11

Mechanical splices

The mechanical splice performs a similar function to the fusion splice except that the fibers are held together by mechanical means rather than by a welding technique. Physically, they often look very similar to splice protectors.

Advantages and disadvantages

There are several advantages. They do not require any power supplies. Indeed, many designs require no tools at all beyond a stripper and cleaver, so the mechanical splice can be used in situations that may be considered hostile to many fusion splicers. Mechanical splices are often reusable and can be fitted in less than a couple of minutes, which makes them ideal for temporary connections.

The disadvantage is that they cause a loss, called the *insertion loss*, of about 0.1–0.3 dB per connection, which is significantly higher than a good fusion splice. This would suggest the use of a fusion splice as the first choice in situations where losses are critical.

Mechanical splices can be used to connect either single mode or multimode fibers although the alignment tolerance required for single mode fibers makes demands that mechanical splices struggle to meet.

Cost

On cost grounds alone, the choice between a fusion splicer and mechanical splices depends on the number of splices to be undertaken. If we already have a fusion splicer, the cost of each fusion splice is negligible but for the cost of a reasonably good fusion splicer we could purchase a thousand or more mechanical splices. It is also possible to hire fusion splicers and other fiber optic equipment.

It is clear though that for somebody in the business of making hundreds of splices a year, fusion splicing would be the obvious economic route to follow.

How they work

In essence, it is very easy. The fiber must be stripped, cleaned and cleaved. They must then be aligned and then held in position either by epoxy resin or by mechanical clips.

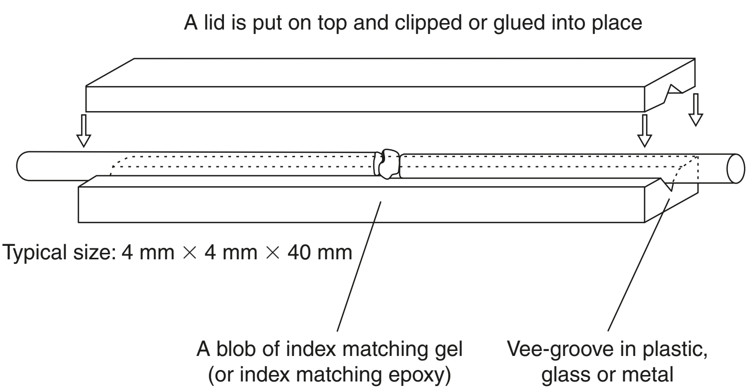
There are only three basic designs.

Vee-groove

This was the obvious choice since it worked so well in positioning the fibers in the fusion splicer. See Figure 11.1.

Most mechanical splices are designed around the vee-groove. They consist of a base plate into which the vee-groove has been cut, ground or molded. The prepared fibers are placed in the groove and their ends are brought into contact. Some index matching gel is used to bridge the gap between the two ends to prevent gap loss and to reduce Fresnel reflection. A gripping mechanism then holds the fibers in position and provides mechanical protection for the fiber. As an alternative to the index matching gel, an index matching epoxy can be used. This performs the same index matching task as the gel but also holds the fiber in position. It is usually cured by UV light. The long-term performance of index matching gels, especially in hot, dry conditions has been questioned.

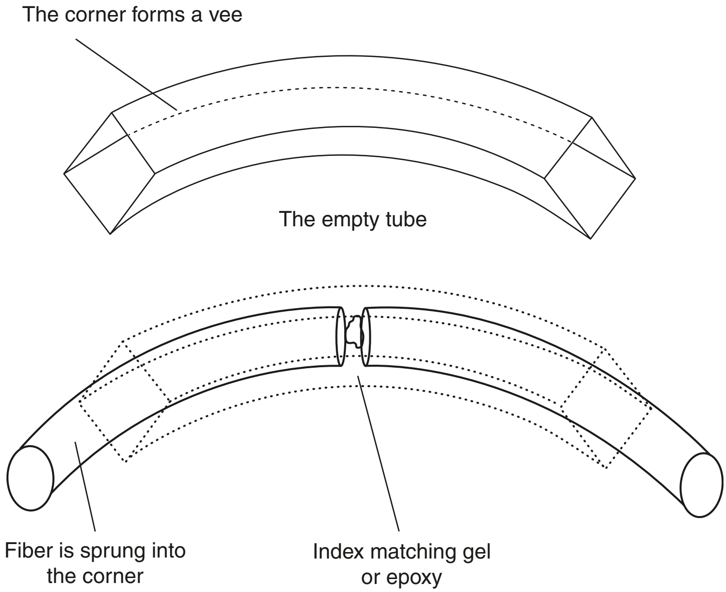
Figure 11.1 The principle of most mechanical splices



Bent tube – Figure 11.2

If a length of fiber is pushed into a tube which is curved, the springiness of the fiber will force it to follow the outside of the curve. Now, if the tube is of square cross-section, the fiber will follow the far corner. This is very similar to a vee-groove since the fiber is now positioned by a vee-shaped wall of the tube. This is called a *bent tube* design. A small spot of index matching gel is added before the fibers are inserted. In some designs, a bent tube with a circular cross-section is used, but the principle is just the same.

Figure 11.2
The bent tube design



Precision tube

This type is very simple. A hole, very slightly larger than the fiber diameter is formed through a piece of ceramic or other material. When a piece of bare fiber is inserted from each end, the two fibers are inevitably aligned when they meet. The insertion losses are higher than the other types due to tolerances in the hole diameter.

Specifications

The specifications will give information about several things.

Cladding and buffer diameter

The cladding diameter will usually be 125 μm for most fibers. The buffer diameter is likely to be either 250 μm or 900 μm.

Insertion loss

This is the loss caused by the device when it is installed in the system. Typical values are around 0.2 dB.

Return loss

This is the proportion of the incoming light that is reflected back along the fiber. Usually between −40 dB and −60 dB. The low loss is the result of adding the index matching gel to reduce Fresnel reflection.

Fiber retention

How much tension can be applied to the completed splice before the splice fails? The failure mode may be obvious and catastrophic as in the fiber actually becoming disconnected or the ends of the fiber being pulled apart very slightly causing enormous gap loss but no visible damage. Typical values are around 4 N but some are much more rugged with figures up to 180 N when the correct external protection is applied.

A practical guide to fitting a typical mechanical splice

All mechanical splices come with an instruction sheet. It is essential that the time is taken to read it as each splice has a slightly different fixing method. As mentioned earlier, some are permanent fixings using epoxy resin and some are designed to be reusable. It is not a good idea to pump in epoxy resin first, and then settle down to read the instructions!

1. Strip, clean and cleave the fiber leaving about 12 mm of primary buffer removed.
2. If reusing the splice (if this is possible), clean with isopropyl alcohol and a piece of lint-free cloth and use a syringe to inject a small bead of index matching gel into the center of the splice.
3. Release the small clip at one end of the splice and insert the fiber until it comes to a stop. Operate the clip to lock the fiber in position.
4. Release the clip at the other end and insert fiber until it comes up against the fiber already loaded. Operate the clip to lock that fiber also.
5. Test the operation and if not satisfactory the clips can be released to allow the fiber positions to be optimized.

Quiz time 11

In each case, choose the best option.

1 The three basic designs used for mechanical splices are:

(a) vee-groove, bent tube and precision hole

(b) vee-groove, PAS and LID

(c) fusion splice, mechanical splice and enclosures

(d) UV curing epoxy, index matching gel and isopropyl alcohol

2 A typical value for the insertion loss for a mechanical splice is:

(a) −50 dB

(b) 0.2 dB

(c) 12 mm

(d) 3 dB

3 Mechanical splices have the advantage that they:

(a) are easily mistaken for splice protectors

(b) have lower losses than fusion splices

(c) are quick and easy to fit

(d) are waterproof

4 A mechanical splice:

(a) always requires an electrical supply

(b) usually takes less than two minutes to complete

(c) does not require any mechanical protection

(d) is only suitable for multimode fiber

5 Some designs of mechanical splice can be easily mistaken for:

(a) an enclosure

(b) a PAS splicer

(c) a splice protector

(d) an all plastic fiber

12

Connectors

Connectors and adapters are the plugs and sockets of a fiber optic system. They allow the data to be re-routed and equipment to be connected to existing systems. Connectors are inherently more difficult to design than mechanical splices. This is due to the added requirement of being able to be taken apart and replaced repeatedly. It is one thing to find a way to align two fibers but it is something altogether different if the fibers are to be disconnected and reconnected hundreds of times and still need to perform well.

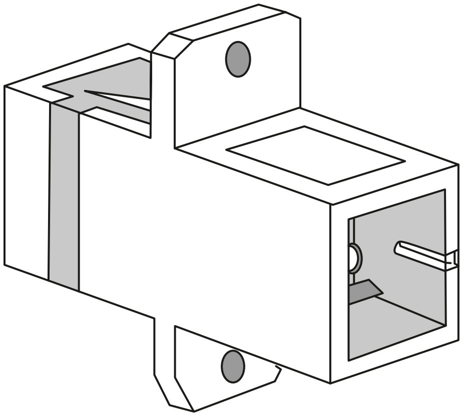
If two fibers are to be joined, each fiber has a connector attached and each is then plugged into an adapter. An adapter is basically a tube into which the two connectors are inserted. It holds them in alignment and the connectors are fixed onto the adapter to provide mechanical support. An adapter is shown as part of Figure 12.1.

Although different makes are sold as compatible, it is good practice to use the same manufacturer for the connector and for the adapter.

The design of connectors originated with the adaptation of those used for copper based coaxial cables, which were usually fitted by the manufacturers onto a few meters of fiber called a *pigtail* which was then spliced into the main system.

Most connectors nowadays are fitted by the installer although pre-fitted ones are still available. The benefit of using the pre-fitted and pigtailed version is that it is much quicker and easier to fit a mechanical splice or perform a fusion splice than it is to fit a connector, so there is some merit in allowing the factory to fit the connector since this saves time and guarantees a high standard of workmanship.

Figure 12.1
Optical
adapter



When a connector is purchased, it always comes with a plastic dust cap to prevent damage to the polished end of the optic fiber. It is poor workmanship to leave fibers lying around without the caps fitted.

Before considering the details of the various types of connector, we will look at the main parameters met in their specifications so that we can make sense of manufacturers' data.

Connector parameters

Insertion loss

This is the most important measure of the performance of a connector. Imagine we have a length of fiber which is broken and reconnected by two connectors and an in-line adapter. If the loss of the system is measured and found to have increased by 0.4 dB then this is the value of the insertion loss. It is the loss caused by inserting a mated pair of connectors in a fiber. Insertion loss for optical connectors only makes sense when considering the loss across two mated connectors, so when a manufacturer claims a loss of x dB per connector they really mean the loss across a mated pair of those identical connectors.

Typical values are 0.2–0.5 dB per mated pair but the international standards recognize and allow a loss of up to 0.75 dB and this would be considered a compliant connector.

Return loss

This is a measure of the Fresnel reflection. This power is being reflected off the connector back towards the light source. The lasers and LEDs used for multimode working are not greatly affected by the reflected power and so the return loss is not usually quoted in this instance. In single mode systems the laser is affected and produces a noisy output. The laser suppliers will always be pleased to advise on permitted levels of return loss.

Typical value: −40 dB.

Mating durability

Also called *insertion loss change*. It is a measure of how much the insertion loss is likely to increase in use after it has been connected and disconnected a large number of times.

Typical value: 0.2 dB per 1000 matings.

Operating temperature

These are, of course, compatible with the optic fiber cables.

Typical values: −25°C to +80°C.

Cable retention

Also called *tensile strength* or *pull-out loading*.

This is the loading that can be applied to the cable before the fiber is pulled out of the connector. It is similar in value to the installation tension on a lightweight cable.

Typical value: 200 N.

Repeatability

This is a measure of how consistent the insertion loss is when a joint is disconnected and then remade. It is not a wear-out problem like mating durability but simply a test of whether the connector and adapter are designed so that the light path is identical each time they are joined.

This is an important feature of a connector but is not always quoted in specifications owing to the difficulty in agreeing a uniform method of measuring it. Some manufacturers do give a figure for it; some just use descriptive terms like ‘high’ or ‘very high’. The quoted insertion loss should actually be the average insertion loss over a series of matings, thus taking repeatability into account.

Color schemes

There is a color scheme advised by the international standards which states that there should be a color-coding scheme on the ‘visible’ part of the connector bodies and adaptors.

- ▷ Multimode Beige
- ▷ Singlemode Blue

In addition, ISO 11801:2002 adds that single mode APC connectors shall be green.

A survey of the main connectors

The first connectors were machined from solid brass and had to be factory fitted. Indeed there seemed to be a policy by manufacturers to preserve the ‘factory fitted’ requirement. Then one or two companies sold connectors that could be

Table 12.1 Standards and their approved connectors

Standard	Connector description
IEC 61754-1 (1996-12)	Fiber optic connector interfaces – Part 1: General and guidance
IEC 61754-2 (1996-12)	BFOC/2,5 connector
IEC 61754-3 (1996-12)	LSA connector family
IEC 61754-4 (2002-03)	SC connector family
IEC 61754-5 (1996-12)	MT connector family
IEC 61754-6 (2004-11)	MU connector family
IEC 61754-7 (2000-11)	MPO connector family
IEC 61754-8 (1996-10)	CF08 connector family
IEC 61754-9 (1996-12)	DS connector family
IEC 61754-10 (2000-07)	Mini-MPO connector
IEC 61754-12 (1999-08)	FS connector family
IEC 61754-13 (1999-03)	FC-PC connector family
IEC 61754-15 (1999-09)	LSH connector family
IEC 61754-16 (1999-10)	PN connector family
IEC 61754-18 (2001-12)	MT-RJ connector family
IEC 61754-19 (2001-10)	SG connector family
IEC 61754-20 (2002-08)	LC connector family
IEC 61754-21	SMI connector for plastic fibre
IEC 61754-22	F-SMA connector family
IEC 61754-23	LX5 connector family

fitted with simple hand tools and very quickly the advertisements changed to 'easily fitted'.

Once installed, connectors can last for many years and so earlier designs are still met during maintenance work and are included in this chapter. These oldies are even now available in current catalogs.

For new installations, there are a number of connectors approved by the various ISO and IEC standards. They are listed in Table 12.1.

The main connectors encountered in multimode installations are the ST, SC, LC and MT-RJ. Single mode equipment is commonly fitted with the FC-PC, amongst others. Optical connectors are shown in Figures 12.2, 12.4, 12.5, 12.6 and 12.7.

Apart from the connector style itself, one must also consider whether it is the single mode or multimode version. Outwardly they look identical but a single mode connector and its associated adapter will be made to a tighter tolerance reflecting the very small core diameters of single mode fibers and the need for absolute accuracy when connecting them. Multimode fibers would be very happy in connectors designated as single mode, but putting single mode fibers into multimode connecting equipment would be inviting high losses.

Some connectors, aimed at single mode fibers, also need the method of polishing the end face defined, e.g. flat or at an angle. We might intuitively think that a face-to-face flat connector face would be ideal, but this can lead to return losses being reflected right back down into the laser. So, putting a slight angle across the face will reduce the amount of return loss. These kinds of connectors are called Angle Polished Connectors, APCs.

The largest variance comes from the method used in fixing the fiber to the connector. These are all defined in the following list.

Termination methods

Choosing an optical connector is one thing but how it is fitted to the optical fiber is another issue and there are seven different ways of doing it. The method of termination will have a big impact upon the quality of the termination, time spent on-site and of course overall cost. Usually more expensive connection methods mean less time spent on-site and vice versa.

- ▷ Heat cured epoxy. Sometimes called 'pot-and-polish'. The fiber is first stripped of its primary coating down to the 125 micron cladding layer. Adhesive is injected into the back of the ferrule with a special hypodermic needle. The fiber is then pushed into the back of the ferrule until it protrudes from the front face. The connector is then placed in a specially constructed oven for about ten minutes. The adhesive cures and sets permanently after this time. The protruding fiber end is cleaved off with a scribe and then the connector end-face is polished on a series of abrasive papers. The different grades of abrasive paper have a smaller and smaller grit size until the end of the fiber is perfectly smooth and polished and level with the face of the connector. The fiber end is then inspected with a special microscope, such as a Priorscope, and if it looks optically good it is passed as fit for purpose. The connector may also be optically tested by mating it with a known test connector and measuring the attenuation across the two end faces with a power meter and light source. The whole process, excluding the power meter test, takes about 12–15 minutes per connector. The end result however is a permanent and usually high quality optical termination with good thermal stability.
- ▷ Cold-cure or anaerobic. The fiber is stripped and an adhesive is injected into the back of the ferrule. But this time the adhesive is part of a two-component system. The adhesive is only cured when it comes into contact with an activator. After preparing the fiber and injecting the adhesive into the ferrule, the bare fiber is dipped into the liquid activator. Before the activator can evaporate, the fiber is pushed into the back of the ferrule. Within ten seconds or so the activator and adhesive have reacted and set. The protruding fiber end is then cleaved and polished as before. There is no need for oven curing.
- ▷ Ultraviolet cured. The fiber and adhesive are prepared as before but it is ultraviolet light that cures the adhesive. Once the fiber has been pushed into the back of the ferrule it must be exposed to a strong ultraviolet light. After a few tens of seconds the adhesive is cured. The protruding fiber end is then cleaved and polished as before.

- ▷ Hot-melt. In this method the ferrule is preloaded with an adhesive which softens when heated and then hardens again at room temperature. The ferrule is first heated in a special oven until the adhesive becomes soft enough for the fiber to be pushed through. The connector is left until it has cooled down and the adhesive has set again. The protruding fiber end is then cleaved and polished as before.
- ▷ Crimp and cleave. A very different method, but one promoted for its speed, is called crimp and cleave. The prepared fiber is pushed into the back of the fiber and simply crimped there. The fiber is then cleaved and may be polished to a small extent. Some questions have been raised about the effect of long-term temperature cycling performance on this style. The coefficients of thermal expansion for glass and ceramic (or polymer) are different. As the temperature goes up and down an effect called pistoning may take place if the fiber is not permanently secured in the ferrule, i.e. the fiber will try and retract down the ferrule when it gets colder and will try and protrude beyond the ferrule when it gets hotter.
- ▷ Splicing pre-made tails. All the above methods are suitable for on-site termination by the installer. A different approach is to terminate the fiber, using any of the above methods, in a clean factory environment, onto a half a meter or more of tight-buffered fiber. This is called a *tail*, a *tail cable* or a *pigtail*. The installer will then splice the tail, by fusion or mechanical means, onto the end of the main fiber. This method is preferred when the installation site is very dirty or otherwise difficult to work in and is the main method chosen for single mode fiber systems.
- ▷ Hybrid mechanical splice connectors. A mechanical splice is a precision made tube, 126–128 microns internal diameter, that allows two accurately cleaved fibers to be brought into contact with each other. The hybrid connector is a factory-terminated connector with the fiber tail pre-mounted into one half of a mechanical splice. On site the installer merely has to cleave the optical fiber and push it into the other side of the splice where it is retained either by glue or by crimping. This method gives quick and high quality results, but at a price.

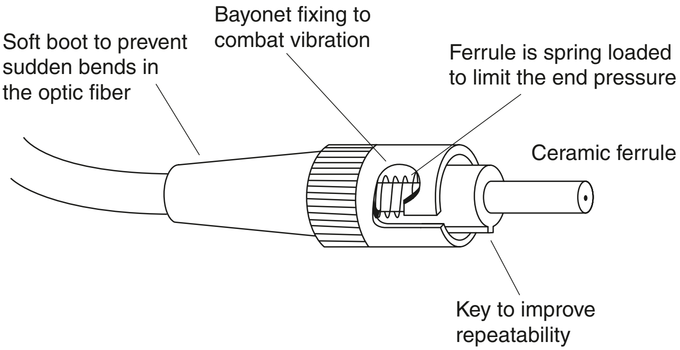
ST (straight tip) – Figure 12.2

This was developed by the US company, AT&T, to overcome many of the problems associated with the first widespread optical connector known as the SMA. The ST was the main choice of connector in the data communications world for many years before being slowly overhauled by the SC connector. The ST is also available for single mode systems but is not a common connector in that arena.

The problem of repeatability seen in earlier connectors is overcome by fitting a key to the connector and a corresponding keyway cut into the adapter. There is now only one position in which the connector can fit into the adapter.

The screw thread of the old SMA has been replaced by a bayonet fitting so that there is no worry about the connector becoming loose when exposed to

Figure 12.2
The ST connector

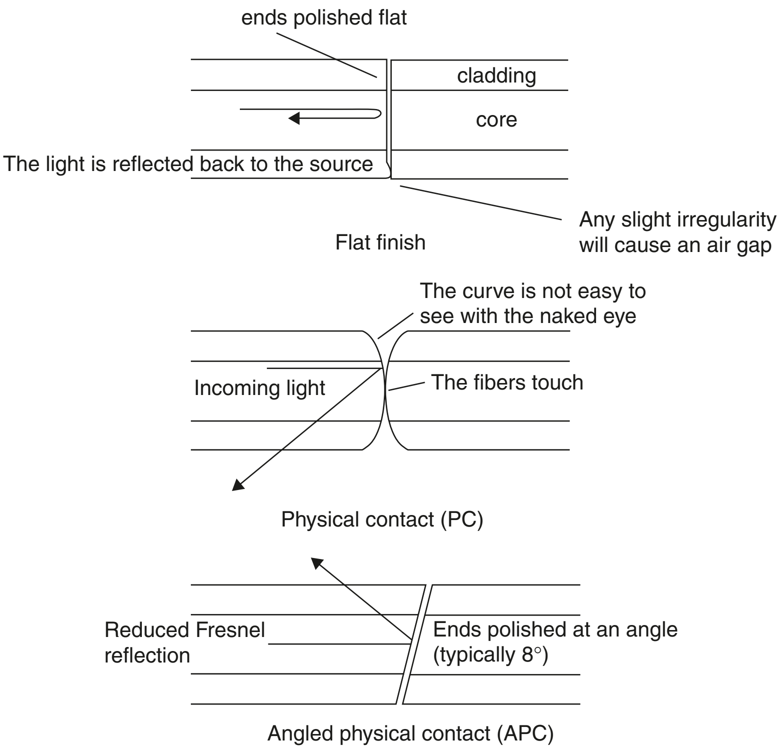


vibration. The ferrule is spring loaded so that the pressure on the end of the ferrule is not under the control of the person fitting the connector.

Polishing styles – Figure 12.3

The fiber through the center of the connector is polished during the assembly of the connector to improve the light transfer between connectors. There are three different styles called flat finish, physical contact (PC), and angled physical contact (APC). Many of the connectors are offered in different finishing styles

Figure 12.3
The alternative finishes



so we see the connector name with a PC or APC added on the end. If nothing is mentioned, we assume a flat finish.

A flat finish is simply polished to produce a smooth flat end to the fiber so that the light comes straight out of the connector within the acceptance angle of the other fiber. In the case of the PC finish, the fiber is polished to a smooth curve. There are two benefits of a PC connector. As the name implies, the two fibers make physical contact and therefore eliminate the air gap resulting in lower insertion losses. The curved end to the fiber also reduces the return loss by reflecting the light out of the fiber.

The APC finish results in very low return losses. It is simply a flat finish set at an angle of typically 8°. The effect of this is that when the Fresnel reflection occurs, much of the reflected power is at an angle less than the critical angle and is not propagated back along the fiber.

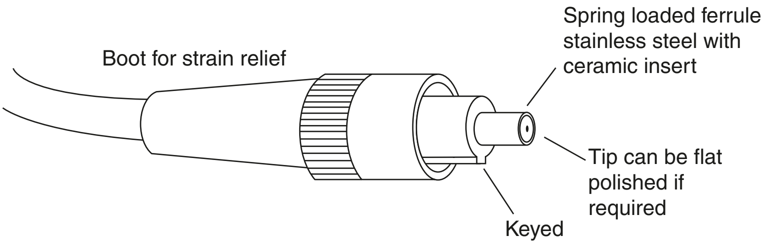
Fiber connector, physical contact (FC-PC) – Figure 12.4

This connector is also available as FC (flat finished) or FC APC (angled physical contact).

The FC-PC is a high quality connector designed for long-haul single mode systems and has very low losses. It can also be used for high quality multimode work if required and is often found on test equipment.

The ferrule can be steel or ceramic inset in steel and is spring loaded or *floating*. The end of the fiber is polished into the curved PC pattern. It can be polished flat if required and in this case it loses its PC suffix and just becomes an FC connector.

Figure 12.4
The FC-PC connector



Subscriber connector (SC) – Figure 12.5

Also available in PC and APC versions and suitable for single mode and multimode systems, it is illustrated in Figure 12.5.

This connector was designed for high performance telecommunication and cable television networks but is now the mainstay of data communications networks. There is a different feel about this connector when compared with the previous types. The body is of light plastic construction and has a more *domestic* or *office* feel about it. It has low losses and the small size and rectangular shape allow a high packing density in patch panels. It plugs into the adapter with a very positive click action, telling us it's definitely engaged.

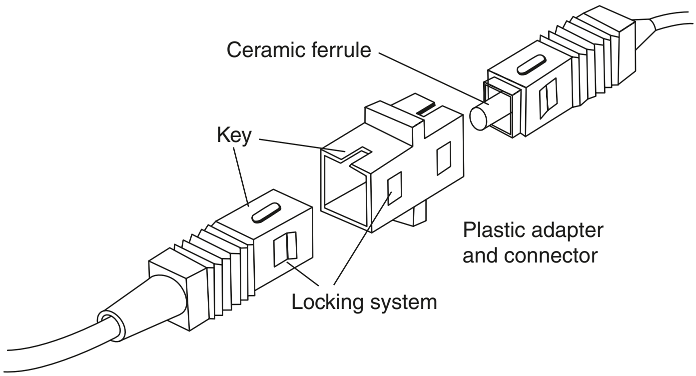


Figure 12.5 The SC connector

The SC is now usually specified in its duplex form, which is essentially two single connectors held together in a plastic shroud to form a double fiber, or duplex, circuit.

The LC connector – Figure 12.6

The LC connector is one of the new generation of optical connectors that attempts to fit a duplex (i.e. two fibers) into roughly the same space as taken up by a copper RJ45 data connector, and is generically given the title *Small Form Factor* or *SFF*. The LC connector looks very similar to a duplex SC connector but scaled down by about 50%.

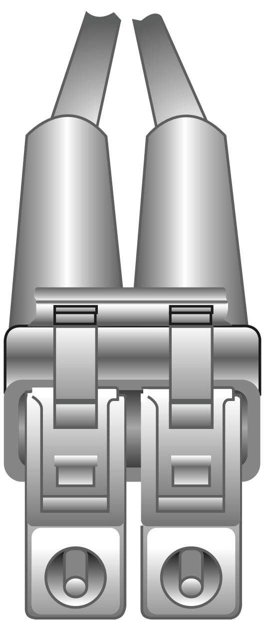
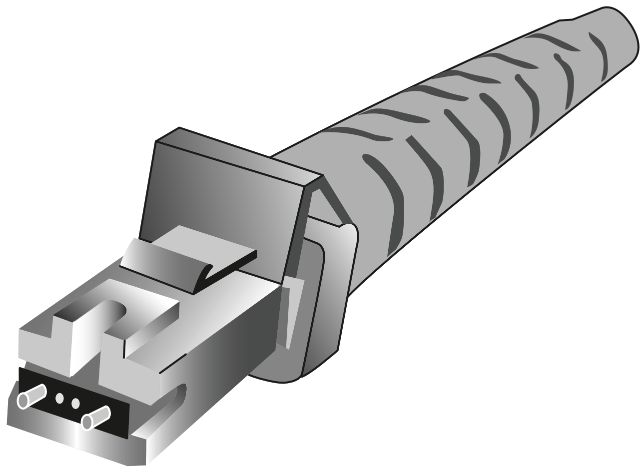


Figure 12.6 The LC connector

The MT-RJ connector – Figure 12.7

The MT-RJ is the other leading contender in the new duplex SFF optical connector market. It is based on the original NTT MT or *mass termination* ferrule specifically for ribbon fiber cables. The MT-RJ only accommodates two fibers but the rectangular ferrule it is based upon could have had 4, 8, 12 or even 16 fibers terminated within it. Two alignment pins sit at either end of the ferrule giving this connector, unusually for fiber connectors, female and male versions, i.e. depending upon which ferrule gets the pins.

Figure 12.7
The MT-RJ connector



The MPO accommodates the MT ferrule in a spring loaded plastic housing and the MT-RJ is a logical development from that.

Adapters

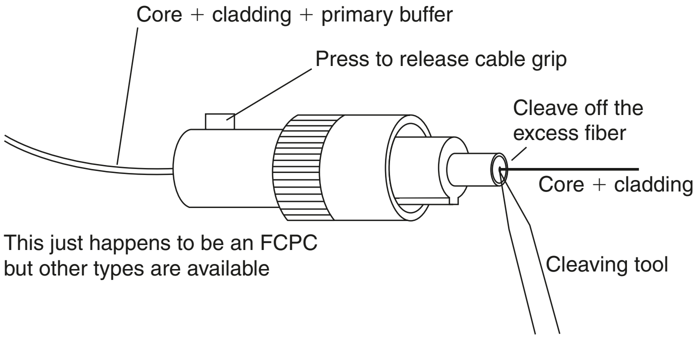
Generally a system is designed to use the same type of connector throughout, and to ensure complete compatibility, and hence best performance, they are normally sourced from the same manufacturer.

Occasionally however, we meet two new problems.

The first is to connect two cables fitted with non-compatible connectors, say, an ST connector to one fitted with an SC connector. Such problems are easily solved by a wide range of 'something-to-something' type adapters. Some of these adapters do introduce a little extra insertion loss but not more than about 1 dB.

The second is to join a bare fiber to a system, quickly and easily, perhaps to connect a piece of test equipment or to try out a new light source. This is achieved by a bare fiber adapter. This is a misleading name since it is actually a connector, as can be seen in Figure 12.8. It is really a bare fiber connector since it has to be plugged into an adapter. The only difference is that the fiber is

Figure 12.8
A bare fiber adapter



held in position by a spring clip rather than by epoxy so that it can be readily reused.

Fitting the bare fiber adapter

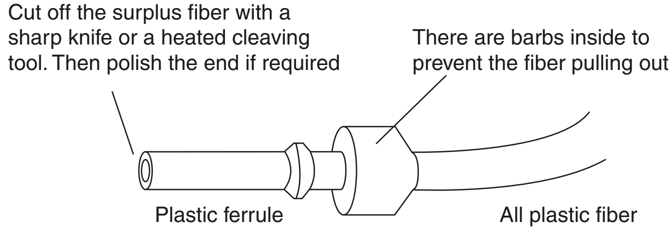
1. Strip off the primary buffer for about 25 mm or so and clean the fiber.
2. Press the cable grip and push in the fiber until it comes to a stop then release the cable grip. The primary buffer will not pass down the ferrule.
3. Cleave off the bit that sticks out of the end of the ferrule.

Obviously the results depend on the quality of the cleave and are not as good as with a permanently fitted connector.

Plastic fiber connector – Figure 12.9

Plastic fiber connectors are very quick and easy to fit but the insertion loss is higher than normal for glass fibers – between 1 dB and 2 dB. The cables are connected in the usual method of having two connectors plugged into an inline adapter. Sometimes the end of the plastic fiber is polished using a simplified version of the techniques used on glass fiber and sometimes it is cleaved off as in the bare fiber adapter.

Figure 12.9
A connector for plastic fibers



Fitting a plastic fiber connector

1. The outer jacket (2.2 mm) is stripped off for about 25 mm.
2. The fiber is pushed into the connector as far as it will go.

3 The end is cleaved or polished according to the manufacturer's instructions.

Note: there are barbs inside the connector to prevent the fiber pulling out in use. This also means that, once assembled, it is very difficult to get the connector off again so we need to study the instructions before the fiber is inserted.

Optical patchcords

We mustn't forget the role that optical patchcords play in the practical use of a fiber optic cable system.

A patchcord is a short length of a simple optical cable, typically one to five meters, that is used to connect the active or final equipment into the cable plant, usually by way of the patch panel.

The patchcord can be of a single fiber, simplex, or two fibers, duplex. If it is duplex then the convention is to cross the circuit so that A goes to B and B to A, as seen in Figure 12.10.

Figure 12.10 Optical patchcord with crossover

The patchcord must incorporate exactly the same fiber as is contained within the rest of the cable plant. There is no reason why the connectors on each end need to be the same. What is important is that one end of the patchcord matches that found on the active equipment and the other end matches the patch panel.

Terminating a silica glass optic fiber (fitting the connector)

To avoid the job altogether, buy the connector already attached to a pigtail. Everything is done for us; all we have to do is to join it to the rest of the system by means of a fusion splice or mechanical splice.

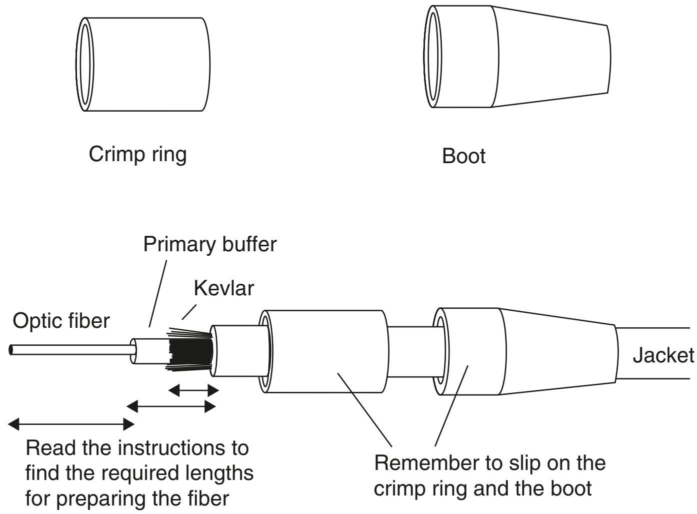
The most usual method is called glue and polish, or epoxy polish or *pot-and-polish*. In essence, all that happens is that the fiber is stripped, glued into the connector and the end of the fiber is polished with abrasive film.

As usual, it is most important that we take some time out to read the instructions. It can save a lot of time and money in second attempts.

Fitting a connector on a silica fiber

1 Strip off the outer jacket, cut the Kevlar, and remove the primary buffer to the dimensions supplied with the connector (Figure 12.11).
2 Slip the flexible boot and the crimp ring onto the fiber. The crimp ring is a metal tube about 10 mm in length which will grip the Kevlar and the connector to provide the mechanical support.

Figure 12.11
Preparing the fiber



3 Clean the fiber with isopropyl alcohol in the way that was done prior to cleaving. Just as a practice run, carefully insert the stripped fiber into the rear of the ferrule and ease it through until the buffer prevents any further movement. If this proves difficult, it may help if the connector is twisted backwards and forwards slightly, but be careful, the fiber must not break. Check that the fiber sticks out from the end of the ferrule. If it does break, the piece of fiber can be released with a 125 μm diameter cleaning wire which is available from suppliers.

4 Mix some two-part epoxy and load it into a syringe. The epoxy is often supplied in a sealed polyethylene bag with the hardener and adhesive separated by a sliding seal. Remove the seal and mix the adhesive and hardener by repeatedly squeezing the bag between the fingers. The mixing process can be aided by the use of a grooved roller which is rolled to and fro across the packet.

5 Insert the syringe into the connector until it meets the rear of the ferrule. Squeeze epoxy in slowly until a tiny bead is seen coming out of the front end of the ferrule. This shows that the ferrule is well coated with epoxy.

6 Carefully insert the stripped fiber into the rear of the ferrule until the buffer prevents any further movement. Again, take care not to break the fiber. If it does break, the fiber must be prepared again, as the dimensions will now be incorrect. The epoxy is very difficult to remove from the ferrule and the cleaning wire is not guaranteed to work under these conditions. Acetone may be helpful. This is a job best avoided.

7 Arrange the Kevlar over the spigot at the back end of the connector and slide the crimp ring over the Kevlar as shown in Figure 12.12. One end of the crimp ring should overlap the spigot and the other should cover the fiber jacket.

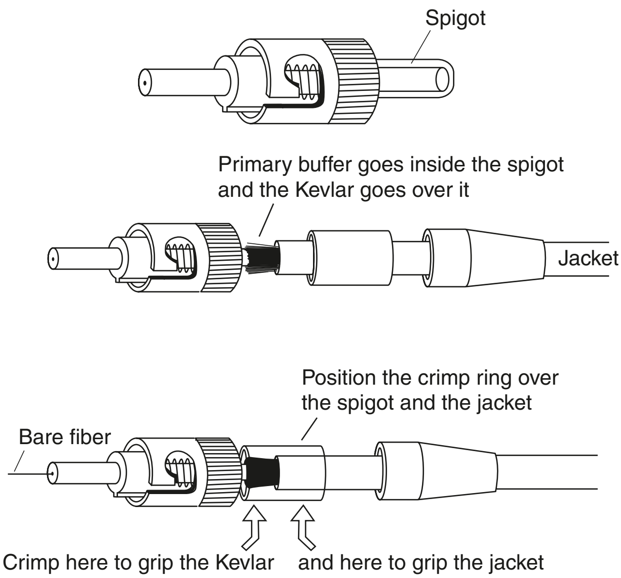


Figure 12.12
Crimping

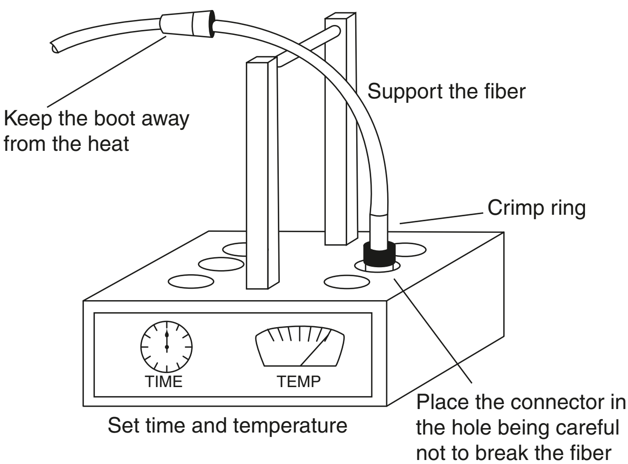


Figure 12.13
The connector goes in the oven

8. Using a hand crimping tool, crimp the Kevlar to the spigot and at the other end of the crimp ring, grip the cable jacket. This ensures that stress is taken by the Kevlar strength members and not by the optic fiber.
9. Put the connector into a small oven to set the epoxy. The oven, shown in Figure 12.13, is an electrically heated block of metal with holes to take the connectors. This will take about ten minutes at 80°C. When cured, the golden epoxy may have changed color to a mid to dark brown.
10. When it has cooled down, fit the boot.
11. Using a hand cleaver, gently stroke the fiber close to the end of the ferrule and lift off the end of the fiber (Figure 12.14). Store the broken end safely in a sealed receptacle for disposal.

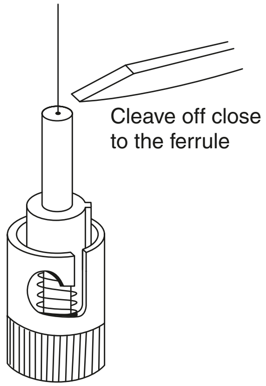


Figure 12.14
Cleave off the surplus fiber

12 The end of the fiber must now be polished. The easy way is to insert the fiber into a portable polishing machine and switch on. After about one minute it's all over; the fiber is polished. The alternative is to do it ourselves, which is fine for flat face finishes but not PC or APC finishes.

13 Consult the instructions at this stage – each manufacturer has a recommended procedure for each type of connector and they usually know best. We will need a flat base of plate glass, hard rubber or foam about 200 mm^2. The abrasive sheet is called a lapping film. It is a layer of aluminum oxide on a colored plastic sheet. Silicon carbide and diamond films are also available. The roughness of the abrasive is measured by the size of the particles and is colored to aid recognition. Grades vary from the coarse 30 μm colored green down to the ultra smooth white at 0.3 μm. Beware – not all types of film employ the same colors.

14 Using a magnifying glass, observe the end of the ferrule to see how much glass is protruding above the tiny bead of epoxy (Figure 12.15). This unsupported glass is easily broken and should be abraded down to the epoxy level by using a strip of coarse grade film (9 μm), held in the hand and stroked gently over the fiber. Be very careful not to apply too much pressure and stop when the epoxy is reached. If the fiber is too long or too much pressure is applied at this stage, the course lapping film will send shock waves down the fiber and it will crack. The crack has the characteristic 'Y' shape shown in Figure 12.16. It runs vertically down into the fiber and no amount of polishing will do anything to help the situation. We have lost a connector and gained some experience.

15 The fiber is supported perpendicular by a polishing tool called a dolly or a polishing guide (Figure 12.17). Each dolly is designed for a particular type of connector to ensure the correct dimensions and fitting mechanisms. The suppliers will always advise on the grades of film and methods to be used. Once again it is worth reading the instructions

Figure 12.15
Carefully remove the surplus fiber

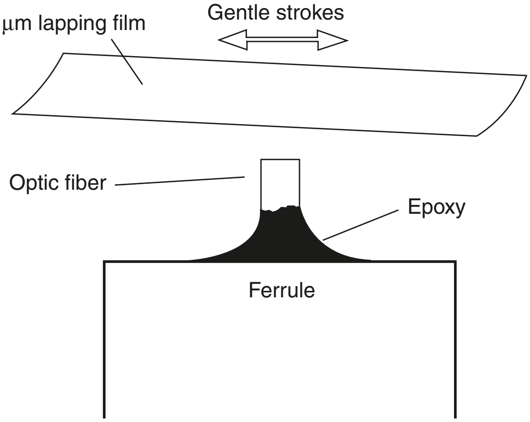
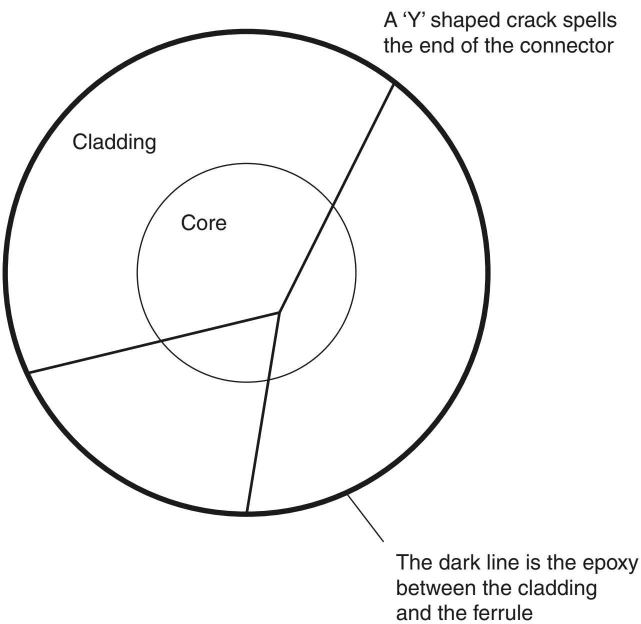


Figure 12.16
A characteristic crack

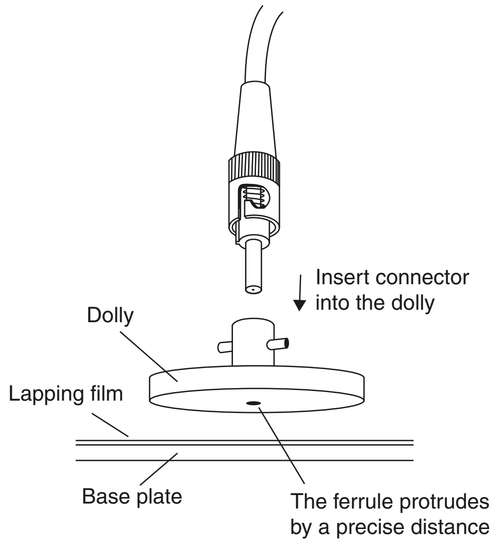


carefully if an unfamiliar connector is being fitted. We start with the coarsest grade recommended, probably about 3 µm. Lay the film on the base material and attach the fiber in the dolly. Using only the weight of the dolly, slide the dolly in a figure of eight pattern for about eight circuits.

16 Using a microscope or magnifying eyeglass, observe the end of the ferrule. There will be a large dark area which is the epoxy. If this is the case, repeat the above stage until the epoxy becomes lighter in color and eventually has a transparent feathered edge.

17 When this happens, remove the 3 µm film and clean the whole area, including the dolly and the connector. Clean it very carefully with a

Figure 12.17



tissue moistened in alcohol or demineralized water. Make quite certain that no trace of abrasive is transferred from one stage to the next.

Cleanliness is essential

18 Using a fine grade, about 0.3 μm, repeat the figures of eight. The end of the fiber takes on a bluish hue with some pale yellow from any remaining resin. Black marks are, as yet, unpolished areas or possibly water on the surface of the ferrule (dry it off before checking). A little more polishing is required as the resin finally disappears. If the end of the fiber is not clear and blue with no marks or scratches, polishing should be continued.

19 Fit a dust cap to protect the fiber.

Some alternatives

Another version of these same connectors is manufactured with hot-melt glue, coating the inside as an alternative to using epoxy. This is convenient since we can always remelt it if we need to reposition the fiber.

Some epoxy resin is cured by ultra-violet light rather than by heat and yet others consist of a two-component adhesive similar to 'superglue'.

The polishing can be performed either dry or wet. Metal ferrules are often polished wet and ceramic dry, but there are too many exceptions to offer this as a rule. If wet polishing is recommended in the instructions, a few drops of wetting agent are applied to the surface of the lapping film. Not too much, otherwise the dolly will tend to aquaplane over the surface without any polishing action.

We should not use tap water as it includes impurities which under the microscope look like boulders and would scratch the surface of the fiber.

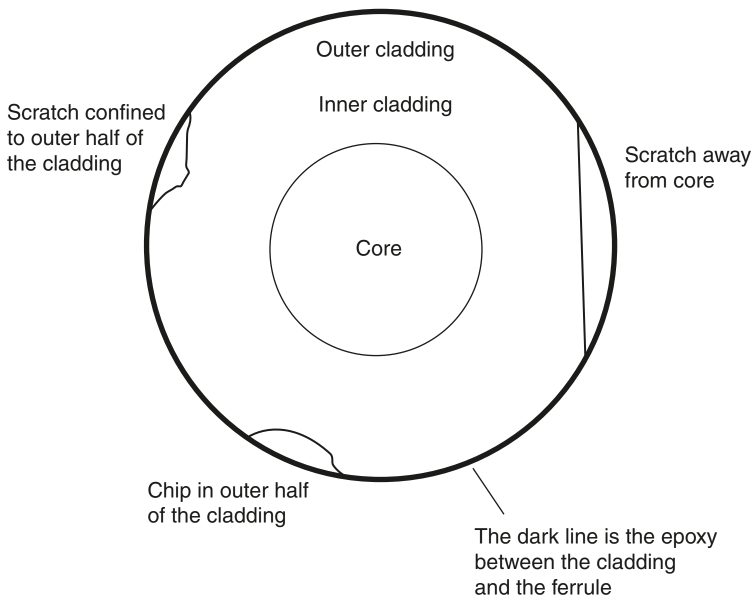
Final inspection

The finished connector should be inspected by a microscope with a magnification of at least 100 times. We are checking for surface scratches and chips caused by the polishing and also for cracks within the fiber rather than on the surface. Front lighting is good for spotting surface defects. Rear lighting, obtained by shining light down the fiber from the far end and therefore passing through the fiber, is better for locating cracks within the fiber.

When observing any possible defects, the core is obviously of primary importance. The cladding is split into two halves. The outer part of the cladding does not greatly affect the operation of the fiber and we can be more forgiving of any failings in this area.

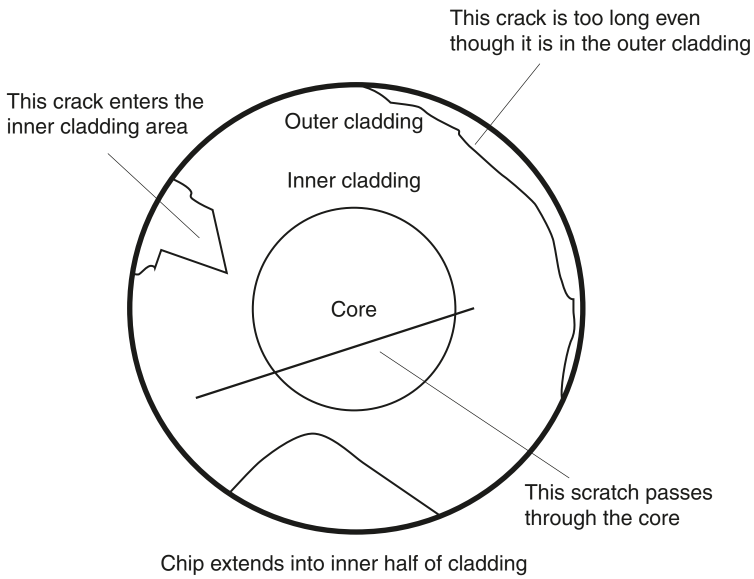
Main failing points – Figures 12.18 and 12.19

Figure 12.18 Acceptable defects



- ▷ Chips and cracks which extend into the inner part of the cladding
- ▷ Cracks that extend for more than 25% of the circumference of the cladding
- ▷ Scratches in the core area of a severity which is not consistent with the polishing techniques suggested by the manufacturer. This is what will happen if the grit from one stage in the polishing process is able to contaminate the finer grade lapping film.

Figure 12.19
A total failure



Quiz time 12

In each case, choose the best option.

1 Two fibers can be joined by:

(a) two adapters plugged into each end of a connector
(b) a bare fiber connector
(c) two connectors and one adapter
(d) a single connector

2 A connector with a rectangular plastic push-to-lock shroud is likely to be an:

(a) SC
(b) FC-PC
(c) ST-PC
(d) SMA 906

3 A PC finish:

(a) reduces both the return loss and the insertion loss
(b) makes physical contact but damages the end of the fiber
(c) is the result of polishing on a hard surface
(d) is the result of using an incorrect dolly

4 'SFF' stands for:

(a) Small Fiber Form

(b) Small Form Factor

(c) Sub Fiber Factor

(d) Simple Fiber Face

5 During polishing of a silica fiber, final inspection reveals a large scratch running right across the fiber. A likely cause of this is:

(a) contamination of the final lapping film with some coarse grit from a previous stage of the polishing

(b) using diamond lapping film instead of aluminum oxide film

(c) using the wrong dolly

(d) water laying on the surface of the fiber. Simply wipe it off with lint-free tissue