Reliability and Transmission Characteristics of Low NA SI-POF

Tomonari Yoshimura[a], Kazuki Nakamura[b] and Akimitsu Okita[a]

[a]Specialty Products Development Center, Mitsubishi Rayon Co., Ltd.,
4-1-2, Ushikawadori, Toyohashi, Aichi 440, Japan

[b]Central Technology Research Laboratories, Mitsubishi Rayon Co., Ltd.,
20-1, Miyukicho, Otake, Hiroshima 739-06, Japan

This paper proves the performance of a low numerical aperture (NA) step index plastic optical fiber (SI-POF) to support higher-speed networks. The possibility of high speed transmission with the POF is described and examined using a high speed visible LED with small emission angle. A low NA SI-POF having an NA of 0.3 has been realized by Mitsubishi Rayon in 1995. The POF has a bandwidth of over 100 MHz at 100 m, which is about three times wider than that of conventional POFs. Attenuation of this low NA SI-POF is almost the same as that of conventional datacom grade POFs. 156 Mbps 100 m transmission is possible with this low NA SI-POF if the fiber NA and the radiation pattern of the source LED are optimized. The POF has been confirmed to have enough reliability and mechanical durability to be used for horizontal cabling of LAN and HAN over a hundred Mbps.

1. INTRODUCTION

Plastic optical fiber has come into wide use for various purposes since it was introduced into the market in 1977. POF links have recently been greatly concerned with the idea of fiber to the home (FTTH) and have been good candidates for desktop LAN like asynchronous transfer mode (ATM) systems and Fast Ethernet systems. It has especially been discussed to be used for ATM systems on the ATM Forum.

POFs exhibit considerably greater attenuation than glass fibers, and they have several advantages for use in the telecommunication field. First, POFs have no radiated emissions and susceptibility because they have the same dielectric nature as glass fiber. Secondly, it is possible to achieve POF links which consist of LED transmitter and plastic connectors, to lower total system costs. Cost effectiveness is considered particularly important in the desktop LAN environment which requires a large number of connections and transmitters in a short distance. Thirdly, POF links with LEDs which exhibit the toughness and durability have the advantages of ease of handling and eye safety without special care. Therefore, connectors can be installed on the spot.

Recently, high speed visible LED have been developed for POFs light sources in the region of communication [1]. And high speed data links have been placed on the market. Two types of high speed POF as graded index (GI) type and low NA step index (SI) type are known. Dr. Koike had a breakthrough in developing a new method making GI-POF [2-3]. On the other hand low NA SI-POF named ESKAMEGA have been developed based on conventional SI-POF [4].

This paper proves the general performance of this low NA SI-POF such as reliability and transmission characteristics.

2. PROFILE OF LOW NA SI-POF

Suppose that the NA of SI-POF is lower, then the pulse broadening is further minimized and the bandwidth is widened. Obviously, the low NA SI-POF cuts high-modes off. The bandwidth of a SI-POF can be estimated by the following equation:

$$Bandwidth \propto \frac{n_{core}}{NA^2} \quad (1)$$

If the NA of POF is reduced from 0.5 to 0.3 without changing the index of the core, then the bandwidth will become about three times wider.

However, such small refractive index difference which is the consequence of the low NA causes an increase of bending loss and coupling loss.

A low NA SI-POF, ESKAMEGA and a conventional datacom grade SI-POF, ESKA PREMIER were tested and compared. They have core diameters of 0.98 mm and cladding diameters of 1.0 mm. And they are surrounded by a polyethylene sheath of 2.2 mm in diameter. Their core materials are made from a pure poly (methyl methacrylate) (PMMA) which has a refractive index of 1.495. The major difference between these two POFs is the refractive index of cladding. Refractive indices of cladding of the low NA POF and the conventional one are 1.456 and 1.402 respectively; consequently their theoretical NAs are 0.3 and 0.5.

The POF has been confirmed to have sufficient reliability and transmission characteristics to be used for over a hundred Mbps as follows.

3. TRANSMISSION CHARACTERISTICS

3.1. Bandwidth

The bandwidths were measured by the time domain method using a 650 nm laser diode. This experiment was performed under over-fill condition that yields minimum bandwidth.

Fig. 1 shows the bandwidths versus fiber length. The low NA SI-POF having 105 MHz had about three times wider bandwidth than the conventional SI-POF having 38 MHz at 100m as equation (1).

3.2. Typical attenuation

Attenuation spectra were measured by the cut-back method using a monochromator with collimated lens as in Fig. 2. Attenuation of POF were caused by the absorption and the scattering of the core. These two types of SI-POF have almost the same attenuation spectrum characteristics because of the same core materials.

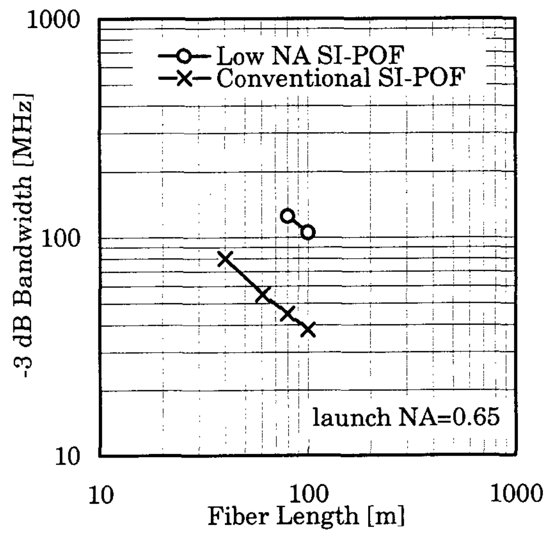

Fig. 1 Bandwidths versus fiber length measurement under the launch NA of 0.65

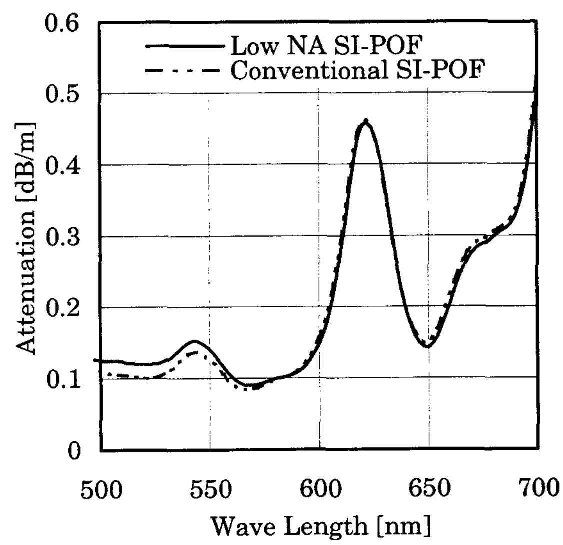

Fig. 2 Typical attenuation spectra measurement with collimated light.

3.3. BER characteristics

Bit error rates are measured for both ESKAMEGA and ESKA PREMIER before and after 100 m, using a LED as the light source. This LED is designed to yield launch NA of 0.3 [5]. The driver of the LED is a custom-designed circuit which is optimized to get a high speed response. The LED was driven at an average current of 35 mA and mean signal power coupled into the fiber under test was -8.0 dBm.

Fig. 3 shows BER versus received power measured with the LED. 100 m - 156 Mbps transmission was possible at BER 10^{-9} using the low NA SI-POF. Then the mode dispersion penalty after 100 m transmission was kept to as small as 1.8 dB. For this configuration a 2^{23}-1 non-return to zero pseudo-random bit stream (PRBS) was transmitted at a data rate of 156 Mbps.

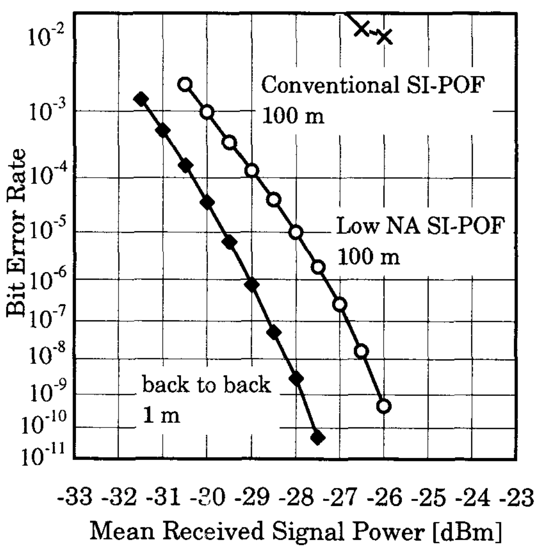

Fig. 3 BER characteristics of 156 Mbps 100m SI-POF transmission experiment with a high speed visible LED

4. RELIABILITY

4.1. Bending Endurance

The bandwidth change and the loss increment were measured at several bend radii. Measurements were made at a 650 nm laser diode using a 50 m length of the low NA SI-POF. The bend kept 90 degree was at the point of 2 m from the launching end.

Fig. 4 shows bandwidths and loss increments as functions of bending curvature from 0 to 100 m^{-1}. Bandwidths were measured under two different launch conditions. In the case of higher launch NA (=0.65), the bandwidth value slightly decreases in the range of large bending curvature. On the other hand, in the case of lower launch NA (=0.1), the bandwidth increases in the same range.

The loss increment of the low NA SI-POF changes slightly in the range of large bending curvature. The amounts of the variations are small enough for practical use.

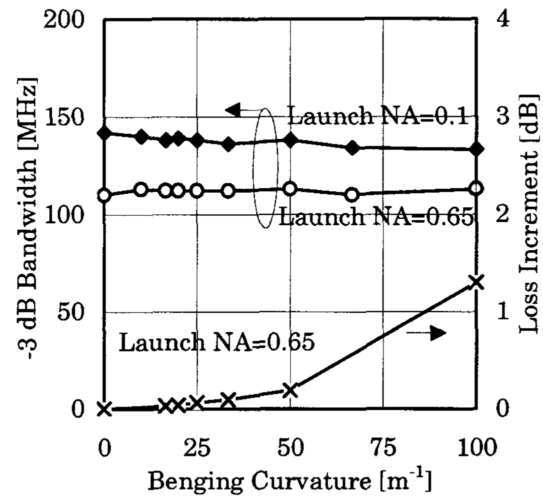

Fig. 4 Bandwidths and loss increments as functions of bending curvature

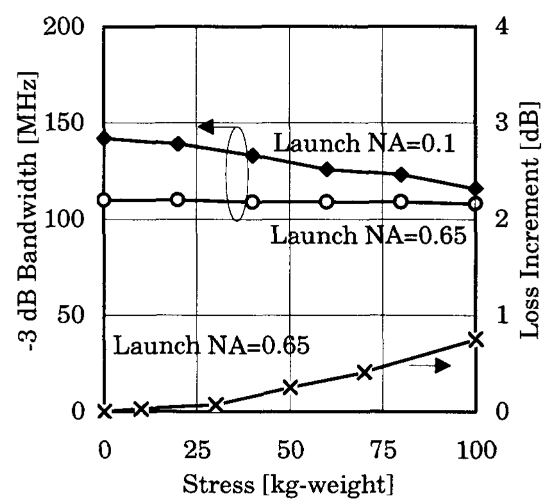

Fig. 5 Bandwidths and loss increments as functions of stress

4.2. Compressive load bearing

The bandwidth change and the loss increment were measured for given stress. Measurements were made at a 650 nm laser diode using a 50 m length of the low NA SI-POF.

Fig. 5 shows bandwidths and loss increments as functions of stress. Compressive load does not affect bandwidth under full mode launch conditions (launch NA = 0.65). Bandwidth shows a gradual decrease under low NA launch conditions. Loss increment of single-sheath POF cord is less than 1 dB under 100 kg compressive load. Compressive load smaller than 30 kg causes almost no less increment. These changes are permissible in practical use.

4.3. Impact durability

Impact durability was tested as shown in Fig. 6. drop impact causes absolutely no less increment with an impact energy up to 4 Joule, which corresponds to 2 kg dropped from 20 cm. Thus the POF cable has a good impact resistance, even for a simple single-sheath cord.

4.4. Heat resistance

Loss increment during long time heat exposure was measured. Fig. 7 shows the result. There is no additional loss after 1,000 hours of exposure in 85 degree atmosphere.

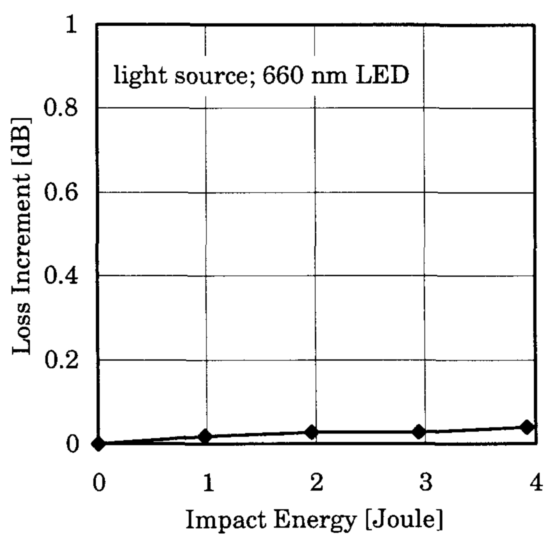

Fig. 6 Loss increment due to impact energy

5. CONCLUSION

The low NA SI-POF has a satisfactorily wide bandwidth and small loss of increment under some stressed conditions. We have shown the possibility of 156 Mbps 100 m transmission using an LED and the POF.

And environmental durability test have confirmed the POF to have enough reliability and mechanical durability to be used for fast LAN over a hundred Mbps.

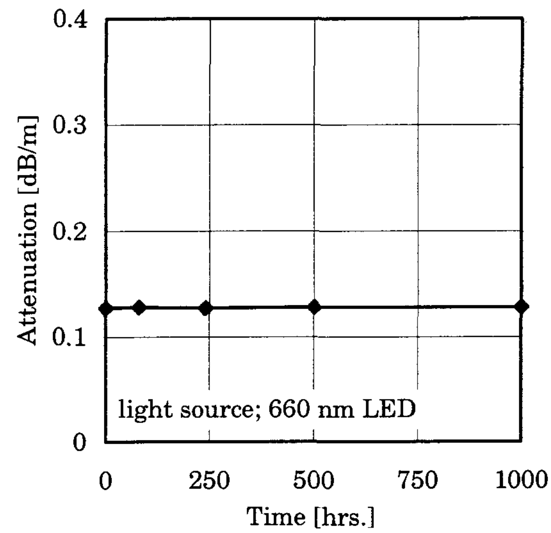

Fig.7 Loss increment during long time heat exposure

ACKNOWLEDGMENT

The authors would like to thank Satoshi Takahashi for his continuous support.

REFERENCES

1. A. K. Dutta, A. Suzuki, F. Miyasaka, K. Kurihara. H. Hotta, T. Nyu. S. Yamazaki and K. Sugita, "Visible LED for POF Based Data Link." Proc. of the 1995 society conference of IEICE

2. Y. Koike, T. Ishigure and E. Nihei, J. Lightwave Tech., vol. 13, No. 7, pp. 1475-1489

3. T. Ishigure, A. Horibe, E. Nihei and Y. Koike, J. Lightwave Tech., vol. 13, No. 8, pp. 1686-1691

4. K. Nakamura, J. Okumura, K. Irie and K. Shimada, proc. POF '95, pp. 114-116

5. T. Yoshimura, K. Nakamura, A. Okita, T. Nyu, S. Yamazaki and A. K. Dutta, Proc. POF '95, pp. 119-121