MF11 **5:30 PM**

Current Status of Perfluorinated GI-POF and 2.5 Gbps Data Transmission Over It

Y. Watanabe, *Asahi Glass Co.,Ltd., Yokohama, Japan*; C. Tanaka, *Asahi Glass Co.,Ltd., Lucina Div., Japan, Email: y_wata@agc.co.jp*.

We report the current status of perfluorinated graded index polymer optical fiber and its installation in premises. The capability to transmit data at more than 2.5 Gbps is also mentioned.

1. Introduction

The demand for bandwidth in the premises is increasing rapidly because video and graphical rich contents are exchanged through the corporate network or the Internet. The Gigabit Ethernet became commonly used in the corporate network backbone, and 10Gbit Ethernet will be adopted in the near future. Meanwhile in the home, the demand for high-speed network becomes popular as the wide spread of broadband access, e.g. CATV, xDSL, and FTTH. The transmission medium with capablity to transmit high bit rate signal is necessary to satisfy these requirements. Unshielded twist pair (UTP) cable and multi-mode fiber (MMF) cable are conventional transmission media for premises and residential area network, but Plastic Optical Fiber (POF) has became worthy to consideration in these years due to its improvement on performance. Especially, perfluorinated Graded Index POF (GI-POF) has experienced great progress in its attenuation and bandwidth, and acquired the capability to transmit up to 200 m at 1.25 Gbps with commercially available transceivers. We report in this paper that the current performance of perfluorinated GI-POF and its application, as well as possibility for more than 2.5Gbps data transmission.

2. Current status of perfluorinated GI-POF

Perfluorinated GI-POF is commercialized in Japanese market. The core diameter of perfluorinated GI-POF is 120 µm and outer diameter is 500 µm. The core diameter was chosen to strike a balance between the ease of connection and the accommodation to high-speed photodiode whose active area is less than 100 µm [1].

According to improvement of fiber manufacturing process, the attenuation of perfluorinated GI-POF has been reduced year after year. Fiber attenuation of 17 dB/km at 850 nm is obtained in 420 m fiber. An example of spectral attenuation is shown in Fig 1. Perfluorinated GI-POF has low attenuation from visible ray to 1300 nm. The reason of low attenuation in near infrared wavelength is caused by usage of perfluorinated polymer that has no C-H bond in its chemical structure. The C-H bond has high absorption in these wavelengths. Besides the transparency of material, the reduction of extrinsic losses effects to lower the attenuation in visible light. Attenuation at 650 nm is less than PMMA based POF.

We developed SC compatible glue-less connector and space saving cable branch box as well as duplex and multi core cables [2]. We have installed perfluorinated GI-POF cables in more than 60 sites in Japan for various applications from March 2000. The benefit of customer to use perfluorinated GI-POF is they can enjoy the high-speed network with low installation cost, because fiber optic specialists are not required for installation and connector termination is easy.

The categories of installation are as listed in Table 1. Not only for horizontal and interconnection application, but also for vertical cabling, perfluorinated GI-POF has been deployed in offices, schools, condominiums and hospitals. Multi core cables that utilized slotted core with 8,12,64 fibers are available for vertical cabling. In condominium or apartment complex, multi core cables are installed with branch box that branches off fibers to each home, to realize the fiber to the home (FTTH). In this branch box, fibers in multi core cable are connected with duplex cable with a mechanical splice unit. Since the size of branch box is smaller than standard splice box for silica fiber, it can be placed on multi core cable, therefore, required space to install branch box is smaller comparing with silica fiber cabling. The common space for utility is limited in a condominium, perfluorinated GI-POF cabling is very suitable in this application. In hospital, terminals at doctor's desk are connected with an image server using perfluorinated GI-POF with 1Gbps Fibre Channel for managing pictures of X-ray or CT images that have very big file sizes. In school, perfluorinated GI-POF is used with the equipment to transmit digital video (DV) signal over IP in order to realize real time communication between geometrically remote places. This system is used for remote lecture, and communication with a foreign school to support language lesson.

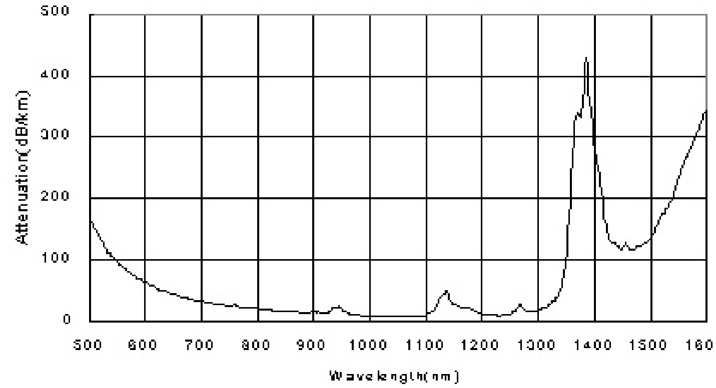

Fig 1. Example of spectral attenuation

Table 1. Application of perfluorinated GI-POG in Japan

Application	Type of cable	Bit rate	Installation location
Vertical cabling	Multi core cable	125, 1250 Mbps	Office, school
Horizontal cabling	Duplex and multi core cable	125, 1250 Mbps	Office, school, hospital
Interconnection	Duplex cable	125, 1250 Mbps	Server room, IDC
FTTH in apartment complex building	Multi core cable, Duplex cable With branch box	125 Mbps 1250 Mbps (Trial)	Apartment complex, Condominium

Data rates of these applications mentioned above are 125 Mbps (Ethernet 100BASE-FX) or 1.25 Gbps (Gigabit Ethernet 1000BASE-SX), and standard LAN equipments (L3 switch, media converter, etc.) designed for MMF are used with perfluorinated GI-POF. If 850 nm VCSEL is used in a transceiver, the sensitivity of -35 dBm and power budget of more than 19 dB was obtained for 125 Mbps. We use 850 nm VCSEL transceiver in 125 Mbps media converter and no error transmission was observed with 540 m fiber with three connections.

In current premises wiring, structured cabling is dominant. But centralized cabling system becomes under consideration recently because equipment cost can be reduced. In centralized cabling system, all terminals on each floor are connected with main switches with star topology. In residential buildings in Japan, this centralize cabling system is adopted with perfluorinated GI-POF due to the limitation of space to install sub switches in apartment complex. The cable length of centralized cabling system tends to be long, and more than 100 m cables are necessary for many cases. Therefore, UTP cable is difficult to use for all terminals because of its length limitation. MMF has no length limitation in premises wiring, but installation cost is much higher than UTP. Perfluorinated GI-POF that has transmission capability more than 100 m at 125 Mbps and 1.25Gbps with low installation cost is a suitable medium for centralized cabling.

3. Further capability of perfluorinated GI-POF

The transmission capability more than 1 Gbps of perfluorinated GI-POF has been reported. 11 Gbps over 100 m transmission was carried out using 1300 nm FP-LD and PIN-PD in 1999 [4]. 1.25 Gbps over 1006 m is reported using 1300 nm FP-LD and APD in 2002. Utilizing low attenuation in near infrared region and low chromatic dispersion, very course WDM transmission was examined. 200 m transmission with 645, 840 and 1300 nm light sources was reported in 1999, and 840 and 1300 nm transmission was conduced over 456 m in 2000. [3]. Although transmission capability was proved previously, the operability with commercially available transceiver is important for actual use of perfluorinated GI-POF. Since 2.5 Gbps transceiver with 850nm VCSEL is commercially available at present, we conducted

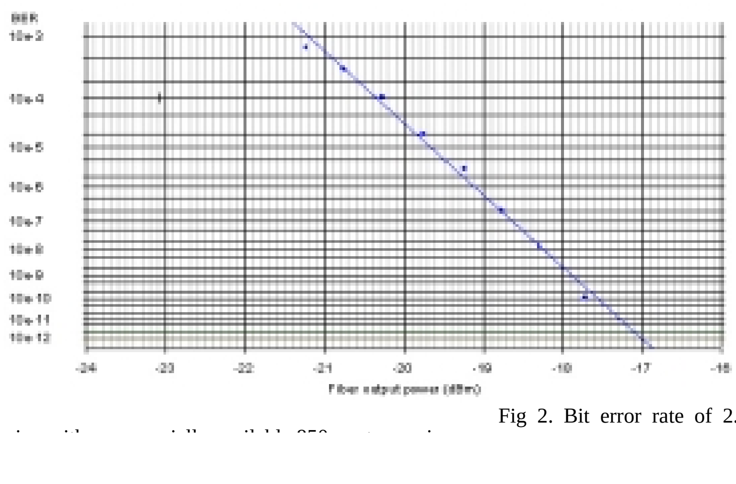

Fig 2. Bit error rate of 2.5 Gbps

the transmission test with this 2.5 Gbps transceiver with 144 m perfluorinated GI-POF. The result of bit error rate is plotted in Fig 2. The sensitivity to acquire BER of 10^-12 was -17dBm, and the output power from 2 m fiber was -5.7 dBm.. Consequently, the power budget of this transceiver was 11.3dB.

4. Conclusion

The installation of perfluorinated GI-POF wiring is going forward in Japanese offices, schools, hospitals and apartment complexes. Perfluorinated GI-POF that has transmission capability more than 100 m at 125 Mbps and 1.25Gbps with low installation cost is a suitable medium for newly proposed centralized cabling. 2.5 Gbps transmission was conducted over 144 m perfluorinated GI-POF with commercially available 850 nm transceiver.

5. References

[1] Y. Watanabe et al. "Transmission test results of perfluorinated GI-POF using commercially available transceivers." Proceedings of POF conference 1999, pp. 56-59.

[2] Y. Watanabe et al. ThG12 "The new optical wiring system for LAN in premises and residential area using perfluorinated GI-POF." Proceedings OFC 2002, OSA Proceedings Series (Optical Society of America, Washington, D.C., 2002), pp. 629-630.

[3] G. D. Khoe et al. "High capacity polymer optical fiber systems." Proceedings of ECOC2002, Vol.2, 3.4.1.

MF12 5:30 PM

Influence of Wavelength and Temperature Changes on Optical Performance of Fiber Joints

M. Kihara, M. Onishi, *NTT Access Network Service Systems Laboratories, Tsukuba-city, Japan, Email: kihara@ansl.ntt.co.jp*.

We investigated the characteristics of various types of fiber joint contact. When there is an air gap between fiber ends, the optical performance becomes dependent on wavelength. The reflections at joints where there is index-matching material are influenced by temperature.

1. Introduction

A large number of optical fiber connectors and mechanical splices will be needed in such optical subscriber networks as FTTH systems [1]. Physical contact (PC) type connectors without index-matching material are employed in these fiber joints for intra-office use and on premises where frequent reconnections are required. By contrast, connectors and mechanical splices with index-matching material are used in outside plants where frequent reconnections are unnecessary but low cost joints are needed. The optical performance of these fiber joints has already been reported [2]. However, these studies have largely been discussions of the performance at room temperature. When these fiber joints are applied to actual systems, the optical performance must be stable over a wide temperature range. Furthermore, unexpected failure when installing fiber joints might have a detrimental effect on performance. It is important to understand the worst possible optical performance of fiber joints to make it possible to guarantee the overall performance of a system.

We have investigated the influences of wavelength and temperature changes on optical performance for various types of fiber joint contact. This paper details some significant properties and summarizes the characteristics of various contact types. These results can usefully support the design and implementation of optical network systems.

2. Wavelength dependence

The optical properties of fiber joints have three fundamental origins: fiber misalignment, mode mismatch, and the Fresnel reflection that occurs because of refractive discontinuity. This paper focuses mainly on Fresnel reflection at the fiber ends, which would affect the optical properties in

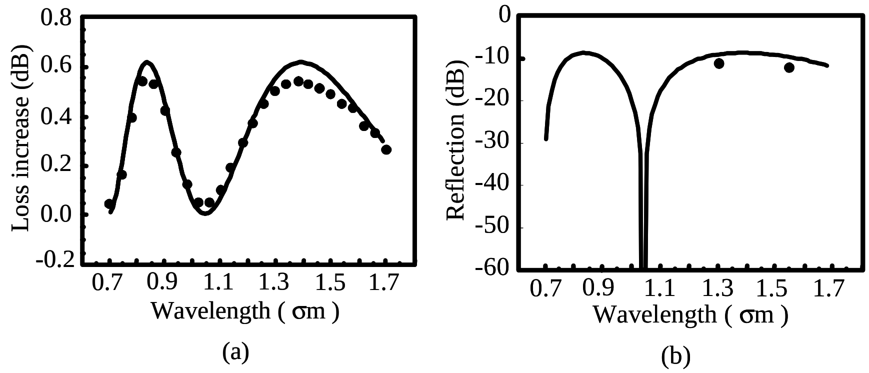

Fig. 1 Wavelength dependence of optical performances of a fiber joint with an air gap, (a) relationship between connection loss increase and wavelength, (b) relationship between reflection and wavelength.

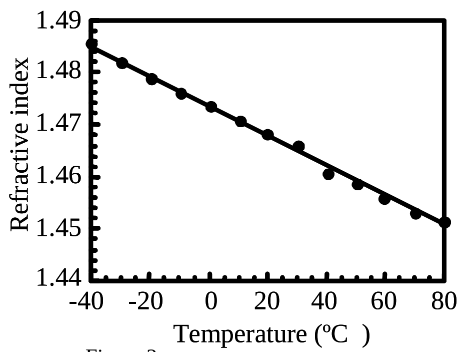

Figure 2

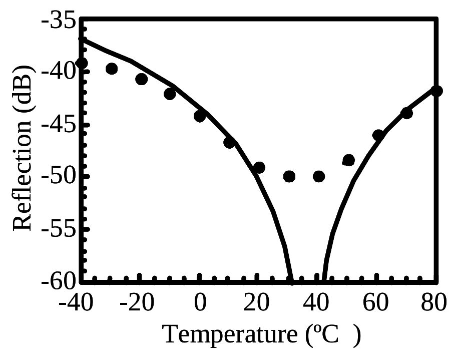

Figure 3

Fig. 2 Dependence of refractive index of index-matching material on temperature.

Fig. 3 Temperature dependence of the reflection of a fiber joint with index-matching material

Table 1 Characteristics of fiber joints.

	Perfect physical contact	Contact with air gap	Contact via index-maching material
Connection loss	**Stable**	**Wavelength dependent (Worsens +0.6 dB)**	**Stable**
Reflection	**Stable**	**Wavelength dependent (Worsens -8.5 dB)**	**Temperature dependent (Worsens -35 dB)**

An air gap between fiber ends causes a severe reflection from the contact point. In such cases, some of the light is multiply reflected in the small gap. As the phase of the multiply reflected light changes whenever it is reflected, this interfaces with the light power. This occurs with an optical connector whose physical contact fails unexpectedly, for example, as the result of a faulty installation or the presence of dust between the fiber ends. This optical condition is almost the same as that of the Fabry-Perot etalon interferometer model [3]. The transmitted and returned lights depend on the gap length and the wavelength of the incident light. Figure 1 (a) and (b) show typical results for a connection loss increase, and the reflection of a connector with an air gap between the fiber ends, respectively. The circles in (a) and (b) represent measured data. The solid lines are calculated results based on the interferometer model for a gap of about 1.0 µm. The measured and calculated results are in good agreement. The connection loss increase varies from 0.0-0.6 dB over a wide wavelength range. The reflections are also dependent on wavelength. Almost all the reflection data are large enough (up to -25 dB) to influence the transmission characteristics of the system [4].

3. Temperature dependence

The precision required for fiber joints employing index-matching material is not as severe as for PC type connectors with regard to eliminating air matching material is more dependent on temperature than that of optical fiber [5], because its molar refractivity is more dependent on temperature. Figure 2 shows the temperature dependence of the index-matching material. The circles show the measured data and the solid line is a fitted calculation. The refractive index changes linearly with temperature from -40 to 80 ºC. We obtained a thermal coefficient φn/φT of -2.9×10^{-4} /ºC at a wavelength of 1.3 µm. This slight refractive index change dependence on temperature exhibited by the index-matching material has a great influence on the reflection from a fiber joint at which such material is employed.

Figure 3 shows the temperature dependence of the reflection from a connector with index-matching material. The solid lines represent calculated results based on the interferometer model. Here the reflection depends on the gap between the fiber ends, as well as on the refractive index of the index-matching material. The line shows the worst values in relation to the gap. The circles represent measured data. The measured and calculated reflections vary greatly and the lowest values are below -50 dB. The measured results in the 30-50 ºC region are a little higher than the calculated values, however the results are in good agreement. There were slight differences between the reflection results for wavelengths of 1.3 µm and 1.55 µm. In contrast, the connection losses of the fiber joints did not change significantly when