



# Fiber Optics (Volume 2) - Cable Design

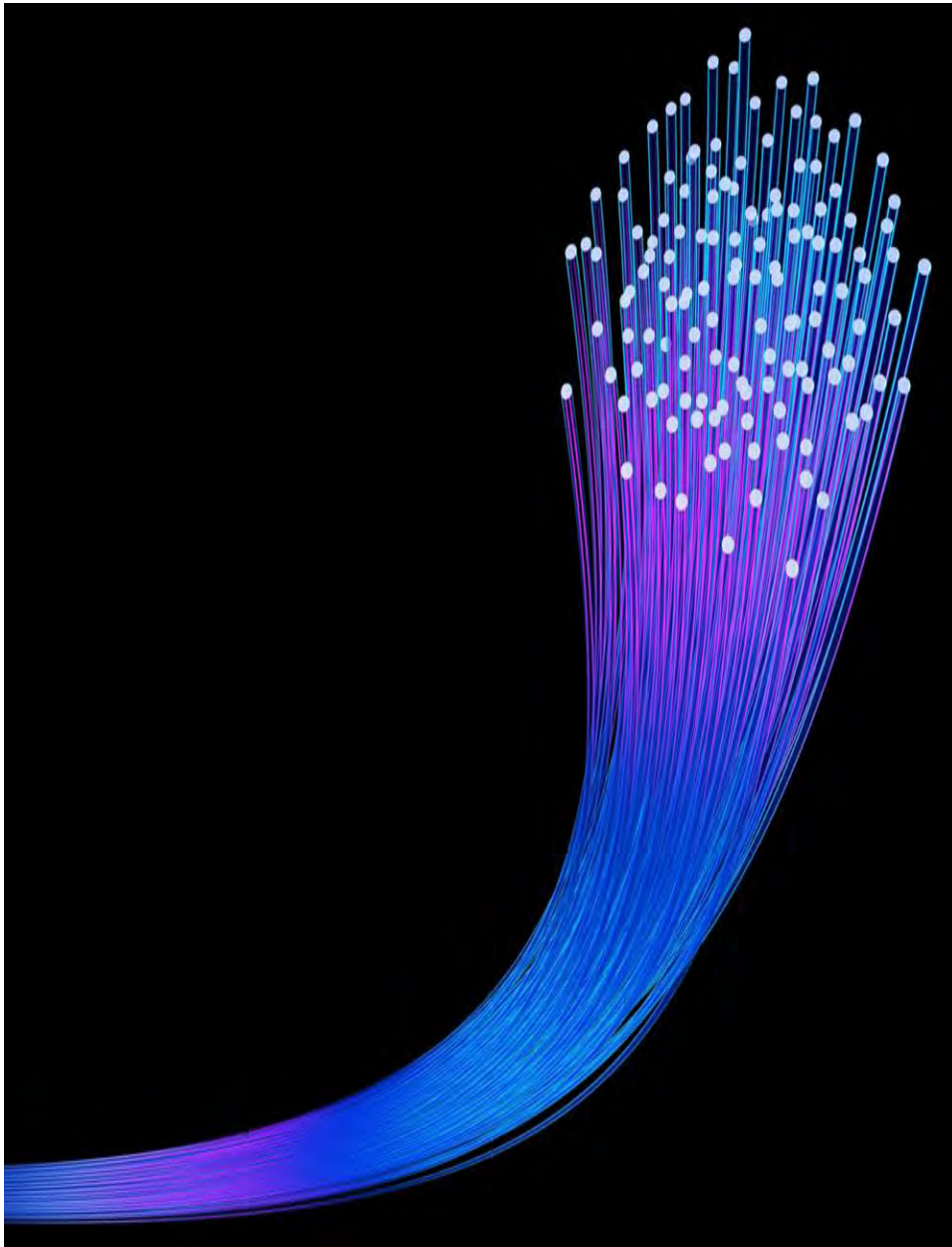
An Online Continuing Education Course for Engineers

**Course Number: IC-3006**

**Credit: 3 Hours / 3 PDH / 3 CPD**

# Fiber Optics (Volume 2) – Cable Design

Lee Layton, P.E.



# Table of Contents

<u>Section</u>	<u>Page</u>
Preface .....	3
Introduction .....	4
Chapter 1 – Optical Fiber Designs .....	5
Chapter 2 – Optical Cable Design .....	15
Summary .....	28

## Preface

This is the second 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 the best comprehension it is suggested that the courses be taken in the order presented.

## Introduction

This is Volume II of five volumes on fiber optics systems. This volume is concerned with the basic design of fiber optic cables. Optical fibers are thin cylindrical dielectric (non-conductive) waveguides used to send light energy for communication. Optical fibers consist of three parts: the core, the cladding, and the coating or buffer.

This course describes multimode and single mode step-index and graded-index fibers, explains the terms refractive index profile, relative refractive index difference, and profile parameter and lists the performance advantages of multimode graded-index fibers.

The choice of optical fiber materials and fiber design depends on operating conditions and intended application. Optical fibers are protected from the environment by incorporating the fiber into some type of cable structure. Cable strength members and outer jackets protect the fiber. Optical cable structure and material composition depend on the conditions of operation and the intended application.

The course also describes fabrication processes including the vapor phase oxidation and direct-melt optical fiber fabrication procedures. Basic cable components, such as buffers, strength members, and jacket materials are explained as well as the advantages and disadvantages of OFCC cable, stranded cable, and ribbon cable designs.

# Chapter One

## Optical Fiber Designs

Optical fibers are either single mode or multimode fibers. Fibers are classified according to the number of modes that they can propagate. Single mode fibers can propagate only the fundamental mode. Multimode fibers can propagate hundreds of modes. However, the classification of an optical fiber depends on more than the number of modes that a fiber can propagate.

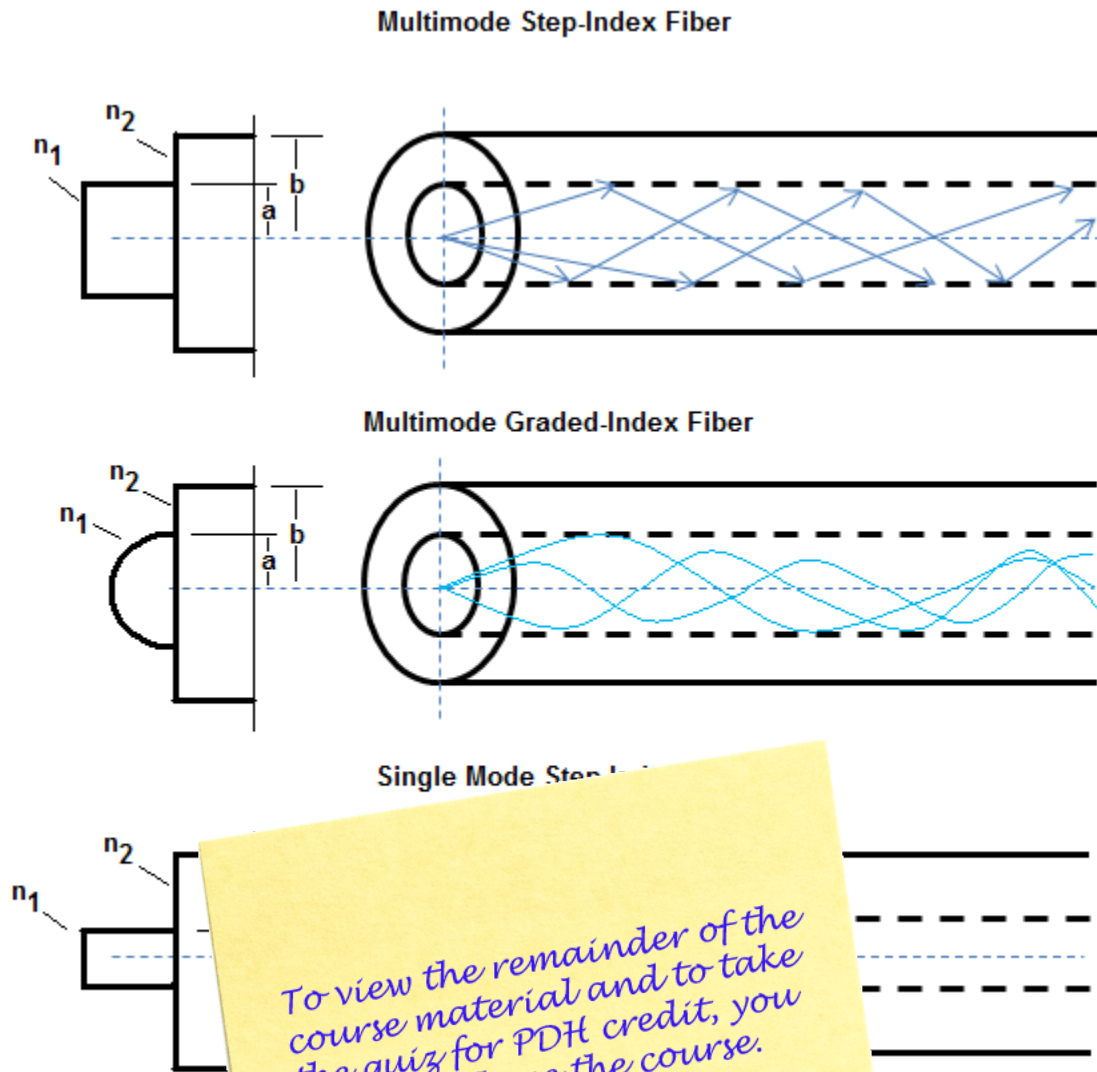
An optical fiber's refractive index profile and core size further distinguish single mode and multimode fibers. The *refractive index profile* describes the value of refractive index as a function of radial distance at any fiber diameter. Fiber refractive index profiles classify single mode and multimode fibers as follows:

- Multimode step-index fibers
- Multimode graded-index fibers
- Single mode step-index fibers
- Single mode graded-index fibers

In a *step-index* fiber, the refractive index of the core is uniform and undergoes an abrupt change at the core-cladding boundary. Step-index fibers obtain their name from this abrupt change called the step change in refractive index. In *graded-index* fibers, the refractive index of the core varies gradually as a function of radial distance from the fiber center.

Single mode and multimode fibers can have a step-index or graded-index refractive index profile. The performance of multimode graded-index fibers is usually superior to multimode step-index fibers. However, each type of multimode fiber can improve system design and operation depending on the intended application. Performance advantages for single mode graded-index fibers compared to single mode step-index fibers are relatively small. Therefore, single mode fiber production is almost exclusively step-index. Figure 1 shows the refractive index profile for a multimode step-index fiber and a multimode graded-index fiber. Figure 1 also shows the refractive index profile for a single mode step-index fiber. Since light propagates differently in each fiber type the figure also shows the propagation of light along each fiber.

Figure 1. - The refractive index profiles and light propagation in multimode step-index, multimode graded-index, and single mode step-index fibers.



*To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.*

*Close this window and click "Add to cart" on the product page.*

Fiber core size and material composition, core size and material composition, and material composition dispersion.

small change in core attenuation and

When selecting an optical fiber, the core size and material composition is appropriate for the application.

the size and material

Standard core sizes for multimode step-index fibers are 50  $\mu\text{m}$  and 100  $\mu\text{m}$ . Standard core sizes for multimode graded-index fibers are 50  $\mu\text{m}$ , 62.5  $\mu\text{m}$ , 85  $\mu\text{m}$ , and 100  $\mu\text{m}$ . Standard core sizes for single-mode fibers are 9  $\mu\text{m}$  and 10  $\mu\text{m}$ .

Standard core sizes for multimode step-index fibers are 50  $\mu\text{m}$  and 100  $\mu\text{m}$ . Standard core sizes for multimode graded-index fibers are 50  $\mu\text{m}$ , 62.5  $\mu\text{m}$ , 85  $\mu\text{m}$ , and 100  $\mu\text{m}$ . Standard core sizes for single-mode fibers are 9  $\mu\text{m}$  and 10  $\mu\text{m}$ .