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Fiber Optic Communication Systems

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Course No.:
FIB101

Publication Source:

US Navy
Engineering Aid Basics
"Chapter 9 – Communications and Lighting Systems"
Pub. # NAVEDTRA 14026A

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Chapter 9

Communications and Lighting Systems

Topics

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Overview

Communications and Lighting Systems play an important role in mission accomplishment. Operating fiber optic, public address, and interoffice communication systems or area, security, and floodlight lighting systems requires a through knowledge of their hookup, operation, maintenance, and repair.

As a Construction Electrician, you may have the responsibility for the installation, maintenance, and repair of all these systems and their associated equipment.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Describe the purpose and components of fiber optic systems.
2. Describe advanced operational procedures associated with fiber optics.
3. Describe optical detectors and fiber optic receivers.
4. Identify fiber optic topology.

1.0.0 FIBER OPTICS

People have used light to transmit information for hundreds of years. However, it was not until the 1960s with the invention of the ***laser*** that widespread interest in optical (light) systems for data communications began. The invention of the laser prompted researchers to study the potential of fiber optics for data communications, sensing, and other applications. Laser systems could send a much larger amount of data than the telephone, microwave, and other electrical systems. The first experiment with the laser involved letting the laser beam transmit freely through the air. Also, researchers conducted experiments that transmitted the laser beam through different types of waveguides. Glass fibers, gas-filled pipes, and tubes with focusing lenses are examples of optical waveguides.

Glass fibers soon became the preferred medium for fiber-optic research. Initially, the large losses in the optical fibers prevented them from replacing coaxial cables. Loss is the decrease in the amount of light reaching the end of the fiber. Early fibers had losses around 1,000 dB/km, making them impractical for communications use. In 1969, several scientists concluded that impurities in the fiber material caused the signal loss in optical fibers. The basic fiber material did not prevent the light signal from reaching the end of the fiber. These researchers believed it was possible to reduce the losses in optical fibers by removing the impurities. By removing the impurities, researchers made possible the construction of low-loss optical fibers.

Developments in semiconductor technology that provided the necessary light sources and detectors furthered the development of fiber optics. Conventional light sources, such as lamps or lasers, were not easy to use in fiber-optic systems. These light sources tended to be too large and required lens systems to launch light into the fiber. In 1971, Bell Laboratories developed a small area light-emitting diode (LED). This light source was suitable for a low-loss coupling to optical fibers. Researchers could then perform source to fiber jointing easily and repeatedly. Early semiconductor sources had operating lifetimes of only a few hours; however, by 1973, projected lifetimes of lasers advanced from a few hours to greater than 1,000 hours. By 1977, projected lifetimes of lasers advanced to greater than 7,000 hours. By 1979, these devices were available with projected lifetimes of more than 100,000 hours.

In addition, researchers also continued to develop new fiber-optic parts. The types of new parts developed included low-loss fibers and fiber cables, splices, and connectors. These parts permitted demonstration and research on complete fiber-optic systems.

Advances in fiber optics have permitted the introduction of fiber optics into present applications. These applications are mostly in telephone long haul systems but are growing to include cable television, computer networks, video systems, and data links. Research should increase system performance and provide solutions to existing problems in conventional applications. The impressive results from early research show there are many advantages offered by fiber-optic systems.

1.1.0 Fiber Optic Systems

System design has centered on long-haul communications and subscriber-loop plants. The subscriber-loop plant is the part of a system that connects a subscriber to the nearest switching center. Cable television is an example. Also, limited work has been done on short-distance applications and some military systems. Initially, central office trunking required multimode optical fibers with moderate to good performance. Fiber performance depends on the amount of loss and signal distortion introduced by the fiber when it is operating at a specific wavelength. Two basic types of optical fibers are used in industry: multimode and single mode.

Future system design improvements depend on continued research. Researchers expect fiber-optic product improvements to upgrade performance and lower costs for short-distance applications. Future systems center on broadband services that will allow transmission of voice, video, and data. Services will include television, data retrieval, video word processing, electronic mail, banking, and shopping.

1.2.0 Advantages and Disadvantages of Fiber Optics

Fiber-optic systems have many attractive features that are superior to electrical systems. These include improved system performance, immunity to electrical noise, signal security, and improved safety and electrical isolation. Other advantages include reduced size and weight, environmental protection, and overall system economy. Table 9-1 details the main advantages of fiber-optic systems.

Despite the many advantages of fiber-optic systems, there are some disadvantages. Because of the relative newness of the technology, fiber-optic components are expensive. Fiber-optic transmitters and receivers are still relatively expensive compared to electrical interfaces. The lack of standardization in the industry has also limited the acceptance of fiber optics. Many industries are more comfortable with the use of electrical systems and are reluctant to switch to fiber optics; however, industry researchers are eliminating these disadvantages.

Standards committees are addressing fiber-optic part and test standardization. The cost to install fiber optic systems is falling because of increased use of fiber-optic technology. Published articles, conferences, and lectures on fiber optics have begun to educate managers and technicians. As the technology matures, the use of fiber optics will increase because of its many advantages over electrical systems.

Table 9-1 — Advantages of Fiber Optics.

System Performance	Greatly increased bandwidth and capacity Lower signal attenuation (loss)
Immunity to Electrical Noise	Immune to noise (electromagnetic interference [EMI] and radio frequency interference [RFI]) No cross talk Low bit error rates
Signal Security	Difficult to tap Nonconductive (does not radiate signals)
Electrical Isolation	No common ground required Freedom from short circuits and sparks
Size and Weight	Reduced size and weigh cables
Environmental Protection	Resistant to radiation and corrosion Resistant to temperature variations Improved ruggedness and flexibility Less restrictive in harsh environments
Overall System Economy	Low per channel cost Lower installation cost Principal material, silica is abundant, and inexpensive (source is sand)

1.3.0 Basic Structure of an Optical Fiber

The basic structure of an optical fiber consists of three parts: the core, the ***cladding***, and the coating or buffer. The basic structure of an optical fiber is shown in *Figure 9-1*. The core is a cylindrical rod of dielectric material. Dielectric material conducts no electricity. Light propagates mainly along the core of the fiber. The core is generally made of glass. It is surrounded by a layer of material called the cladding. Even though light will propagate along the fiber core without the layer of cladding material, the cladding does perform some necessary functions.

The cladding layer is also made of a dielectric material, generally glass or plastic, and performs the following functions:

- Reduces loss of light from the core into the surrounding air
- Reduces scattering loss at the surface of the core
- Protects the fiber from absorbing surface contaminants
- Adds mechanical strength

For extra protection, the cladding is enclosed in an additional layer called the coating or buffer.

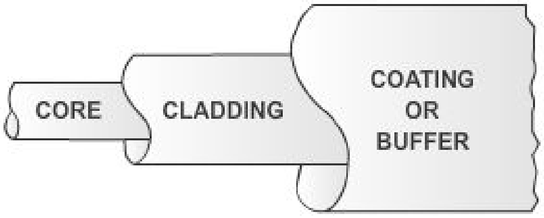

Figure 9-1 — Basic structure of an optical fiber

The coating or buffer is a layer of material used to protect an optical fiber from physical damage. It is made of a type of plastic. The buffer is elastic in nature and prevents abrasions. It also, prevents the optical fiber from scattering losses caused by microbends. ***Microbends*** occur when an optical fiber is placed on a rough and distorted surface. Microbends are discussed later in this chapter.

1.4.0 Optical Cables

Optical fibers have small cross sectional areas. Without protection, optical fibers are fragile and can be broken. The optical cable structure, which includes buffers, strength members, and jackets, protects optical fibers from environmental damage. Many factors influence the design of fiber-optic cables. The cable design depends on the intended application of the cable. Properly designed optical cables perform the following functions:

- Protect optical fibers from damage and breakage during installation and over the lifetime of the fiber
- Provide stable fiber transmission characteristics compared with uncabled fibers. Stable transmission includes stable operation in extreme climate conditions
- Maintain the physical integrity of the optical fiber by reducing the mechanical stresses placed on the fiber during installation and use. Static fatigue caused by tension, torsion, compression, and bending can reduce the lifetime of an optical fiber.

1.5.0 Fiber Buffers

Coatings and buffers protect the optical fiber from breakage and loss caused by microbends. During the fiber drawing process, the addition of a primary coating protects the bare glass from abrasions and other surface contaminants. For additional protection, manufacturers add a layer of buffer material, which provides additional mechanical protection for the fiber and helps preserve its inherent strength.

Manufacturers use a variety of techniques to buffer optical fibers. The types of fiber buffers include tight buffered, loose tube, and gel filled loose tube. *Figure 9-2* shows each type of fiber buffer. The choice of buffering techniques depends on the intended application. In large fiber count commercial applications, manufacturers use the loose tube buffers. In commercial building and Navy applications, manufacturers use tight buffers.

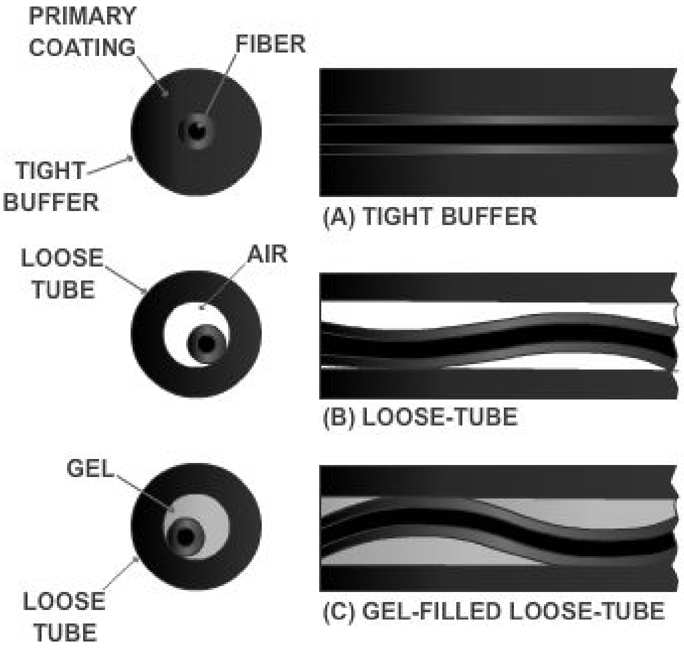

Figure 9-2 — Tight buffered, loose tube, and gel filled loose tube buffer techniques.

1.6.0 Cable Strength and Support Members

Fiber-optic cables use strength members to increase the strength of the cable and protect the fiber from strain. Fiber-optic cables may use central support members in cable construction. The central support members generally have buffered fibers or single fiber sub cables stranded over their surface in a structured, ***helical*** manner. The central members may support the optical fibers as cable strength members or may only serve as fillers. Strength and support members must be light and flexible. The materials used for strength and support include steel wire and textile fibers (such as nylon and arimid yarn). They also include carbon fibers, glass fibers, and glass reinforced plastics.

1.7.0 Cable Jacket Material

The jacket, or sheath, material provides extra environmental and mechanical protection. Jacket materials may possess any number of the following properties:

- Low smoke generation
- Low toxicity
- Low halogen content
- Flame retardance
- Fluid resistance
- High abrasion resistance
- Stable performance over temperature

It is difficult to produce a material compound that satisfies every requirement without being too costly. Jacket materials currently used include polyethylene, polyvinyl chloride, polyurethane, and polyester ***elastomers***. Most commercial jacket materials are unsuitable for use in naval applications.

1.8.0 Cable Designs

Manufacturers design fiber-optic cables for specific applications. For example, is the cable buried underground or hung from telephone poles? Is the cable snaked through cableways, submerged in water, or just laid on the ground? Is the cable used in industrial, telecommunication, utility, or military applications? Each type of application may require a slightly different cable design.

Agreement on standard cable designs is difficult. Cable design choices include jacket materials and water optic cables. Some fiber-optic cables are used in commercial applications, others in military applications. Standard commercial cable designs will develop over time as fiber-optic technology becomes more established.

1.9.0 Fiber Optic Data Links

A fiber-optic data link sends input data through fiber-optic components and provides this data as output information. It has the following three basic functions:

- To convert an electrical input signal to an optical signal
- To send the optical signal over an optical path
- To convert the optical signal back to an electrical signal

A fiber-optic data link consists of three parts: transmitter, optical fiber, and receiver**.** *Figure 9-3* is an illustration of a fiber-optic data-link connection. The transmitter, optical fiber, and receiver perform the basic functions of the fiber-optic data link. Each part of the data link is responsible for the successful transfer of the data signal. A fiber-optic data link needs a transmitter that can effectively convert an electrical input signal to an optical signal and launch the data-containing light down the optical fiber. Also, the fiber-optic data link needs a receiver that can effectively transform this optical signal back into its original form. This means that the electrical signal provided as data output should exactly match the electrical signal provided as data input.

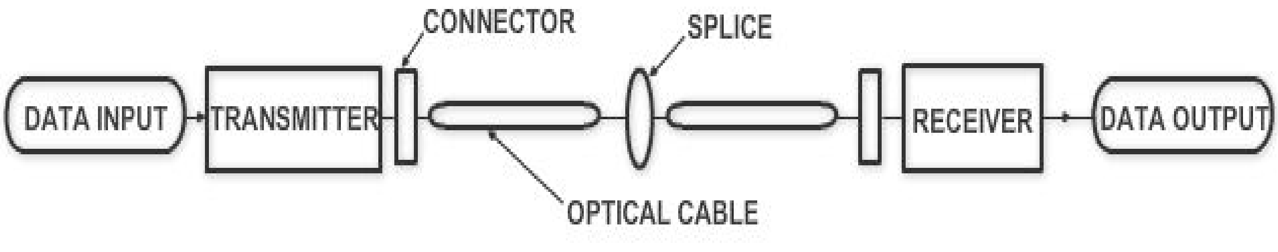

Figure 9-3 — Parts of a fiber optic data link.

1.10.0 Fiber Optic Splices

A fiber-optic ***splice*** is a permanent fiber joint the purpose of which is to establish an optical connection between two individual optical fibers. System design may require that fiber connections have specific optical properties (low loss) that are met only by fiber splicing. Also, fiber-optic splices permit the repair of optical fibers damaged during installation, accident, or stress. System designers generally require fiber splicing whenever repeated connection or disconnection is unnecessary or unwanted.

Mechanical and fusion splicing are the two broad categories of fiber splicing technique. A mechanical splice is a fiber splice where mechanical fixtures and materials perform fiber alignment and connection. A fusion splice is a fiber splice where localized heat fuses or melts the ends of two optical fibers together. Each splicing technique seeks to optimize splice performance and reduce splice loss. Low-loss fiber splicing results from proper fiber end preparation and alignment.

1.11.0 Fiber Optic Connectors

A fiber-optic connector is a device that permits the coupling of optical power between two optical fibers or two groups of fibers. Designing a device that allows for repeated fiber coupling without significant loss of light is difficult. Fiber-optic connectors must maintain fiber alignment and provide repeatable loss measurements during numerous connections. Fiber-optic connectors should be easy to assemble (in a laboratory or field environment), cost effective, and reliable. Fiber-optic connections using connectors should be insensitive to environmental conditions, such as temperature, dust, and moisture. Fiber-optic connector designs attempt to optimize connector performance by meeting each of these conditions.

1.11.1 Butt Joined Connectors and Expanded Beam Connectors

Butt jointed connectors and expanded beam connectors are the two basic types of fiber-optic connectors. Fiber-optic butt jointed connectors align and bring the prepared ends of two fibers into close contact. The end faces of some butt-jointed connectors touch, but others do not. depending upon the connector design. Types of butt-jointed connectors include cylindrical ferrule and biconical connectors. *Figure 9-4* shows a basic ferrule design. Fiber-optic expanded beam connectors use two lenses to first expand and then refocus the light from the transmitting fiber into the receiving fiber.

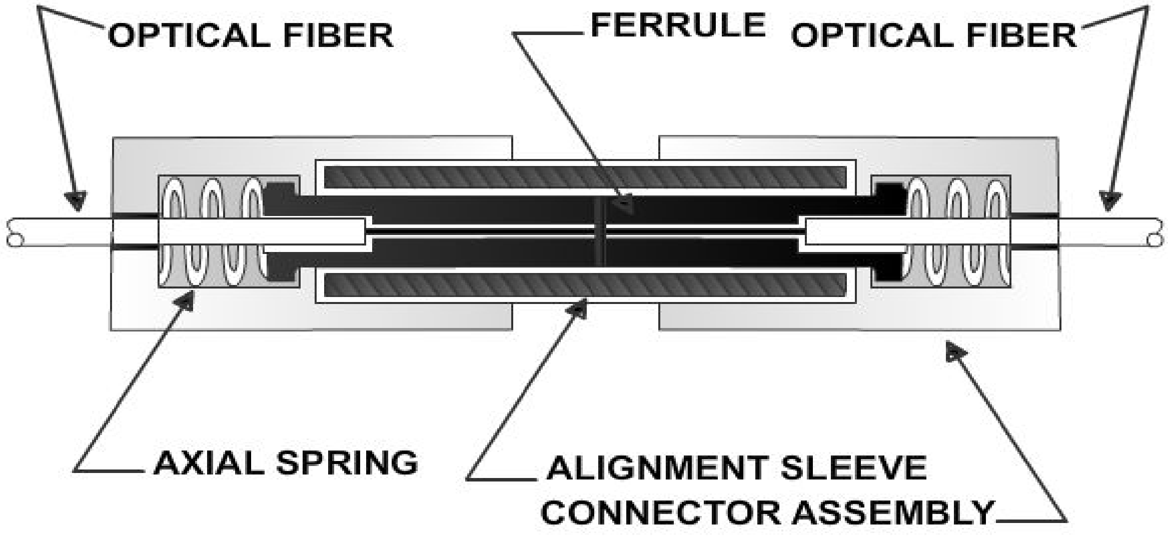

Figure 9-4 — Basic ferrule connector design.

Single fiber butt-jointed and expanded beam connectors normally consist of two plugs and an adapter (coupling device) (*Figure 9-5*).

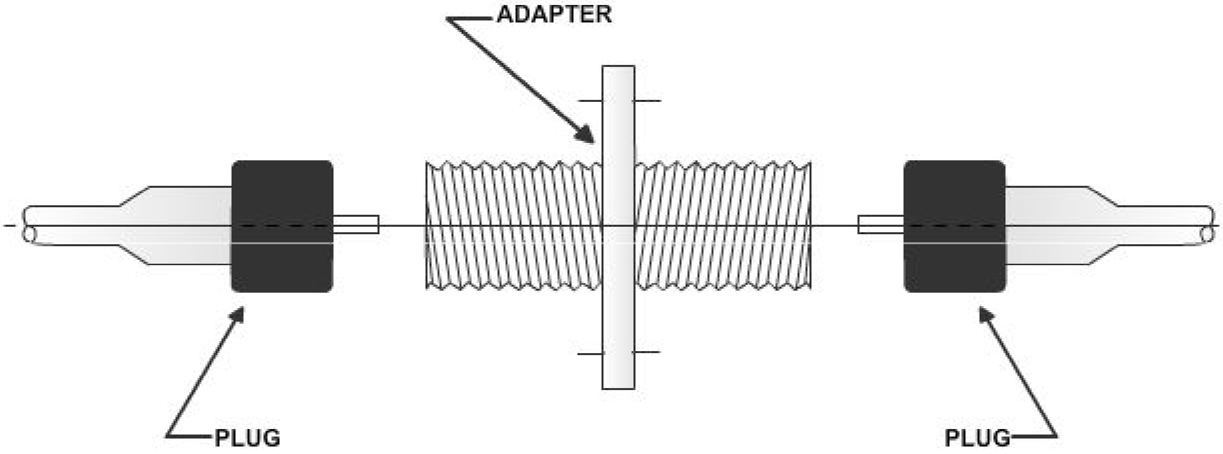

Figure 9-5 — Plug adapter plug configuration.

1.11.2 Expanded Beam Connector

The expanded beam connector, shown in *Figure 9-6*, uses two lenses to expand and then refocus the light from the transmitting fiber into the receiving fiber. Expanded beam connectors are normally plug adapter plug type connections Fiber separation and lateral misalignment are less critical in expanded beam coupling than in butt jointing. The same amount of fiber separation and lateral misalignment in expanded beam coupling produces a lower coupling loss than in butt jointing; however, angular misalignment is more critical. The same amount of angular misalignment in expanded beam coupling produces a higher loss than in butt jointing. Also, expanded beam connectors are much harder to produce. Recent applications for expanded beam connectors include multi-fiber connections, edge connections for printed circuit boards, and other applications.

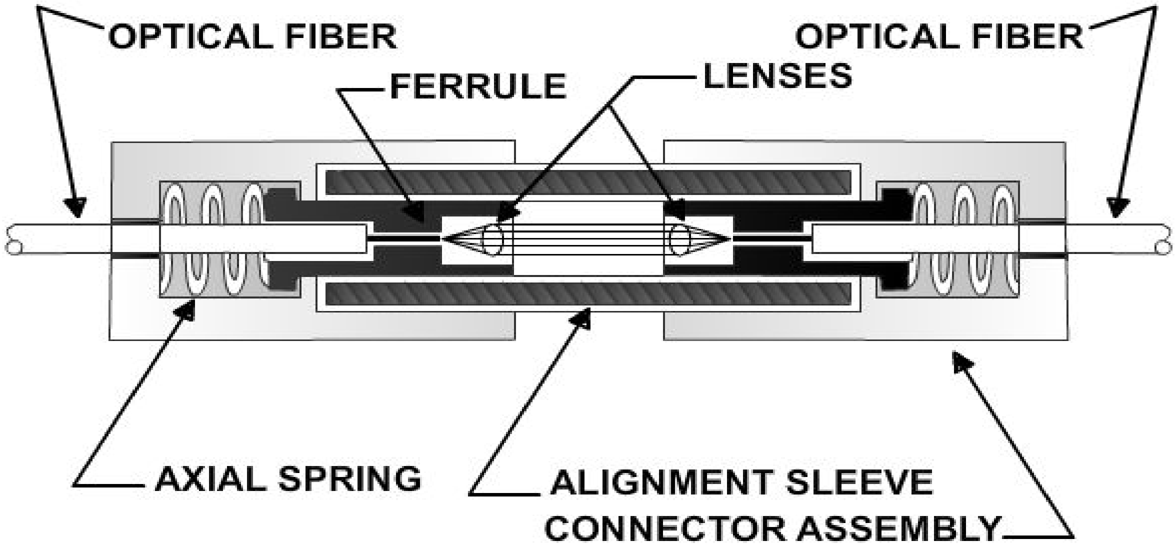

Figure 9-6 — Expanded beam connector operation.

1.12.0 Fiber Optic Couplers

Some fiber-optic data links require more than simple point-to-point connections. These data links may be of a much more complex design that requires multiport or other types of connections. In many cases, these types of systems require fiber-optic components that can redistribute (combine or split) optical signals throughout the system.

One type of fiber-optic component that allows for the redistribution of optical signals is a fiber-optic coupler. A fiber-optic coupler is a device that can distribute the optical signal (power) from one fiber among two or more fibers or combine the optical signal from two or more fibers into a single fiber.

Fiber-optic couplers can be either active or passive devices. The difference between active and passive couplers is that a passive coupler redistributes the optical signal without optical-to-electrical conversion. Active couplers are electronic devices that split or combine the signal electrically and use fiber-optic detectors and sources for input and output.

Figure 9-7 shows the design of a basic fiber-optic coupler. A basic fiber-optic coupler has N input ports and M output ports, which typically range from 1 to 64. The number of input ports and output ports varies, depending on the intended application for the coupler. Types of fiber-optic couplers include optical splitters, optical combiners, X couplers, star couplers, and tree couplers.

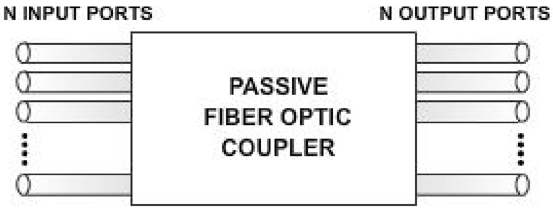

Figure 9-7 — Basic passive fiber optic coupler design.

Test your Knowledge (Select the Correct Response)

1. How many parts make up a fiber optic cable?

   A. 1
   B. 2
   C. 3
   D. 4

2.0.0 FIBER OPTICS ADVANCED

2.1.0 Fiber Optics

As stated earlier, a fiber optic data link had three basic functions:

- To convert an electrical input signal to an optical signal
- To send the optical signal over an optical fiber
- To convert the optical signal back to an electrical signal

The fiber-optic data link converts an electrical signal into an optical signal, permitting the transfer of data along an optical fiber. The fiber-optic device responsible for that signal conversion is a fiber-optic transmitter. A fiber-optic transmitter is a ***hybrid*** device. It converts electrical signals into optical signals and launches the optical signals into an optical fiber. A fiber-optic transmitter consists of an interface circuit, a source drive circuit, and an optical source.

The interface circuit accepts the incoming electrical signal and processes it to make it compatible with the source drive circuit. The source drive circuit intensity modulates the optical source by varying the current through the source. An optical source converts electrical energy (current) into optical energy (light). Light emitted by an optical source is launched, or coupled, into an optical fiber for transmission.

Fiber-optic data link performance depends on the amount of optical power (light) launched into the optical fiber. This section provides an overview of optical sources and fiber optic transmitters.

2.1.1 Optical Source Properties

The development of efficient semiconductor optical sources, along with low-loss optical fibers, has led to substantial improvements in fiber-optic communications. Semiconductor optical sources have the physical characteristics and performance properties necessary for successful implementations of fiber-optic systems. Optical sources should do the following:

- Be compatible in size to low loss optical fibers by having a small light emitting area capable of launching light into fiber
- Launch sufficient optical power into the optical fiber to overcome fiber attenuation and connection losses, allowing for signal detection at the receiver
- Emit light at wavelengths that minimize optical fiber loss and dispersion. Optical sources should have a narrow spectral width to minimize dispersion
- Allow for direct modulation of optical output power
- Maintain stable operation in changing environmental conditions (such as temperature)
- Cost less and be more reliable than electrical devices, thereby permitting fiber optic communication systems to compete with conventional systems

Semiconductor optical sources suitable for fiber optic systems range from inexpensive light-emitting diodes (LEDs) to more expensive semiconductor lasers. Semiconductor LEDs and laser diodes (LDs) are the principal light sources used in fiber optics.

2.1.2 Semiconductor Light Emitting Diodes and Laser Diodes

Semiconductor LEDs emit ***incoherent light***. Spontaneous emission of light in semiconductor LEDs produces light waves that lack a fixed-phase relationship. Those light waves are referred to as incoherent light. LEDs are the preferred optical source for multimode systems because they can launch sufficient power at a lower cost than semiconductor laser diodes (LDs).

Semiconductor LDs emit coherent light, i.e., light waves having a fixed-phase relationship. Since semiconductor LDs emits more focused light than LEDs, they are able to launch optical power into both single mode and multimode optical fibers; however, LDs usually are used only in single mode fiber systems because they require more complex driver circuitry and cost more than LEDs.

Optical power produced by optical sources can range from microwatts (µw) for LEDs to tens of milliwatts (mw) for semiconductor LDs; however, it is not possible to couple all the available optical power effectively into the optical fiber for transmission.

The amount of optical power coupled into the fiber is the relevant optical power. It depends on the following factors:

- The angles over which the light is emitted
- The size of the light emitting area of the source relative to the fiber core size
- The alignment of the source and fiber
- The coupling characteristics of the fiber

Typically, semiconductor lasers emit light spread out over an angle of 10 to 15 degrees. Semiconductor LEDs emit light spread out at even larger angles. Coupling losses of several decibels (dB) can easily occur when coupling light from an optical source to a fiber, especially with LEDs.

2.1.3 Semiconductor Material

Understanding optical emission in semiconductor lasers and LEDs requires knowledge of semiconductor material and device properties. Providing a complete description of semiconductor properties is beyond the scope of this text. In this section, we will only discuss the general properties of semiconductor LEDs and LDs.

Semiconductor sources are diodes, with all of the characteristics typical of diodes except that their construction includes a special layer, called the active layer, that emits photons (light particles) when a current passes through it. The particular properties of the semiconductor are determined by the materials used and the layering of the materials within the semiconductor. Silicon (Si) and gallium arsenide (GaAs) are the two most common semiconductor materials used in electronic and electro-optic devices. In some cases, other elements, such as aluminum (Al), indium (In), or phosphorus (P), are added to the base semiconductor material to modify the semiconductor properties. These elements are called ***dopants***. Current flowing through a semiconductor optical source causes it to produce light.

LEDs generally produce light through spontaneous emission when a current passes through them. Spontaneous emission is the random generation of photons within the active layer of the LED. The emitted photons move in random directions. Only a certain percentage of the photons exit the semiconductor and are coupled into the fiber. Many of the photons are absorbed by the LED materials and the energy is dissipated as heat. This process causes the light output from an LED to be incoherent, have a broad spectral width, and have a wide output pattern.

Laser diodes are much more complex than LEDs. Laser is an acronym for Light Amplification by the Stimulated Emission of Radiation. Laser diodes produce light through stimulated emission when a current is passed through them. All types of lasers produce light by stimulated. In this process, in the laser diode, photons, initially produced by spontaneous emission, interact with the laser material to produce additional photons. This process occurs within the active area of the diode called the laser cavity.

As with the LED, not all of the photons produced are emitted from the laser diode. Some are absorbed and the energy dissipated as heat. The emission process and the physical characteristics of the diode cause the light output to be coherent, have a narrow spectral width, and have a narrow output pattern.

It is important to note that in both LED and laser diodes not all of the electrical energy is converted into optical energy. A substantial portion is converted to heat. Different LED and laser diode structures convert different amounts of electrical energy into optical energy.

2.1.4 Fiber Optic Transmitters

As stated previously, a fiber-optic transmitter is a hybrid electro-optic device. It converts electrical signals into optical signals and launches the optical signals into an optical fiber. A fiber-optic transmitter consists of an interface circuit, a source drive circuit, and an optical source. The interface circuit accepts the incoming electrical signal and processes it to make it compatible with the source drive circuit. The source drive circuit intensity modulates the optical source by varying the current through it. The optical signal is coupled into an optical fiber through the transmitter output interface.

Although semiconductor LEDs and LDs have many similarities, unique transmitter designs result from differences between LED and LD sources. Transmitter designs compensate for differences in optical output power, response time, linearity, and thermal behavior between LEDs and LDs to ensure proper system operation. Fiber-optic transmitters using LDs require more complex circuitry than transmitters using LEDs.

Transmitter output interfaces generally fall into two categories: optical connectors and optical fiber pigtails (*Figure 9-8*). Optical pigtails are attached to the transmitter optical source. This pigtail is generally routed out of the transmitter package as a coated fiber in a loose buffer tube or a single fiber cable. The pigtail is either soldered or epoxied to the transmitter package to provide fiber strain relief. The buffer tube or single fiber cable also is attached to the transmitter package to provide additional strain relief.

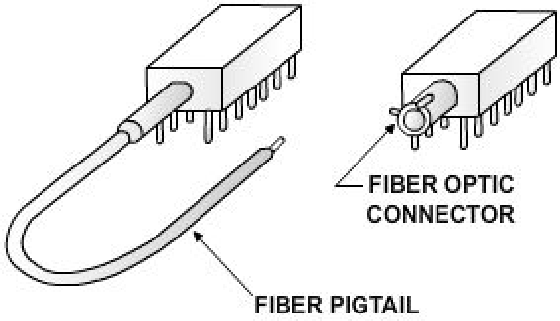

Figure 9-8 — Pigtailed and connectorized fiber optic devices.

The transmitter output interface may consist of a fiber-optical connector. The optical source may couple to the output optical connector through an intermediate optical fiber. , one end of which is attached to the source. The other end terminates in the transmitter optical output connector. The optical source may also couple to the output optical connector without an intermediate optical fiber. The optical source is placed within the transmitter package to launch power directly into the fiber of the mating optical connector. In some cases, lenses are used to more efficiently couple light from the source into the mating optical connector.

3.0.0 OPTICAL DETECTORS and FIBER OPTIC RECEIVERS

A fiber-optic transmitter is an electro-optic device capable of accepting electrical signals, converting them into optical signals, and launching those signals into an optical fiber. Scattering, absorption, and dispersion weaken and distort the signals propagating in the fiber. The fiber-optic device responsible for converting the weakened and distorted optical signal back to an electrical signal is a fiber-optic receiver.

A fiber-optic receiver is an electro-optic device that accepts optical signals from an optical fiber and converts them into electrical signals. A typical fiber optic receiver consists of an optical detector, a low noise amplifier, and other circuitry used to produce the output electrical signal (*Figure 9-9*). The optical detector converts the incoming optical signal into an electrical signal. The amplifier then amplifies the electrical signal to a level suitable for further signal processing. The type of other circuitry contained within the receiver depends on the type of modulation used and the receiver's electrical output requirements.

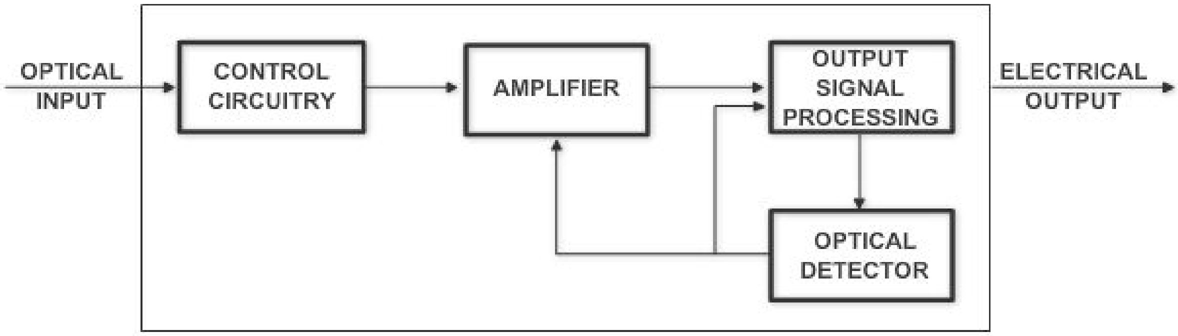

Figure 9-9 — Block diagram of a typical fiber optic receiver.

A ***transducer*** is a device that converts input energy of one form into output energy of another. An optical detector is a transducer that converts an optical signal into an electrical signal. It does this by generating an electrical current proportional to the intensity of incident optical radiation. The relationship between the input optical radiation and the output electrical current is given by the detector responsivity.

4.0.0 FIBER OPTIC SYSTEM TOPOLOGY

A point-to-point fiber-optic data link consists of three specific parts: an optical transmitter, an optical fiber, and an optical receiver. In addition, it includes any splices or connectors used to join individual optical fiber sections to each other and to the transmitter and receiver. *Figure 9-10* provides a schematic diagram of a point-to-point fiber-optic data link.

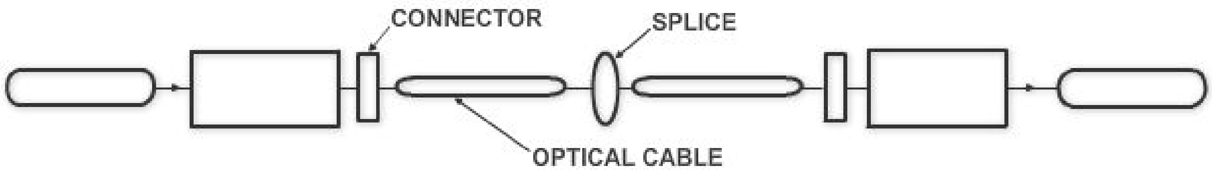

Figure 9-10 — A schematic diagram of a point to point fiber optic data link.

A common fiber-optic application is the full duplex link, which consists of two simple point-to-point links. These links transmit in opposite directions between the equipment. This application may be configured using only one fiber. If it is, fiber-optic splitters are used at each end to couple the transmit signal onto the fiber and receive signals to the detector.

All fiber-optic systems are simply sets of point-to-point fiber optic links. Different system topologies arise from the different ways that point-to-point fiber optic links can be connected between equipment. The term topology, as used here, refers to the configuration of various types of equipment and the fiber optic components interconnecting them. This equipment may be computers, workstations, consoles, or other equipment. Point-to-point links are connected to produce systems with linear bus, ring, star, or tree topologies. Point-to-point fiber optic links are the basic building block of all fiber optic systems.

5.0.0 FIBER OPTICS SYSTEM INSTALLATION

The Navy has a standard to provide detailed information and guidance to personnel concerned with the installation of fiber optic cables and cable plants. The fiber optic cable plant consists of all the fiber optic cables and the fiber optic interconnection equipment, including connectors, splices, and interconnection boxes. The fiber optic cable and cable plant installation standard consists of the following:

- Detailed methods for cable storage and handling, end sealing, repair, and splicing
- Detailed methods for fiber optic equipment installation and cable entrance to equipment
- Detailed methods to install fiber optic cables in cableways
- Detailed methods for installing fiber optic connectors and other interconnections, such as splices
- Detailed methods for testing fiber optic cable plants before, during, and after installation and repair

There are other standards that discuss fiber optic system installation. Many of these standards incorporate procedures for repair, maintenance, and testing. The techniques developed for installing fiber optic hardware are not much different than for installing hardware for copper-based systems: however, the primary precautions that need to be emphasized when installing fiber optic systems are as follows:

- Optical fibers or cables should never be bent at a radius of curvature less than a certain value, called the minimum bend radius. Bending an optical cable at a radius smaller than the minimum bend radius causes signal loss.
- Fiber optic cables should never be pulled tight or fastened over or through sharp comers or cutting edges. Extremely sharp bends increase the fiber loss and may lead to fiber breakage.
- Fiber optic connectors should always be cleaned before mating. Dirt in a fiber optic connection will significantly increase the connection loss and may damage the connector.
- Precautions must be taken so the cable does not become kinked or crushed during installation of the hardware. Extremely sharp kinks or bends increase the fiber loss and may lead to fiber breakage.

6.0.0 FIBER OPTIC MEASUREMENTS

Fiber optic data links operate reliably if fiber optic component manufacturers and you perform the necessary laboratory and field measurements. Manufacturers must test how component designs, material properties, and fabrication techniques affect the performance of fiber-optic components. These tests can be categorized as design tests or quality control tests. Design tests are conducted during the development of a component. Design tests measure the performance of the component (optical, mechanical, and environmental) in the intended application. Once the performance of the component is characterized, the manufacturer generally conducts only quality control tests. Those tests verify that the parts produced are the same as the parts on which the design tests were conducted. When manufacturers ship fiber optic components, they provide quality control data detailing the results of measurements performed during or after fabrication of the component.

You, as the installer, should measure some of these parameters upon receipt before installing the component into the fiber optic data link. These tests determine if the component has been damaged in the shipping process. In addition, measure some component parameters after installing or repairing fiber optic components in the field. Compare the values you obtain to the system installation specifications. These measurements determine if the installation or repair process has degraded the performance of the component and will affect data link operation.

6.1.0 Field Measurements

Field measurements measure the transmission properties of installed fiber optic components. You must perform field measurements to evaluate those properties most likely affected by the installation or repair of fiber optic components or systems.

This discussion on field measurements is limited to optical fiber and optical connection properties. Optical fiber and optical connection field measurements evaluate only the transmission properties affected by component or system installation or repair. Because optical fiber geometrical properties, such as core and cladding diameter and numerical aperture, are not expected to change, there is no need to remeasure these properties. The optical connection properties that are likely to change are connection insertion loss and reflectance and return loss.

Field measurements require rugged, portable test equipment, unlike the sophisticated test equipment used in the laboratory. Field test equipment must provide accurate measurements in extreme environmental conditions. Since electrical power sources may not always be available in the field, test equipment should allow battery operation. In addition, while both fiber ends are available for conducting laboratory measurements, only one fiber end may be readily available for field measurements. Even if both fiber ends are available for field measurements, the fiber ends are normally located some distance apart, requiring two people to perform the measurements.

The main field measurement technique involves optical time domain reflectometry (*Figure 9-11*). An optical time domain reflectometer (OTDR) is recommended for conducting field measurements on installed optical fibers or links of 50 meters or more in length. An OTDR requires access to only one fiber end. It measures the ***attenuation*** of installed optical fibers as a function of length, identifies and evaluates optical connection losses along a cable link, and locates any fiber breaks or faults.

Figure 9-11 — Optical time domain reflectometer.

Users also can measure fiber attenuation and cable plant transmission loss, using an optical power meter and a stabilized light source. Use this measurement technique when optical time domain reflectometry is not recommended. Measurements obtained with a stabilized light source and power meter are more accurate than those obtained with an OTDR. Measuring fiber attenuation and transmission loss using a power meter and light source requires access to both ends of the fiber or link. An optical loss test set (OLTS) combines the power meter and source functions into one physical unit.

6.2.0 Optical Time Domain Reflectometry

Use optical time domain reflectometry to characterize optical fiber and optical connection properties in the field. In optical time domain reflectometry, an OTDR transmits an optical pulse through an installed optical fiber. The OTDR measures the fraction of light that is reflected back. By comparing the amount of light the OTDR scatters back at different times, you can determine fiber and connection losses. When several fibers are connected to form an installed cable plant, the OTDR can characterize optical fiber and optical connection properties along the entire length of the plant. A fiber optic cable plant consists of optical fiber cables, connectors, splices, mounting panels, jumper cables, and other passive components. It does not include active components, such as optical transmitters or receivers.

The OTDR displays the backscattered and reflected optical signal as a function of length. The OTDR plots half the power in decibels (dB) versus half the distance. Plotting half the power in dB and half the distance corrects for round-trip effects. By analyzing the OTDR plot, or trace, you can measure fiber attenuation and transmission loss between any two points along the cable plant. You also can measure insertion loss and reflectance of any optical connection. In addition, use the OTDR trace to locate fiber breaks or faults. *Figure 9-12* shows an example OTDR trace of an installed cable plant.

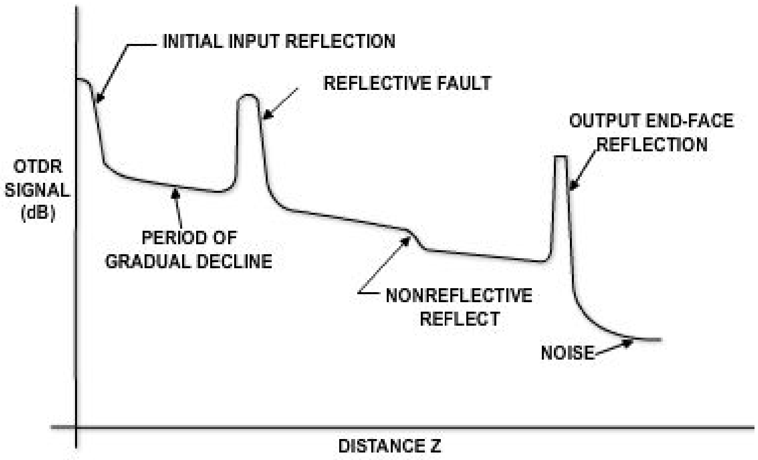

Figure 9-12 — OTDR trace of an installed cable plant.

7.0.0 MECHANICAL and FUSION SPLICES

Mechanical splicing methods use mechanical fixtures to align and connect optical fibers and may involve either passive or active core alignment. Active core alignment produces a lower loss splice than passive alignment; however, passive core alignment methods can produce mechanical splices with acceptable loss measurements even with single mode fibers.

In the strictest sense, a mechanical splice is a permanent connection made between two optical fibers. Mechanical splices hold the two optical fibers in alignment for an indefinite period of time without movement. The amount of splice loss is stable over time and unaffected by changes in environmental or mechanical conditions.

The types of mechanical splices used for mechanical splicing include glass, plastic, metal, and ceramic tubes; also included are V-groove and rotary devices. Materials that assist mechanical splices in splicing fibers include transparent adhesives and index matching gels. Transparent adhesives are epoxy resins that seal mechanical splices and provide index matching between the connected fibers.

7.1.0 Glass or Ceramic Alignment Tube Splices

Mechanical splicing may involve the use of a glass or ceramic alignment tube or ***capillary.*** The inner diameter of this glass or ceramic tube is only slightly larger than the outer diameter of the fiber. A transparent adhesive, injected into the tube, bonds the two fibers together. The adhesive also provides index matching between the optical fibers. *Figure 9-13* illustrates fiber alignment using a glass or ceramic tube. This splicing technique relies on the inner diameter of the alignment tube. If the inner diameter is too large, splice loss will increase because of fiber misalignment. If the inner diameter is too small, it is impossible to insert the fiber into the tube.

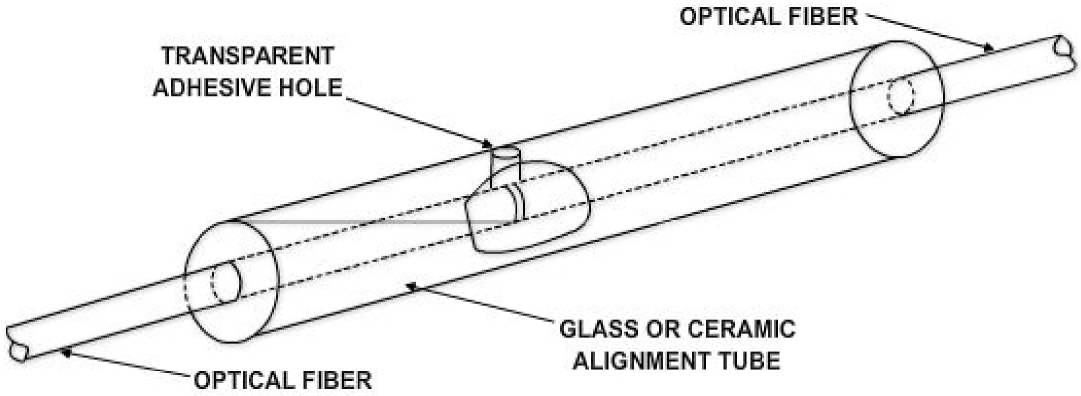

Figure 9-13 — Glass or ceramic alignment tube for mechanical splicing.

7.2.0 V – Grooved Splices

Mechanical splices also may use either a grooved ***substrate*** or positioning rods to form suitable V-grooves for mechanical splicing. The basic V-grooved device relies on an open-grooved substrate to perform fiber alignment. When you are inserting the fibers into the grooved substrate, the V-groove aligns the cladding surface of each fiber end. A transparent adhesive makes the splice permanent by securing the fiber ends to the grooved substrate. *Figure 9-14* illustrates this type of open V-grooved splice.

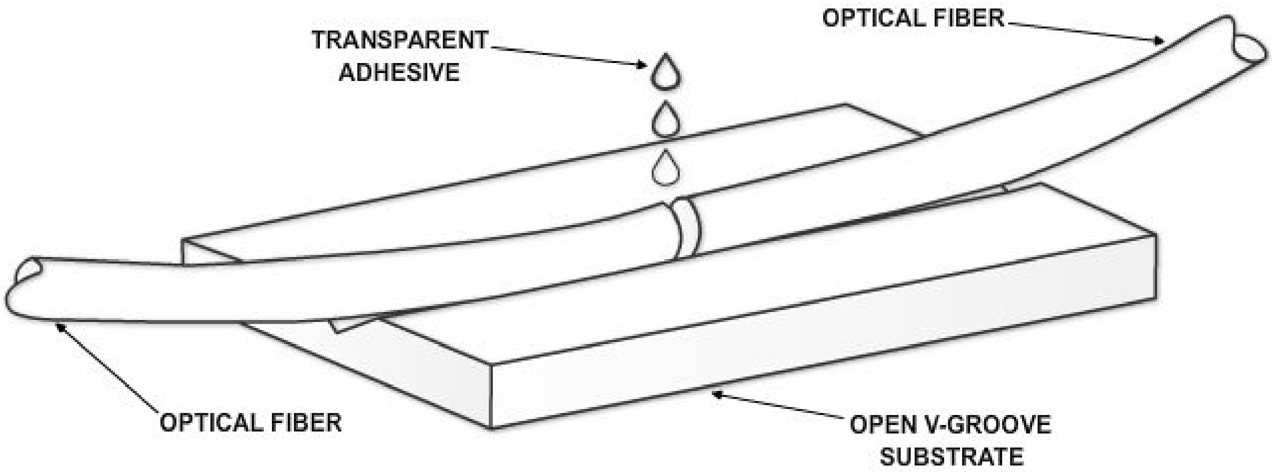

Figure 9-14 — Open V – grooved splice.

V-grooved splices may involve sandwiching the butted ends of two prepared fibers between a V-grooved substrate and a flat, glass plate. Additional V-grooved devices use two or three positioning rods to form a suitable V-groove for splicing. The V-grooved device that uses two positioning rods is the spring V-grooved splice. This splice uses a groove formed by two rods positioned in a bracket to align the fiber ends. The diameter of the positioning rods permits the outer surface of each fiber end to extend above the groove formed by the rods. A flat spring presses the fiber ends into the groove that maintains fiber alignment. Transparent adhesive completes the assembly process by bonding the fiber ends and providing index matching. *Figure 9-15* is an illustration of the spring V-grooved splice. A variation of this splice uses a third positioning rod instead of a flat spring. The rods are held in place by a heat-shrinkable band or tube.

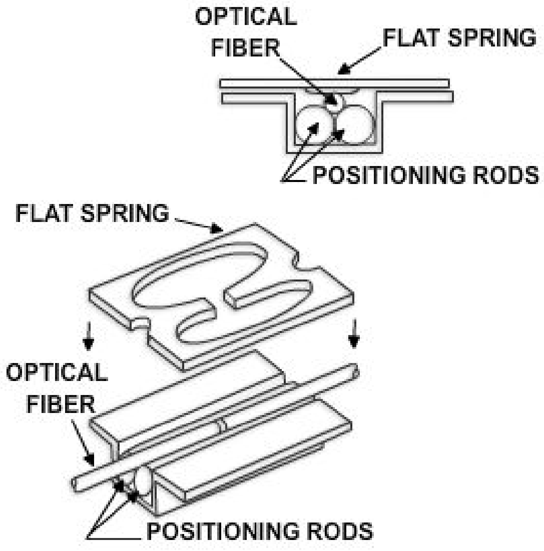

Figure 9-15 — Spring V – grooved mechanical splice.

7.3.0 Rotary Splices

In a rotary splice, the fibers are mounted into a glass ***ferrule*** and secured with adhesives. The splice begins as one long glass ferrule that is broken in half during the assembly process. A fiber is inserted into each half of the tube and epoxied in place, using an ultraviolet cure ***epoxy***. The end face of the tubes is then polished and placed together, using the alignment sleeve. *Figure 9-16* is an illustration of a rotary mechanical splice. The fiber ends retain their original orientation and have added mechanical stability since each fiber is mounted into a glass ferrule and alignment sleeve. The rotary splice may use index matching gel within the alignment sleeve to produce low-loss splices.

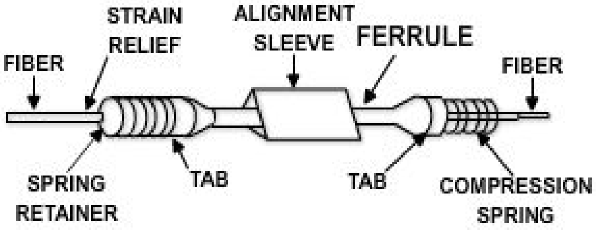

Figure 9-16 — Rotary mechanical splice.

7.4.0 Fusion Splices

The process of fusion splicing involves using localized heat to melt or fuse the ends of two optical fibers together. The splicing process begins by preparing each fiber end for fusion. Fusion splicing requires that all protective coatings be removed from the ends of each fiber. The fiber is then ***cleaved***, using the score-and-break method. The quality of each fiber end is inspected with a microscope. In fusion splicing, splice loss is a direct function of the angles and quality of the two fiber end faces.