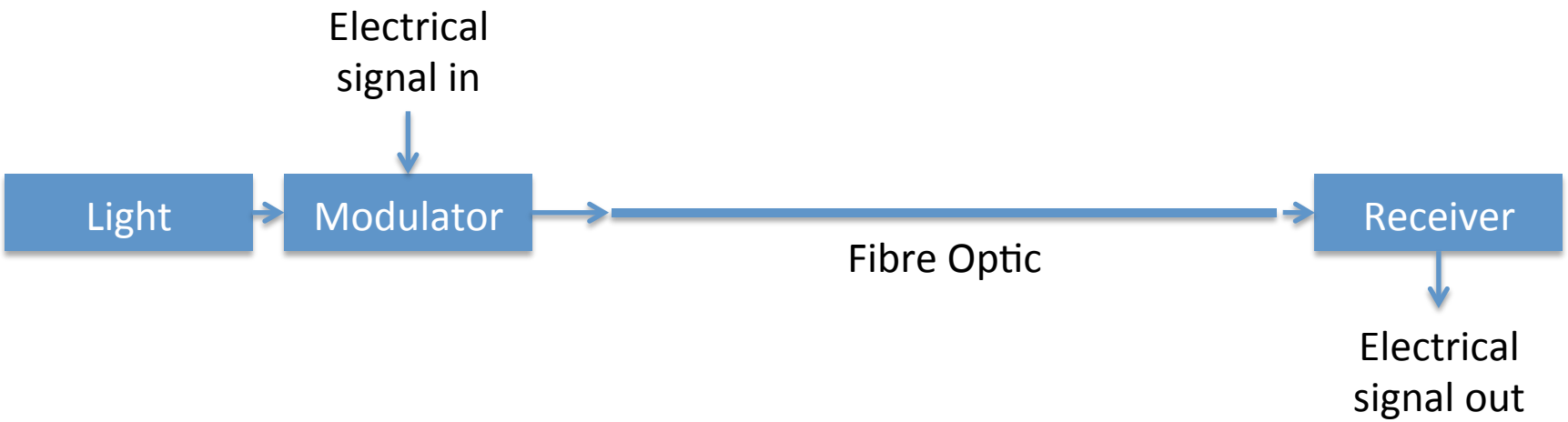
Ethernet Optical

- 10BaseFL
  - 850nm 2km
- 100Base …
  - FX – 1300nm, 2km
  - SX – 850nm, cheaper
  - LX – 1300nm, 10/20/40km
    - "single mode" fibre
- 1000Base
  - even more variants
- 10G
  - and even more…



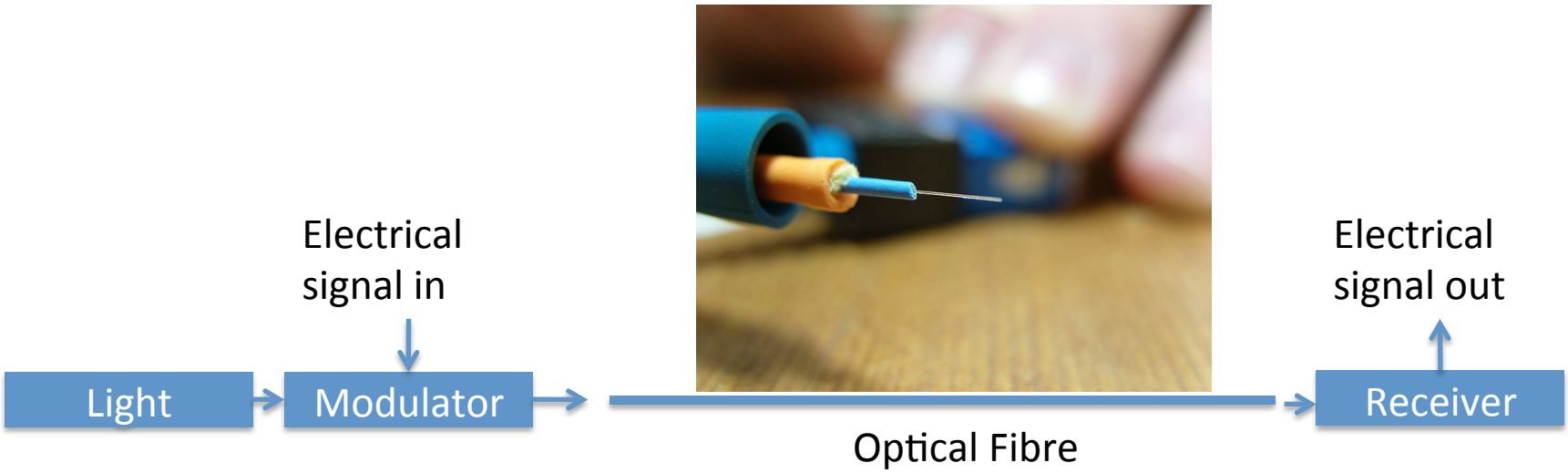
Why?

Optical Fibre

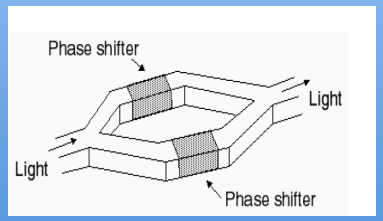


- Light sources (lasers, LEDs) generate continuous light
- Signal modulated onto light
- Received by photo-detector

Optical Fibre



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



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

Optical Fibre Impact

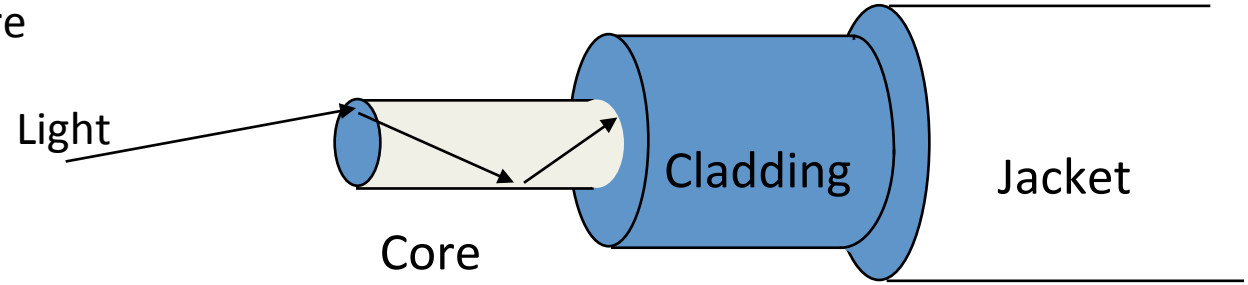
- Transmission has significant properties
  - Very long distances (> 1000 km)
  - Very high speeds (> 40 Gb/s per wavelength)
  - Nearly error-free (BER of 10^{-15})
- Profound influence on network architecture
  - Dominates long distance transmission
  - Distance less of a cost factor in communications
  - Plentiful bandwidth for new services

Content

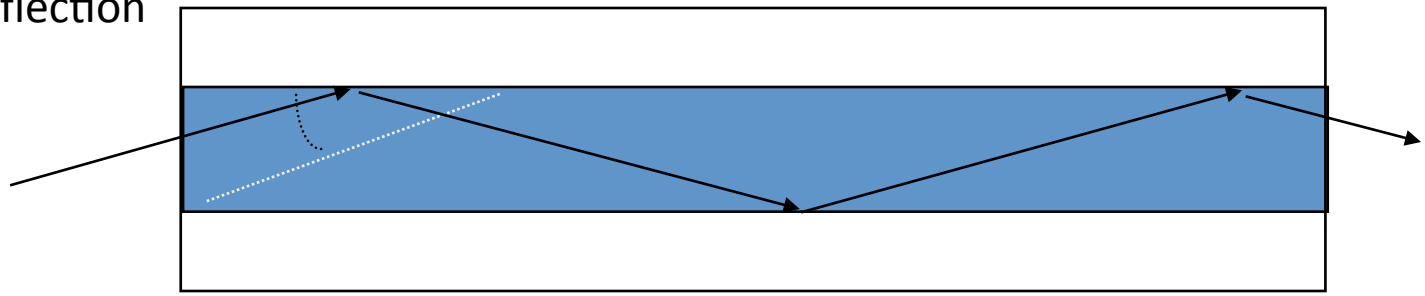
- Optical Fibres
- Transmission
  - Multi-mode
  - Single-mode
  - Very low attenuation
- Properties

Transmission in Optical Fibre

Geometry of optical fibre

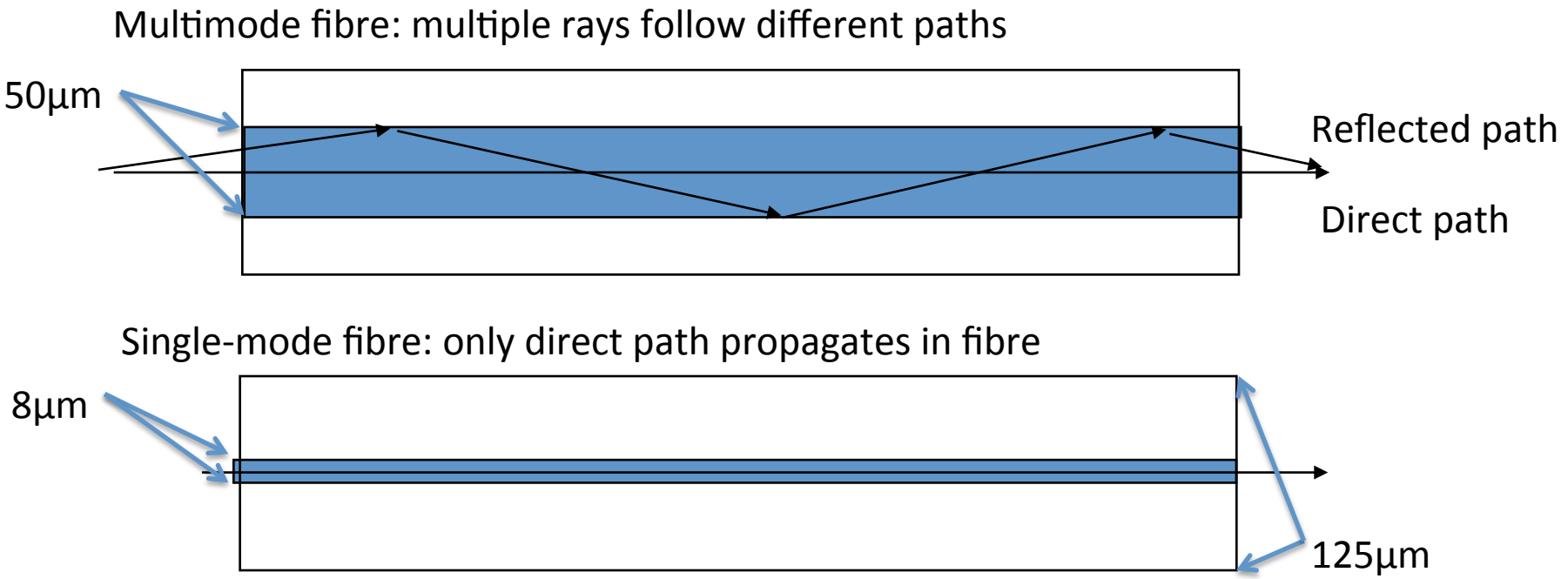


Total Internal Reflection in optical fibre



- 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 Fibre



- 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

Content

- Optical Fibres
- Transmission
- Properties
  - Wavelength division multiplexing
  - Regenerators
  - Amplifiers

Optical Fibre Properties

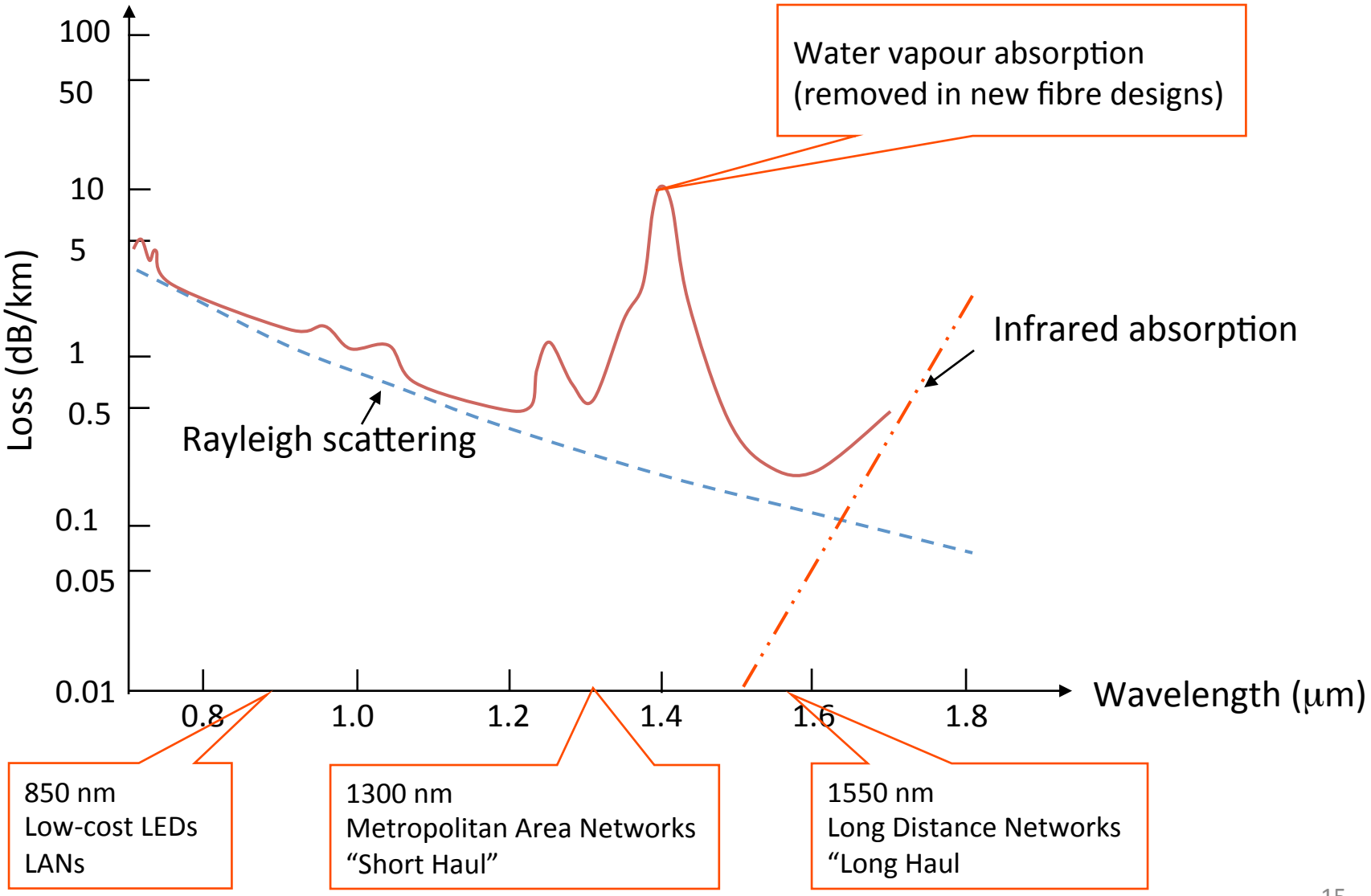
Advantages

- 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}

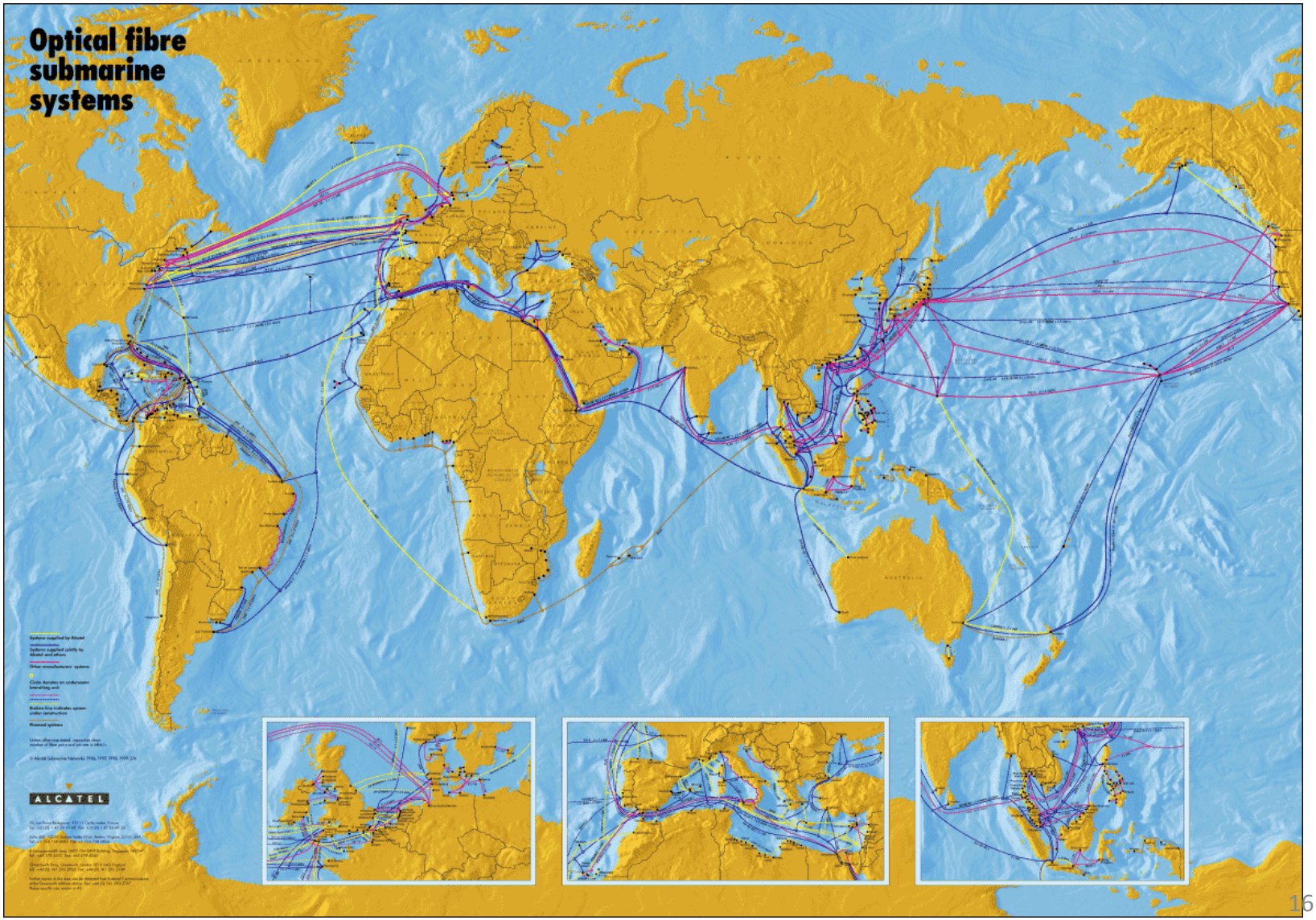
Disadvantages

- 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 Fibre Systems



(Not A New Phenomenon – 1891)

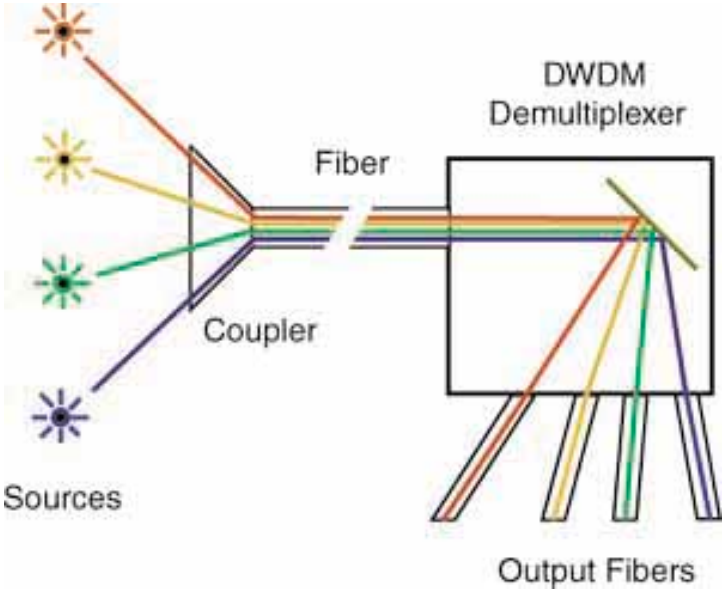
Wavelength Division Multiplexing

- Different wavelengths carry separate signals
- Multiplex into shared optical fibre
- A single fibre can carry

  160 wavelengths

  @ 10 Gb/s per wavelength

  = 1.6 Tb/s



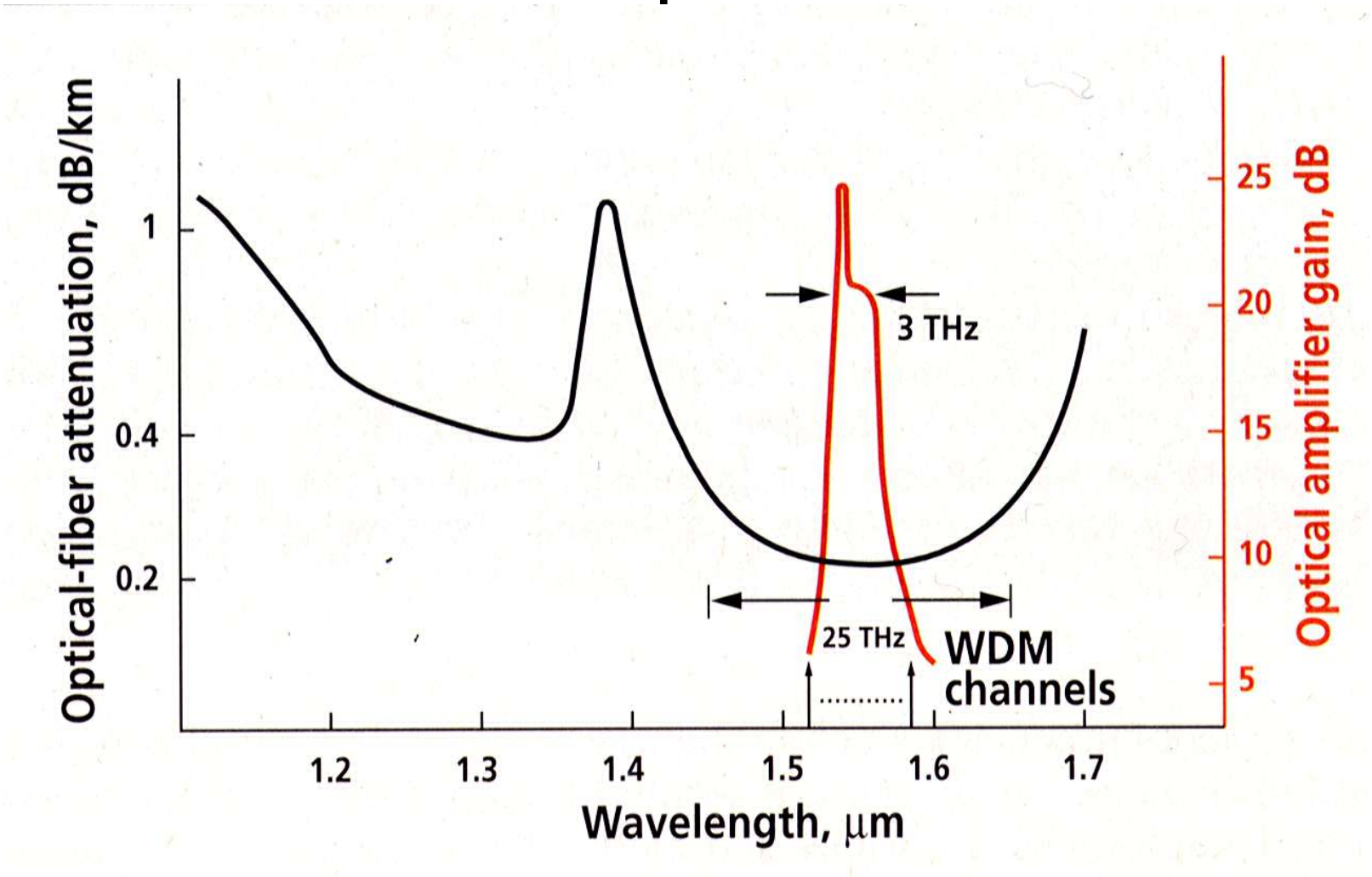
Amplification & Regeneration

- Maximum span of an optical signal determined by available power & attenuation
  - E.g., 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

Limits on Amplification

- 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 Fibre Attenuation & Fibre Amplifier Gain



Content

- Optical Fibres
  - Ethernet
  - Impact
- Transmission
  - Multi-mode
  - Single-mode
  - Very low attenuation
- Properties
  - Wavelength division multiplexing
  - Regenerators
  - Amplifiers

Summary

- Optical fibres revolutionised long-distance communications
  - Long distances, Low cost, Low error rates
  - Multi-mode, single-mode fibres
- Light (Laser, LED) signal electronically modulated
- Amplification extends reach, but eventually require regeneration

Quiz

1. Why are there so many different Ethernet standards?
2. Show, with a diagram, the basic operations of transmission and reception on an optical fibre.
3. What impact have optical fibres had on networking generally?
4. Describe, in simple terms, how signals propagate down an optical fibre?
5. What problems occur with optical fibres that do not occur with copper cables?
6. How does WDM work?
7. When and why is optical amplification required?
8. When and why is optical regeneration required?