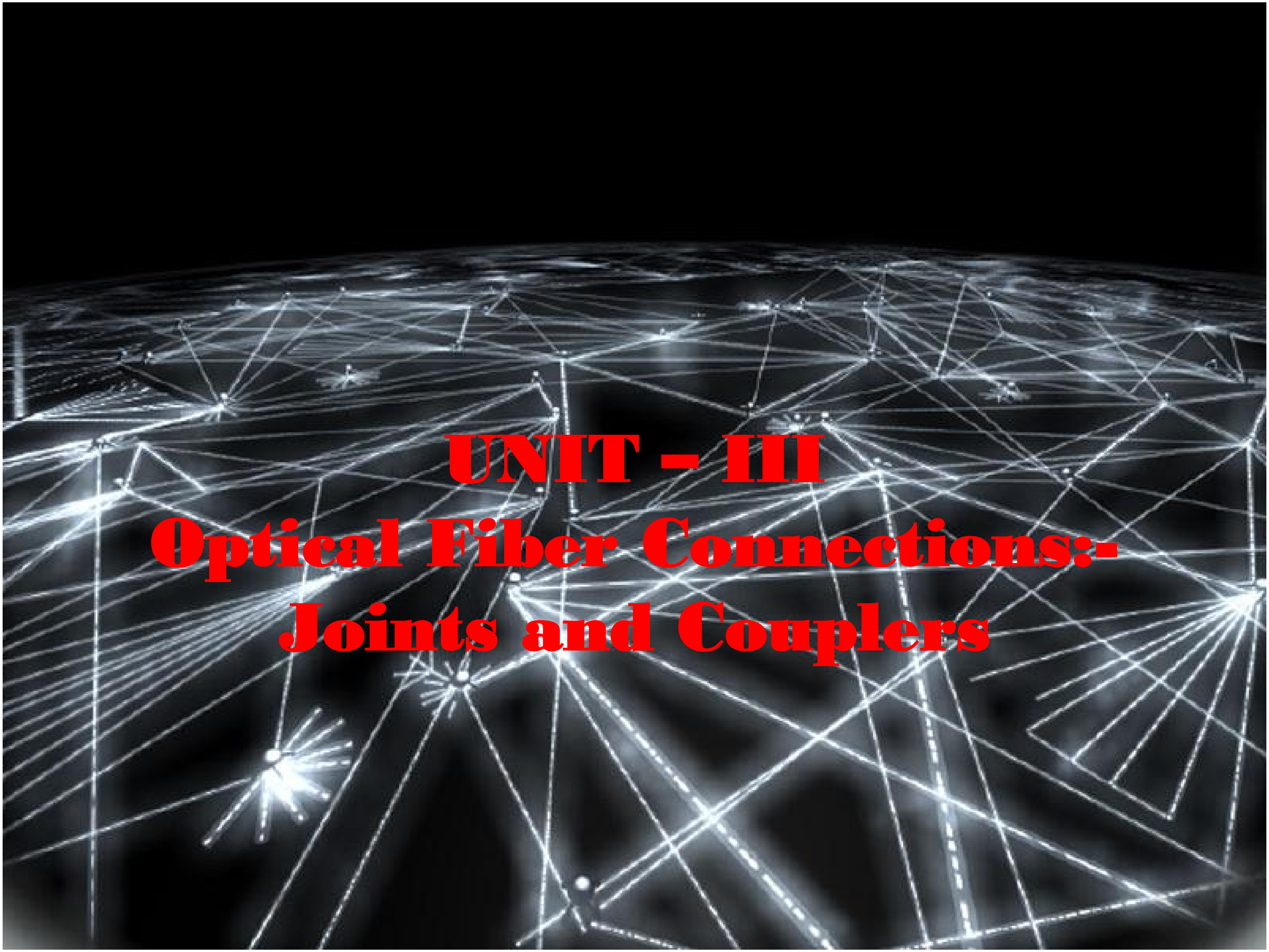


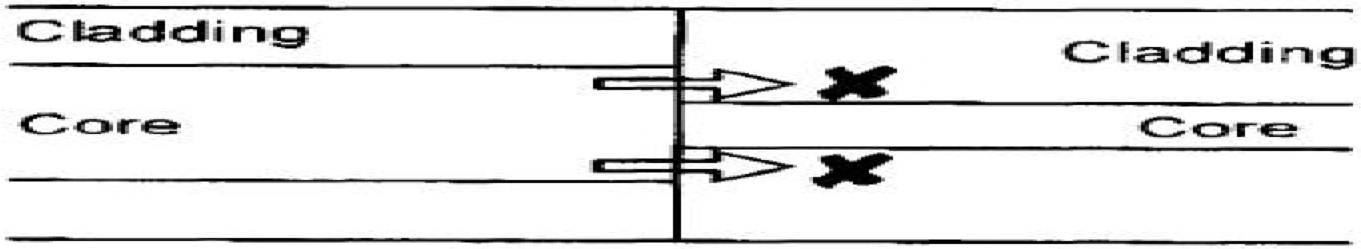
UNIT – III
Optical Fiber Connections:-
Joints and Couplers

Coupling losses

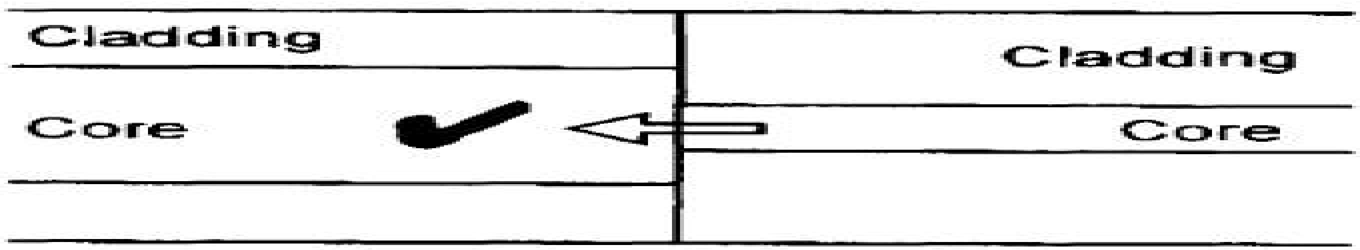
Fiber-to-fiber connection loss is increased by the following sources of intrinsic and extrinsic coupling loss:

- Reflection losses.
- Fiber separation.
- Lateral misalignment.
- Angular misalignment.
- Core and cladding diameter mismatch.
- Numerical aperture (NA) mismatch.
- Refractive index profile difference.
- Poor fiber end preparation

Losses due to unequal core sizes



Some light cannot enter the core

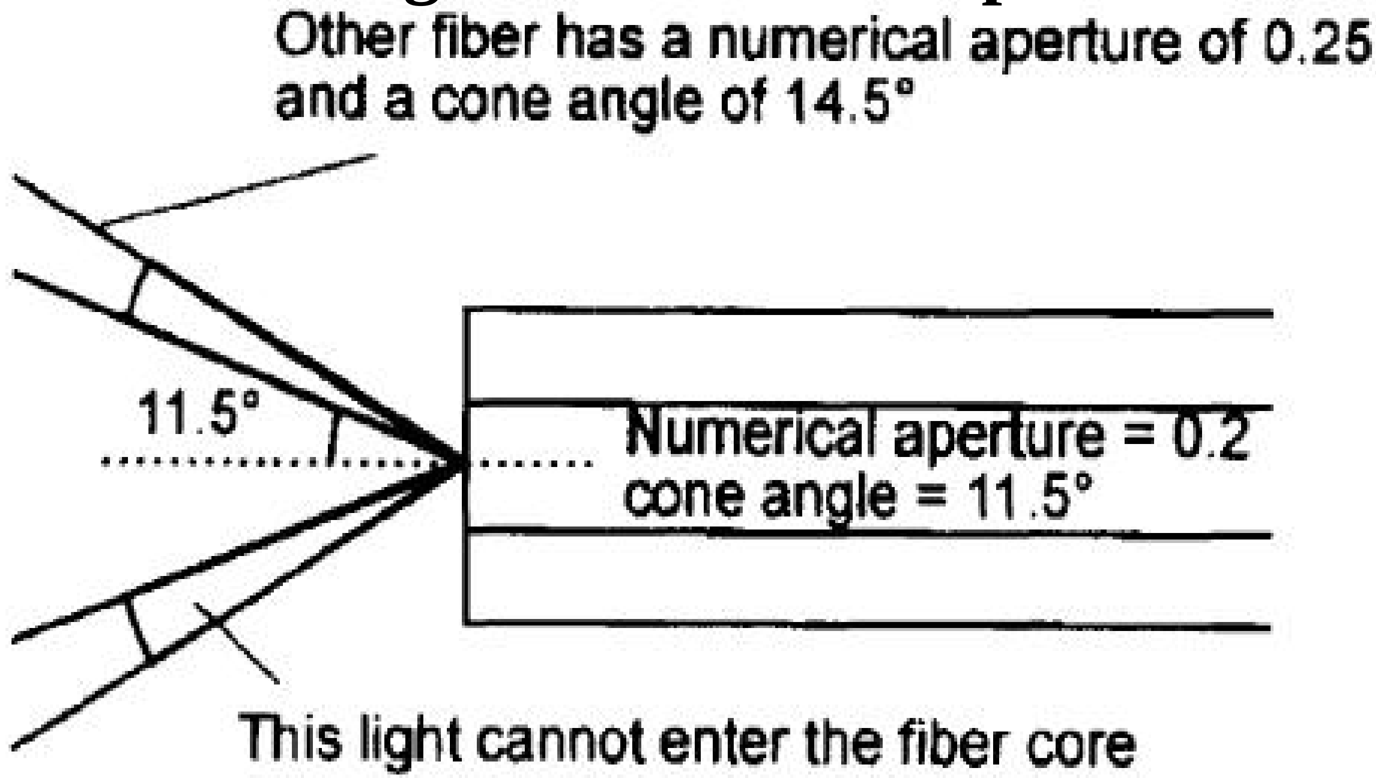


Small core to large core - no losses

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

Losses can be high

Losses due to changes in numerical aperture

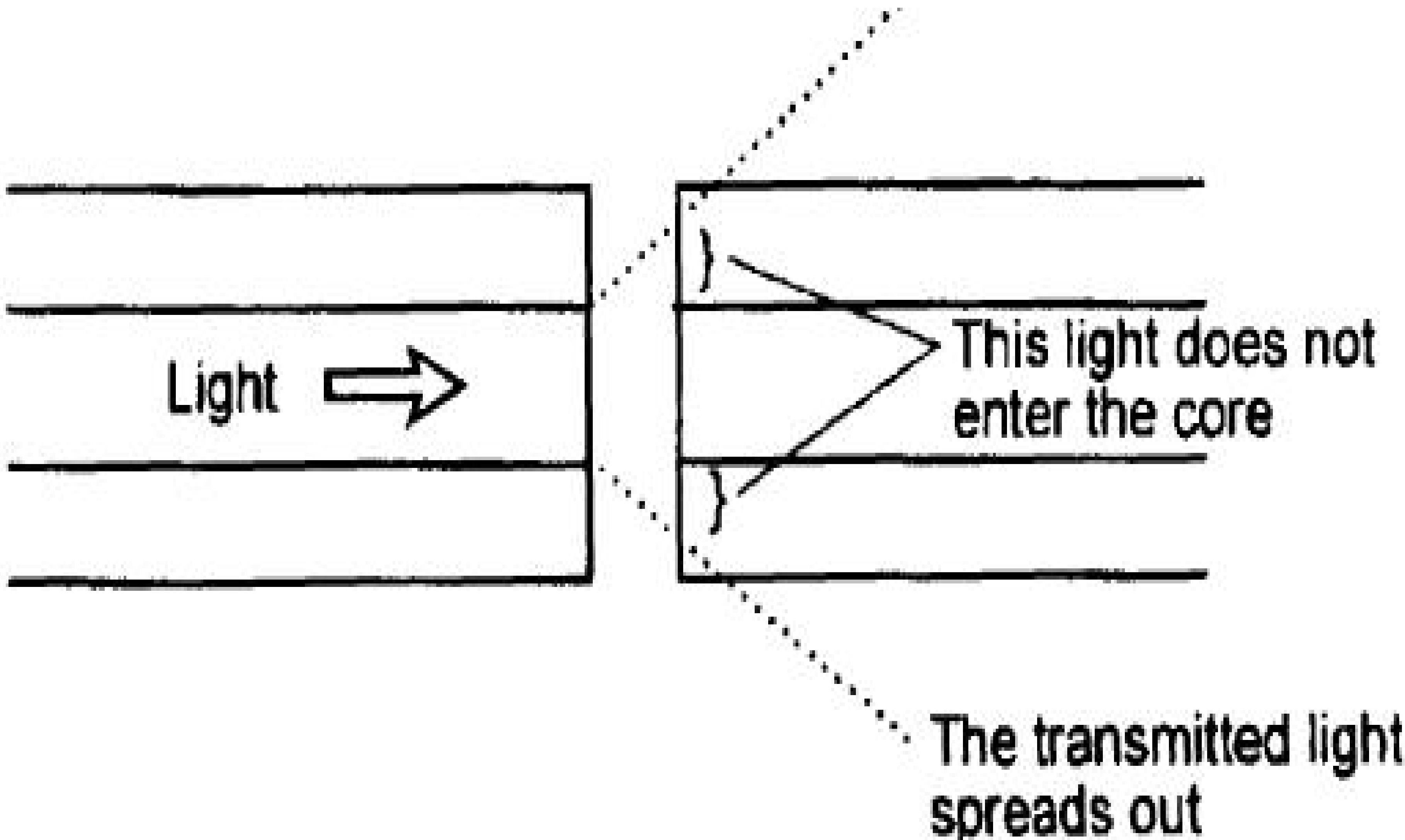


Launch fiber NA

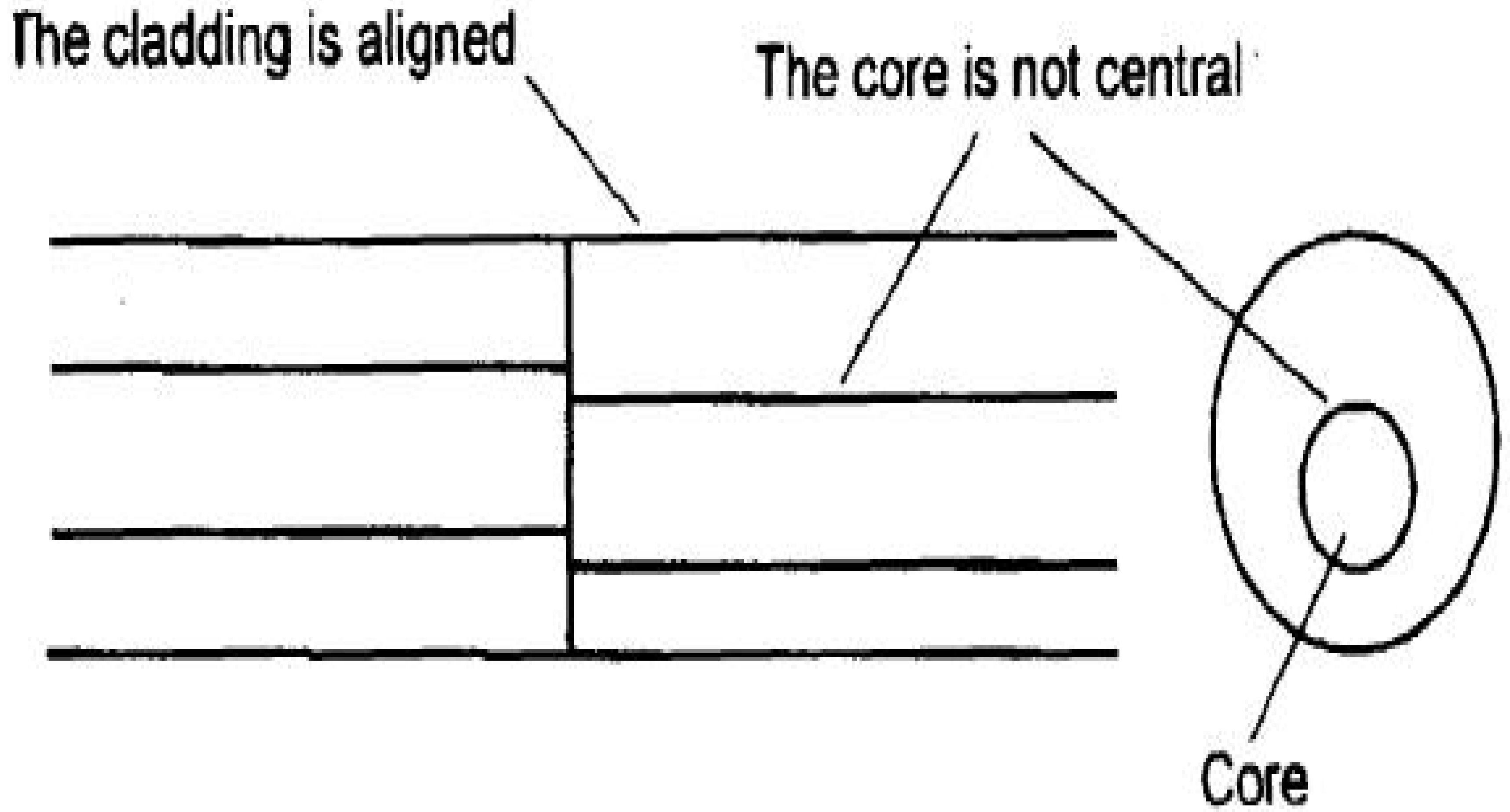
Receive fiber NA	0.1	0.2	0.275
0.1	0	6 dB	0.36 dB
0.2	0	0	2.8 dB
0.275	0	0	0

Example losses

Gap loss

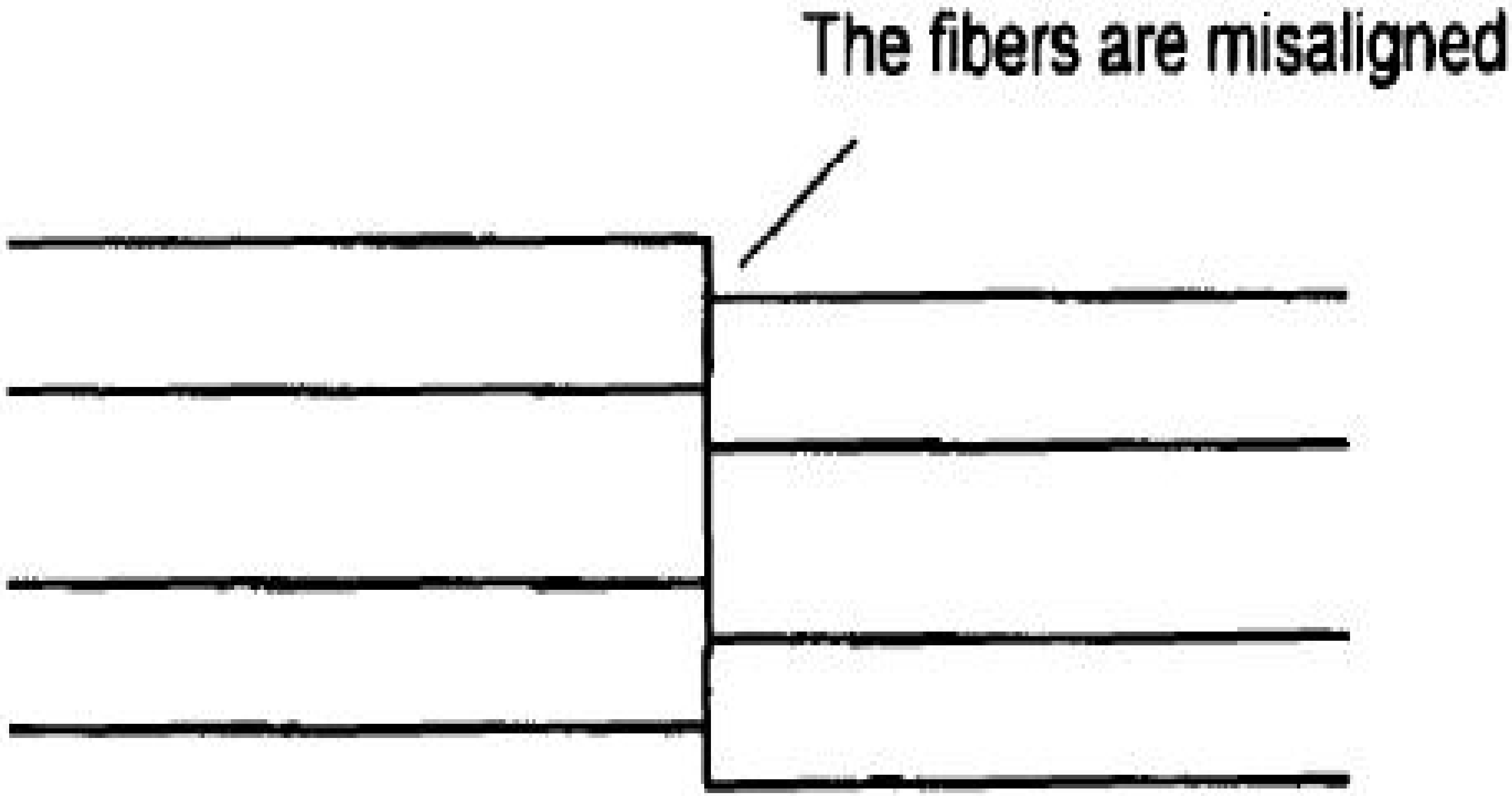

Light
This light does not enter the core
The transmitted light spreads out

Alignment problems

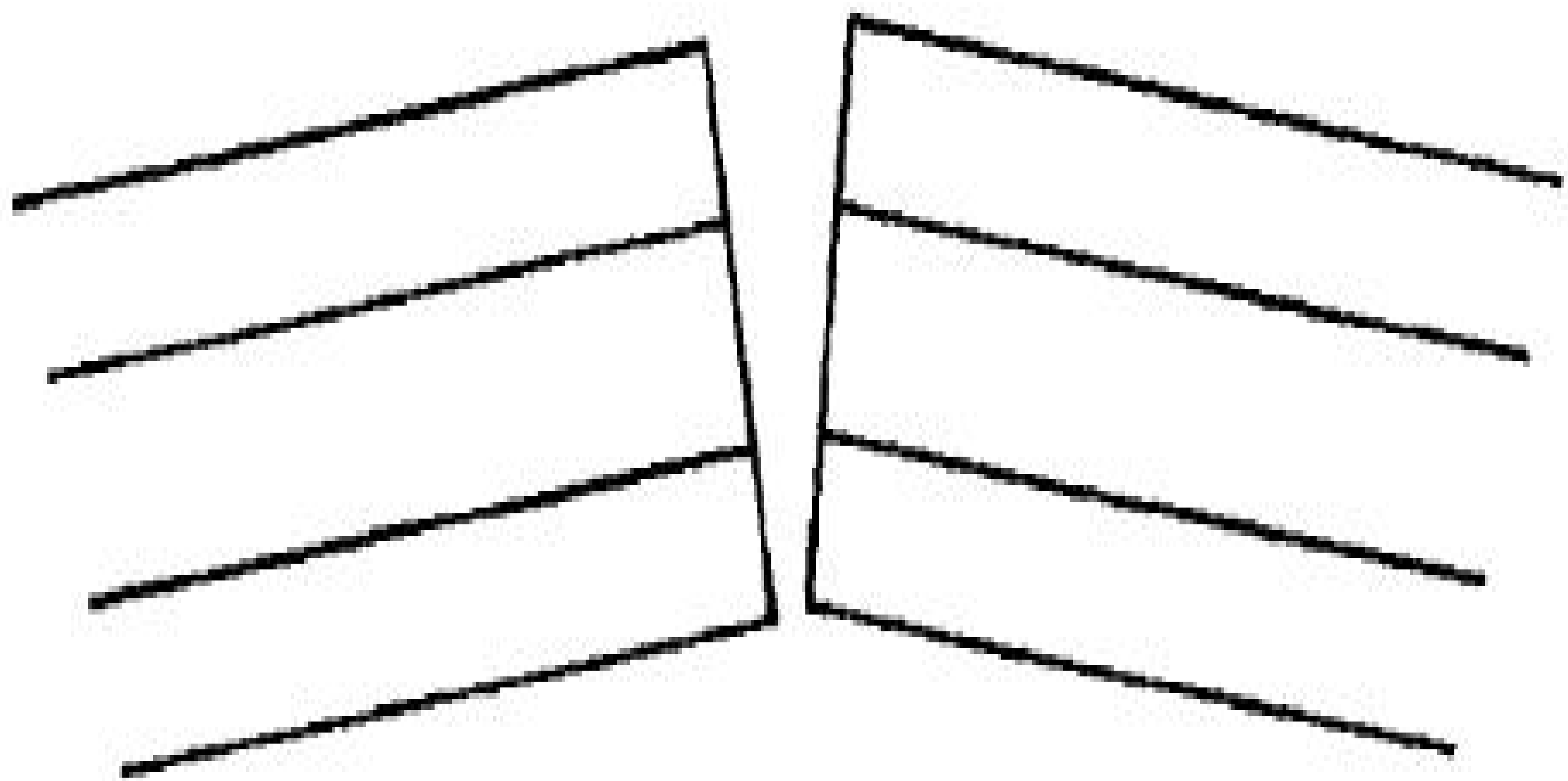


Core alignment

Lateral misalignment



Angular misalignment



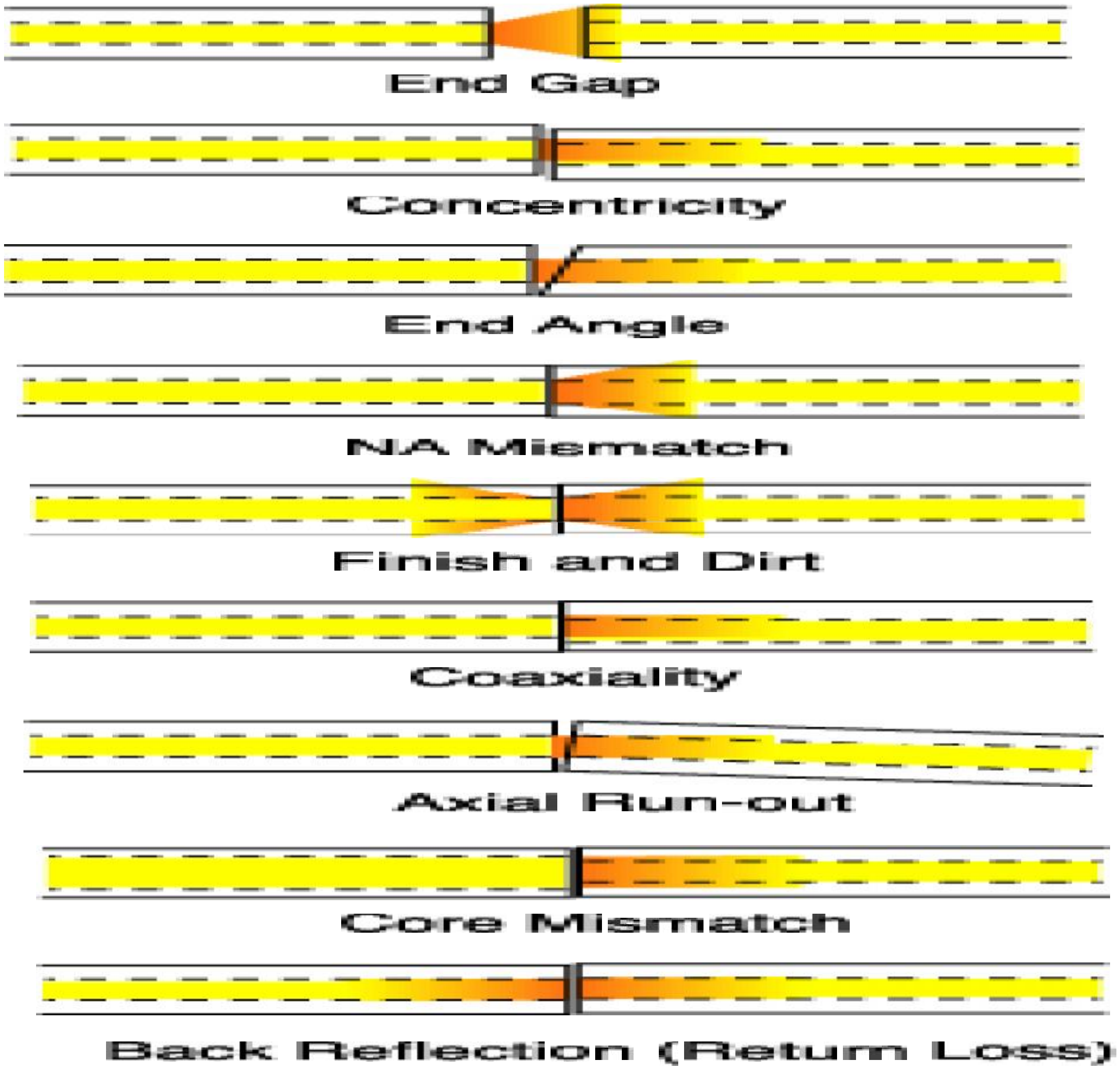
Fiber Splicing

- We terminate fiber optic cable two ways –
  - ✓ Connectors that can mate two fibers to create a temporary joint.
  - ✓ Connect the fiber to a piece of network gear or with splices which create a permanent joint between the two fibers.
- Connector and splice loss is caused by a number of factors.
- Loss is minimized when the two fiber cores are identical and perfectly aligned, the connectors or splices are properly finished and no dirt is present.
- Only the light that is coupled into the receiving fiber's core will propagate, so all the rest of the light becomes the connector or splice loss.

Continued..

- End gaps cause two problems, insertion loss and return loss. The emerging cone of light from the connector will spill over the core of the receiving fiber and be lost.
- In addition, the air gap between the fibers causes a reflection when the light encounters the change in refractive index from the glass fiber to the air in the gap.
- This reflection is also referred to as back reflection or optical return loss, which can be a problem in laser based systems.
- Connectors use a number of polishing techniques to insure physical contact of the fiber ends to minimize back reflection.

Varies reasons of attenuation



Continued..

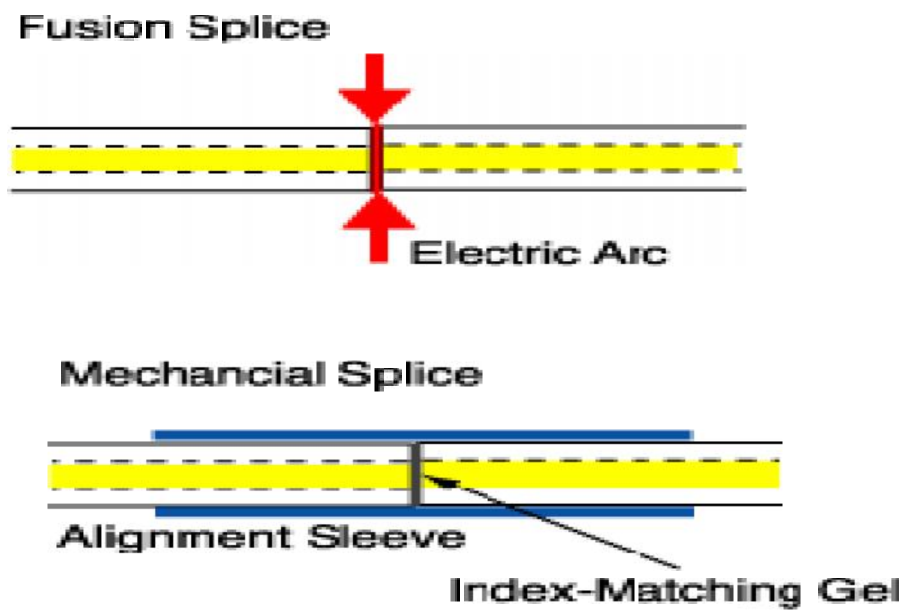
- A rough surface will scatter light and dirt can scatter and absorb light.
- Since the optical fiber is so small, typical airborne dirt can be a major source of loss.
- Two sources of loss are directional; NA and core diameter.
- Light from a fiber with a larger NA will be more sensitive to angularity and end gap, so transmission from a fiber of larger NA to one of smaller NA will be higher loss than the reverse.
- Likewise, light from a larger fiber will have high loss coupled to a fiber of smaller diameter, while one can couple a small diameter fiber to a large diameter fiber with minimal loss, since it is much less sensitive to end gap or lateral offset.

Splicing techniques

➢ Splicing is only needed if the cable runs are too long for one straight pull or you need to mix a number of different types of cables.

➢ Splices are "permanent" connections between two fibers.

➢ There are two types of splices, fusion and mechanical, and the choice is usually based on cost or location.



Fusion splicing

- Fusion Splices are made by "welding" the two fibers together usually by an electric arc.
- Fusion splicing is the 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 only splice multimode to multimode or single mode to single mode.

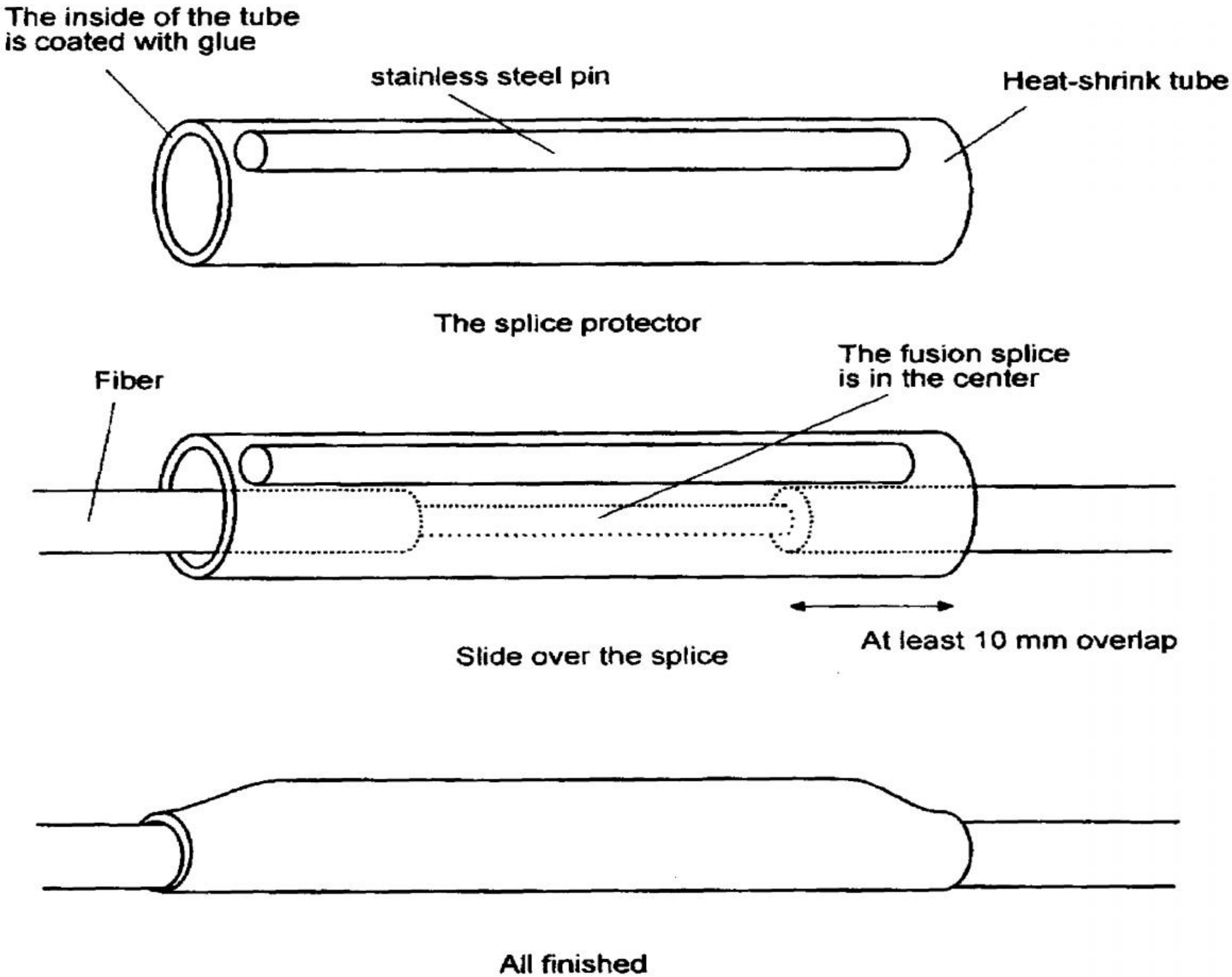
Continued..

- Fusion splices are made by positioning cleaned, cleaved fiber ends between two electrodes and applying an electric arc to fuse the ends together.
- A fusion arc is applied to the fiber while the ends are still separated to vaporize volatile materials which could cause bubbles.
- Final precise alignment is done by moving fiber ends together until there is slight pressure between end surfaces.

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 stain- less steel wire rod as seen in Figure.

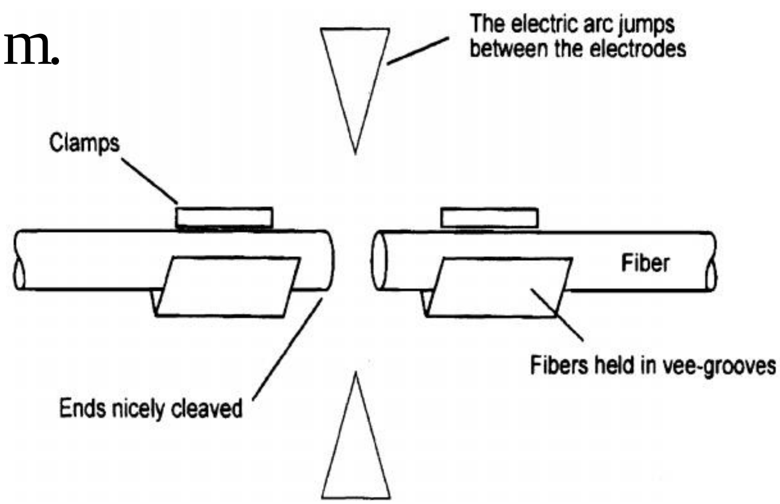
Continued..



The inside of the tube is coated with glue
stainless steel pin
Heat-shrink tube
The splice protector
Fiber
The fusion splice is in the center
Slide over the splice
At least 10 mm overlap
All finished

Holding and moving the fibers in the splicer

- The fibers are held in vee-grooves cut into steel or ceramic blocks (Figure).
- As usual, cleanliness is all-important. 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 µm.



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.

Mechanical splicing

- 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. Mechanical Splices are alignment gadgets that hold the ends of two fibers together with some index matching gel or glue between them.
- There are a number of types of mechanical splices, like little glass tubes or V-shaped metal clamps.
- The tools to make mechanical splices are cheap, but the splices themselves are expensive.

Continued..

- Many mechanical splices are used for restoration, but they can work well with both single mode and multimode fiber.
- Mechanical splicing systems position fiber ends closely in retaining and aligning assemblies.
- Focusing and collimating lenses may be used to control and concentrate light that would otherwise escape.
- Index matching gels, fluids and adhesives are used to form a continuous optical path between fibers and reduce reflection losses.

Advantages and disadvantages

- 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 re-usable 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.

Which Splice?

- If cost is the issue, I have given you the clues to make a choice: fusion is expensive equipment and cheap splices, while mechanical is cheap equipment and expensive splices.
- So if you make a lot of splices (like thousands in a big Telco or CATV network) use fusion splices. If you need just a few, use mechanical splices.
- Fusion splices give very low back reflections and are preferred for single mode high speed digital or CATV networks.
- However, they don't work too well on multimode splices, so mechanical splices are preferred for multi mode, unless it is an underwater or aerial application, where the greater reliability of the fusion splice is preferred.

Continued..

- Fiber ends must be generated that are smooth and perpendicular to the fiber axis.
- Mechanical alignment in the fiber cores in three axes must be accomplished to micron tolerances for single mode fibers.
- Index of refraction matching material is usually added between the fiber ends to optically couple the light from one fiber to the other in non-fusion splices.
- Contamination of splice region must be avoided. Some splicing techniques retain alignment mechanically and others heat and fuse the fibers together, which requires accurate control of fusion conditions to minimize core deformation loss.

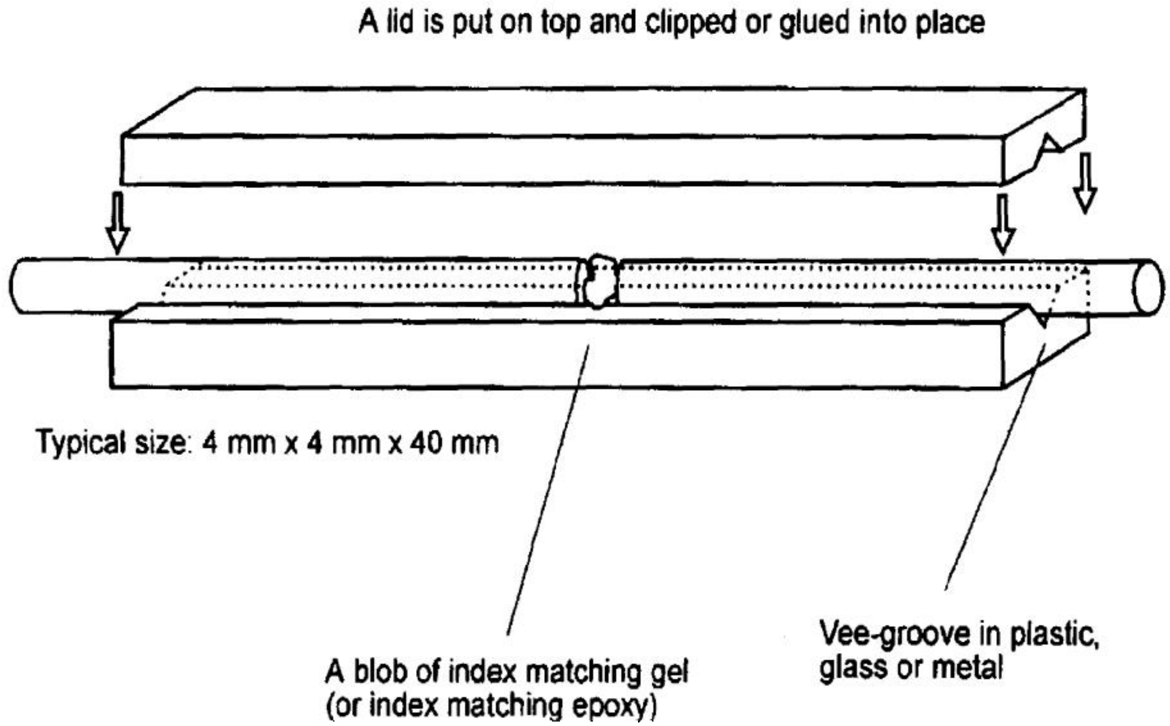
Continued..

- Loss in multimode, splices and connectors is caused by differences in the fibers being connected (intrinsic parameters) and the quality of the connection (extrinsic parameters).
- Extrinsic losses can be minimized by proper connection design and depend on fiber end quality, alignment (transverse, angular and longitudinal), cleanliness, degree of index matching in the connection and core deformation (fusion splices).
- Retention of fiber alignment is vitally necessary to assure low splice loss over the service life of the splice.

Continued..

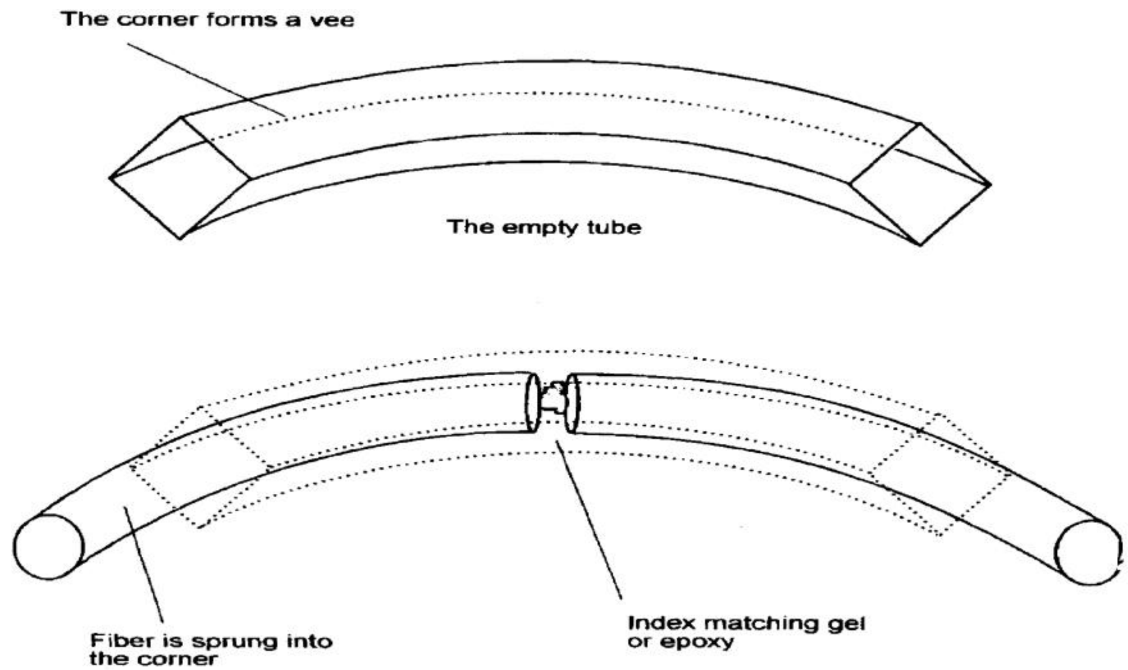
- Indeed, many splicing techniques (bonding, fusion) concentrate on this aspect of splicing to such an extent that additional constraints are placed on end preparation and fiber alignment.
- The achievement of stable splice loss over the service life of the splice is not assured by the demonstration of low splice loss at room temperature.
- 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 of mechanical splice

Vee-groove



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.

Bent tube



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.

Fiber Connectors

- Connectors and adapters are the plugs and sockets of a fiber optic system.
- They allow the data to be rerouted 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 a thousand times and still need to perform well.

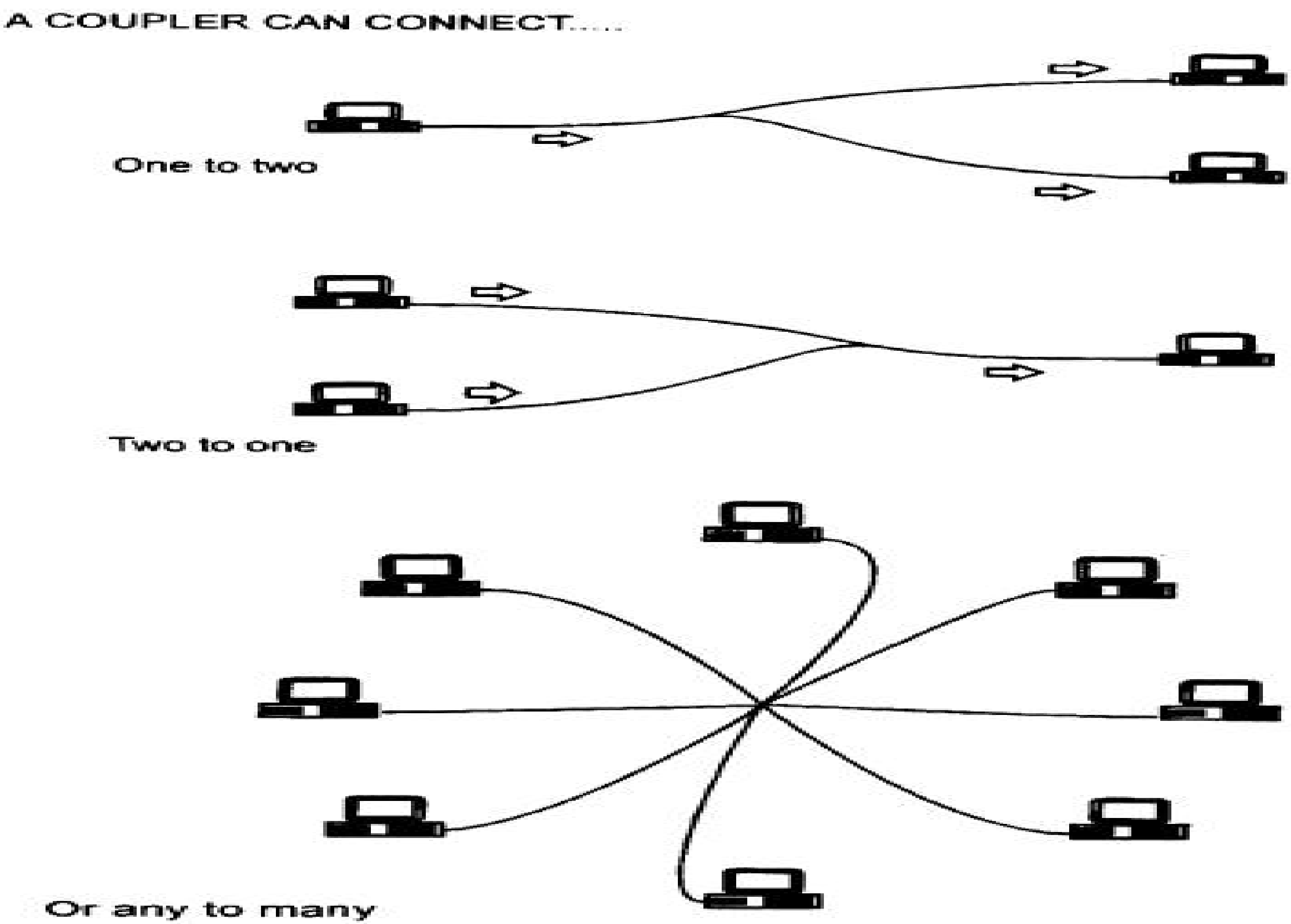
Continued..

- 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.

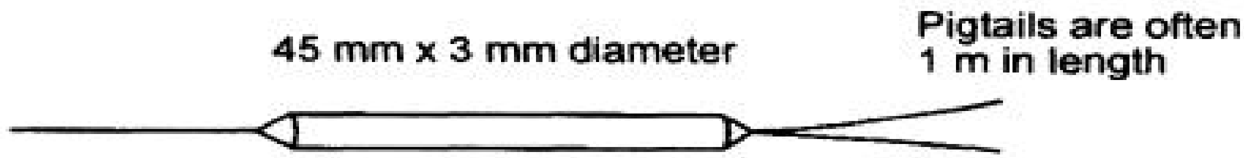
Couplers

- Imagine an optic fiber carrying an input signal that needs to be connected to two different destinations. The signal needs to be split into two. This is easily achieved by a ***coupler.***
- When used for this purpose, it is often referred to as a splitter.
- Couplers are bi-directional, they can carry light in either direction. Therefore the coupler described could equally well be used to combine the signals from two transmitters onto a single optic fiber.
- In this case, it is called a ***combiner.*** It is exactly the same device, it is just used differently. The various ways of using couplers are shown in Figure.

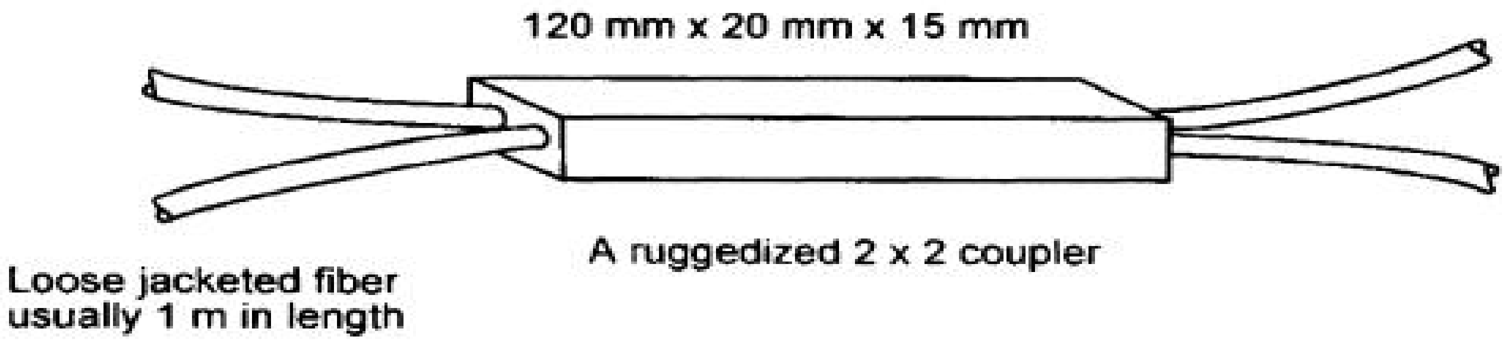
The uses of couplers



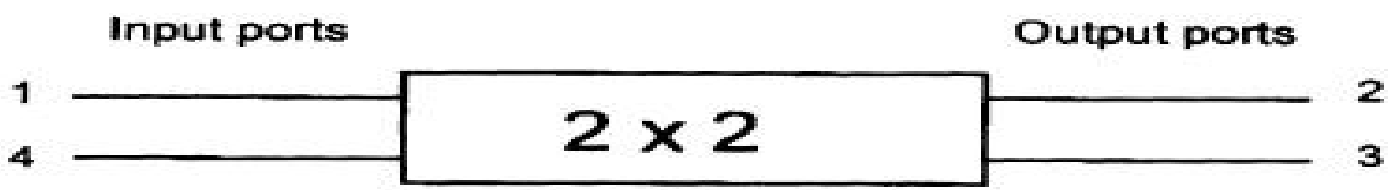
The most common types of coupler & One possible numbering system for the ports



A miniature 1 x 2 coupler



A ruggedized 2 x 2 coupler



Splitting ratio or coupling ratio

- The proportion of the input power at each output is called the splitting ratio or coupling ratio. In a 1 X 2 coupler, the input signal can be split between the two outputs in any desired ratio.
- In practice however, the common ones are 90:10 and 50:50. These are also written as 9:1 and 1:1.
- In the cases where the splitting ratio is not 1:1, the port which carries the higher power is sometimes called the ***throughput port*** and the other is called the ***tap port.***

Losses

- The losses are stated in decibels and assume that the input is applied to port 1 and the output is taken from ports 2 and 3.
- For the moment, we will ignore the other connection shown as port 4.
- This will be discussed further when we look at directionality loss.
- We may recall that, generally, the loss in decibels is derived from the standard formula:

$$Loss = 10\ \log\left(\frac{Power_{out}}{Power_{in}}\right)\ dB$$

Excess loss

Excess loss is a real loss. If 10 mW goes into a device and only 9 mW comes out, then it is reasonable enough to think of the other 1 mW to be a loss. The light energy has been scattered or absorbed within the coupler and is not available at the output. So what we are really saying is that the loss is dependent on the total output power compared to the input power. In the case of the coupler in Fig., the output power is the sum of ports 2 and 3 and the input is at port 1. So excess loss would look like this:

$$Excess\ Loss = 10 \log\left(\frac{P_2 + P_3}{P_1}\right) dB$$

Where P_1, P_2, P_3 are the power levels at the respective ports.

Directionality loss or crosstalk or directivity

- When we apply power to port 1 we expect it to come out of ports 2 and 3 but not out of port 4, the other input port. Unfortunately, owing to backscatter within the coupler, some of the energy is reflected back and appears at port 4.
- This backscatter is very slight and is called directionality loss or crosstalk. The fact that the backscatter comes out of port 4 accounts for the direction of the arrow in Fig.

$$\mathit{Directionality\,Loss} = 10\,\log\left(\frac{P_4}{P_1}\right)\,dB$$

- A typical figure is –40 dB. Directivity puts the same information around the other way, if the reflected power has a level of –40 dB, then the power which is *not* reflected has a ratio of +40 dB. In the formula, the power levels are just inverted.

$$\mathit{Directivity} = 10\,\log\left(\frac{P_1}{P_4}\right)\,dB$$

Insertion loss or port-to-port loss or throughput loss or tap loss

This looks at a single output power compared with the input power, so in Fig. There are two possibilities. We could look at the power coming out of port 2 and compare it with the input power at port 1 or we could do a similar thing with port 3 compared with the input power at port 1. Generally, insertion loss for any output port could be written as:

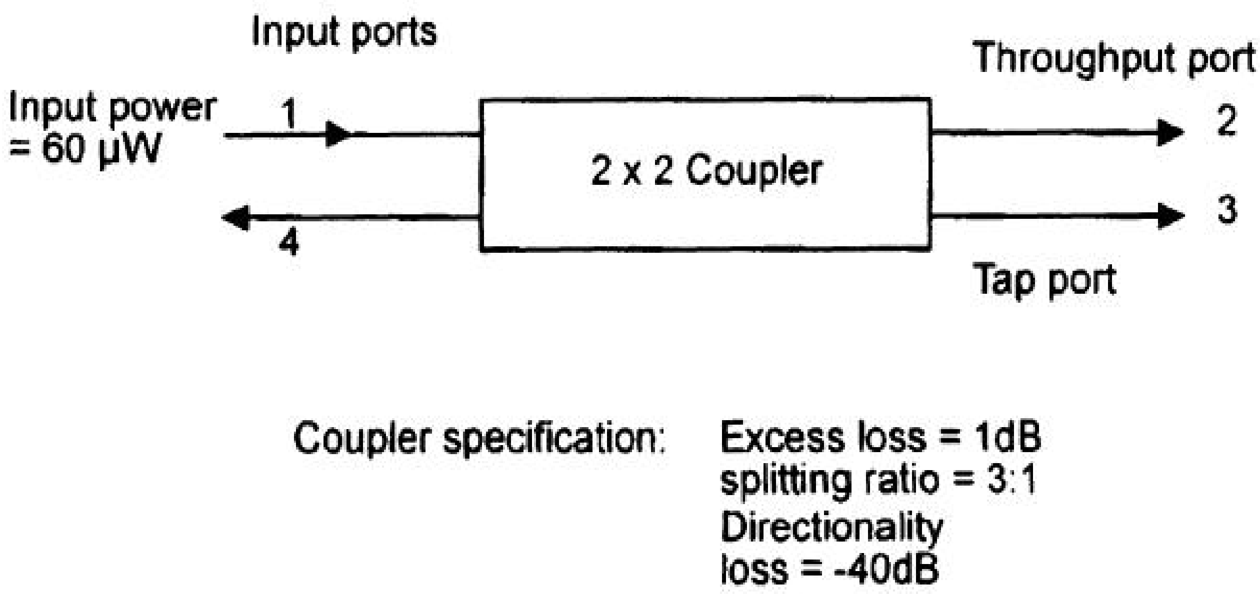
$$\text{Insertion } Loss = 10 \log\left(\frac{P_{output\ port}}{P_{input\ port}}\right) dB$$

As an example, the insertion loss at port 2 is:

$$\text{Insertion } Loss = 10 \log\left(\frac{P_2}{P_1}\right) dB$$

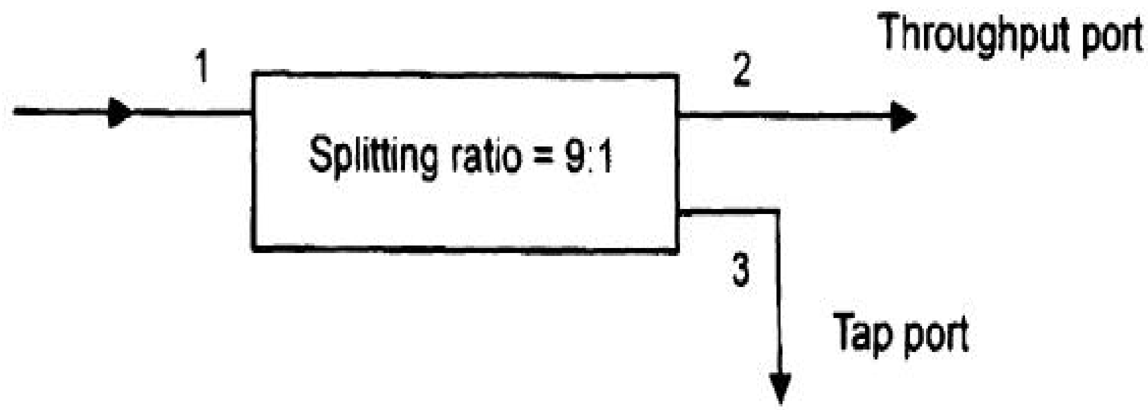
This would then be referred to as the insertion loss of port 2 or simply the *port - to - port loss* between ports 1 to port 2. If, in the above example, the splitting ratio was not 1:1, then port 2 may be referred to as the throughput port and so the formula above becomes the throughput loss. Similarly, if ports 3 and 1 were used, the loss could be called the tap loss.

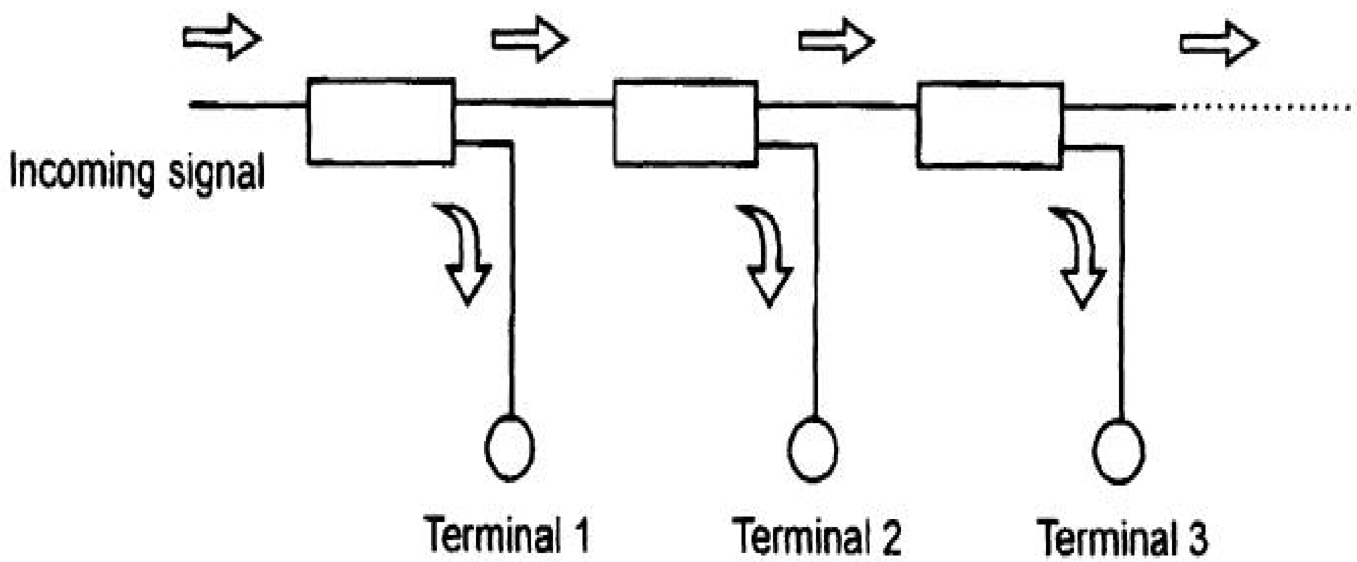
Calculate the output power at each port in the coupler shown in Fig.



What is the value of the output power at each port?

A tee network

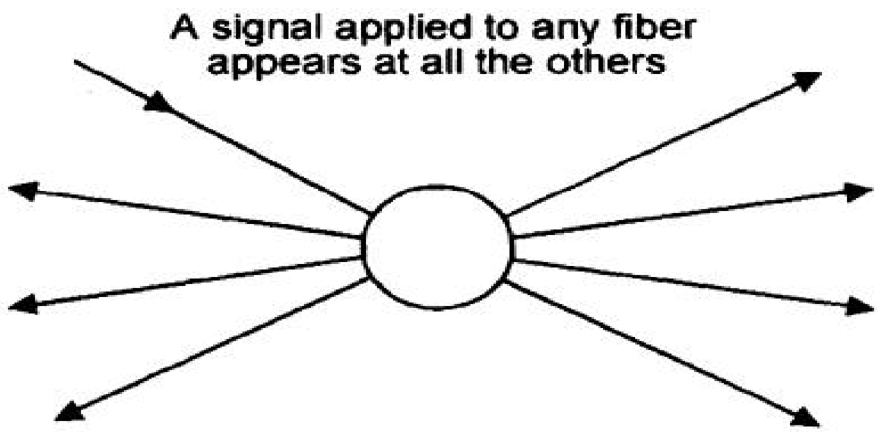




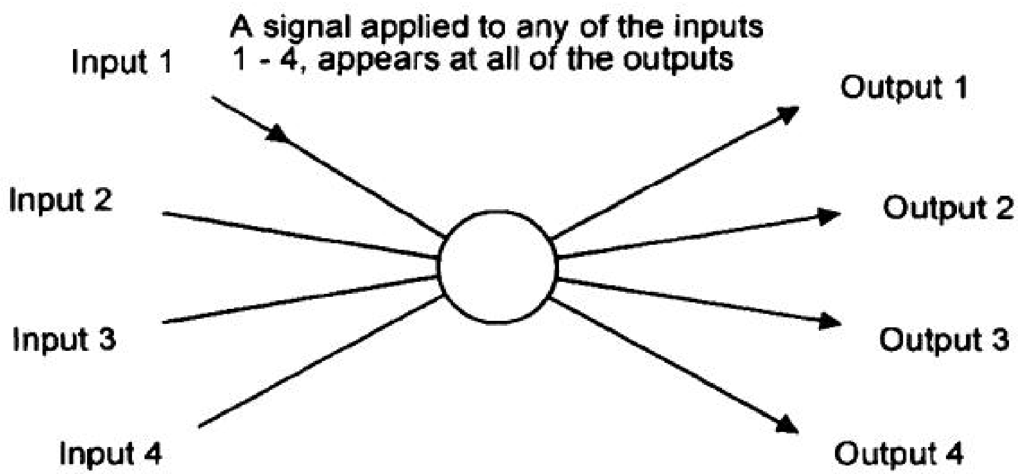
Advantages and disadvantages of a tee network

- The main advantage is its simplicity.
- The couplers are readily available and, if required, can be supplied with connectors already fitted. This means that the network can be on-line very quickly indeed.
- The disadvantage is the rapid reduction in the power available to each of the workstations as we connect more and more terminals to the network.
- As the power is reduced, the number of data errors increases and the output becomes increasingly unreliable.
- At first glance we could solve this problem by simply increasing the input power level. However we run the very real risk of overloading the first workstation.

Two forms of 4 X 4 star couples



Reflective star



Transmissive star

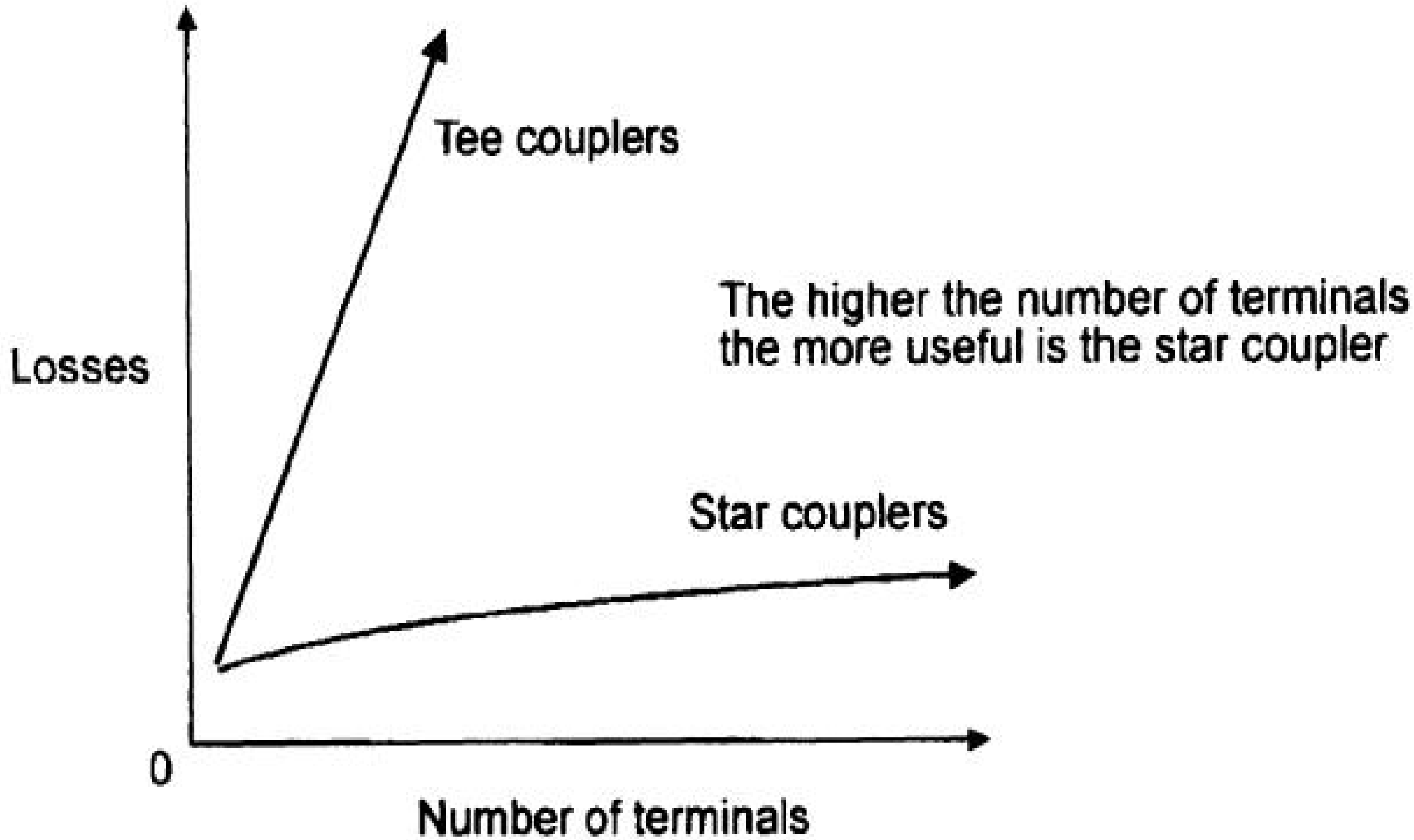
Continued..

- This is an alternative to the tee coupler when a larger number of terminals are involved as shown in Fig.
- The star coupler takes the input signal to a central location, and then splits it into many outputs in a single coupler.
- Styles of up to 1 X 32 and up to 32 X 32 are commonly available.

Advantages and disadvantages

- The main advantage of using star couplers is that the losses are lower than a tee coupler for networks of more than three or four terminals as in Fig.
- This is because the star coupler requires only one input connector and suffers only one excess loss. The larger the numbers of terminals, the more significant are the benefits.
- The disadvantage is that the star coupler will normally use much larger quantities of cable to connect the terminals since the star is located centrally and a separate cable is connected to each of the terminals. A tee network can use one cable to snake around the system from terminal to terminal.

Loss comparison




Thank You