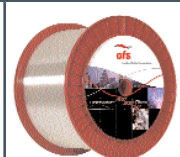
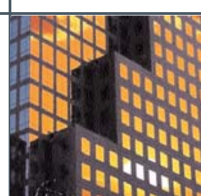
Leading Optical Innovations

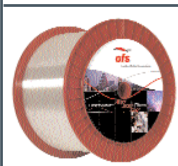
Manufacturing Multimode Fiber

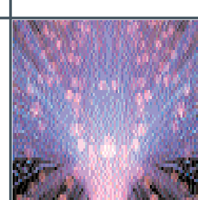
Precise Control of Production and Testing Ensures High Performance

David Mazzarese
Technical Manager









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Multimode optical fiber makes it possible for businesses and organizations around the world to transmit enormous volumes of information over their premises networks. Long the preferred medium for data communications, multimode fiber systems have become the most cost-effective option for sending information at the Gigabit Ethernet speeds in today's local area network (LAN) installations.

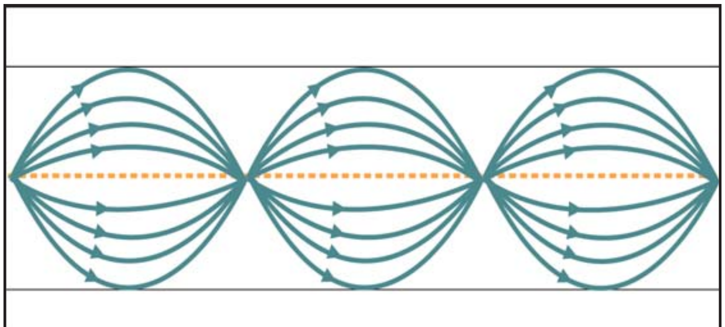

Figure 1 Modes of Light in a Multimode Fiber

As user demand pushes networks to transmission speeds of 10 Gigabits per second (Gb/s) and beyond, it's more important than ever to specify the best fiber for your needs. A basic understanding of the design and manufacture of multimode fiber will help you make the most informed choice for your specific applications.

Multimode fibers have a central region, called a *core*, through which light signals travel. (The core is surrounded by the *cladding*, which confines the signals along their path.) The light travels through the fiber along different paths, called *modes* (see Figure 1). Some of these paths are longer than others. The core's *graded index profile* is designed so that modes having a longer path through the fiber travel just fast enough to arrive at the end of the fiber at about the same time as modes traveling shorter paths.

The difference in arrival time for these modes is called *modal dispersion*, also known as *differential mode delay* (DMD). It can result in detection errors at the receiver. The fiber's *bandwidth* is the amount of information that can travel through the fiber per unit of time and is inversely proportional to the modal dispersion. Therefore, the lower the DMD, the higher the bandwidth. As transmission speeds reach 10 Gb/s, DMD measurement becomes the only reliable method of ensuring bandwidth.

Manufacturing the Preform

There are several processes that can be used to manufacture optical fiber. One of the most versatile methods, shown in Figure 2, is the *modified chemical vapor deposition* (MCVD) process. This highly stable, patented process, which was developed at Bell Labs, starts with a high purity quartz tube mounted on a special glass-working lathe.

A mixture of ultra-pure gases flow through the inside of the tube while a heat source is applied on the outside. The heat source converts the gases into glass "soot." As the burner traverses along the outside of the tube, it creates the fine soot particles and sinters them into a thin layer of doped glass on the inside of the tube.

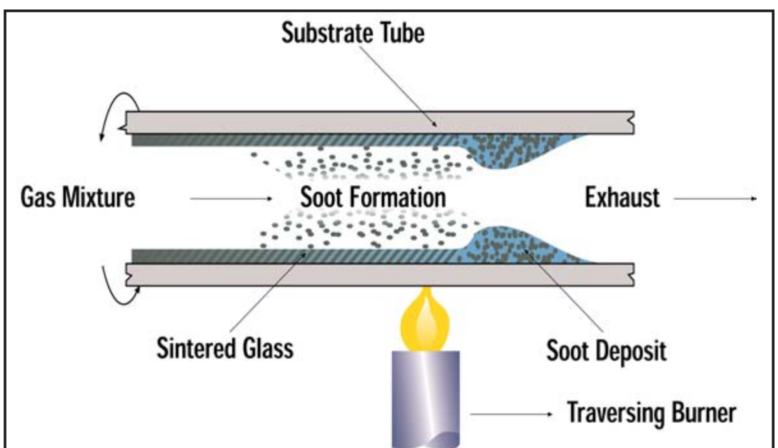

Figure 2 Modified Chemical Vapor Deposition (MCVD)

After the first layer is deposited, the mixture of reactive gases is changed and the burner is brought back to the starting position. This process is continued, layer by layer, to construct the complex core structure in the optical fiber.

Once the glass is deposited, the tube is collapsed into a solid rod called a *preform*. This process must be carefully controlled to assure that there are no defects such as a "center dip" or a "center-line spike" in the index profile. Such defects can significantly degrade the DMD and bandwidth of a multimode fiber. OFS uses a special patented process that essentially eliminates the formation of center-line defects.

The symmetry of the core relative to the cladding (called *core/clad offset*) is critical, especially for Gigabit Ethernet applications, where Vertical Cavity Surface Emitting Lasers (VCSELs) are used as the light source. Precise core/clad offset helps ensure proper coupling of the VCSEL into the fiber core and reduces splice losses. Tight process control of the central regions and core/cladding symmetry are essential steps in manufacturing fiber for laser optimized 1 Gb/s and 10Gb/s applications.

Fiber Draw

The preform manufactured on the MCVD lathe is heated and “drawn down” to the accepted standard diameter of 125 microns. Each preform generates many kilometers of fiber. The operation is performed on a draw tower as shown in Figure 3.

The tower has a furnace at the top to melt the glass preform. Gauges are used to measure and control the diameter of the glass fiber to 125+/-1 microns as it is pulled from the preform. This level of control improves the connectorization process and also helps to ensure proper coupling of the light source to the fiber's core. Additionally, the fiber draw process must be very carefully controlled to prevent negative impacts to the fiber DMD and bandwidth.

During the draw process, an acrylate coating is applied to protect the pristine silica fiber from the environment. If a state-of-the-art draw process is used, the fiber has the same index profile as the preform from which it is drawn.

Test & Measurement

At OFS, each spool of fiber is measured to validate that the product will meet stringent industry and internal specifications. These tests measure mechanical strength, geometric properties and optical properties.

One key test for laser-optimized multimode fibers is high-resolution differential mode delay (HRDMD). This measurement compares the difference in arrival times of principal mode groups traveling down the fiber. The measurement is done by launching pulses of light at different locations across the diameter of the fiber core and comparing the arrival time for the pulse with a detector at the opposite end of the fiber.

The HRDMD measurement serves two purposes in measuring this essential parameter. First, it validates that the fiber has sufficient bandwidth for 10 Gb/s systems. Second, it provides feedback to enable accurate and precise control of the preform process. The steps taken in the MCVD process to help ensure a defect-free refractive index profile at the central region and across the entire diameter of the core enable good DMD performance.

Precise control and tuning of the preform manufacturing process requires a thorough understanding of how MCVD and Fiber-Draw process parameters influence the fiber profile. The HRDMD measurement provides an excellent map of the modal delays. These are used as inputs to a process-tuning algorithm, which optimizes the process parameters to minimize modal delay. This feedback mechanism is essential to manufacturing 1 and 10 Gb/s fibers with superior performance. The HRDMD process allows us to optimize the fiber profile to a degree that is not possible using other bandwidth measurements such as over-filled bandwidth (OFL) and restricted modal launch (RML).

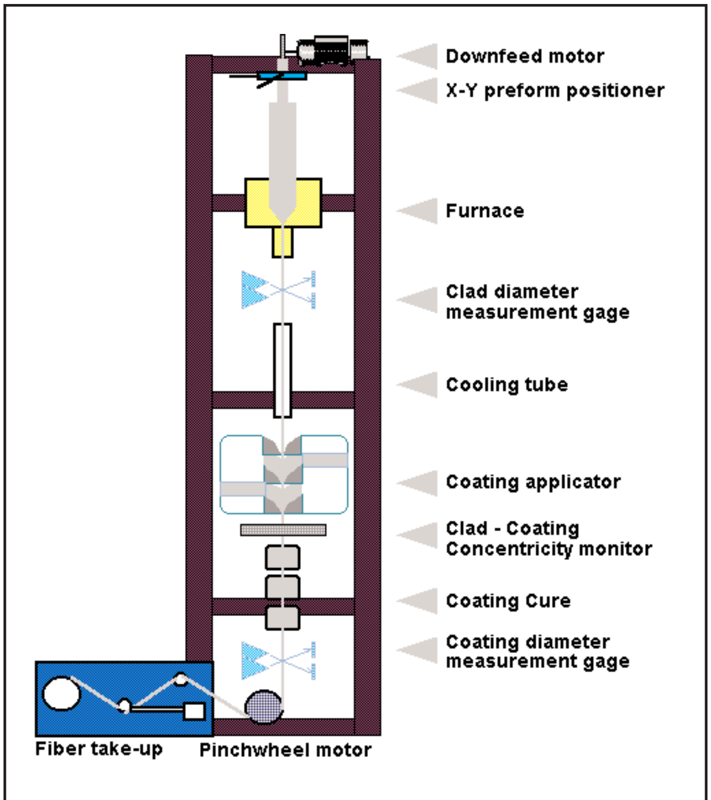

Figure 3 The Fiber Draw Process

Summary

Fabricating high-performance fibers requires innovative designs and processes. A stable, accurate manufacturing process, such as MCVD, is essential to produce these products in significant quantities. Measurement data such as HRDMD must be fed back to the process to assure that consistent high performance is maintained. A leading-edge fiber draw process must be used to optimize fiber performance and precisely control dimensions. Sophisticated process control tuning methods are required to adjust manufacturing conditions to create and maintain precise fiber profiles.

Together, these manufacturing and testing processes can produce laser optimized multimode fibers that provide customers with cost effective solutions for today's networks.

About the Author

David Mazzarese is the technical manager of preform and measurements development and engineering at OFS Sturbridge. He has lead the development of various multimode, single-mode and specialty products over the past 10 years. He holds a PhD in Chemical Engineering and a MS in Electrical Engineering from the University of Massachusetts at Amherst.

The OFS Multimode Optical Fiber Center of Excellence

Dedicated to innovation in the development of multimode fiber, OFS designs and manufactures graded-index multimode fiber capable of high bandwidth performance over long distances.

Among U.S. manufacturers, OFS offers the widest range of graded-index multimode fibers as standard selections. Products include fibers with core/clad ratios of 50/125 µm and 62.5/125 µm, and laser-certified fiber designed for transmission speeds of up to 10 Gb/s.

Founded as SpecTran Communication Fiber Technologies, the OFS Multimode Optical Fiber Center of Excellence operates a state-of-the-art facility that has been supplying leading cable manufacturers with high-performance optical fiber since 1981.

Once a part of Lucent Technologies, the facility benefits from the full technical support of OFS Laboratories, the direct descendant of Bell Labs, with its unmatched reputation for communications technology expertise.

The OFS Multimode Optical Fiber Center of Excellence is located in Sturbridge, Massachusetts.

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