Fiber Optics (Volume 3) - Connectors

An Online Continuing Education Course for Engineers

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Fiber Optics (Volume 3) - Connectors

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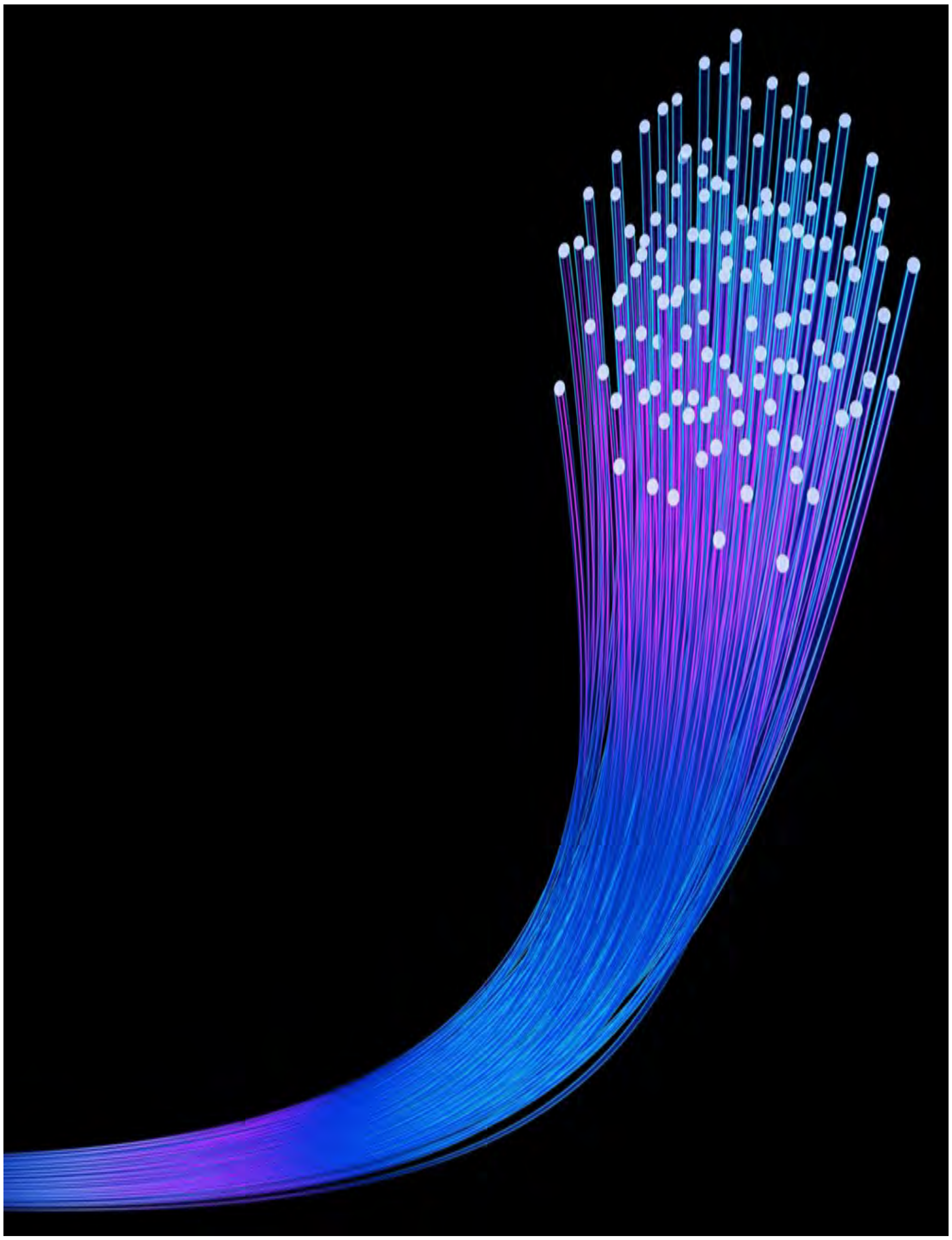

Preface

This is the first in a series of five courses about fiber optic cable systems. The series covers fiber optics from basic light theory transmission to cables, connectors, testing, and signal transmission.

The complete series includes these five courses:

1. Fiber Optics I – Theory
2. Fiber Optics II – Cable Design
3. Fiber Optics III – Connectors
4. Fiber Optics IV – Testing
5. Fiber Optics V – Equipment

The first course, *Fiber Optics I –Theory*, is an overview of the technology of fiber optic cables including a description of the components, history, and advantages of fiber optic cables. This course also discusses the electromagnetic theory of light and describes the properties of light reflection, refraction, diffusion, and absorption.

The second course, *Fiber Optics II – Cable Design*, explains the basic construction of fiber optic cables including the types of cables, cable properties, and performance characteristics. The course reviews multimode, single mode step-index and graded index fibers, and fabrication procedures.

The third course, *Fiber Optics III - Connectors*, describes fiber optic splices, connectors, couplers and the types of connections they form in systems. It includes a discussion on the types of extrinsic and intrinsic coupling losses, fiber alignment and fiber mismatch problems, and fiber optic mechanical and fusion splices.

The fourth course, *Fiber Optics IV - Testing*, describes the optical fiber and optical connection laboratory measurements used to evaluate fiber optic components and system performance, including the near-field and far-field optical power distribution of an optical fiber. This course also reviews optical time-domain reflectometry (OTDR).

The fifth course, *Fiber Optics V - Equipment*, explains the principal properties of an optical source and fiber optic transmitters, the optical emission properties of semiconductor light-emitting diodes (LEDs) and laser diodes (LDs), and explains the operational differences between surface-emitting LEDs (SLEDs), edge-emitting LEDs (ELEDs), superluminescent diodes (SLDs), and laser diodes.

It is not necessary to take the courses in sequence. However, for best comprehension it is suggested that the courses be taken in the order presented.

Introduction

This is Volume III of five volumes on fiber optics systems. This volume is concerned with the connectors that are used to join fiber optic cables and includes splices, connectors, and couplings.

This course describes fiber optic splices, connectors, couplers and the types of connections they form in systems. It includes a discussion on the types of extrinsic and intrinsic coupling losses, fiber alignment and fiber mismatch problems, and fiber optic mechanical and fusion splices. Issues such as how optical power is transferred from one fiber optic component to another is considered as well as how an optical source launches optical power into a fiber and how one optical fiber couples light into another fiber.

Fiber Optic Connections

With a fiber optic system, the data link transmitter converts an electrical input signal to an optical signal. Then, the optical fiber transmits this optical signal. Finally, the data link receiver converts the optical signal back to an electrical signal identical to the original input.

This volume describes how optical power is transferred from one fiber optic component to another. It describes how an optical source launches optical power into a fiber as well as how one optical fiber couples light into another fiber. In fiber optic system design, this launching or coupling of optical power from one component to the next is important.

Fiber optic connections permit the transfer of optical power from one component to another. Fiber optic connections also permit fiber optic systems to be more than just point-to-point data communication links. In fact, fiber optic data links are often of a more complex design than point-to-point data links.

A system connection may require either a fiber optic splice, connector, or coupler. One type of system connection is a permanent connection made by splicing optical fibers together. A *fiber optic splice* makes a permanent joint between two fibers or two groups of fibers. There are two types of fiber optic splices--mechanical splices and fusion splices. Even though removal of some mechanical splices is possible, they are intended to be permanent. Another type of connection that allows for system reconfiguration is a fiber optic connector. Fiber optic connectors permit easy coupling and uncoupling of optical fibers. Fiber optic connectors sometimes resemble familiar electrical plugs and sockets. Systems may also divide or combine optical signals between fibers. *Fiber optic couplers* distribute or combine optical signals between fibers. Couplers can distribute an optical signal from a single fiber into several fibers. Couplers may also combine optical signals from several fibers into one fiber.

Fiber optic connection losses may affect system performance. Poor fiber end preparation and poor fiber alignment are the main causes of coupling loss. Another source of coupling loss is differences in optical properties between the connected fibers. If the connected fibers have different optical properties, such as different numerical apertures, core and cladding diameters, and refractive index profiles, then coupling losses may increase.

Optical Fiber Coupling Loss

Ideally, optical signals coupled between fiber optic components are transmitted with no loss of light. However, there is always some type of imperfection present at fiber optic connections that causes some loss of light. It is the amount of optical power lost at fiber optic connections that is a concern of system designers.

The design of fiber optic systems depends on how much light is launched into an optical fiber from an optical source and how much light is coupled between fiber optic components, such as from one fiber to another. The amount of power launched from a source into a fiber depends on the optical properties of both the source and the fiber. The amount of optical power launched into an optical fiber depends on the radiance of the optical source. An optical source's *radiance*, or brightness, is a measure of its optical power launching capability. Radiance is the amount of optical power emitted in a specific direction per unit time by a unit area of emitting surface. For most types of optical sources, only a fraction of the power emitted by the source is launched into the optical fiber.

The loss in optical power through a connection is defined similarly to that of signal attenuation through a fiber. Optical loss is also a log relationship. The loss in optical power through a connection is defined as:

$$\textbf{Loss} = \mathbf{10 * \log 10 \left(\frac{P_i}{P_0}\right)}$$

Where,

Loss = Optical power loss in the connection.

P_i = The power accepted by the connected fiber

P_0 = The power emitted from the source fiber in a fiber-to-fiber connection

In any fiber optic connection, P_o and P_i are the optical power levels measured before and after the joint, respectively.

Fiber-to-fiber connection loss is affected by intrinsic and extrinsic coupling losses. *Intrinsic coupling losses* are caused by inherent fiber characteristics. *Extrinsic coupling losses* are caused by jointing techniques. 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

Intrinsic coupling losses are limited by reducing fiber mismatches between the connected fibers. This is done by procuring only fibers that meet strin… …trical and optical specifications. Extrinsic coupling losses ar… …connection procedures.

Some fiber optic comp… …reduce coupling losses between components. … …moved from any system. For example, fi… …components. Fiber optic transmitters and r… …red with fiber pigtails or fiber optic connector… …gth of optical fiber (usually 1 meter or less)… …or. Manufacturers supply transmitters and … …er coupling to sources and detectors m… …pling loss results when source-to-fiber and… …manufacturing environment. Since optica… …ized, launching optical power is reduced t… …most fiber optic connections can be consid…

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Figure 1…