Noise Sources in Photodetecors

- The principal noises associated with photodetectors are :

1- Quantum (Shot) noise: arises from statistical nature of the production and collection of photo-generated electrons upon optical illumination. It has been shown that the statistics follow a Poisson process.

2- Dark current noise: is the current that continues to flow through the bias circuit in the absence of the light. This is the combination of **bulk dark current**, which is due to thermally generated e and h in the *pn* junction, and the **surface dark current**, due to surface defects, bias voltage and surface area.

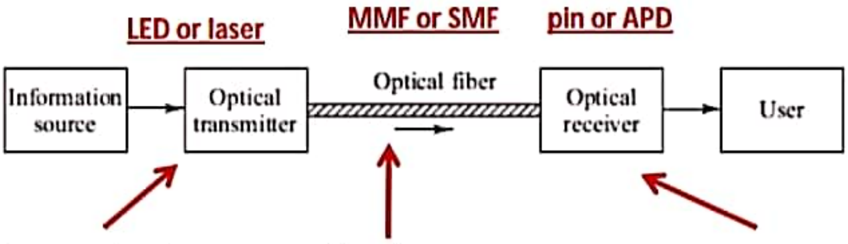
In order to calculate the total noise presented in photodetector, we should sum up the root mean square of each noise current by assuming that those are uncorrelated.

Total photodetector noise current=quantum noise current +bulk dark current noise + surface current noise

Point-to-Point Links

Key system requirements needed to analyze optical fiber links:

1. The desired (or possible) transmission distance
2. The data rate or channel bandwidth
3. The desired bit-error rate (BER)



(a) Emission wavelength
(b) Spectral line width
(c) Output power
(d) Effective radiating area
(e) Emission pattern

(a) Core size
(b) Core index profile
(c) BW or dispersion
(d) Attenuation
(e) NA or MFD

(a) Responsivity
(b) Operating λ
(c) Speed
(d) Sensitivity

Selecting the Fiber

Bit rate and distance are the major factors

Other factors to consider: attenuation (depends on?) and distance-bandwidth product (depends on?) cost of the connectors, splicing etc.

Then decide

- Multimode or single mode
- Step or graded index fiber

Selecting the Optical Source

- Emission wavelength depends on acceptable attenuation and dispersion
- Spectral line width depends on acceptable ………… dispersion (LED → wide, LASER → narrow)
- Output power in to the fiber (LED → low, LASER → high)
- Stability, reliability and cost
- Driving circuit considerations

Selecting the detector

- Type of detector
  - APD: High sensitivity but complex, high bias voltage (40V or more) and expensive
  - PIN: Simpler, thermally stable, low bias voltage (5V or less) and less expensive
- Responsivity (that depends on the avalanche gain & quantum efficiency)
- Operating wavelength and spectral selectivity
- Speed (capacitance) and photosensitive area
- Sensitivity (depends on noise and gain)

Typical bit rates at different wavelengths

Wavelength	**LED** Systems	**LASER** Systems.
800-900 nm (Typically Multimode Fiber)	150 Mb/s.km	2500 Mb/s.km
1300 nm (Lowest dispersion)	1500 Mb/s.km	25 Gb/s.km (InGaAsP Laser)
1550 nm (Lowest Attenuation)	1200 Mb/s.km	Up to 500 Gb/s.km (Best demo)

Wavelength Division Multiplexing (WDM)

Why Is WDM Used?

With the exponential growth in communications, caused mainly by the wide acceptance of the Internet, many carriers are finding that their estimates of fiber needs have been highly underestimated. Although most cables included many spare fibers when installed, this growth has used many of them and new capacity is needed. Three methods exist for expanding capacity: 1) installing more cables, 2) increasing system bitrate to multiplex more signals or 3) wavelength division multiplexing.

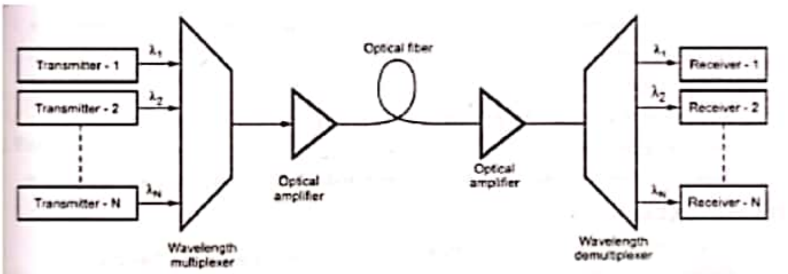


Fig. 7.1.1 WDM scheme

- To prevent spurious signals to enter into receiving channel, the demultiplexer must have narrow spectral operation with sharp wavelength cut-offs. The acceptable limit of crosstalk is – 30 dB.

Features of WDM

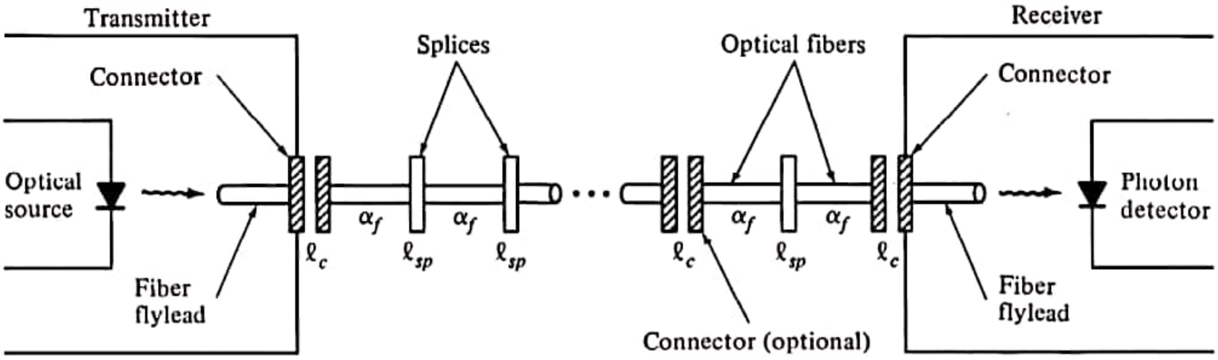
- Important advantages or features of WDM are as mentioned below –
  1. Capacity upgrade : Since each wavelength supports independent data rate in Gbps.
  2. Transparency : WDM can carry fast asynchronous, slow synchronous, synchronous analog and digital data.
  3. Wavelength routing : Link capacity and flexibility can be increased by using multiple wavelength.
  4. Wavelength switching : WDM can add or drop multiplexers, cross connects and wavelength converters.

Design Considerations

- Link Power Budget
  - There is enough power margin in the system to meet the given BER
- Rise Time Budget
  - Each element of the link is fast enough to meet the given bit rate

These two budgets give necessary conditions for satisfactory operation

Optical power-loss model



$$P_T = P_s - P_R = ml_c + nl_{sp} + \alpha_f L + \text{System Margin}$$

P_T: Total loss; P_s : Source power; P_R: Rx sensitivity

m connectors; n splices