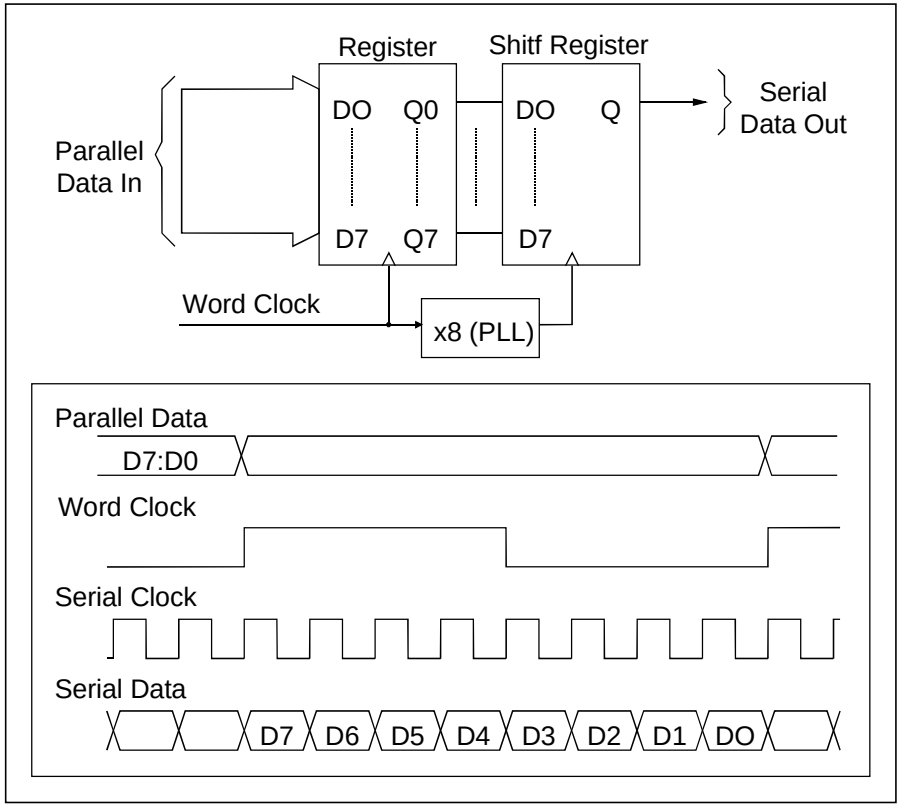
Serial communications principles

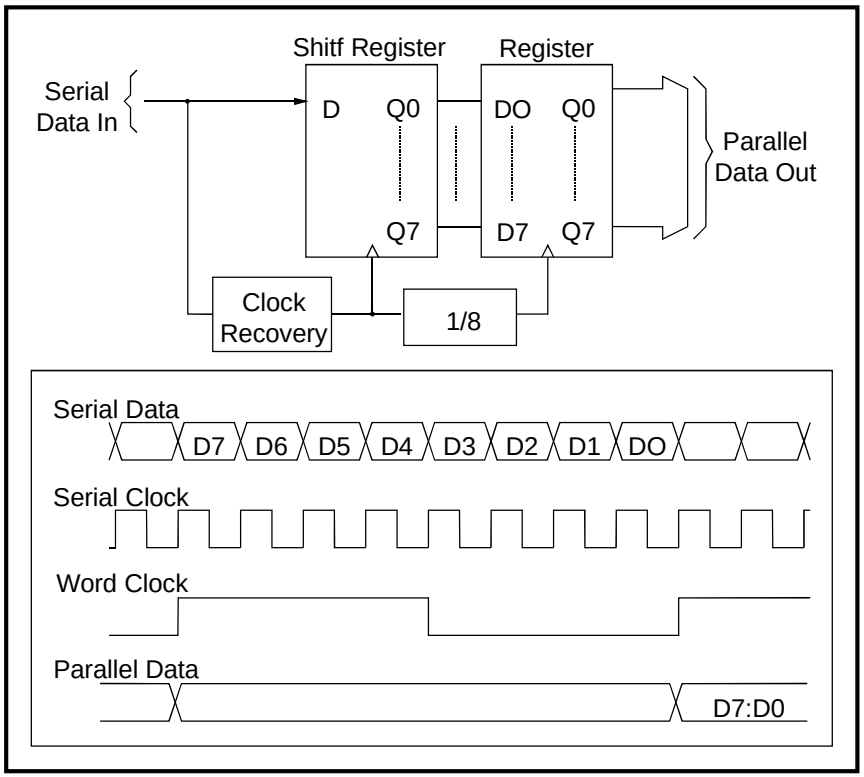
- Serial communication principles
  - Parallel/serial & serial/parallel converters
  - Physical media: cable & optical fiber
  - Advantages of optical fiber systems
- Optical signaling
  - Intensity modulation
  - Other methods: PSK and FSK

Parallel/Serial Conversion



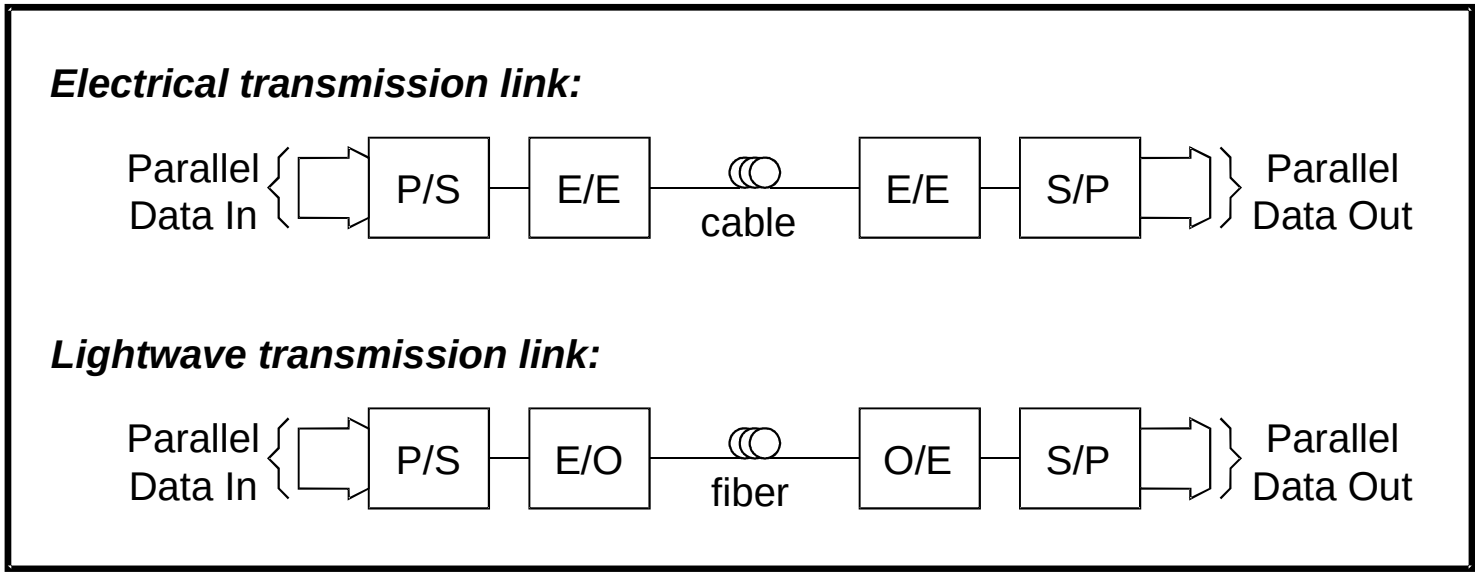
- Bits in word are time division multiplexed
- Bit Rate = (Word Rate) x (# Bits in Word)
- Advantage: Physically simpler system
- HEP disadvantage: adds at least one clock cycle of latency

Serial/Parallel Conversion



- Serial bits are time division de-multiplexed
- Requires:
  - Clock recovery or
  - Transmitted “bit clock”
- HEP disadvantage: Adds at least one clock cycle of latency

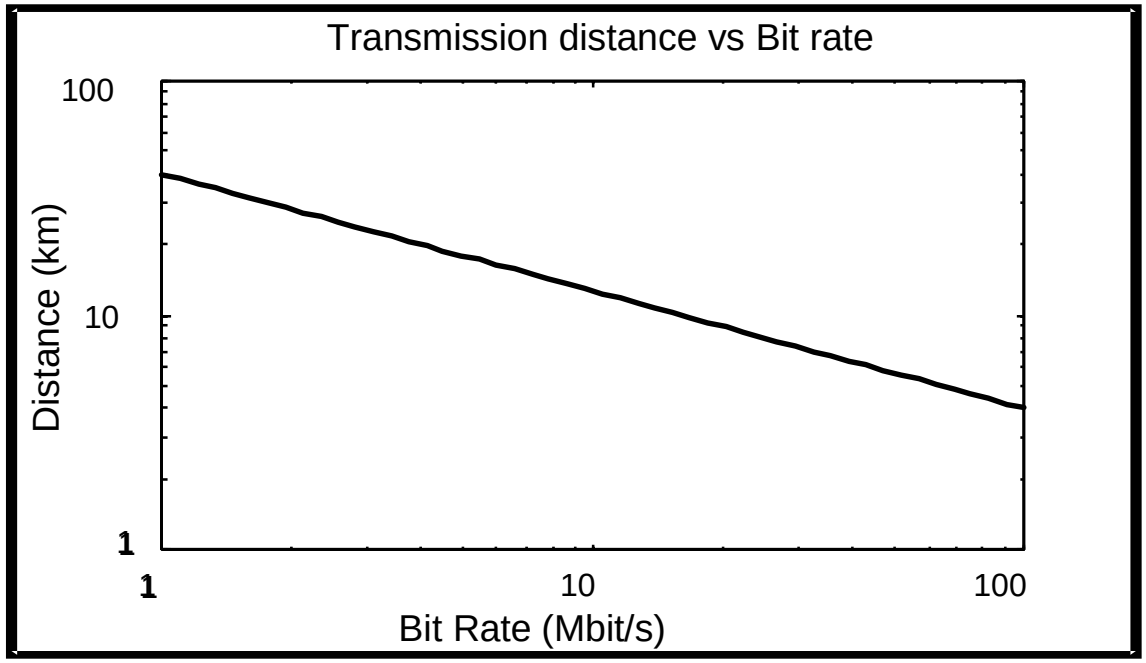
Physical Media: Cable & fiber



- After P/S conversion a physical medium is necessary to "transport" the data
- An electrical link requires an E/E interface:
  - Driving capability
  - Impedance matching
  - Differential signaling
  - Ground potential differences accommodation, etc.
- A Lightwave link requires an optoelectronics interface:
  - Electrical/Optical conversion (E/O)
  - Optical/Electrical conversion (O/E)

Cable Link Capacity

- Capacity is limited by the cable attenuation and bandwidth
- Attenuation is typically 20-30dB/km (coaxial cable)
- The cable transfer function is inversely proportional to: $\sqrt{frequency}$
- For high bit rates the capacity is mainly limited by the cable bandwidth:
  - 1Mbit/s => L(max) = 40km
  - 100Mbit/s => L(max) = 4km



Optical fiber Link Capacity

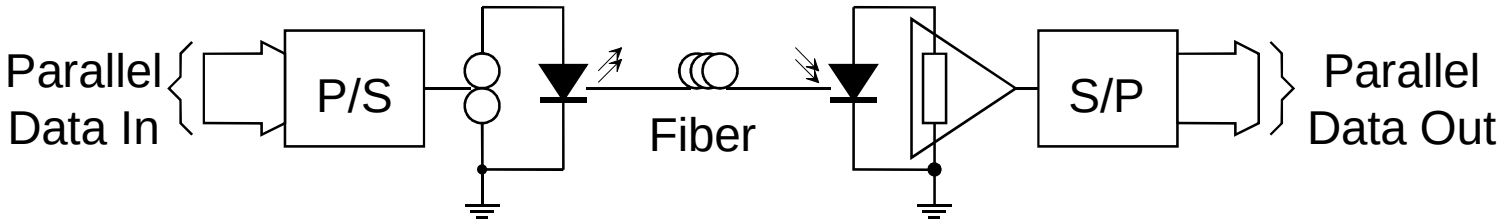
- Optical fiber systems capacity is limited by fiber attenuation and bandwidth (dispersion)
- For a typical long haul 1300nm fiber system:
  - fiber attenuation: 0.4dB/km
  - Dispersion limit: 250 Gbit/s*km
- For low to high bit rates the system span is limited by attenuation
  - 100Mbit/s => 120km
- For very high bit rates the system span is dispersion limited
  - 10 Gbit/s => 25km
- The capacity of optical fiber systems is orders of magnitude higher than that of cable systems

Advantages of Optical fiber Communications

- Enormous potential bandwidth
- Small size and weight (+ for HEP)
- Electrical isolation (+ for HEP)
- Immunity to noise and crosstalk (+ for HEP)
- Signal security
- Low transmission loss
- Raggedness and flexibility

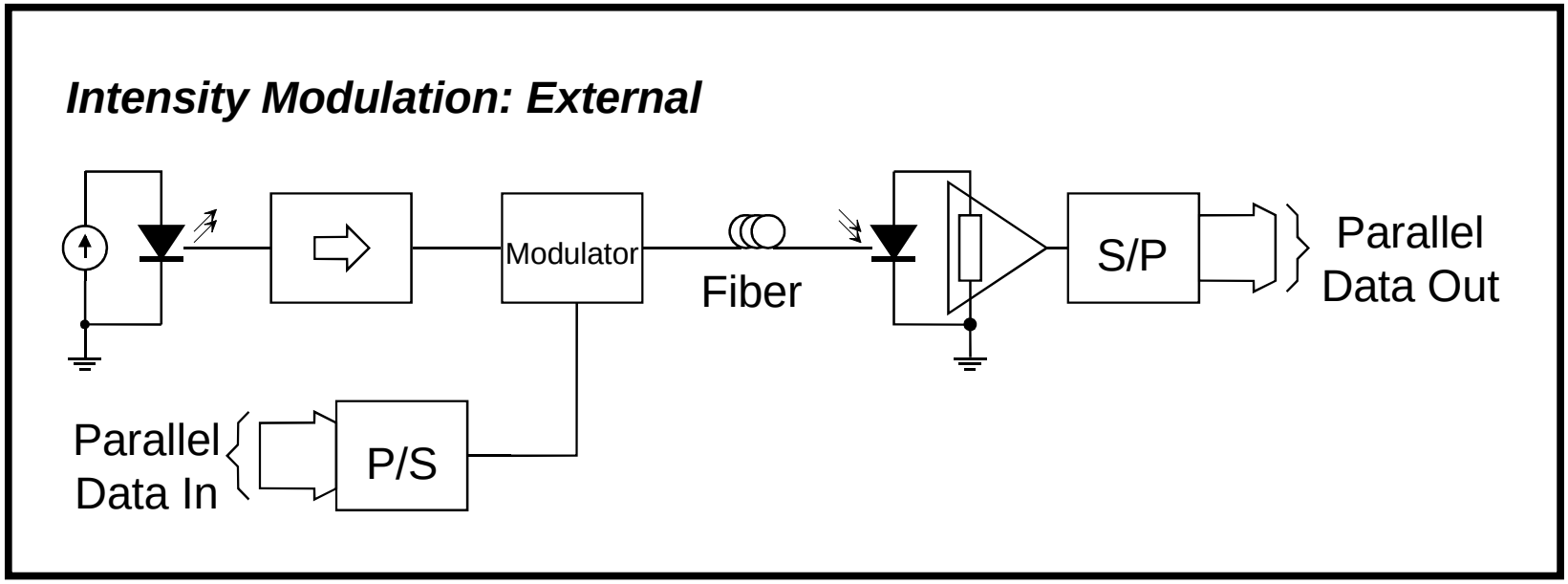
Direct Intensity Modulation

Intensity Modulation: Direct



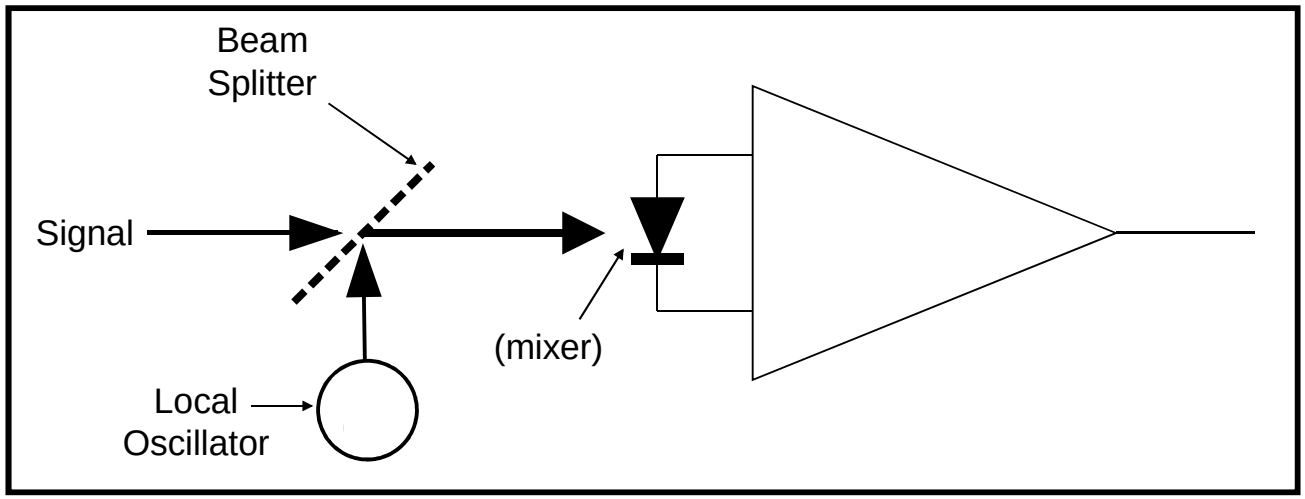
- The serial data stream out of the serializer is converted into current pulses
- The current pulses are used to directly modulate the light produced by a laser-diode
  - “0” - light “OFF”
  - “1” - light “ON”
- The light is coupled into the optical fiber
- The light out of the optical fiber is detected by a photo-diode, which converts the optical pulses into electrical pulses
- The current pulses are converted into a voltage and amplified before they are feed to the serial to parallel converter
- Direct intensity modulation can be used for data rates up to a few Gbit/s

External Intensity Modulation



- A laser diode is operated continuously and its light is coupled to an external modulator
- The external modulator modulates the light in “on” / “off” according to the data pattern
- External modulation reduces the spectral broadening of the light source
- External modulation allows data rates of the order of several tens of Gbit/s

Coherent detection



- In coherent detection systems the signal information is carried by the phase, the frequency or the intensity of the optical carrier
- At the receiver the signal is mixed with a local oscillator signal: homodyne or heterodyne
- The PIN diode is used as the mixer (square law device)
- Coherent receivers can achieve close to quantum limited noise performance
- However, they are complex and expensive and consequently not used in practice