Multimode Fiber Implications for the AV Market

Because of its history, ease of use and presumed cost efficiency, multimode fiber (MMF) is the most ubiquitous type of fiber used in the professional Audio/Video market. Graded Index multimode fiber for applications such as communications, CCTV security, audio/video, broadcast, etc, comes in two different physical sizes – fibers with a 50µm or 62.5 µm core diameter. The outside or cladding has an industry-standard diameter of 125 µm. The standard representation of these fibers is 50/125 µm or 62.5/125 µm. The first of these multimode fibers was the 50/125 µm fiber developed in the mid 1970's. Shortly afterward the 62.5/125 µm fiber was introduced. At the time, it was thought that this fiber with the larger core diameter would be more beneficial because more light could be coupled into it from the optical emitter (LED) and that this larger core would be more tolerant of manufacturing tolerances of the fiber itself, connectors, splices, etc. At that time it was hard to imagine that this large core fiber would have such significant bandwidth limitations in terms of transmission distance. Europe standardized on the 50/125 µm fiber while North America held on to the 62.5/125 µm version of this multimode fiber.

Due to modulation limitations of the LED, a faster light source, the VCSEL (Vertical Cavity Surface Emitting Lasers) was developed. Besides providing vastly improved bandwidth values, the spatial distribution of light from the VCSEL also provides for significantly increased coupling efficiency into both the 62.5 & 50 µm core multimode fibers. There is still approximately a 3dB decrease in coupling efficiency between the 62.5 and 50 µm fibers but the limiting factor now is one of fiber bandwidth for these high data rate signals, not necessarily optical loss budget.

Figure 1 illustrates the basic difference between the core & cladding diameters of both the 50 & 62.5µm multimode fiber.

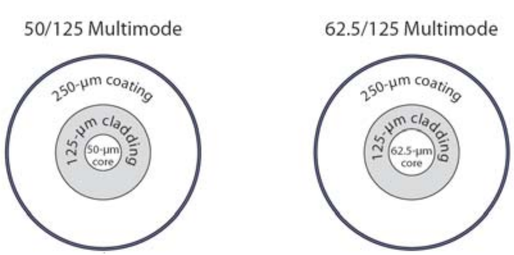

Figure 1
Multimode Fiber Cross Section

Introduced a number of years ago, a new version of the legacy 50/125µm is the laser-optimized fiber. This fiber is designed to have significantly improved performance in only one wavelength range – 850nm.

Table 1 shows the difference in bandwidth and attenuation as a function of fiber core diameter and type of laser-optimized fiber.

700 Elmont Rd, Elmont, NY 11003, Tel: 516-285-1000; Fax: 516-285-6300
www.Meridian-tech.com

Table 1 Multimode Fiber Key Specifications					
Fiber Type	**Fiber Designation**	**Nominal Attenuation (dB/Km)**		**Nominal Bandwidth (MHz-Km)**	
		850nm	1300nm	850nm	1300nm
62.5µm (Legacy)	OM1	3.5	1.5	160	500
50µm (Legacy)	OM2	2.5	0.8	500	500
50µm (Laser-Optimized)	OM3	2.5	0.7	2,000	500
50µm (Laser-Optimized)	OM4	2.5	0.7	4,000	500

(Note that these fibers are now designated with the OM1 through OM4 types as specified by the ISO (International Standards Organization) standard 11801). The specifications shown above are typical and will vary somewhat between manufacturers. The color codes of the fiber jacket (patch cord) are also defined to differentiate legacy multimode fiber from laser-optimized multimode fiber. The traditional orange colored patch cord jacket material indicates that the fiber is legacy 62.5/125 or 50/125 µm fiber. An aqua colored jacket indicates that the fiber inside is laser-optimized multimode fiber.

Since most optical transport systems will have an optical budget of 12-20 dB, depending on data rate, it is unlikely that any of these systems will be loss-limited. In other words, it is more likely that the system will be signal-quality (bandwidth) limited instead of signal-quantity (attenuation) limited. As such, it's important to understand how the bandwidth of these fibers affects the maximum transmission distance of high-definition video signals.

As mentioned in a previous application note, the bandwidth of the fiber is inversely proportional to the distance. For example, if the fiber has a bandwidth of 500 MHz-km, the bandwidth of the fiber at a distance of 1 km will be 500 MHz. At 2 km, the bandwidth will have been reduced to 250 MHz and at 5 km, the end-to-end bandwidth of that same fiber will now be 100MHz.

Many of the multimode RGB, DVI and HDMI fiber transmission equipment operates in the 850nm wavelength region. Using a typical CWDM approach of wavelength multiplexing the RGB colors along with the sync pulses, a typical wavelength will have a data rate in the region of 2 Gbps. This, obviously, depends on the resolution, refresh rate, compression (if any) and will vary somewhat around this number. One of the unique advantages of wavelength multiplexing in fiber is that each wavelength can utilize the fiber's full bandwidth capacity. In other words, if the fiber is capable of transmitting 1 Gbps of data over 1 Km, each wavelength on that fiber can transmit the same 1 Gbps data rate thereby significantly increasing the combined data rate of the fiber.

With this as a reference point, if we assume that each wavelength in a wavelength multiplexed DVI channel is transmitting at a maximum data rate of 2 Gbps, the maximum distance that the signal can be transmitted over multimode fiber can be approximated in the following Table 2:

Table 2
Multimode Fiber Distance @ 2Gbps

Wavelength (λ)	62.5µm (OM1)	50µm (OM2)	50µm (Laser-Optimized) (OM3)	50µm (Laser-Optimized) (OM4)
850nm	160m	500m	2000m	4000m
1300nm	500m	500m	500m	500m

These distances will vary with fiber manufacturer, data rate, video resolution and other extrinsic factors related to the signal transmission. Notice that the laser-optimized fiber is only optimized in the 850nm region of wavelengths. While laser-optimized fiber can significantly increase the maximum distance of the signal being transmitted, it's important to know what wavelengths the transmitter is utilizing. As the table indicates, using a laser-optimized fiber while transmitting at 1300nm will not help to increase the maximum distance. However, using 850nm, the maximum distance can be significantly increased by over a factor of 10 just by changing the type of fiber. Transmitting at 1.485 Gbps, a standard HDSDI signal will have similar distance constraints while a 3G video channel will be limited even further because of the higher signal data rate.

As the data rates of these signals continue to increase, it's becoming more important to understand both the capabilities and limitations of the fiber infrastructure. Each fiber type has its advantages and disadvantages and, used properly, can yield a high-performance, high-reliability system that can support emerging technology trends. It's incumbent upon all fiber system and equipment designers to understand and properly utilize the capabilities of these fibers.

If you have any questions or if you have any particular topic on fiber optics you would like to know more about, please send an email to emiskovic@meridian-tech.com.

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