GIPOF의 최적 굴절률 분포와 최대 전송거리에 대한 연구

Theoretical analysis of optimum refractive index profile and maximum transmission length of a GIPOF

정 훈, 김승택, 강성복, 이경규, 강희석, 조영준
Micro Mechatronics team, Korea Institute of Industrial Technology
hoonj@kitech.re.kr

Polymer optical fibers (POFs) are being considered as important high-speed communication media in the area of local area networks, datalinks and optical sensors. Large core diameter (500~1500 μm) and large numerical aperture (0.2~0.9) in a POF allow easy processing and connectorization, low cost, high efficiency of beam coupling from LDs or LEDs, and complete immunity to EMI/EMR.

There are many reports about 2.5 Gbps transmission through the polymethylmethacrylate (PMMA) graded index (GI) POF over a distance of 100 m.[1~3] Therefore, in order to analyze the ultimate bandwidth characteristics of the GIPOF, we theoretically evaluated the optimum refractive index profile by considering not only the intermodal dispersion but also the intramodal dispersion and discussed the maximum transmission length (or maximum data rate) for a given index profile.

The core refractive index profile was described by $n(r) = n_1[1-\left(\frac{r}{a}\right)^{\alpha}\triangle]$, where r is a distance from the core center, n_1 is the refractive index at the center axis, a is the radius of the core, α is the index exponent, and Δ is the relative index difference. From the WKB method the output pulse width from the GIPOF was calculated as shown in following equations.[4]

$$\sigma_{intermodal} = \frac{LN_1\triangle}{2c}\frac{\alpha}{\alpha+1}\left(\frac{\alpha+2}{3\alpha+2}\right)^{1/2}\left[C_1^2+\frac{4C_1C_2\triangle(\alpha+1)}{2\alpha+1}+\frac{4\triangle^2C_2^2(2\alpha+2)^2}{(5\alpha+2)(3\alpha+2)}\right]^{1/2}$$

$$\sigma_{intramodal} = \frac{\sigma_s L}{\lambda c}\left[\left(-\lambda^2\frac{d^2n_1}{d\lambda^2}\right)^2-2\lambda^2\frac{d^2n_1}{d\lambda^2}(N_1\triangle C_1)\left(\frac{2\alpha}{2\alpha+2}\right)+(N_1\triangle)^2\left(\frac{\alpha-2-y}{\alpha+2}\right)^2\left(\frac{2\alpha}{3\alpha+2}\right)\right]^{1/2}$$

where σ_s is the spectral width of the light source, L is the fiber length, $C_1=\frac{\alpha-2-y}{\alpha+2}$, $C_2=\frac{3\alpha-2-2y}{2(\alpha+2)}$, $y=\frac{-2n_1}{N_1}\frac{\lambda}{\triangle}\frac{d\triangle}{d\lambda}$, and $N_1=n_1-\lambda\frac{dn_1}{d\lambda}$. We assumed the core and cladding materials followed a three term Sellmeier equation from Ref. [5] and the spectral width of the light source was 2 nm. Then the total root mean square pulse width can be calculated as $\sigma_{total}=(\sigma^2_{intermodal}+\sigma^2_{intramodal})^{1/2}$.

Figure 1 shows the calculated pulse width versus index exponent for PMMA-based GIPOF at 100 m in fiber length. Parameters y and $\sigma_{intramodal}$ were zero and N_1 equaled n_1 for the pulse width calculated only by intermodal dispersion (curve (A) in Fig. 1). In this case, pulse width was minimized at index exponent of 1.97.

However, when the intramodal dispersion was considered together with intermodal dispersion the index exponent showing mimimum pulse width was shifted from 1.97 to 2.33 and 2.14 at 650 nm and 780 nm, respectively. Also the total pulse width increased several tens times larger compared with pulse width calculated only by intermodal dispersion.

Figure 2 shows maximum fiber length versus data rate for attenuation- and dispersion-limited transmission. The attenuation-limited transmission was calculated as $L_{\max} = \frac{P_T(dBm) - P_R(dBm)}{\alpha_{fiber}}$, where P_T and P_R are the power of the tranmitter and power that the receiver requires to maintain the given BER. We assumed P_T was 0 dBm and P_R was *-80+15log(data rate)*. Note that the maximum link length is attenuation limited for data rate below about 1 Gbps, and dispersion limited for above about 1 Gbps.

In summary, the optimum refractive index profile of the GIPOF and maximum transmission length were analyzed with both intermodal and intramodal dispersion considered. We showed that the data rate performance of the GIPOF was seriously affected by the intramodal dispersion. For a higher data rate more than 1 Gbps in a GIPOF link, attenuation of a fiber as well as dispersion should be considered at system design.

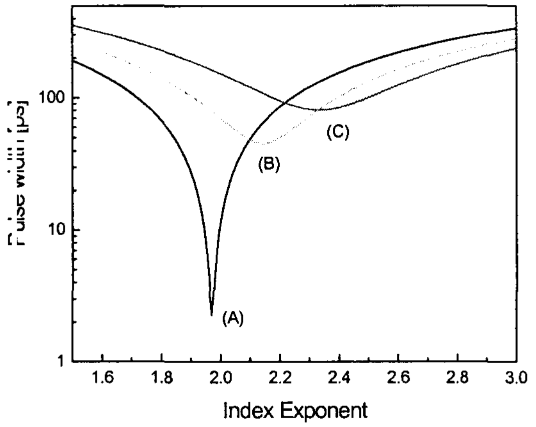

Fig. 1. Total pulse width (σ_{total}) versus index exponent of PMMA-GIPOF assuming equal power distribution of all modes. (A) only intermodal dispersion was considered, (B) both intermodal and intramodal dispersion were considered at 780 nm, (C) same as (B) at 650 nm.

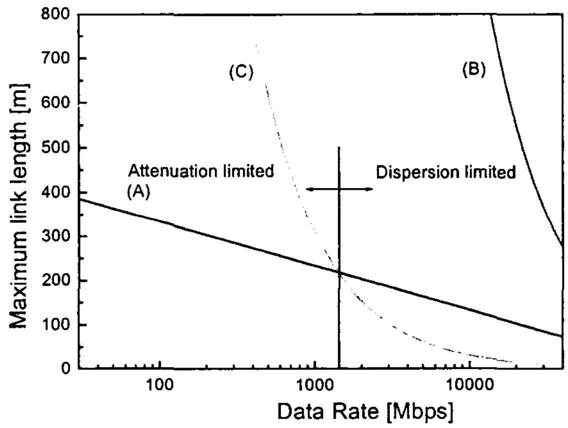

Fig. 2. Transmission distance versus data rate for attenuation limited situation, (A), only intermodal dispersion limited situation at index exponent of 1.97, (B), and both intermodal and intramodal dispersion limited situation at index exponent of 2.33, (C).

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