

9

Connecting optic fibers – the problems

There are only three real problems involved in connecting optic fibers:

- ▷ the fibers must be of compatible types
- ▷ the ends of the fiber must be brought together in close proximity
- ▷ they must be accurately aligned.

Compatibility problems

A curious feature of these compatibility problems is that they result in the degree of loss being dependent on the direction of travel of the light along the fiber. Hitherto, we have always considered light direction to be irrelevant.

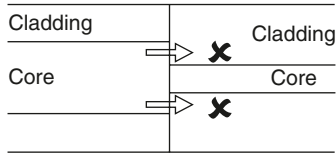
Core diameters

Multimode fibers come in a wide variety of core sizes between 7 μm and 3 mm, of which the most usual are 50 μm , 62.5 μm , 100 μm , and 200 μm . The industry standard for data communications is now 50/125 and 62.5/125 μm multimode using silica fiber with a slow but steady growth of single mode. Telecommunications uses exclusively single mode. Similarly, the all-plastic fibers range from 0.25 mm to 3 mm of which 1 mm is the most common.

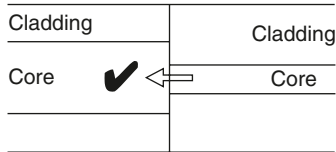
When we purchase components, such as a laser, they often come attached to a length of optic fiber (called a *pigtail*) which we cannot disconnect. If this fiber has characteristics different to those of our main system, then we must be aware of a possible power loss at the point of connection.

Figure 9.1

Losses due to unequal core sizes



Some light cannot enter the core



Small core to large core – no losses

		Launch fiber core size (μm)		
		9	50	62.5
Receive fiber core size (μm)	9	0	14.8 dB	16.8 dB
	50	0	0	1.9 dB
	62.5	0	0	0

Losses can be high

Single mode fibers are restricted to a size very close to 8 μm, so core size problems are not common but the very small sizes involved bring their own problems of tight-tolerance engineering when trying to align such small cores together.

If we connect a multimode fiber with a large core to one with a smaller core, as shown in Figure 9.1, only some of the light emitted by the larger core will enter the smaller core, due to the reduced area of overlap, and a power loss will occur. If, however, the light traveled from the smaller core to the larger, all the active core is overlapped and no losses will occur.

The size of the loss can be calculated using the formula:

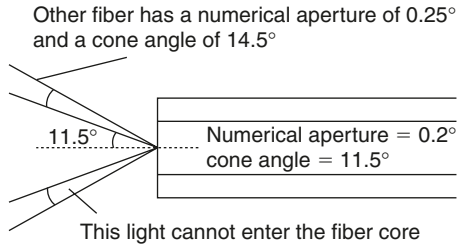
$$\text{Loss} = -10 \log_{10} \left(\frac{\text{core diameter}_{\text{receive}}}{\text{core diameter}_{\text{launch}}} \right)^2 \text{ dB}$$

Remember that this formula only applies when the diameter of the launch fiber is greater than that of the receiving fiber otherwise there are no losses.

Numerical apertures

A very similar effect occurs with changes in the numerical apertures. If the receiving fiber has a numerical aperture which is equal to, or greater than the launch fiber, no losses will occur.

Figure 9.2
Losses due to changes in numerical aperture



		Launch fiber NA		
		0.1	0.2	0.275
Receive fiber NA	0.1	0	6 dB	0.36 dB
	0.2	0	0	2.8 dB
0.275	0	0	0	

Example losses

The reasoning behind this is that the numerical aperture determines the cone of acceptance.

Let us assume a typical fiber with a numerical aperture of 0.2, resulting in a cone of acceptance of 11.5° is connected to a fiber with NA = 0.25, with a cone of acceptance of 14.5° (Figure 9.2). Using this direction of transmission, all of the ray angles would be accepted by the other fiber and no losses would occur. If, however, we transmitted light in the other direction, the light rays with angles between 11.5° and 14.5°, which are outside the cone of acceptance of the receiving fiber, would not be accepted and would result in a loss.

The formula looks very similar to that used for the problem of the core diameters:

$$\text{Loss} = -10 \log_{10} \left(\frac{\text{NA}_{\text{receive}}}{\text{NA}_{\text{launch}}} \right)^2 \text{ dB}$$

Remember that the formula only applies when the numerical aperture of the launch fiber is greater than that of the receiving fiber. Otherwise no losses occur.

What if both the core sizes and the numerical apertures differ?

Good news!

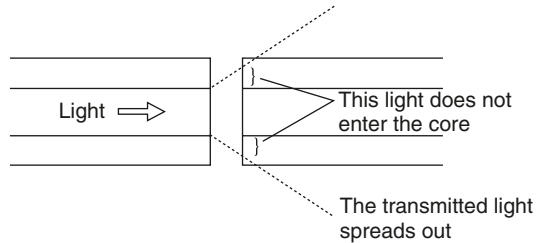
We can find the total loss by simply adding the two separate losses.

Example

What loss would result from connecting a fiber with a core size of 62.5 μm and NA of 0.275 to a fiber of core size 50 μm and NA of 0.2?

From the formulae, or reading off the tables, we obtain a loss due to core size of 1.9 dB and a NA loss of 2.8 dB. The total loss will be: 1.9 + 2.8 = 4.7 dB

Figure 9.3
Gap loss



Gap loss - Figure 9.3

As the ends of the fiber are separated, the light from the core spreads out at an angle equal to the acceptance angle as we saw in Chapter 4. Less light strikes the core area of the receiving fiber and a loss occurs.

The degree of loss is not severe, with a value of less than 0.5 dB when the ends of the fiber are separated by a distance equal to a core diameter. The loss is reduced even further by the use of index matching gel which is added in the joint to make the fiber core appear continuous. Index matching gel has a refractive index similar to the core of an optic fiber and is used to fill the gap between the fibers to make the light path appear to be continuous. It is normally added to reduce Fresnel reflections but it helps with gap loss at the same time.

Gap loss increases linearly with the size of the gap.

Alignment problems - Figure 9.4

Lateral misalignment

This has a certain similarity to the loss due to differences in core size. As the fibers are moved the area of overlap between the two cores is reduced and hence less light transfer occurs. This alignment is quite critical, much more so than gap loss, and a misalignment of one quarter of a core diameter will cause a loss of 1.5 dB. Thereafter the loss increases rapidly in a non-linear manner.

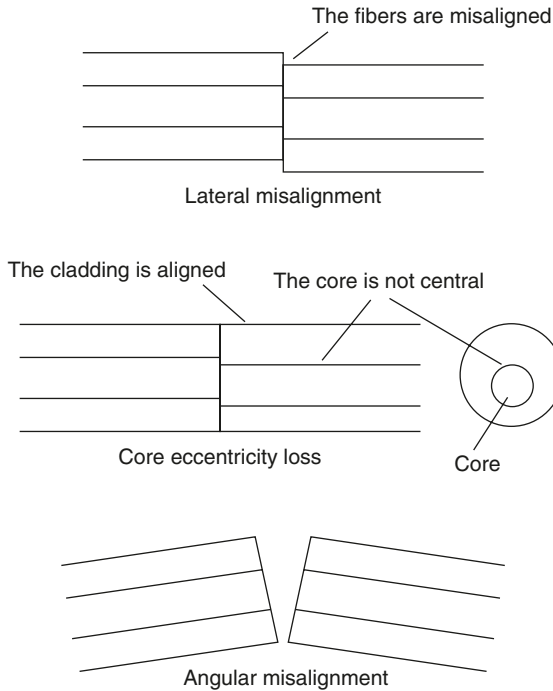
Core alignment (eccentricity loss)

This happens when the core is not positioned exactly in the center of the fiber. When optic fibers are connected, they are normally aligned by reference to the outside of the cladding. If the core is not placed centrally within the fiber the result will be misalignment of the core, giving results similar to those caused by lateral misalignment. Using modern manufacturing techniques, serious examples of this fault are rare.

Angular misalignment

As the angular displacement increases, the light from one core progressively misses the other. With an air gap, angles of misalignment up to three or four degrees cause losses of less than 1 dB. At increased angles, the losses increase at

Figure 9.4
Angular
misalignment



faster rates in a non-linear fashion. The use of index matching gel actually makes the situation worse as it prevents the spreading effect of the cone of acceptance which would normally occur in an air gap.

Connecting optic fibers – the preparation

Whatever method we choose to connect fibers we need to prepare the fibers by stripping off the primary buffer to expose the cladding. The cladding is used to position the fibers to prevent misalignment losses and, ignoring eccentricity loss, ensures that the cores are aligned. The primary buffer is not sufficiently accurate or stable for this purpose.

Safety points – don't get optic fiber inside you

Once the primary buffer is removed, the core and cladding are, of course, very thin. This means that a gentle pressure applied to the fiber will translate into extremely high concentrations of force over the end area of the fiber, easily puncturing the skin, often without being felt if it misses a nerve ending. Worse than that, it can then break off inside your hand. We have yet to discover the long-term medical effects but it is certainly not going to prove beneficial.

Wear eye protection to prevent fiber entering the eyes.

Don't eat or drink when working with fiber. Small pieces can easily be swallowed with unknown consequences in years to come.

Protect other people, birds and animals by disposing of fiber scraps very carefully in an approved 'sharps' container. We must be careful to ensure that fiber scraps never finish up inside anyone else, or are eaten by an animal or bird. The fiber should be placed inside a permanently sealed container before disposal.

Stripping

The primary buffer is first exposed by removing the outer jackets. This may mean a few seconds with a simple wire stripper tool such as is used for electrical wiring or an hour fighting your way through layers of armoring.

There are two approaches to stripping off the primary buffer – chemical or mechanical. There are a variety of plastics used for this buffer and the suppliers will advise on the best method. Whatever the method used, the aim is to remove about 50 mm of the buffer without scratching or nicking the surface of the cladding, as this would cause the fiber to break.

Chemical

The advantage of the chemical method is that there is no danger of any mechanical damage to the cladding.

A small bottle of stripper is supplied. The liquid or gel is brushed onto the surface of the buffer and left for two or three minutes. It softens the plastic which can then be wiped off with a tissue. The stripper smells remarkably like paint stripper and gives off equally unpleasant fumes. It should be treated with respect, ensuring that it does not come into contact with eyes, skin or naked lights. Use fingerstalls to avoid contact with the skin and safety glasses. Remember, we cannot see with glass eyes.

Mechanical

There is a range of hand tools that can provide the same service without the use of chemicals, an example is shown in Figure 9.5. Their operation is basically the same as copper wire strippers except that they are built with much greater accuracy. The principle is to cut through the buffer with a blade, stopping just short of touching the surface of the cladding. The fiber is then pulled through the jaws and the blade tears off the primary buffer. Because of the precision of construction, the tools are made for specific buffer sizes.

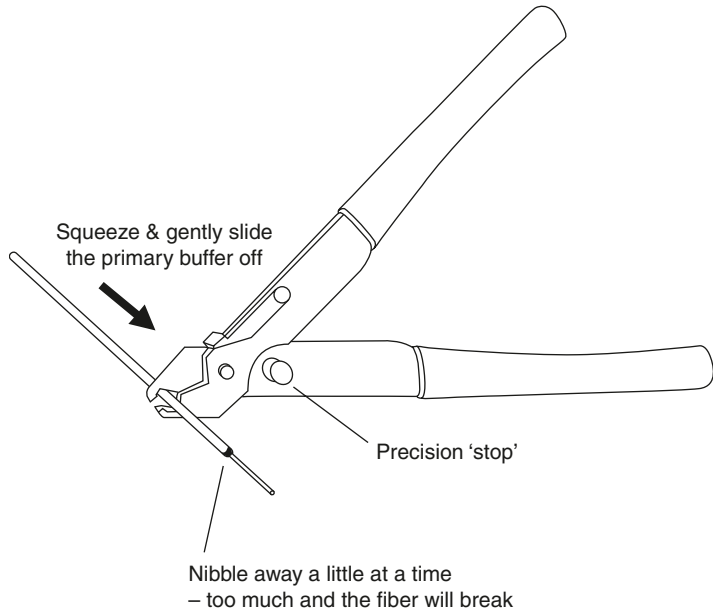
Cleaning

Every trace of the buffer or other contamination must be carefully removed. A single speck of buffer, dust or grease will cause the misalignment of fibers and the consequent loss of light.

The most usual method of cleaning is to moisten some lint-free cloth or tissue with isopropyl alcohol (IPA), fold it over and pull the fiber through the tissue. When the fiber is clean it gives off a squeal so is, quite literally, squeaky clean. It is good to avoid too much contact with IPA and the use of fingerstalls is a good idea. Acetone is sometimes offered as an alternative cleaning fluid but the health hazards of skin contact and breathing the fumes are considered even worse than

Figure 9.5

Remove the
primary buffer



isopropyl alcohol. Mixing cleaning fluids can be dangerous so choose one and stay with it.

If the cable is gel-filled, it is essential that the gel is not allowed to contaminate the tools or the cladding. Turpentine or white spirit can be used as a cleaning agent at this stage.

Once the fiber is completely clean, ensure that it is not recontaminated. This is so easily done, almost without a thought. Some people, having cleaned the fiber, feel an overwhelming urge to pull it through between their finger and thumb just to make sure, others are careful to avoid this and carefully lay the fiber down on the dusty work surface!

Cleaving

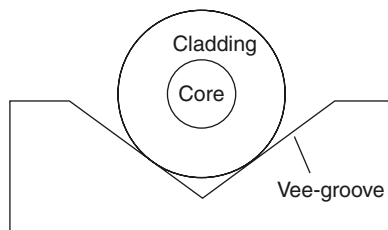
To connect two fibers, as well as being stripped and totally clean, the end of the fiber must be cut cleanly at right angles. This process is called *cleaving*. We are looking for the error in this angle to be no more than 1° . Any greater error will give rise to angular losses. We want the fiber to break very cleanly leaving the end face with no flaws.

In Chapter 4, when we were discussing the need for a primary buffer, we saw how cracks could be propagated through the fiber by introducing a small nick in the surface and then introducing some stress in the fiber. We use exactly this process for cleaving the fiber.

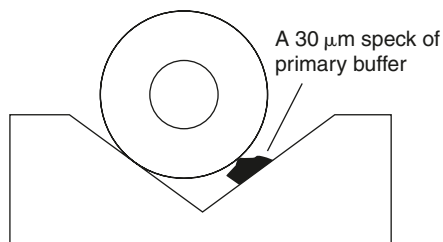
There are many different cleaving tools on the market ranging in size, (claimed) accuracy, and price. The price difference between the top and bottom of the range is in the order of thirtyfold. Generally, the small inexpensive ones tend to

Figure 9.6

The vee-groove



The vee-groove positions the fiber with precision



The slightest contamination can ruin the effect

be a little more difficult to use and require practice to obtain the 'knack'. The more expensive ones are easier to use giving quality cleaves every time with the minimum of training. It is a good idea to try several types, perhaps at an exhibition or when attending a training course – there is always a range of opinion as to which is best. The 'best' one is probably the one you feel most happy using.

The perfectly clean fiber is supported in position, often by a vee-groove as can be seen in Figure 9.6. If a vee shaped groove is accurately cut in a stable material the fiber will fall to the bottom and will align itself with the groove. Any contamination must be avoided at all costs – both the vee-groove and the fiber must be scrupulously clean otherwise it will prove disastrous.

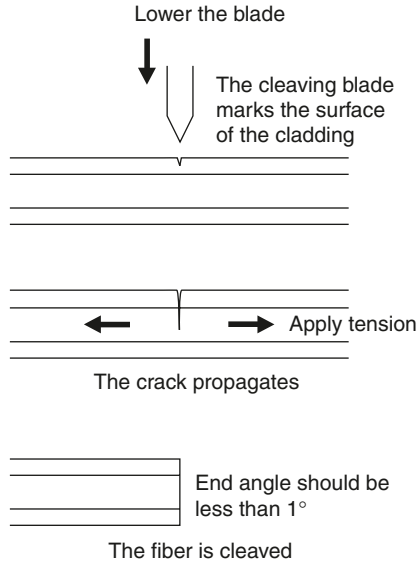
A blade is brought up to the surface of the cladding and makes a minute mark or witness on the surface (Figure 9.7). The blade must be at 90° to the fiber and the mark should be no more than 5 μm deep.

In the more sophisticated cleavers there is considerable research and engineering precision employed in achieving this and it is fully automatic. At the cheap end of the market a hand tool is provided consisting of an artificial sapphire mounted in a pen-type holder. The operator must support the fiber against one finger as the 'pen' is stroked gently across the fiber. It takes much practice to produce the correct mark on the cladding. The results are quite literally left in the hands of the operator.

Once the witness, or mark, is made, the fiber is stressed by being pulled and the crack propagates across the fiber and, hopefully, it is cleaved. The waste fiber must be disposed of in sealed containers.

Figure 9.7

The cleaving process

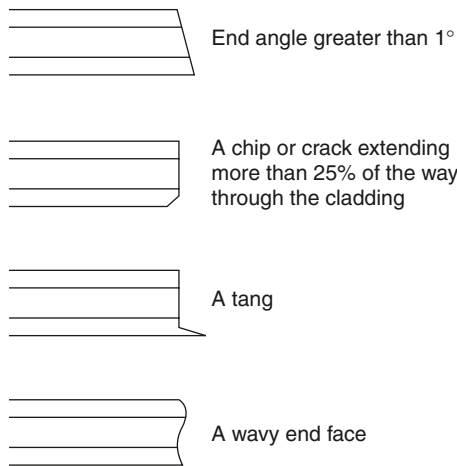


Inspection of the cleave

The end condition is checked using a microscope or a magnifying glass. A watchmaker’s eyeglass is useful for this. We are interested in the end angle, and checking for any tangs, chips or cracks (Figure 9.8). If any of these are present it will prevent efficient light transfer and there is no alternative but to start the cleave again.

Figure 9.8

Unacceptable cleaves



Plastic fiber

The outer jacket is removed with a pair of wire strippers, then the end of the fiber is ready for cleaving. The cleaving process is really simple – the fiber is simply

cut with a sharp knife. Things are not so critical with plastic nor the results so good.

Quiz time 9

In each case, choose the best option.

1 If light is launched from a fiber with a core diameter of 50 μm into a fiber of core 62.5 μm diameter, the loss would be:

- (a) + 1.9 dB
- (b) zero
- (c) - 1.9 dB
- (d) 16.8 dB

2 Cleaving is the process of:

- (a) removing the cladding before connecting fibers together
- (b) cutting the end of the fiber in preparation for connecting two fibers
- (c) cleaning the surface of optic fibers
- (d) inspecting fibers for flaws

3 A tang is most likely to give rise to:

- (a) increased values of NA
- (b) eccentricity
- (c) amplification
- (d) gap loss

4 The core of a typical single mode fiber would have a diameter of:

- (a) 50 μm
- (b) 50 nm
- (c) 8 μm
- (d) 1 mm

5 Stripping off the primary buffer can be achieved by:

- (a) chemical or mechanical means
- (b) cleaving the buffer off
- (c) isopropyl alcohol
- (d) brushing on index matching gel then wiping off with lint-free cloth

10

Fusion splicing

Fusion splicing is the most permanent and lowest loss method of connecting optic fibers. In essence, the two fibers are simply aligned then joined by electric arc welding. The resulting connection has a loss of less than 0.05 dB, about 1% power loss. Most fusion splicers can handle both single mode and multimode fibers in a variety of sizes but, due to the losses involved, we can only splice multimode to multimode or single mode to single mode. There are also splicers that can automatically splice multicore and ribbon cable up to 12 fibers at a time.

Preparation of the fiber

The fibers must first be stripped, cleaned and cleaved as we have seen in Chapter 9. To allow spare fiber for easy access and to allow for several attempts, a length of at least five meters of jacket should be removed. The primary buffer is only stripped to about 25 mm. The exact length is determined by the fusion splicer in use.

The quality of the cleave is of paramount importance. However much money we spend on buying the most sophisticated splicing apparatus, it will all be wasted if we cannot cleave the fiber accurately. Both cleavers and splicers come in a range of prices with splicers being the more expensive by a factor of at least ten and sometimes a hundred. It is never a good idea to save money by buying an inadequate cleaver – it is always better to buy the cleaver you have confidence in, then, if necessary, recover the money by buying a slightly cheaper version of the splicer. Most splicers nowadays measure the accuracy of the cleave and if found wanting, the fiber is rejected until you have redone it to a satisfactory standard. Most splicers consider an end angle of better than about 3° as satisfactory.

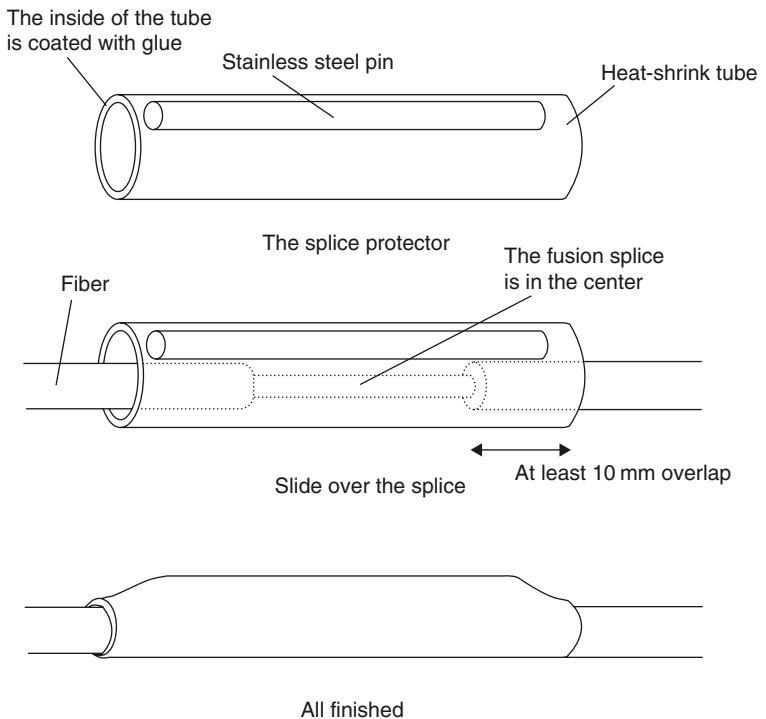
Protecting the fiber

Splice protector

In the preparation phase, we have stripped the fiber of all its mechanical and waterproof protection. Once the fiber has been spliced, some protection must be restored since the splicing process will have reduced the fiber strength to less than 30% of its former value.

This is achieved by a device called a splice protector. It consists of a short length (about 60 mm) of heat-shrink sleeving enclosing some hot-melt glue and a stainless steel wire rod as seen in Figure 10.1.

Figure 10.1
Don't forget
the splice
protector



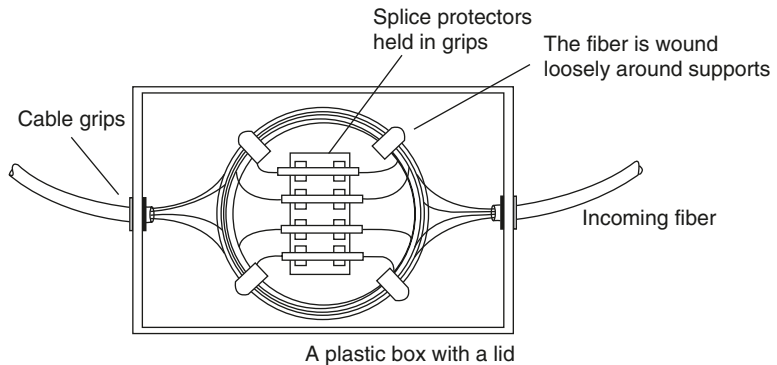
Prior to joining the fiber, the splice protector is slid onto the fiber. After the splice is completed, the protector is centered over the splice and heated, usually in a purpose-built oven although a hot-air gun can be used. The oven is a simple tray with a lid, a heater and a timer, which are normally built-in features of the splicers. The hot-melt glue keeps the protector in position whilst the stainless steel rod provides proof against any bending that may occur. The outer sleeve offers general mechanical and water protection to replace the buffer that has been removed. To ensure that the fiber is fully protected along its length, at least 10 mm of the protector must overlap the primary buffer at each end of the splice.

Enclosures (termination enclosures)

After the splice is completed, we are left with a length of fiber deprived of its outer jacket. The fiber must be protected from mechanical damage, and from water. This is achieved by an enclosure (Figure 10.2). The design, and cost, of the enclosures depend on the environment in which the fiber is going to live.

Figure 10.2

A very simple splice enclosure



Obviously something to protect fiber under water has to be superior to a plastic box in an air-conditioned office.

The significant feature is a means of ensuring that the fiber is well supported within the container in such a way that bending loss is avoided. This is done by having something to wind the fiber around, like a reel which, if enclosed, is referred to as a cassette, or at least a few clips to support the fiber and the splices. Single mode fiber is very sensitive to handling within the enclosure (bend radius infringements, microbending, etc.) whereas multimode is slightly more forgiving.

They are readily available in different sizes to hold everything from four to hundreds of fibers. Each fiber must be identified; otherwise a simple job could become a real nightmare. This is achieved by attaching labels to the fibers or splice protectors and by using colored splice protectors.

There are some other factors to consider which may not immediately spring to mind such as:

- ▷ security of the data: with the outer jacket removed a simple live fiber detector can be clipped onto the fiber and all the data being passed can be copied
- ▷ access to an enclosure is the easy way to sabotage a communication system
- ▷ there is also a problem with light, again with no jacket and as bends are inevitable, there is a risk of light entering the system so the container should be lightproof
- ▷ unpleasant environments: salt spray, acids, high temperatures, crushing and all sorts of other nasties
- ▷ access for repairs or for testing purposes.

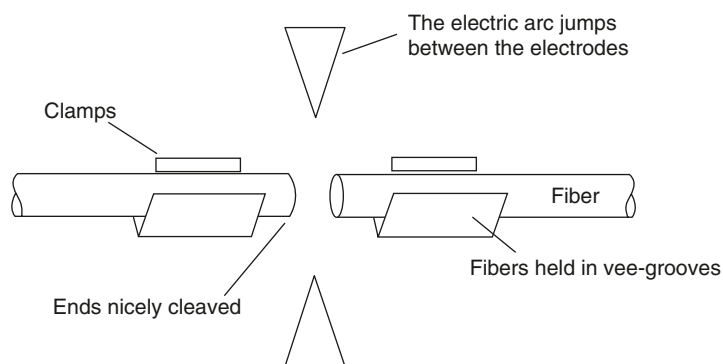
We stripped off five meters of outer jacket to enable the fiber to be lifted out of the enclosure with enough spare fiber to be easily connected to test equipment or a fusion splicer.

Holding and moving the fibers in the splicer

The fibers are held in vee-grooves cut into steel or ceramic blocks (Figure 10.3). As usual, cleanliness is all-important. The fiber is cleaned and cleaved then the vee-groove is cleaned by a lint-free cloth, tissue or a 'cotton bud' moistened with isopropyl alcohol. Do not use compressed air cleaners as any contamination will turn it into a grit blaster and damage the critical dimensions of the vee-groove. The fiber is gently pressed into the vee-groove by a magnetic or gravity clamp.

Figure 10.3

The fiber is held in position



Once the fibers are safely clamped into their vee-grooves, they are moved, vee-grooves and all, until the fibers are aligned with each other and positioned directly under the electrodes from which the electric arc will be produced. We are aiming to achieve positioning with an accuracy of better than $1\ \mu\text{m}$.

In the least accurate splicers, suitable only for multimode fibers, this can be achieved by simple micro gears operated manually. More precision is required for single mode fibers since the core is so much smaller. A $1\ \mu\text{m}$ error in positioning an $8\ \mu\text{m}$ core causes a lateral misalignment of 12.5% whereas the same error on the larger $62.5\ \mu\text{m}$ core in a multimode fiber would represent a lateral misalignment of less than 2%.

The extra precision is provided by using stepper motors or piezo-electric drive blocks. A stepper motor is an electric motor that behaves in a different manner to a 'normal' electric motor. We usually picture electric motors spinning round as power is applied. Stepper motors, instead, turn a set number of degrees and then lock in that position. The amount it turns can be precisely controlled by digital input signals and, in conjunction with a gear train, is able to provide extremely accurate alignment of the fibers.

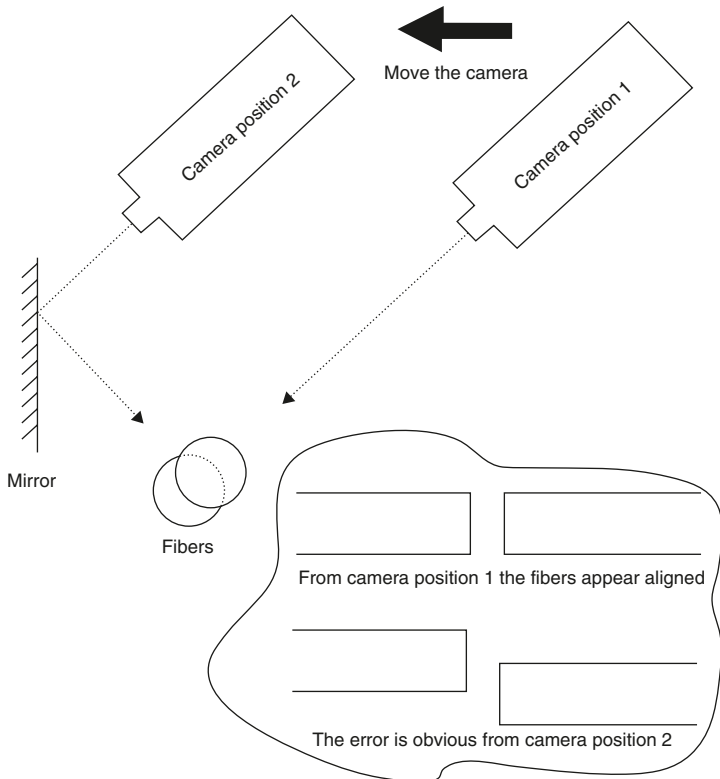
A piezo drive makes use of the property of some crystals to extend or contract when voltages are applied across them. This property is reciprocated because when those same crystals have force applied across them, voltages appear across the affected faces.

Observing the alignment

All fusion splicers are fitted with some means to observe the fiber positioning and the condition of the electrodes. This is achieved by either a microscope or by a CCD camera (CCD = charge coupled device – a semiconductor light sensor) and a liquid crystal display (LCD). The trend is towards CCD cameras since they are more pleasant to use and have the safety advantage of keeping our eyes separated from the infrared light, which can, of course, cause irreparable damage to the eyes if we accidentally observe an active fiber through the microscope.

The optic system always allows viewing from two angles as fibers can otherwise hide one behind the other and appear to be aligned. One way of achieving this is shown in Figure 10.4.

Figure 10.4
Observing the
fiber positions



Automatic positioning

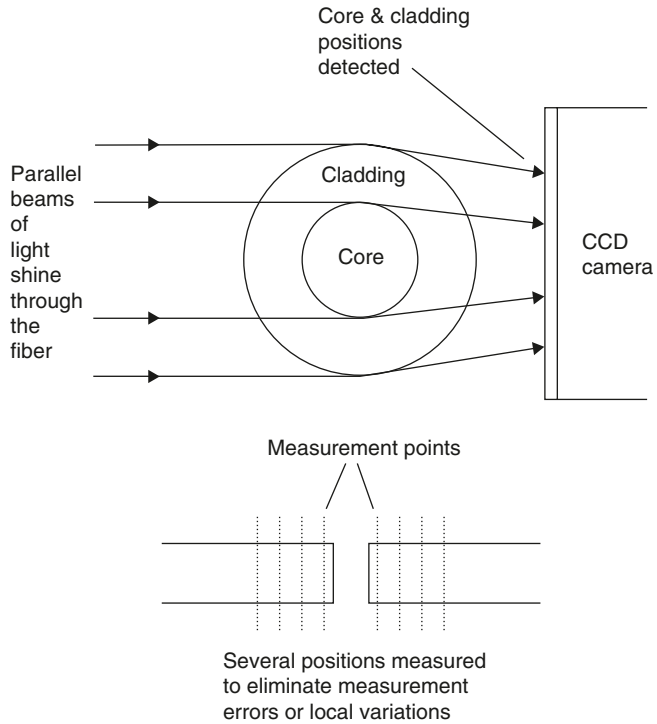
There are two methods.

PAS – the profile alignment system – Figure 10.5

This is the standard method of aligning the fibers in modern fusion splicers. The idea is very simple. A light is shone through the fiber and is detected by a CCD

camera. The change of light intensity at the edge of the cladding and at the core, due to the changes in refractive indices, allows the system to detect their positions. Several readings are taken from each fiber and averaged out to reduce any slight errors.

Figure 10.5
PAS – detecting
the position of
the fiber



Once the positions are detected, small stepper motors are activated to bring the two fibers into alignment. The viewing angle is switched through 90° to allow the system to check in both planes and further small adjustments are made until the splicer is quite satisfied.

The whole operation is usually automatic but we can follow the process on the liquid crystal display. As the system is able to detect the core position as well as the cladding, any eccentricity error in the core can be compensated for.

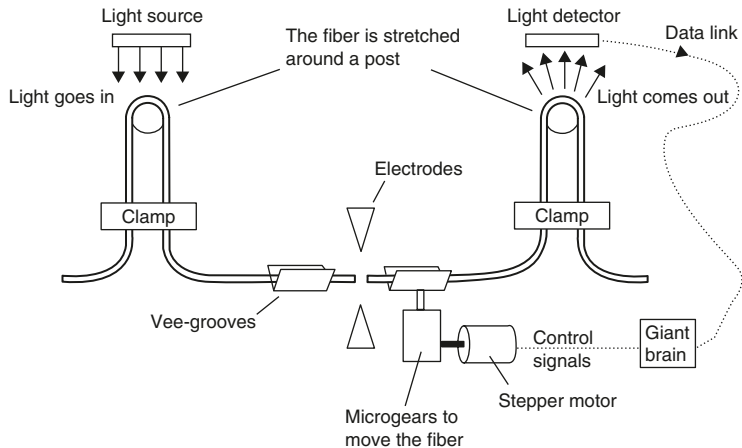
LID – light injection and detection system – Figure 10.6

This system makes use of bend loss, the light leakage that occurs when moderately tight bends are introduced into a fiber. Remember that the light can go into the fiber at a bend as well as being able to escape from it.

A bend is introduced at the input side of the splicer and light is injected into the fiber through the primary buffer. The light travels down the fiber and jumps the gap into the other fiber. A similar bend in the other length of fiber allows light to escape.

A stepper motor or piezo drive is used to move one of the fibers horizontally and the output light is monitored to detect the point of maximum light transfer. This means that the cores are aligned, at least in one plane. The fiber is then moved in the vertical plane until, once again, the point of maximum light transfer is discovered. The whole process is repeated once or twice making finer and finer adjustments until it homes in on the point of best light transfer. Once this has been achieved, the fibers are spliced.

Figure 10.6
A simplified
LID system



Fusion splicing of the fibers

The arc that occurs between the two electrodes is about 7000 volts with an adjustable current up to 25 mA – a very unpleasant and dangerous combination. Safety precautions are built in to splicers to ensure that we cannot accidentally come into contact with the arc. There are two approaches to this problem, the first is to be sure we know where our fingers are before the arc starts. This is done by involving two buttons both of which must be held down during the operation and are spaced so that both hands must be used. The alternative is to enclose the dangerous area with a cover that must be closed before the arc can be energized. Most splicers employ both methods.

Prefuse

The first stage of the fusing process is to align the fibers with an end gap equal to one fiber diameter and apply a short, relatively low power arc. This is called a prefuse. Its purpose is to clean and dry the end surfaces of the cleaves so that nothing untoward gets trapped inside the splice. It can remove very slight tangs from the cleave but don't expect miracles, it won't repair a poorly prepared fiber.

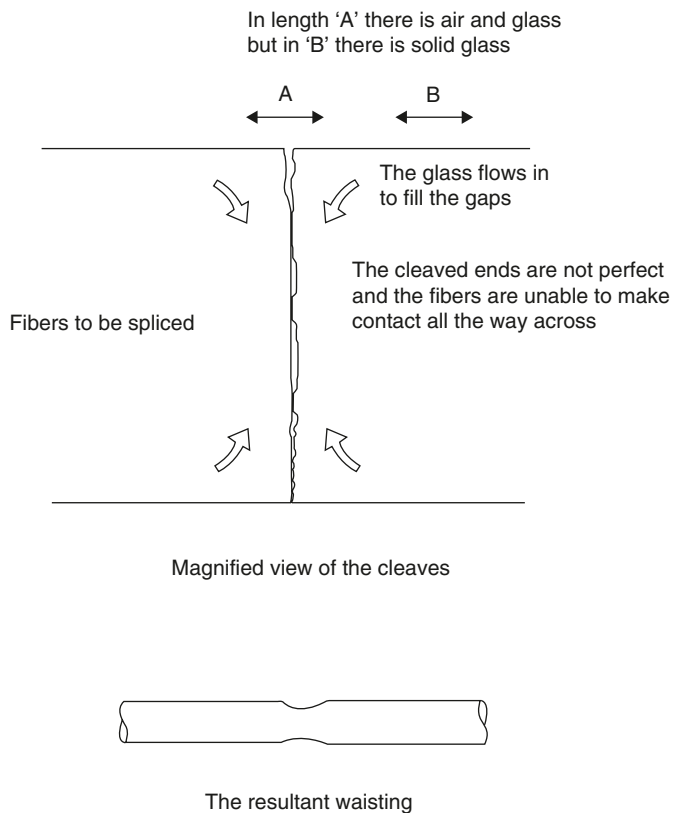
Main fuse

The fibers are then brought together and some additional end pressure is applied. The additional pressure allows the fibers to move towards each other slightly as

they melt. How far they move, called the *overfeed*, *autofeed* or *stuffing distance*, is critical. Too much or too little and the splice will not be satisfactory.

The reason for introducing the overfeed is illustrated in Figure 10.7. In the figure, the cleaved end of the fiber is shown greatly magnified and, even with a good cleaver, the surface is never completely smooth. When two fibers are brought together there are some small air gaps present which means that within the area marked A there is actually less glass than in a similar length, shown as B. When the electric arc melts the end of the fiber, the glass tends to collapse inwards, filling the air gaps. This produces some waisting as shown in 'Splicing disasters!' (see Figure 10.9).

Figure 10.7
The need for
some overfeed

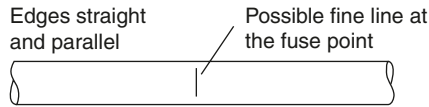


The main fusing arc is more powerful and lasts for a longer period of time, between 10 and 20 seconds.

If the splicer is fitted with a microscope, it is important to check in the instruction book to see if the fiber can be viewed during splicing. The arc emits ultraviolet light and as the microscope concentrates the light there is a danger of suffering from arc-eye, a temporary or permanent damage to the eyes. This is the result of electric arc welding without eye protection. Most viewing microscopes have a UV filter (and an infrared filter) to prevent eye damage, but check the manual first. This is another advantage of choosing one with a CCD camera and monitor.

Figure 10.8

This is what we
hope to see



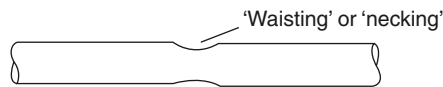
Once fusing is completed have a good look at the splice. If it is difficult to see where the splice is, then it's probably a good one (Figure 10.8). We are looking for the outer edges of the cladding to be parallel, just like a new continuous length of fiber. Sometimes a small white line appears across the core but this is not important and can be ignored. See Figure 10.9 for all the disasters.

Figure 10.9

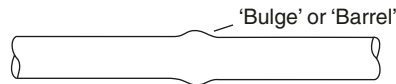
Splicing
disasters!



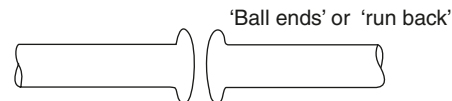
Misaligned – more likely on manual multimode splicers



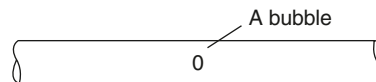
Stuffing distance too short or
fuse time too long



Stuffing distance too short



Arc current too high



Fiber contamination, incorrect arc current
or possibly poor fibers



Incomplete fusion

Setting up the splicer

Different types of fibers require particular values of arc current and lengths of time since this determines the temperature to which the fiber rises. There are several automatic programs installed as well as user-defined settings that we can employ in the light of experience.

The equipment is powered by nicad batteries giving up to 300 splices per charge, somewhat less (50 or so) if the oven is used to shrink the splice protector.

Automatic splice testing

When the splice is completed, the fiber positions are rechecked and an estimated splice loss is calculated and displayed. Although the estimate is reasonably accurate, it is only an estimate and not a measurement. To be really certain, the loss must be measured and this must be done after the splice protector has been fitted, just in case the splice is damaged during this operation. Testing is described in Chapter 15.

Some splicers also provide a tensile test – just a gentle pull of 200 grams or so. It won't damage the fiber but will test the mechanical integrity of the splice.

Practical summary – how to do it

- 1 Consult the instruction books of the splicer and the splice protector to find the recommended stripping lengths of the primary buffer.
- 2 Strip off the outer jackets and the required length of the primary buffer.
- 3 Slip on a splice protector.
- 4 Clean the fiber.
- 5 Cleave it.
- 6 If you are not familiar with the splicer, read the handbook. They all differ in the requirements for loading and positioning the fiber.
- 7 In a typical case, the fibers are inserted into the vee-grooves and moved until the ends of the fibers meet guide lines visible through the lens or camera. Clamp them in position. Have a look at the standard of the cleaves and, if necessary, take the fiber out and try again.
- 8 Set the splicing program to match the fiber in use. The handbook will provide guidance.
- 9 Press the start button and leave it to it. The program will run through its positioning and splicing procedure, and then stop.
- 10 Carefully lift it out of the vee-grooves and slide the splice protector along the fiber until it is centered over the splice. Make sure you have at least 10 mm of primary buffer inside the splice protector and place it gently in the oven. On some splicers, even this is done for you.
- 11 Switch on the oven and in a minute or two it will switch off.

And that's it.

Quiz time 10

In each case, choose the best option.

1 Too much overfeed whilst splicing will cause:

- (a) waisting
- (b) a bubble being formed due to air being trapped inside the fiber
- (c) a bulge in the fiber
- (d) runback

2 The main fusing arc is likely to have a duration of:

- (a) 15 s
- (b) 62.5 ns
- (c) 10–20 minutes
- (d) less than a second

3 PAS stands for:

- (a) position adjustment system
- (b) profile alignment standard
- (c) plane alignment system
- (d) profile alignment system

4 For viewing the splicing process, a CCD camera is preferable to a microscope because:

- (a) higher magnification can be achieved
- (b) better resolution is possible
- (c) there is no risk of eye damage
- (d) a CCD camera can operate at very low light levels

5 A splice protector:

- (a) provides more flexibility at the mechanical joint
- (b) is not needed inside an enclosure
- (c) protects against unauthorized copying of data
- (d) provides mechanical protection to the fusion splice