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Characterizing Bandwidth Length Uniformity of 50/125 μm Multimode Optic Fiber for High speed Data Communication

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ABSTRACT

Multimode optical fiber mostly used for communication over shorter distance. Multimode fibers support from 10 M bit / s to 10 Gb/s over link length upto 550 meters.

Multimode optical fiber has higher light gathering capacity than single mode. LED and VCSEL, which operate at the 850 nm wavelength. It has a larger numerical aperture. It supports more than one propagation mode; hence it is limited by modal dispersion.

50 / 125 μm multimode fibers were widely deployed in premises applications. Application ranging from Ethernet to Gigabit Ethernet because of their relatively large core size. 50 / 125 μm (OM3) fiber provides sufficient bandwidth to support 10 Gigabit Ethernet upto 300 meters and recently 10 Gigabit Ethernet upto 550 meters also.

The bandwidth of 50 / 125 μm multimode optical fiber cable can be kept in length uniformity by different methods and at the time of manufacturing bandwidth is measured using different formulas for high-speed data communication.

Categories and Subject Descriptors

- B.4 Input and output data communications
  - B.4.3Interconnections (Subsystems)
  - *Fiber optics*

General Terms

Computer Networks
Miscellaneous

Keywords

Multimode fiber optics, LED, VCSEL, Bandwidth, Ethernet.

1 INTRODUCTION

In the new era of Information technology, information gathering, processing, distribution are the key elements for human development. Knowledge updating is important for all human being. Peoples are constantly checking their e-mails, banking on-line, airline booking, sports scores, etc. The demand forever increasing volumes of data transmission is creating new developments in data communication. Ethernet implementation with improvement results into fast Ethernet and again in Gigabit Ethernet. This paper introduces the development in multimode optical fiber data communication.

2 MULTIMODE FIBER

Multimode fiber is a type of optical fiber mostly used for communication over shorter distances. It has a larger core, allowing less precise, cheaper transmitters and receivers to connect as well as cheaper connectors. Multimode fiber introduces multimode distortion, which often limits the bandwidth and length of the link.

2.1 Multimode Step Index Fiber (MSIF)

It has a large core and a large numerical aperture (NA), so it can couple to a light source such as LED. It contains many hundreds mode of propagations. The amount of light power couple to the light guide is determined by the core size and the core cladding refractive index differences. Such fibers used for conventional image transfer limited to short distances for information transmission because of pulse broadening. An initial sharp pulse made up of many modes broadens as it travels a long distances in the fiber.

2.2 Multimode Graded Index Fiber (MGIF)

It has a large core. The core refractive index varies across the core diameter and is used to minimize pulse broadening due to intermodal dispersion.

Multimode fibers are described by their core and cladding diameters. The 62.5 / 125 μm multimode fiber has a core size 62.5 μm and cladding diameter of 125μm. But in 50 / 125μm multimode fiber has a core size 50 μm and cladding 125μm.

The multimode fibers support 10 Mb/S to 10Gb/S over link length of upto 550 meters. Typical transmission speed by distances is 100 Mb/S upto 2 km, 1 Gb/s for distance upto 500-600 meters and 10 Gb/s for distance 300 meters. Compare to single mode fibers the limit on speed X distance is lower because multimode fiber has a larger numerical aperture than single mode multimode fiber.

3 ETHERNET

Ethernet was first invented in 1973 by Dr. Metcalfe to interconnect the personal computer. It was first designed as a low cost but high-speed solution to ensure compatibility and providing equal access to all the nodes connected to the network. The data transmission was done through broadcasting. In physical medium only one station may transmit at a time, so a protocol is needed to ensure that all stations will fairly share access. So Digital equipments, Intel's and Xerox standardize the original protocol by Metcalf and it is known as DIX.

The early 1980s, the IEEE created a framework encompass all existing and yet to be invented LAN technology. Ethernet is persistent CSMA/CD (Carrier Sense Multiple Access with Collision Detection) LAN. CSMA/CD is a protocol that enables the medium to be shared fairly among all stations. Carrier sense means that every station that is about to transmit data has to sense the cable to determine if it is being used by another station. If the cable is busy, then the station will wait until cable goes idle and then transmit its frame immediately. The DIX Ethernet was used to connect more than 100 workstations on 1 km cable. Since the system was successful IEEE as IEEE 802.3 standardized it with a data rate of 10 Mb/S. It was used in full duplex operation. After that Gigabit ethernet are invented due to the unpredictable growth rate of computer industry. There has been a major demand for higher bandwidth communication channel. For that more than 120 companies around the world united in Gigabit ethernet alliance to promote a new standard of Ethernet. And introduced a gigabit ethernet fiber channel technology for connecting computers. Also, the Ethernet standard 802.3z (1000 Base-X) supports transmission via multimode optical fiber. The fiber channel technology uses long wavelength lasers to transmit data over fiber optics cable.

Table 1. Year vs. Data rate

Year	Data rate (Mb)
1985	10
1995	100
1998	1000
2002	10000
2005	10000

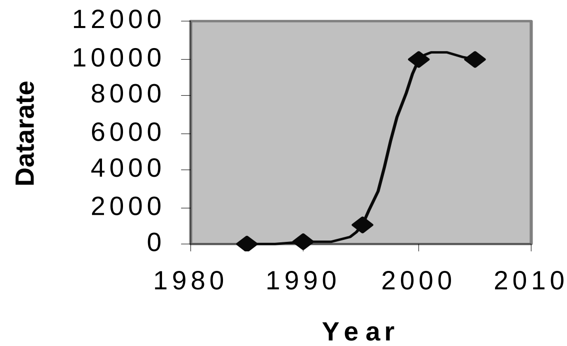

Figure 1. Year vs. Data rate

The 10 GB Ethernet standard was also proposed to expand Ethernet to the WAN. The Ethernet transit from LAN technology into measure player in MAN. The different media are used for different cables and transceivers.

Table 2. Gigabit ethernet over fiber

Cable type	Transceiver	Length bandwidth product (MHz'km)	Distance (meter)
8-10 μm single mode fiber	1300 nm	N/A	5000
50 μm multimode fiber	1300 nm	400	550
62.5 μm multimode fiber	1300 nm	500	550
50 μm multimode fiber	850 nm	400	500
62.5 μm multimode fiber	850 nm	200	275

4 BANDWIDTH

It is a measure of how much information can be transmitted. The higher the value, better the performance. Standard 50-micron fiber has higher bandwidth than 62.5-micron fiber. It is length and data rate dependant. As a given link length get shorter, the bandwidth goes up. As the data rate goes up, the distance that it can be transmitted goes down.

Traditional protocols have used LED as their optical source before gigabit Ethernet. The diameter of the light coming from the LED is much larger than the core of the fiber this is an overfilled launch (OFL).

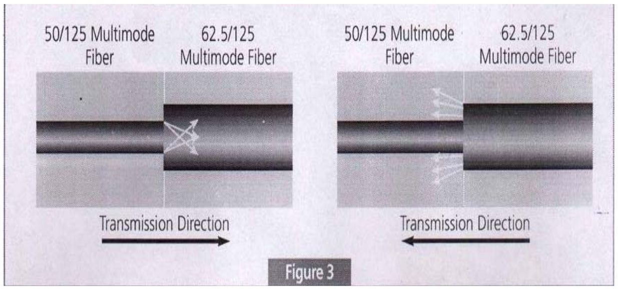

Figure 2. LED and Laser light source

The light coming from laser source is much smaller than the core of the fiber therefore high overfilled launch bandwidth does not ensure improved bandwidth for laser based protocols such as gigabit Ethernet. Multimode optical fiber is sold with a bandwidth specification provided in units of MHz X km, which is frequency measurement against the measurement length. Manufacturing fiber-length upto 17.6 km is used in network link length shorter than 300 meters. It is important to understand how the bandwidth measure in manufacturing relates to the bandwidth of fiber optical communication system. Multimode bandwidth manufacturing measurements are fully standard, reliable and accurate.

4.1 Bandwidth measurement accuracy: -

A common equation addressing the relation between fiber bandwidth and length is as shown in below equation,

$$BW_L / BW_s = [L_S / L_L]^{\gamma} \quad ....1.$$

Where BW_L is the bandwidth of long fiber length, BWs is the bandwidth of short fiber length , L_S is the short fiberlength, L_L is the long fiber length and γ is the length ratio component. The above equation is used to compute fiber bandwidth in a typical calculation. The values BW_L and the L_L are measured and provided by the fiber manufacturer. The length L_S is known. If the value of γ is known, then the value of BW_s can be calculated. The γ can be measure by using formula,

$$\gamma = \log [BW_L / BW_S] / \log [L_s / L_L] \quad .... 2$$

Eq.2 highlights the logarithmic change in bandwidth as length changes. Simply as length is decreased by half, the bandwidth doubles. Using this system short length of optical fiber is measured. Generally $\gamma = 1$.

The nonlinear variability of bandwidth measurement systems effects on bandwidth uniformity.

4.2 Bandwidth Uniformity Method: -

4.2.1 INSIDE VAPOR DEPOSITIONS (IVD):-

This process deposits soot and sinter it into glass. Due to thermophoresis and sintering activation methods this process varies in industry. Some IVD manufacturers only produce 20-30 % of total glass contains in their optical fiber, while the rest of the glass is purchased from the tube suppliers. Tube suppliers may not uniformly control the attributes necessary for reliable field performance of the optical fiber. In this process diameter, wall thickness variations and impurities can lead to significant performance problems in optical fiber. In IVD process axial and radial temperature uniformity is challenged by soot stream heating effect, wall thickness variability and natural sintering temperature fluctuations. The burners and plasma arcs are used for soot deposition are subject to natural temperature variations, creating random temperature discontinuity both axially and radially. This effect causes changes in IVD tube thickness, where thicker glass insulates against outside temperature and creates cool zones on the inside wall. Finally IVD manufacturing processes operate at much higher temperatures in order to sinter the sooty silica and Germania deposits into a solid glass. These higher temperatures are more difficult to maintain and again naturally tend towards non-uniformity. Higher temperature gradient results axial and radial variations, which causes non-uniformity bandwidth in the multimode fibers.

4.2.2 OUTSIDE VAPOR DEPOSITION (OVD): -

In this process, the manufacture of soot fiber preform is consolidated into pure glass. In order to attain good bandwidth uniformity, a uniform soot deposition rate is important which depends on well-controlled temperature gradient thorough out the manufacturing process. For most multimode fibers Germania is used as the principal doping agent to establish a refractive index profile in silica glass. In Germania / Silica glass synthesis, the sensitivity of glass composition to preform surface temperature is important. The Germania gas condenses as the binary stream (chemical and plasma) approaches cooler perform surface. This binary stream transport system is responsible for proportions of Germania and silica that are captured at any discrete axial location. In practice, cooler preform wall temperature that will help to maintain uniformity. The more uniform temperature gradient of an OVD perform lends itself to silica and Germania deposition uniformity, which in term promotes uniformity of refractive index profile across the entire multimode fiber. Since multimode fiber bandwidth uniformity depends on uniformity of the graded index profile, the OVD process is fundamentally better for ensuring bandwidth along the fibers length.

As a result of process and equipment innovations to produce superior axial and radial uniformity and multimode fiber controlled bandwidth uniformity. Due to OVD technology manufacturers can produce superior quality of multimode fibers.

5 CONCLUSION: -

The 10 Gb/s standard was also proposed to expand WAN applications. This is significant to transit LAN technology into MAN, WAN and access application space like Internet. Gigabit Ethernet is a full duplex. The physical medium of 10 Mb/s Ethernet is coax, unshielded twisted pair and fiber; fast Ethernet uses CAT3, UTP and fiber. The physical media used by Gigabit Ethernet are CAT5 and fiber.

Multimode fibers information carrying capacity in terms of bandwidth length product (MHz-km) can be used to determine bit rate. The maximum bandwidth of given multimode fiber is limited by maximum number of mode. Higher bandwidth can be achieved in 50/125 μm multimode fiber, which is maximum than 62.5/125 μm.

In IVD, burners and plasma arcs are used for soot depositions.

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In IVD axial and radial temperature uniformity is challenged by soot stream heating effect that causes changes in IVD tube thickness, temperature variations both axially and radially, that results in non-uniformity bandwidth in the multimode fibers. While in OVD, Germania and silica are used for depositions, which produces superior axial and radial uniformity as well as length uniformity of multimode fiber optic, which is better for high-speed data communication.

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