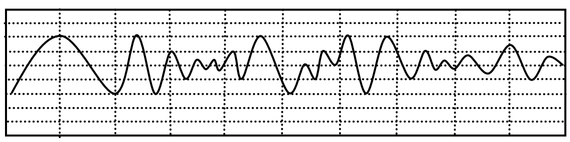
Optical Fibre Communication

Optical fibre, Node or distribution point and home installation

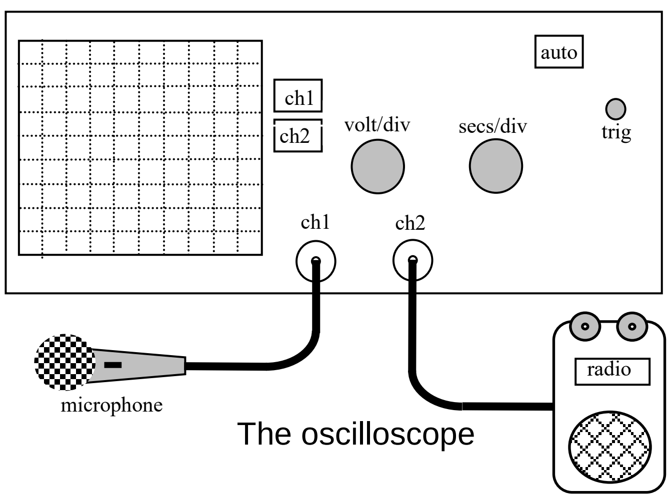
These activities are designed to investigate the transmission of data over a “free space” link and through an optical fibre. The free space link uses the audio output from a radio and the optical fibre link uses a digital signal.

An audio signal constantly changes in amplitude and frequency. This is Analog modulation and can be seen using the microphone. Hum into the microphone and press **auto-set!** Adjust the controls to improve the display.



Analog Modulation

View the microphone and radio at the same time.



The oscilloscope

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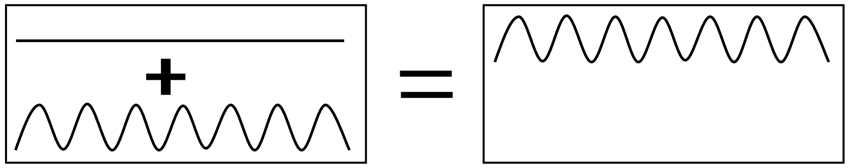
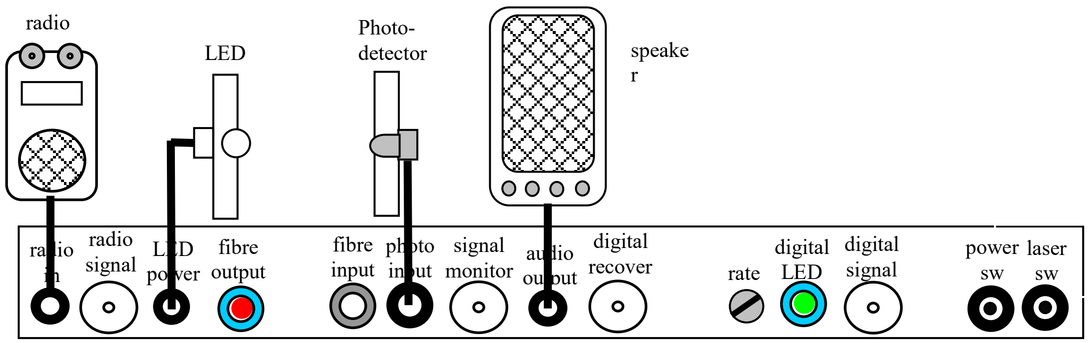
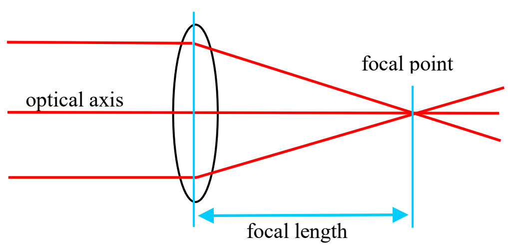
The radio speaker, audio signal, can be carried on a Light Emitting Diode (LED). This causes the brightness to vary with the amplitude and frequency of the signal. The detector is a phototransistor that converts the light into electrical signals that can be seen on the oscilloscope and heard through the speaker.



Audio signal added to voltage supplying the LED



Build the free space link using Minilab & find the optimum distance for clear transmission. Extend the range of the link using a convex lens. Check the focal length by projecting an image of the window or sun onto the wall or a piece of paper. Work out the best position for the lens.

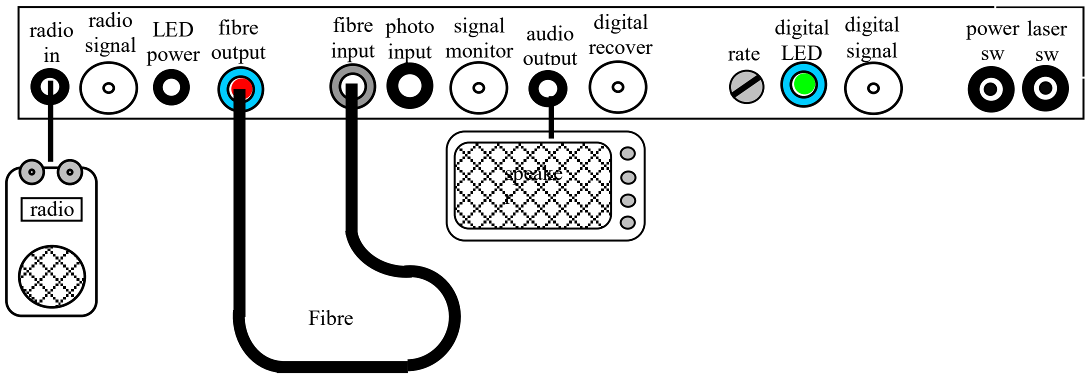


Convex lens: focal length

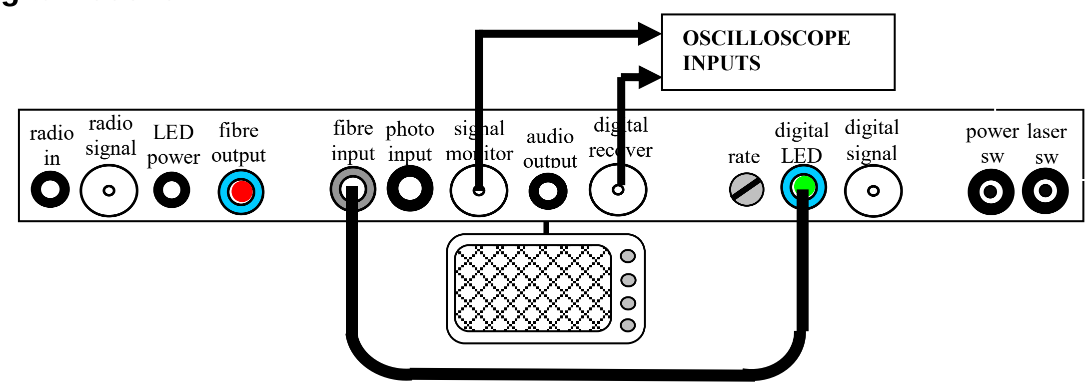
A free space laser link is proposed between this building and the accelerator tower. Why might it not be completely reliable?

Free space laser link across ANU

Optical fibre solves many of these problems and can carry multiple wavelengths down the same fibre. Build the Analog Link shown below using the 1mm diameter polymer optical fibre.



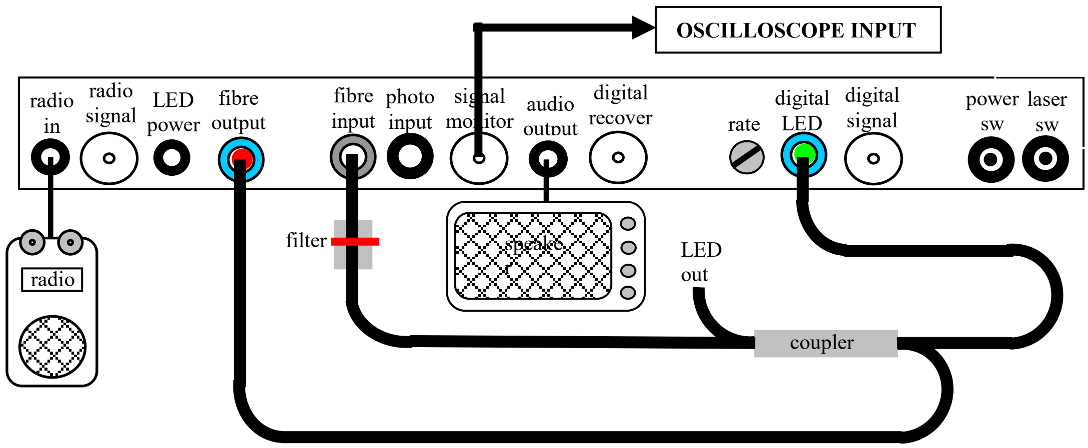
What are the advantages of the optical fibre compared to a free space link? The next task is to investigate digital signals using the Minilab. The green LED provides a digital signal that can be varied using the **rate** control. Connect up the circuit and use the oscilloscope to display signals from **signal monitor** and **digital recover.**



The maximum bit rate or number of pulses per second determines the type of signal that a fibre can carry. Internet radio needs about 20,000 bits/sec and a CD player operates at 44,000 bits/sec.

Calculate the maximum bit rate of the transmitter by connecting the oscilloscope to **Signal Monitor** and decide if the system could potentially transmit internet radio.

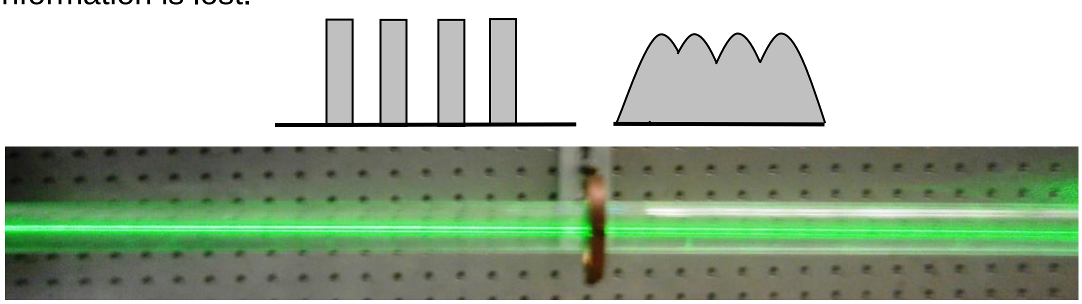
Build the design below to carry two colours simultaneously using the fibre coupler and using the green and red LED outputs. Adjust the speed of the green LED and observe the output from the coupler. The other arm can be plugged into the black photo-detector. What happens?



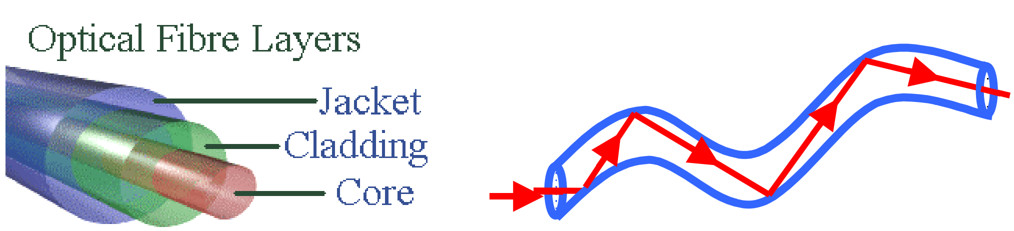
Optical fibres can carry many signals and in this case the optical fibre coupler is used to get the red and green light into a single fibre. The speaker should allow you to hear the radio and digital tone at the same time.

The filters (red and green), holder and another short length of fibre can be used to only allow one signal at a time through.

Light travels through an optical fibre by total internal reflection. Digital pulses of light based on a binary code are normally used to send information through optical fibres. As the pulses of light travel through the fibre they tend to spread out and may eventually overlap. If this occurs the signal becomes corrupted and the information is lost.

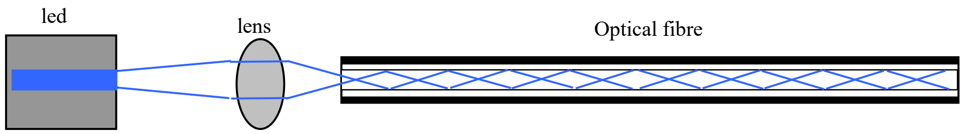


Digital signal showing pulse spreading and laser light transmission in a "fibre"



Optical fibre structure and light transmission

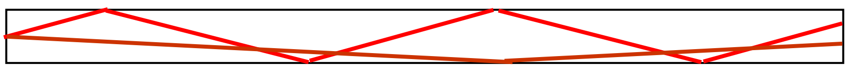
Usually infrared laser light, invisible to the eye is used to transmit signals through fibre. This unit uses visible, low power LEDS coupled into 1mm diameter fibre.



LED Transmitter coupled to a Polymer Fibre

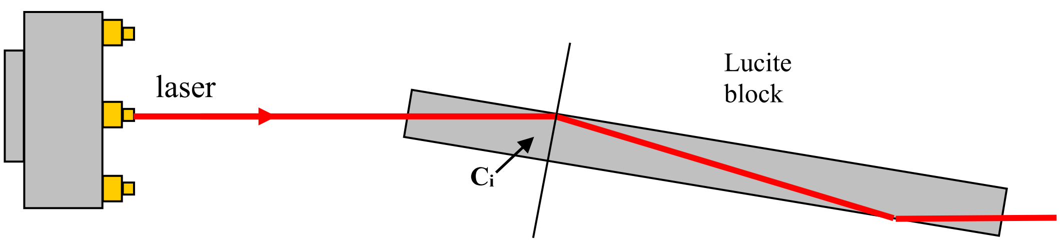
Laser Safety: **Do not stare at the laser beam**
Beware of reflections and view the laser from above
Use card or a screen to trace the path of the laser beam

The experiment concludes using the lasers and optical shapes! Dispersion occurs because the light travels through the fibre by total internal reflection and can take different paths.



Modal dispersion in an optical fibre

Locate the length of smoked Lucite rod and position it so the laser beam passes through the rod as shown. The smoked Lucite should allow the laser beam to be visualised and marked out on a sheet of paper underneath the rod.



Measuring modes

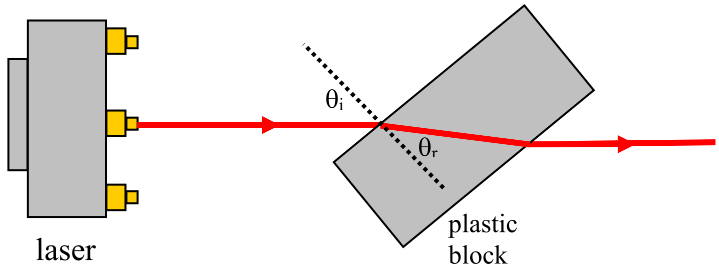
Make sure the laser enters the centre of the rod. Mark and measure the path length of the laser for the direct beam that undergoes no internal reflection. Next mark the path lengths for one, two and three internal reflections and measure their length. The rod acts as a multimode (path) fibre.

What would happen to a very short light pulse?

Multimode fibres are only used for relatively short fibre links whereas especially designed single mode fibre with a very small core diameter (10 microns or less) is used for long distance communications.

For total internal reflection to occur the refractive index of the material carrying the light must be greater than the surrounding medium. In the case of the fibre the refractive index of the core should be greater than the cladding.

Confirm this is correct by measuring the refractive index of the plastic block. In this case the cladding is air with a RI = 1.



Refraction through a plastic block

Place a sheet of paper on the base of the laser bench. Turn on the laser and position the plastic block at an angle to the laser beam.

Draw around the block and use a screen or card to trace the path of the laser beam. Mark where the beam enters and leaves the plastic block. Measure the angle of incidence θ_i and the angle of refraction θ_r.

If the angles of incidence and refraction are different it means the refractive index of the block is different to that of air.

Calculate the refractive index using: $n_1\sin(\theta_i) = n_2\sin(\theta_r)$

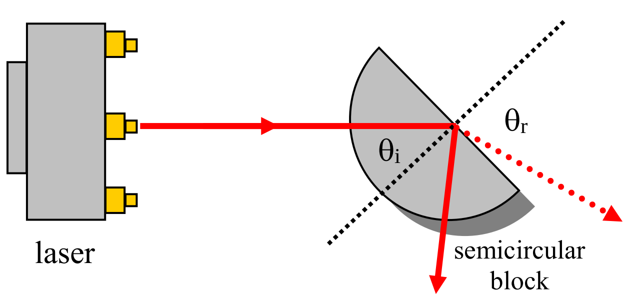
θ_i = Angle of Incidence, n_1 = Refractive Index of Air (1.00), θ_r = Angle of Refraction and n_2 = Refractive Index of the Plastic.

The speed of light (v) in the material is also of interest. If the velocity of light in a vacuum c is 300,000 km/s and the speed of light v is given by:

$$v = \frac{c}{n_2}$$

How fast is the light in the plastic block? Light therefore travels slower through optical fibres than air. Why is an optical fibre link to the USA better than a satellite link with radio waves?

Another important factor is the critical angle. Light is refracted when it meets a boundary of different refractive index. As the angle of incidence θ_i is increased, the refracted angle θ_r of the beam exiting the block increases. When $\theta_r = 90°$ total internal reflection occurs. The angle of incidence is recorded and is called θ_c. This is the critical angle. Use the semicircular block to demonstrate the critical angle.



Critical Angle