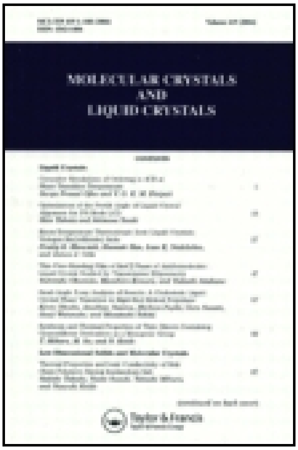

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High-Speed Polymer Optical Fiber Network

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High-Speed Polymer Optical Fiber Network

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The status of the polymer optical fiber (POF) for high-speed data communication is reviewed. Recently, the low-loss and high-bandwidth perfluorinated GI POF which has no serious absorption loss from visible to near infrared region was successfully prepared at Keio University. Since the core diameter (300-1000 μm) of the GI POF is much larger than that of the multimode silica fiber (62.5 μm), the serious modal noise in the conventional multimode silica fiber was virtually eliminated, resulting in stable giga bit order data transmission with inexpensive couplers and connectors.

<u>Keywords</u>: Graded-Index polymer optical fiber; perfluorinated polymer; modal dispersion; material dispersion; modal noise

INTRODUCTION

With increasing demand to access from home or office to Internet, high speed data communication even in the premises area has been of great importance. Growing interests have been focused on high speed optical fiber communication. However, in such short-range network as premises wiring, since the small core (5-10 μm diameter) of the conventional single-mode fiber requires high accuracy in fiber connector, serious increase of the cost of the whole system has been one of the largest problems. The large core (such as 500 μm or more) of the polymer optical fiber (POF) makes it possible to adopt injection-molded plastic connectors, which dramatically decreases the total cost of the system.

We have proposed a high bandwidth graded-index polymer optical fiber (GI POF), and have succeeded in a 2.5 gigabit per second (Gbit/s) transmission in the 100 m GI POF link[1] using LD at 0.65-μm wavelength. However, the transmission distance was limited to approximately 100 m due to the intrinsic absorption loss. In this paper, recent progress in the POF for high-speed network system is described.

GI POF FOR NEAR INFRARED USE

The attenuation of transmission of the PMMA-base POF is shown in Fig. 1. The minimum attenuation was about 150 dB/km at 0.65-μm wavelength which was almost the same as that of the step-index type POF commercially available. However the attenuation of PMMA base POF was abruptly increased from about 0.7-μm wavelength to the infrared region due to the absorption loss of overtones of C-H stretching vibration.

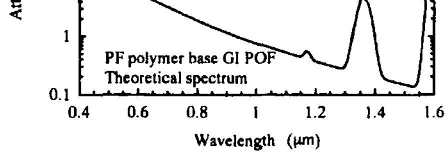

FIGURE 1 Total attenuation spectra of the PMMA-base and PF polymer base GI POFs.

However, it is highly desirable to construct POF network system using commercially available LD and LED which operate in the range of 0.7 -1.5 μm of wavelength.

Deuterated or fluorinated polymer base POF will be one of the promising candidates to eliminate the serious absorption loss in such a wavelength.

We have also succeeded in preparing both perdeuterated (PD) and perfluorinated (PF) polymer GI POFs whose attenuation spectra of 0.5-1.3-μm wavelength are shown in Fig. 1, compared with PMMA base GI POF. It is quite noteworthy that the attenuation of the PF polymer base GI POF even at 1.3-μm wavelength is about 40 dB/km.

In order to clarify the theoretical attenuation limit of this PF polymer base POF, total attenuation spectrum was estimated by calculating the inherent scattering and absorption losses with using Einstein's isothermal fluctuation theory and Morse potential energy theory, respectively. Estimated result is also shown in Fig.1. It should be noted that the theoretical attenuation limit of the PF polymer base POF at 1.3-μm wavelength is 0.25 dB/km, which is much comparable with the conventional silica base fiber.

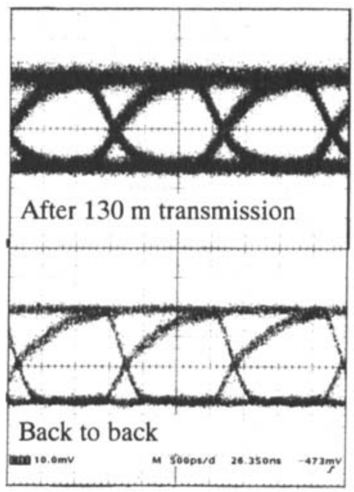

FIGURE 2 Received waveform of 622 Mb/s transmission at 1.3-μm wavelength by PF polymer base GI POF.

BANDWIDTH CHARACTERISTICS

Dramatic decrease in the intrinsic absorption loss in the PF polymer base GI POF enabled to adopt almost any kinds of transmitter and receiver devises in wide range of wavelength in the PF polymer base GI POF link. For instance, the conventional InGaAsP laser diode at 1.3-μm wavelength is one of the transmitter candidates. Therefore, we investigated the bandwidth performance of the PF polymer base GI POF at visible to near infrared region to utilize such optical devises in the POF link.

Figure 2 shows the eye diagram of 622 Mb/s transmission in PF polymer base GI POF link. A good eye opening was observed even after 130 m transmission.

Optimization of the refractive index profile of the GI POF should be the key process in order to minimize the modal dispersion. Figure 3 shows the relation between the bandwidth and refractive index profile of the GI POF by using the WKB method with taking into account both modal and material dispersions[2]. The parameter g in Fig. 3 is called the index exponent when the refractive index profile of the GI POF is approximated by the power-law of the form.

In the case of the PMMA base GI POF, the maximum bandwidth of 100-m fiber at 0.65-μm wavelength is limited to approximately 3 GHz

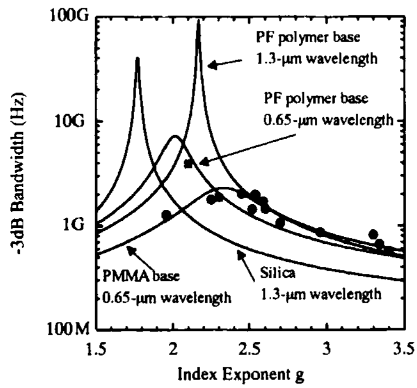

FIGURE 3
Relation between the index exponent g and the bandwidth of 100 m GI POF.
●: Experimental value of PMMA base GI POF at 0.65-μm
■: Experimental value of PF polymer base GI POF at 0.65-μm

even when the refractive index profile is optimized, because of the large material dispersion of the PMMA. Plots in Fig. 3 signify the experimentally measured bandwidths. A good agreement in the theoretical and experimental values is observed in both PMMA and PF polymer base GI POFs, which indicates that the bandwidth estimation by the WKB method is useful in designing the refractive index profile of the GI POF.

As shown in Fig. 3, the bandwidth of the PF polymer base GI POF is three times higher than that of PMMA base GI POF even in 0.65-μm wavelength use, and 100 GHz can be obtained at 1.3-μm wavelength for 100 m transmission.

MODAL NOISE

It has been concerned that the modal noise degraded the bit error rate in the case of multi mode fiber with laser diode in the fiber-optic links. However, we confirmed that the large core (300 - 1000 μm diameter) of GI POF which transmits more than 30,000 modes causes no such degradation of bit error rate even if a laser diode with high coherency was used. We investigated the modal noise effect on the bit error rate in GI POF link as follows: a Fabry-Perot LD at 644 nm with 1 nm spectral width was used as the light source, and the bit error rate of 156 Mb/s system in which one fiber-to-fiber joint had been deliberately misaligned was measured. Figure 4 shows the results of PMMA base GI POF with a 600-μm core diameter.

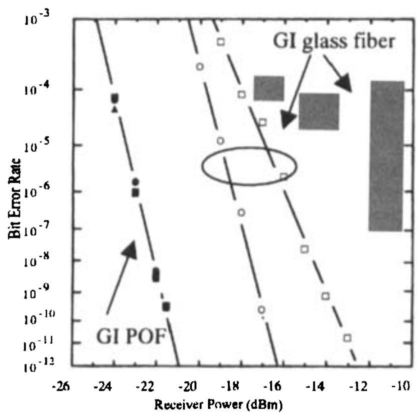

FIGURE 4 Modal noise effect on bit error rate in PMMA base GI POF link.
Misalignment:
GI POF
●: 0 μm ■:100 μm ▲:200 μm
GI glass fiber
O: 0 μm □:10 μm ▩ : 20 μm

Even when 200-μm misalignment is occurred, no significant degradation is observed. On the other hand, in the case of the conventional GI glass fiber whose core diameter was 62.5 μm, it was observed that a 10-μm of displacement caused large bit error rate degradation, and that it was impossible to obtain the accurate bit error rate curve in the case of 20-μm displacement because of a serious fluctuation of the output power from the fiber.

It is concluded that the large core of the GI POF offers low modal noise as well as low coupling loss. The large core of GI POF enables the usage of inexpensive connector made by injection molding which tends to cause 20 to 50-μm misalignment.

CONCLUSION

The status of the GI POF for high-speed data communication is discussed. The perfluorinated polymer base GI POF has two great advantages: one is no serious absorption peak in the range of 0.5-1.3-μm wavelength in its attenuation spectrum, and the attenuation at 1.3 μm where the LD for silica fiber operates is about 50 dB/km. Another is low material dispersion compared with PMMA and silica, which allows more than 10 Gb/s transmission even in 500 m link. In addition, no modal noise in the GI POF link permits the coherent LD usage. We believe that these experimental and theoretical aspects suggest that the PF polymer base GI POF will be one of the promising candidates for "the last one mile".

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