Demonstration of 500 nm-Wide Transmission Window at Multi-Gb/s Data Rates in Low-Loss Plastic Optical Fiber

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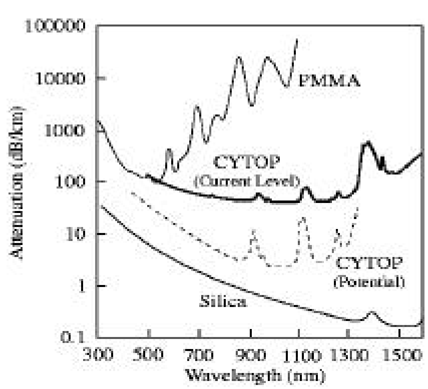
Abstract: Low-loss graded-index perfluorinated plastic optical fibers (GI PF POFs) are investigated for 100 m distance multi-Gb/s data transmission in premise networks, short-reach telecom, and computer interconnections. Several low-cost, uncooled, unisolated data communication sources, namely VCSELs at 0.85 and 0.98mm as well as Fabry-Perot laser sources at 1.3mm, have been tested, demonstrating that such POFs can support high-speed data rates of 9 Gb/s over 100 m, 7 Gb/s over 80 m, and 11 Gb/s over 100 m, respectively. Although these results have been obtained using restricted launch, differential mode delay (DMD) measurements show that large restricted bandwidths can be achieved in a broad wavelength range with large alignment tolerance of the sources.

Introduction

Data transmission in premise networks, short-reach (<100 m) telecom and computer interconnects are dominated from copper interconnections up to 1 Gb/s data rates. Further increases in the data rates demand the use of optical fibers. Single-mode optical fibers are ideal to transmit data at multi-Gb/s speed but suffer from high interconnection and transceiver costs due to tight alignment tolerances. Data transmission for short distances at data rates up to 12.5 Gb/s has been demonstrated previously /1/ but requires careful optimization of the fiber GI profile and a well controlled launch. Recently, low-loss (<100 dB/km) PF POFs have been introduced with very large bandwidths (>1 GHz km) /2/ in the data communication window.

Figure 1: Graded-index plastic optical fiber attenuation characteristics.



Data transmission over 100 m PF POF at up to 11 Gb/s has already been reported /3/. In this article we show that using restricted launches (achievable with large alignment tolerances), GI PF POF can support multi-Gb/s data rates from 0.85 μm to 1.3 μm. Furthermore we show that large tolerances in the restricted launch conditions can be maintained throughout such a broad wavelength range.

Fiber characterization results

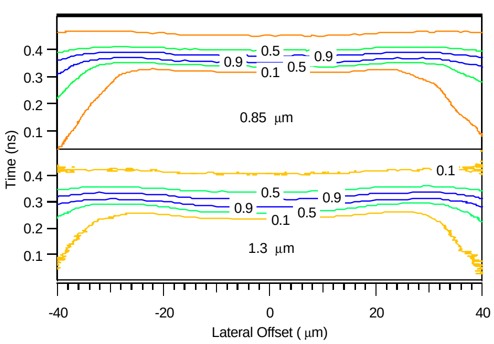
Fig. 1 shows the typical spectral attenuation for GI POFs made of CYTOP®. Our samples have losses that range from 44 dB/km at 0.85 μm to 33 dB/km at 1.3 μm. For the current experiment this implies a fiber loss of less than 5 dB over the whole wavelength window. Such a loss can be easily accomodated in the link power budget using more sensitive receivers or higher power sources.

Fig. 2 displays the results of DMD measurements performed on a 130 μm core diameter, 100 m long POF at 0.85 and 1.3 μm wavelengths. Here, the contour plots show the normalized intensity of the fiber impulse response as a function of the offset restricted launch position. The contours represent 10, 50, and 90 % pulse intensity levels and can be used to estimate the pulse width and mean pulse delay for a given offset. It is clear that such fibers can support data transmission at rates up to 10 Gb/s over 100 m if a restricted launch is used with +/-20 μm tolerance around the center. The large tolerance is due to the strong mode coupling between low order mode groups /4/. To the best of our knowledge this is the first time that a single fiber has been shown to support high bit rates over such a wide wavelength range. This can be explained considering the high mode coupling and low chromatic dispersion in perfluorinated POF.

Laser source characteristics

Both VCSELs and an edge-emitting laser have been selected to evaluate data transmission behavior under various conditions. As long-wavelength source, a Lucent 1.3 μm uncooled and unisolated Fabry-Perot (FP) laser in a single-mode fiber pigtailed package was employed and driven at 0 dBm power launched into the POF. Top emitting VCSELs containing 3 GaAs or InGaAs quantum well active regions have been grown by solid-source molecular beam epitaxy for both the 850 and 980 nm spectral regimes. Lateral current and photon confinement rely on selective oxidation of a 30 nm thick AlAs layer and optimization for high-speed operation involves low-capacitance polyimide mesa planarization /5/. Transverse single-mode emission is achieved with 3 to 4 µm oxide aperture openings accompanied by weak index-guiding /6/. GaAs and InGaAs based VCSELs emit at 830 and 935 nm wavelength and show threshold currents of 0.8 and 1.3 mA, respectively. Bias currents were chosen as 3.2 and 5 mA, delivering 0 and 4 dBm launched optical power levels. Digital modulation signals were supplied from a pattern generator with 1.3 and 1.7 V peak-to-peak, where devices were wire-bonded on an SMA socket or directly probed to a coplanar contact configuration, respectively.

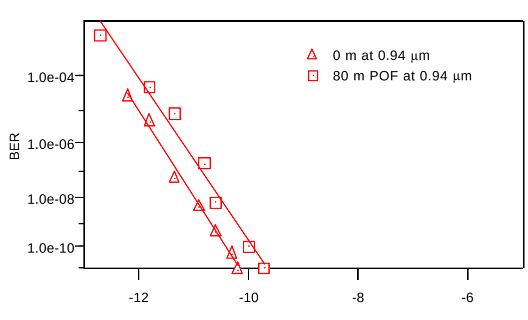
Figure 2: DMD measurement results.



Transmission results

Fig. 3 illustrates bit error rate (BER) transmission results using the 0.94 µm VCSEL source butt-coupled to an 80 m long, 155 µm diameter GI PF POF. The source was modulated up to 7 Gb/s and shows very low power penalties below <0.5 dB at error rates of 10^{-9}. Fig. 4 shows BER data for transmission over a 100 m, 130 µm core, POF using either a VCSEL at 0.83 µm or the FP laser source at 1.3 µm. The VCSEL link has a power penalty of 4 dB at 9 Gb/s, and we believe it was limited by the low source extinction ratio.

Figure 3: 7 Gb/s data transmission through 80 m GI POF using a single-mode oxidized VCSEL at 0.94 µm.

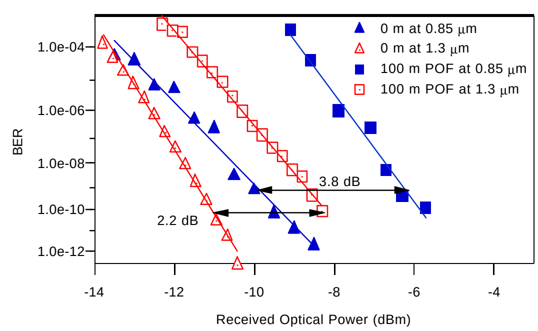


Small coupling loss of less than 2 dB from the POF to a free-space broad-area (70 µm), 9 GHz bandwidth Picometrix pin-photodetector was achieved using 2:1 demagnification optics. The FP laser link was modulated up to 11 Gb/s with a power penalty of 2.2 dB at 10^{-9} BER and was limited by the fiber bandwidth and modal noise arising from a 4.8 dB coupling loss incurred at the receiver end. This loss could be reduced using a similar arrangement as for the VCSEL link. Low numerical aperture coupling, lower bit rate, and shorter fiber length all contribute to more favorable power penalties in case of the InGaAs VCSEL transmission.

Conclusions

We have successfully demonstrated that GI PF POF can support bit rates as high as 11 Gb/s over 100 m fiber lengths using restricted launch. Such high bit rates can be obtained over a 500 nm wide wavelength range using low cost sources like uncooled, unisolated VCSELs and FP lasers. Finally, we have shown that the high POF bandwidth is maintained over a 40 µm lateral offset range.

Figure 4: 11 Gb/s and 9 Gb/s data transmissions using an uncooled, unisolated FP source at 1.3 µm and a single-mode oxidized VCSEL at 0.83 µm, respectively.



Acknowledgement

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