Fibre Optics and Telecommunications

Contents: Reading and questions on the use of optical fibres in telecommunications.

Time: 2 periods.

Intended use: GCSE Physics and Integrated Science. Links with work on light, internal reflection, refractive index and waves.

Aims:

- To complement work on light and internal reflection
- To develop awareness of the past, present and future development and importance of telecommunications
- To show the importance of fibre optics technology in telecommunications
- To develop awareness of the effect of new technologies on society
- To provide opportunities to practise skills in reading, comprehension and communication.

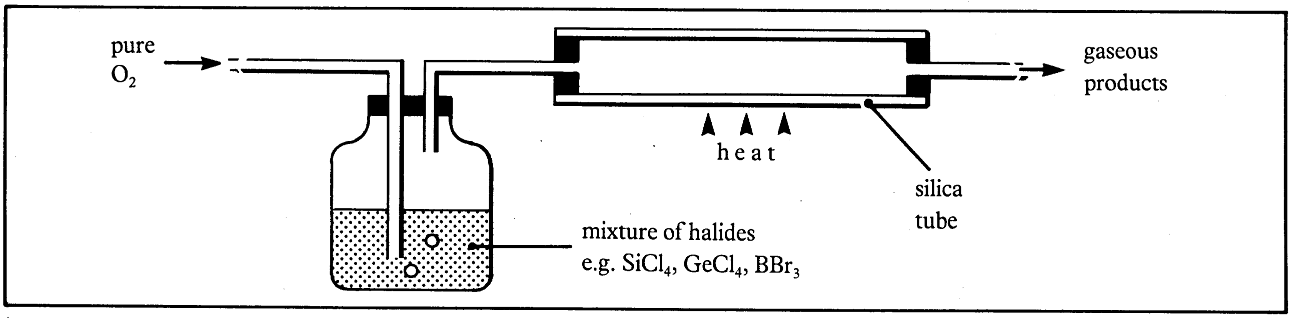
Requirements: Students' worksheets No. 306. It would be helpful to have samples of optical fibre available (see 'Other Resources').

Manufacture of optical fibre

The following information is provided for the teacher, but could be passed on to students if the teacher wished.

The basic principle of manufacture is to draw out a thin fibre from a heated rod of much wider diameter. This 'pre-form' rod must be very accurately made of extremely pure glass. One method of pre-form manufacture involves depositing the glass on the inside of a silica tube. The glass is formed *in situ* by a reaction between halides and oxygen. For example:

$$SiCl_4 + O_2 \longrightarrow SiO_2 + 2Cl_2$$



By varying the composition of the mixture of halides, the composition of the glass can be changed. This in turn varies the refractive index of the glass. Using extremely pure chemicals, and depositing the glass on the *inside* of the tube, keeps contamination by impurities to a minimum.

Notes on some of the questions

Q.4 The advantages of optical fibres mentioned in the students' worksheets are:

(a) Less loss of signal strength, so boosters can be further apart.

(b) Ability to carry large numbers of simultaneous conversations — thousands in the case of a single optical fibre, compared with tens in the case of a single copper wire.

(c) Freedom from interference.

(d) Smaller size and weight.

(e) Optical fibres are made from virtually limitless resources and are potentially cheaper than copper wire. Technological development has helped bring down the price of fibre: between 1982 and 1984 the price of fibre fell from £2000 to £200 per kilometre.

Q.8 Possibilities that could be mentioned here include satellite communication, which is a development already under way; videophones, which combine visual and aural communication; and electronic mail, in which messages arrive at a computer terminal via the telecommunications network. It might be interesting to discuss whether telecommunications will ever replace postal services. Improved telecommunications may lead to changes in travel habits with more people working at home, and increased use of 'video-conferencing'.

Q.9 There are of course many factors which operate to influence the pace and timing of technological development. These include:

(a) The needs of society (telephones would have been of limited value to medieval society, even if they had been a technological possibility, but they filled a need in the nineteenth century).

(b) The state of existing scientific knowledge (clearly telephones could not develop before discoveries concerning electricity).

(c) The state of existing technological knowledge and skill (without the necessary technological skills, glass fibres of suitable purity and accuracy for telecommunications purposes could not have been manufactured, even though the principle was well established).

As a matter of interest, Alexander Graham Bell himself patented a light-communication device called the 'Photophone' in 1880. Bell focused light (from the Sun, a lamp or even a candle) into a beam which was passed through a rotating wheel which 'chopped', or modulated it. The transmitter consisted of a microphone diaphragm connected to this modulator. The receiver used light-sensitive selenium to convert the modulated light to electrical signals. Obviously Bell's Photophone suffered from a number of serious limitations, not least the need for a strong light source and an uninterrupted path for the light beam.

Q.10 Telecommunications illustrate the 'chicken or egg' situation that developing countries are often in. Without a good system of telecommunications, development is held back, yet without development it is difficult to provide the resources needed to install such a system.

Notes for the teacher on the simultaneous transmission of telephone conversations

Some students may be interested to find out how conversations can be transmitted simultaneously, and why optical fibres make it possible to transmit larger numbers of conversations. The following notes may help.

To understand a telephone conversation you do not need to hear the signal the whole time. If the amplitude of the electrical signal is sampled every 125 microseconds then enough information has been gathered for the receiver to reconstruct the original conversation. Each of these samples lasts only 3 microseconds and so there is time to send short bursts of about 40 conversations each sampled in turn. Putting in suitable gaps between samples to avoid confusion leaves you with room for 32 separate conversations.

The sample amplitudes are converted into binary form and transmitted as on-off pulses. Digital coding reduces the seriousness of the inevitable distortion and loss of strength down the line. The receiver can recognize a feeble pulse as a 1, takes everything else as zero and so can restore the signal. This digital system, called 'Pulse Code Modulation', is used on many BT trunk lines and all optical fibre links.

To increase the number of simultaneous conversations carried by a link, the binary code pulses must be closer together. This means that the transmission medium (for example, a cable) should be capable of carrying a high frequency without blurring the pulses to the extent that they overlap. A coaxial cable and microwaves can deal with frequencies up to 100 MHz, but a glass fibre should do better because it transmits light of frequency 10^8MHz. At present, the laser and detector cannot cope with frequencies above 500 MHz (which is still much better than coaxial cable), but future devices should enable the huge potential capacity of optical fibres to be used.

For further details on PCM and optical fibres, see note below on *Telecommunications in Practice.*

Other resources

Video Programmes

1 'The Photon Connection' is a video recording of the 1983 Faraday Lecture on optical communication, and an entertaining introduction to the subject. It runs for 33 minutes and is available on free loan from: Central Film Library, Chalfont Grove, Gerrards Cross, Bucks SL9 8TN.

2 'The History of the Telephone' is a lively programme available on free loan from: British Telecom Film Library, 25 The Burroughs, Hendon, London NW4 4AT.

Telecommunication in Practice, a joint publication by the Association for Science Education and British Telecom, is a useful source of information, including experimental work on optical fibres. Available from: ASE, College Lane, Hatfield, Herts AL10 9AA.

Optical fibres in school physics, a title in the 'Experimenting with Industry' series, has useful information and experimental work. Available from the ASE.

The Telecom Technology Showcase traces the historical development of telecommunications, and also displays some of the latest developments in communications technology. It is situated at: British Telecom, Baynard House, Queen Victoria Street, London EC4. Tel. 01-248 7444. Visits can be booked in advance. Admission free.

Visits to local telephone exchanges. These are very worthwhile, and easily arranged. Simply dial 100 and ask to speak to the supervisor.

Samples of optical fibre can be obtained free of charge by writing to: Marketing Manager, GEC Optical Fibres, Church Road, London E10 7JH. These could be examined under the microscope and used for light transmission experiments.

Acknowledgements Figure 1 from Telefocus: a British Telecom photograph; Figure 5 reproduced by permission of the Department of Trade and Industry.

FIBRE OPTICS AND TELECOMMUNICATIONS

A little history

Humans have always needed to communicate with one another. At first they could only communicate when they met, but later they found ways of communicating at a distance.

Messengers were used to carry communications, and in the nineteenth century the first postal services began. These meant every person could communicate with people far away if they wanted.

In the mid-nineteenth century the Electric Telegraph was developed. This used electric currents to send messages in Morse code long distances along wires. In 1876 Alexander Graham Bell first demonstrated his telephone. This new invention meant that people could actually talk to each other at a distance.

Figure 1 An early telephone, in use from about 1914

The telephone was a great advance in communications technology. When you speak into a telephone mouthpiece, sound signals are converted to electrical signals. These electrical signals pass along a copper wire to the telephone receiver. Here they are converted back to sound signals in the earphone (Figure 2 on the next page).

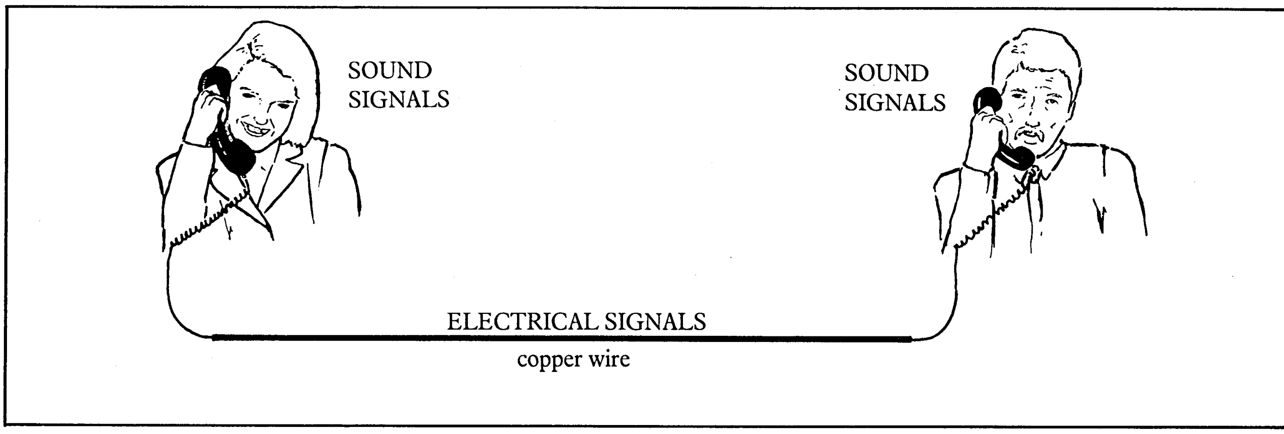


Figure 2 How a telephone sends and receives signals

By the middle of the twentieth century, thousands of kilometres of copper wiring were carrying telephone conversations all over the world. In 1925 there were 2.8 telephones per hundred people in Britain. By 1950 the figure was 10.2, and in 1981 it was 50.

But there are problems with using copper wires to carry conversations.

- The number of conversations that can go down a wire at one time is limited. If you want to carry more conversations, you need more wires.
- The signal carried along the wire gets weaker the further it goes. This means telephone cables need 'boosters' every 2 or 3 km to strengthen the signals.
- Copper wires are heavy and take up quite a lot of space in their underground channels.

Questions

1 What difference would it make to your family's life if telephones did not exist?

2 Choose one business or company which you know about. What difference would it make to them if telephones did not exist?

Optical fibre communications

Optical fibres are rapidly replacing copper wires as a way of carrying telecommunications. In this unit you will find out why.

Light has long been used for communications. Semaphore signals, beacons, flashing lights and the smoke signals used by the North American Indians are all examples. But the main problem is that light travels in straight lines. If something gets in the way, you cannot see the light signals.

Optical fibres were first developed in the 1960s. They enable light to go round corners, and can be thought of as 'light pipes'.

How do optical fibres work?

If you are swimming under water, you cannot usually see the sky. Light is reflected back from the under-surface of the water. This is **total internal reflection**. It happens because air and water have different **refractive indexes**.

A similar thing happens in optical fibres. The fibre is made out of two different kinds of glass. The central **core glass** is surrounded by **cladding glass**. The core glass and the cladding glass have different refractive indexes. Light travels along the central glass core. When light rays hit the boundary between the core and the cladding, they are reflected internally back into the core. In this way, the light is kept inside the core, like water in a pipe. It does not matter if the fibre goes round corners — the light still travels inside the core.

The optical fibre is protected on the outside by a plastic coat. It is very thin — often thinner than a human hair.

Figure 3 shows the arrangement.

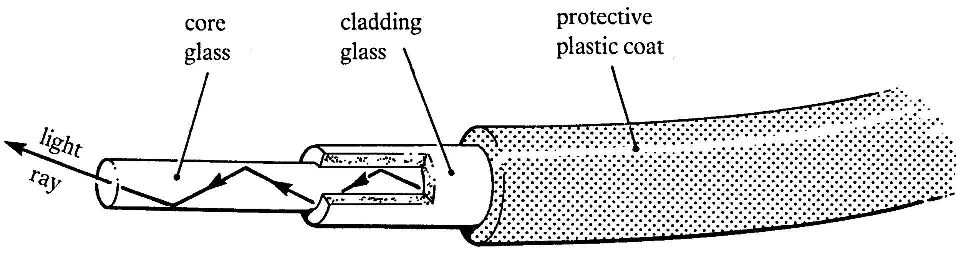


Figure 3 An optical fibre

The glass must be very pure, because impurities would scatter and absorb the light. Keeping the glass pure enough is one of the most difficult parts about making optical fibres. With suitably pure glass, laser light can travel more than a hundred kilometres along a fibre with little loss of strength. The glass used for optical fibres is so pure that you could see through a block of it 1 kilometre thick. (Ordinary glass looks black at a thickness of 1 metre.)

Using optical fibres in telephones

Optical fibres replace the copper wires used to carry telephone conversations (Figure 4).

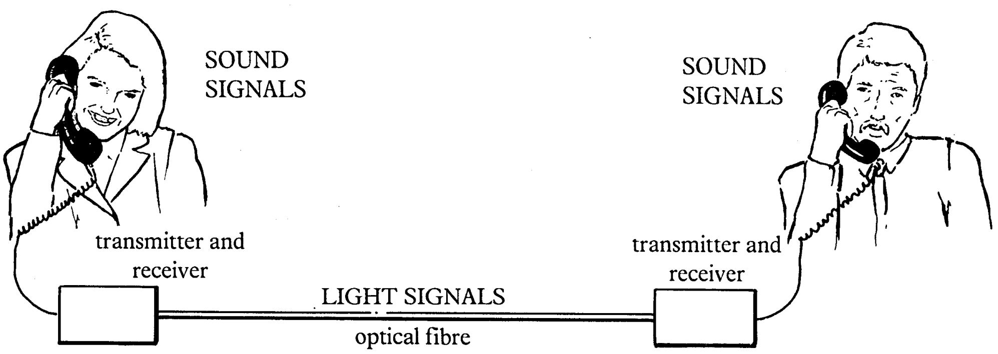


Figure 4 Using optical fibre to carry telephone signals

Signals are carried as pulses of light. The sound signals from the speaker are turned to electrical signals first, in an ordinary telephone mouthpiece. But the electrical signals are then converted to light signals by a transmitter. At the other end of the line, the light signals are converted back to electrical signals by a receiver. These electrical signals operate the telephone earpiece in the usual way.

The signals travel along the optical fibre in the form of pulses, or flashes, of laser light. The laser light source is turned on and off very quickly. The light pulses make up a binary code which is decoded by the receiver.

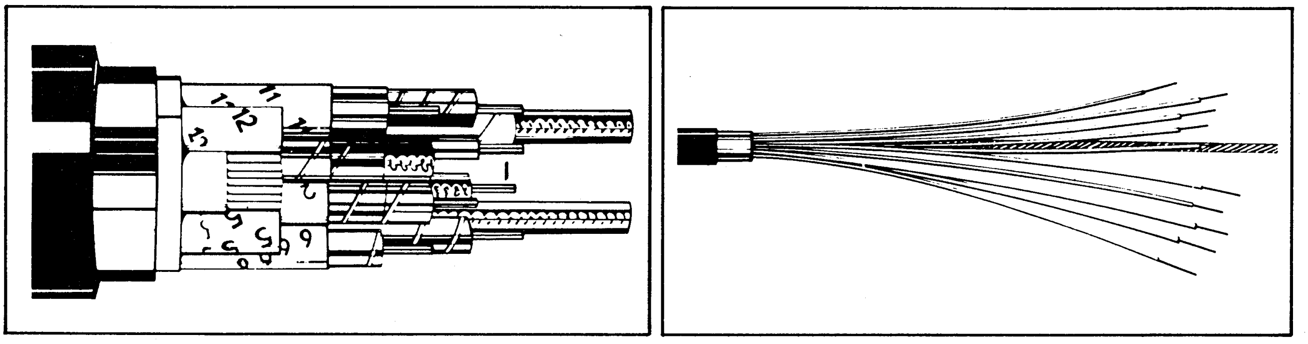
Because the laser light has a high frequency, lots of different signals can be sent at the same time. This means an optical fibre can carry many thousands of different telephone conversations at the same time. What is more, the signals stay strong for long distances. With optical fibres, 'boosters' are only needed every 30 km or more. An optical fibre is much smaller than a copper wire capable of doing the same job (Figure 5). And unlike copper wires, optical fibres do not suffer from interferences from other electrical signals.

Another advantage of optical fibres is that the raw materials for glass are plentiful, unlike copper. This means glass can be made more cheaply than copper.

Questions

3 What job is done by each of the following in an optical fibre communication system?
(a) the transmitter
(b) the receiver
(c) the laser
(d) the optical fibre itself

4 It may not seem to make much difference to you whether your telephone calls are carried by copper wires or optical fibres. But what are the advantages to telephone engineers of optical fibres over ordinary copper wires?



Telephone cable with 10 000 call capacity — made from copper

Telephone cable with 10 000 call capacity — made from optical fibre

Figure 5

Because of all the advantages, British Telecom is replacing copper wire by optical fibres for its telephone network all over the country. The fibres are grouped together in optical cables laid under the ground. By the end of the 1980s, most telephone calls in Britain will be carried by optical fibres.

What other uses are there for optical fibres?

Optical fibres have other applications as well as in telecommunications.

For example, in medicine, optical fibres can be used as 'light pipes' to see inside a patient's body. A bundle of optical fibres, inside a flexible tube, is inserted into, say, the stomach or the lungs, through the body's natural passages. The surgeon can then inspect the organs without having to cut the patient open.

Question

5 Optical fibres are used to link computers together. How might this be done?

Further questions to answer and discuss

You may like to discuss these points in small groups.

6 *New technology often replaces older technology, in the same way as optical fibres are replacing telephone wires. New technology also often has a big effect on people's lives. For* two *of the following examples of new technology, say:*

(a) Which, if any, older technology it is replacing
(b) Why it is replacing the older technology
(c) What effect it has on our lives.

(i) Electronic calculators
(ii) Videocassette recorders
(iii) Microcomputers
(iv) Digital watches.

7 *In their time, each of the following inventions were new technologies. Which older technologies did each replace?*

(a) Steam engines
(b) Polythene
(c) Roofing tiles
(d) Electric lighting
(e) Ballpens.

8 *Apart from fibre optics, what other major technological developments do you think we might see in telecommunications in the future?*

9 *Optical fibres are an example of new technology. When telephones were first invented, they also were new technology. Suggest reasons why:*

(a) Telephones were not developed before 1876
(b) Optical fibres were not developed until the 1960s.

10 *This table shows the number of telephones per hundred people in different countries.*

Country	Number of telephones per hundred people (1976)
USA	*84*
United Kingdom	*49*
Portugal	*14*
USSR	*9*
Brazil	*6*
India	*0.4*
Malawi	*0.3*

(a) Comment on these figures.
(b) In what ways can a good telephone system help the development of a country?