Manufacturing Multimode Fiber

By David Mazzarese and George E. Oulundsen III

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.

As user demand pushes networks to transmission speeds of 10 Gigabits per second (Gbps) 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. 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 Gbps, DMD measurement becomes the only reliable method of ensuring bandwidth.

Manufacturing the Pre-form

There are several processes that can be used to manufacture optical fiber. One of the most versatile methods, shown in Figure 1, 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

Photo Caption: The Modified Chemical Vapor Deposition (MCVD) process, which was developed at Bell Labs and perfected by OFS, starts with a high purity quartz tube mounted on a special glass-working lathe.

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.

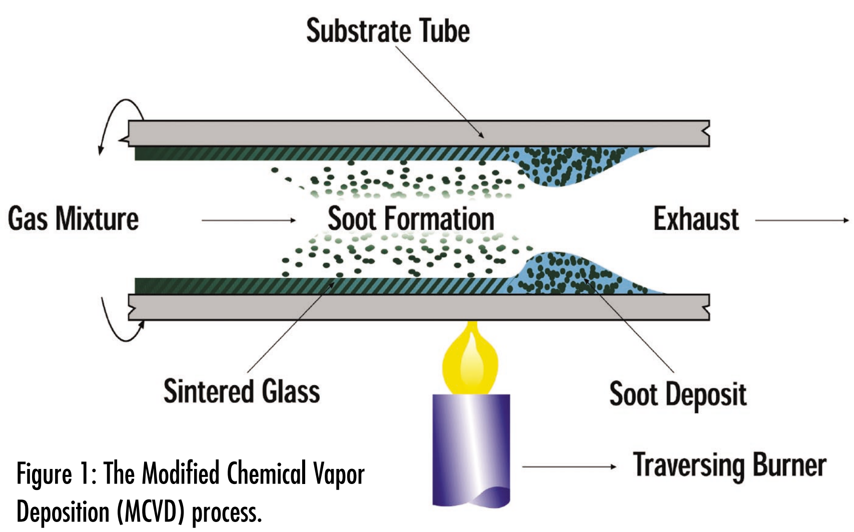

Figure 1: The Modified Chemical Vapor Deposition (MCVD) process.

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 pre-form. This process must be carefully controlled to assure that there are no defects such as a "center dip" or a "centerline 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 centerline 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 one Gbps and 10Gbps applications.

Fiber Draw

The pre-form manufactured on the MCVD lathe is heated and "drawn down" to the accepted standard diameter of 125 microns. Each pre-form generates many kilometers of fiber. The operation is performed on a draw tower as shown in Figure 2.

The tower has a furnace at the top to melt the glass pre-form. Gauges are used to measure and control the diameter of the glass fiber to 125+/-1 microns as it is pulled from the pre-form. 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 pre-form from which it is drawn.

Test and 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 com-

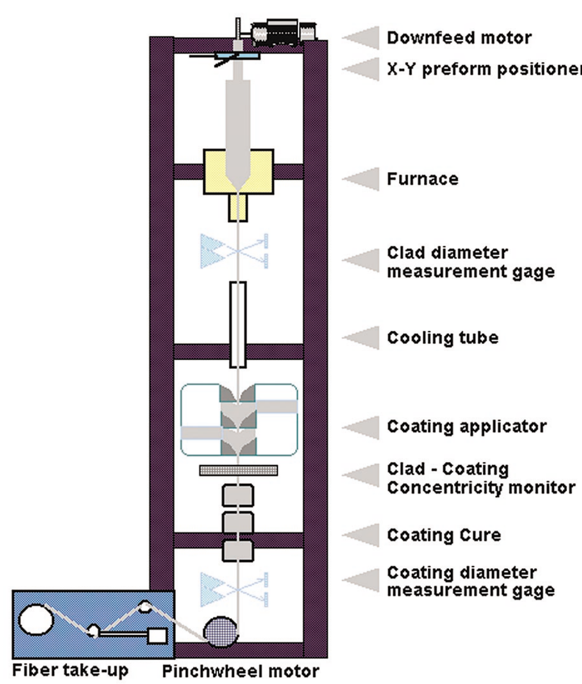

Figure 2: Process used to help ensure the proper coupling of the light source to the fiber's core.

paring 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 Gbps systems.

Second, it provides feedback to enable accurate and precise control of the pre-form 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 pre-form 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 one and 10 Gbps 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 overfilled bandwidth (OFL) and restricted modal launch (RML).

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. **CBM**

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