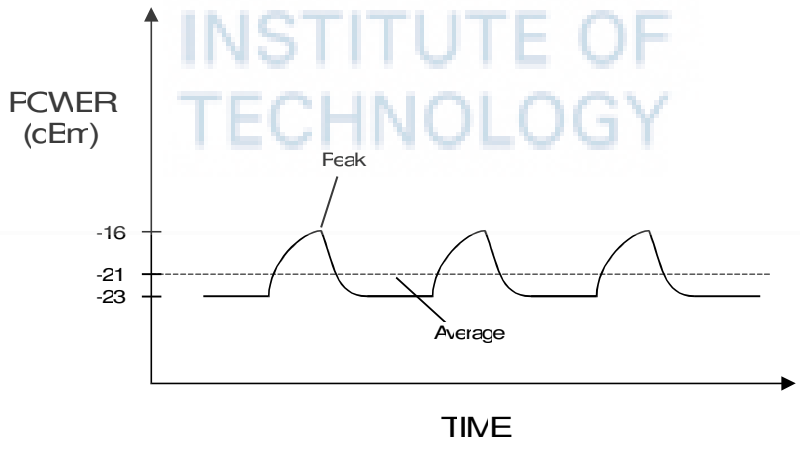
Testing & Troubleshooting of Fibre Optic Cables

- To be discussed
  - Fundamental concepts of optical measurement
  - Standard fibre optic cable tests
  - Standard fibre optic equipment tests
  - Data transmission tests
  - Laboratory measurements

Fundamental concepts of optical measurement

- Optical power
  - Measured in watts
  - Optical measurements relate directly to electrical measurements
  - Optical energy measured as average of incoming optical pulsed signal

Power for received optical waveform



– Light constructed of photons
– The higher the frequency the more energy in the photon
– Light energy is directly proportional to frequency and inversely proportional to wavelength
– $C = \lambda \times f$
– Planck's law
– $Q = h \times f$
  - Q = energy of photon
  - h = Planck's constant

- Electrical power
  – $P = dQ / dt$
    Q = electron energy in joules
- Light power
  – $P = d (nQp) / dt$
    Qp = energy of a single photon
    n = number of photons

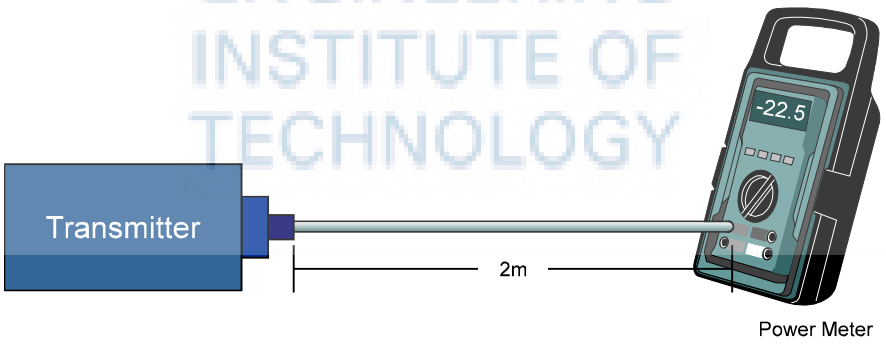
- Power measurement
  - Different materials used for different wavelengths
    - e.g. Silicon reacts strongly at 850 µm
    - Gallium arsenide reacts strongly at 1300 & 1550 µ m
  - Therefore instruments are calibrated for the different wavelengths
  - Measure average power

- Bandwidth
  - 3 dB limits as discussed
  - For optical detector a 3 dB drop in optical level represents a 6 dB drop in electrical output.
  - Power meter shows correct optical power

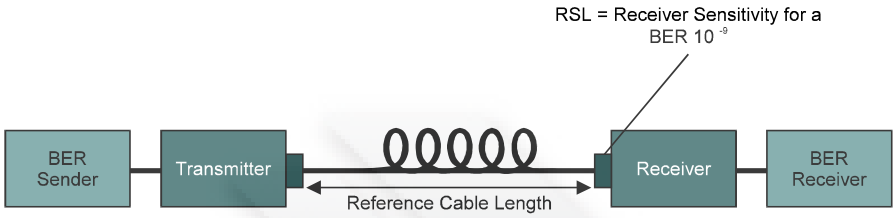
Fibre optic tests

- Generally tests carried out before and after installation
- Transmitter power test
  - Connect Tx device via 2 m fibre to power meter
  - Should be +/- 5% of specified figure
- Receiver performance test
  - Connect Tx to Rx through optical fibre & attenuators. Drop Rx level down to specified receiver sensitivity
  - Check BER is < 10^{-9}

Measuring power into fibre



Testing the Receiver



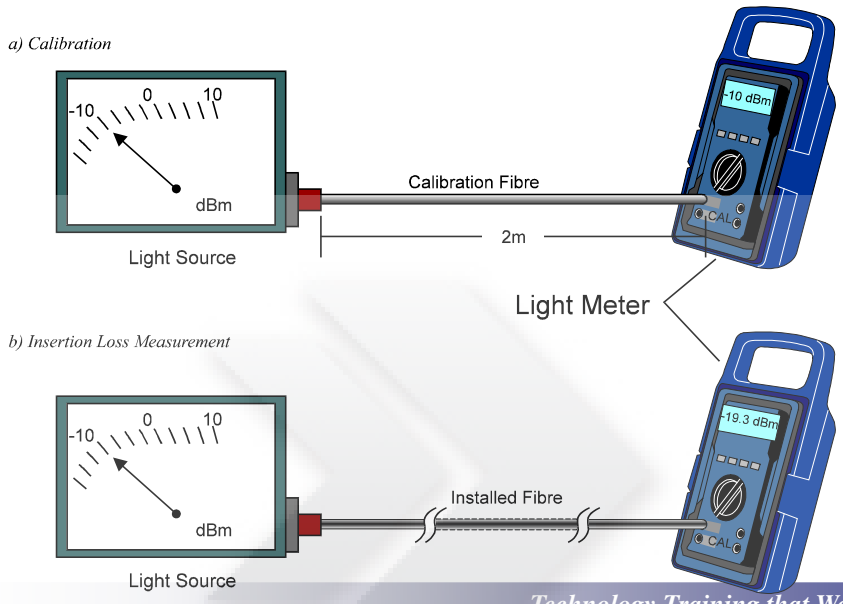
- Continuity testing
  - Very basic test of fibre continuity
  - A continuity tester works at a 650µm wavelength (red).
  - Use physical observation
  - Used for
    - Tracing cores
    - Finding fractures or bad splices with leaking light
    - Locating cores at intermediate points by bending the fibres

- Insertion loss testing
  - The most commonly used test
  - Firstly calibrate the power meter to the optical source
    - Use a 2 metre fibre
    - Generally to -10 dBm
  - Check
    - Calibration fibre is the same type as the installed fibre
    - Test wavelength is the same as the installed operating wavelength
    - Test source is the same as the installed source (led or laser)

» Cont

- Test connectors are the same as the installed connectors
  - Cable insertion loss is calculated as
    - Power source output value minus power meter reading
  - Carry out the test in both directions (diameter and NA mismatches)
  - Perform on every fibre in cable
  - Where possible use the actual transmitter as a source on some cores to compare the results

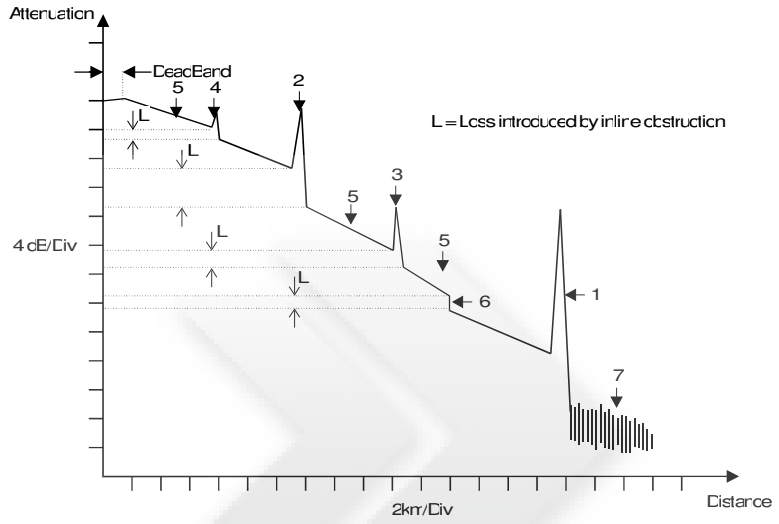
Insertion loss measurement



- Optical time domain reflectometry (OTDR)
  - A short pulse is injected into the fibre
  - The strength of the reflection shows attenuation
  - The time delay in the return of the reflection shows distance to the fault
  - Reflections can be caused by
    - Connectors, cracks, splices, impurities, breaks
    - Continual reflection from backscatter (rayleigh scattering)

Technology Training that Works

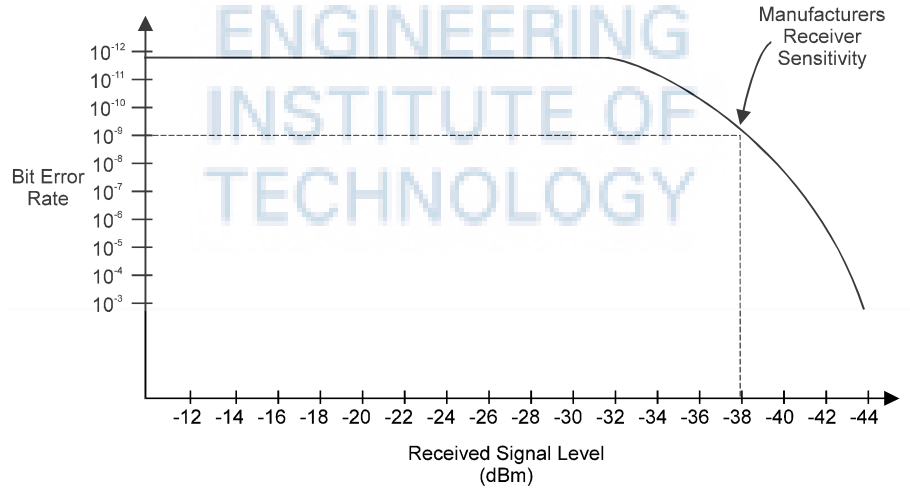
Trace from an OTDR



- Accuracies of 1m and 0.01dB loss are achievable
- Carry out tests on the reel and after installation
- This is a relative measurement therefore should not be used for insertion loss measurements.
- Carry out in both directions (different diameters and NAs)
- For helical fibre laid cables use the fibre / cable length ratio to calculate distance to fault

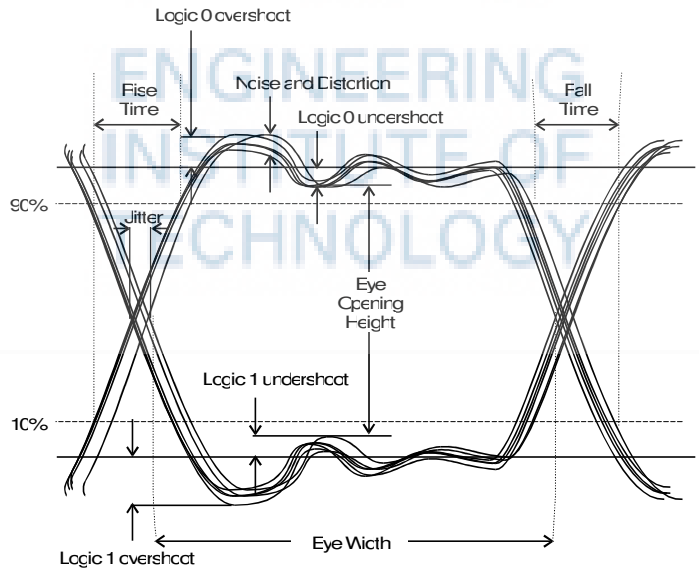
- Bit Error Rate testing
  - BER = errored bits received / total bits sent for a given period of time
  - Normally 30 mins to 1 hr
  - Expect residual BERof 10^{-9}
  - Availability
    - Time that link is available for uninterrupted use over a 12 month period at a BER of 10^{-12}
    - Expect 99.9999% or better

BER vs RSL for optical system



- Eye diagrams
  - Provides analysis of the communications system in real time
  - Formed by continually overlapping the signal at the Rx input on a scope (with a pseudo random signal from the Tx)
  - Measures
    - Noise, jitter, period, duty cycle, settling time, pulse width, rise time, fall time, overshoot, undershoot, preshoot, settling time, pulse quality and extinction ratio.

Eye diagram



Other tests

- Laboratory tests
  - Wavelength measurement
  - Dispersion measurement
  - Bandwidth measurement
  - Phase measurement
  - Polarisation measurement
  - Number of travelling modes
  - NA measurement
  - Core diameter