Transmission Characteristics of Plastic Optical Fiber

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Abstract- *In this article, different transmission characteristics have been investigated using Cyclic Transparent Optical Polymer (CYTOP), a perfluorinated graded index fiber. Graded index perfluorinated fibers can support multi-Gb/s date rates from 0.83 um to 1.3 um. High bit rates can be obtained over 0.5 um wavelength range where optical transmitter and receivers technologies are already matured. A distributed feedback laser source operating at 1.3 um and a low cost InGaAs detector have been used in an error free transmission for both modulated multichannel transmission and directly modulated digital transmission at 2 Gb/s. Two data stream channels at 145 Mb/s are mixed using binary phase shift keying BPSK modulation technique onto two carriers at 1 GHz and 1.4 GHz respectively. An error rate of* $< 10^{-9}$ *is obtained at a modulation index of 6.5 %. Also, the dispersion power penalty of the CYTOP fiber is measured and found to be less than 1 dB suggesting that the fiber induced distortion is small.*

Keywords: Plastic optical fibers, Optical transmission

1. Introduction

Plastic optical fiber (POF) assemblies possess special characteristics that make them an ideal solution for applications where additional glass optical fiber (GOF) products are not well suited. For applications requiring a very tight bend radius, POF products can generally bend to 25 mm with no excessive attenuation. For visible light laser applications, POF assemblies can transmit the signal such that it is visible to the human eye, making the user aware of its attachment to an active laser and allowing them to avoid associated dangers. POF products also have a very wide tolerance for scratching and contamination from the field. This tolerance allows it to perform at acceptable level despite some compromise in physical condition.

POF may be used in medical, automotive, home networks, digital audio/video interfaces, signs/illumination, and instrumentation. Similar to traditional glass fiber, POF transmits light/data through the core of the fiber. However, POF assemblies have a core size; in some cases 100x that of glass fiber. The increased core diameter allows 96% of the core to transmit signal from point-to-point, making it an ideal material for very high bandwidth/signal transmission over very short distances. Also, the ease of installation and low system cost give the POF strong advantages in computer interconnections and local area networks (LAN).

Perfluorinated graded-index polymer optical fibers (GI-POF's) have been developed to offer low losses (<50 dB/km) and high bandwidth (>0.3 GHz km) at data communication wavelengths (0.85 and 1.3 µm). They can support data rates up to 11 Gbit/s for 100 m with low-power penalty and large-power margins [1]. Also, Photonic polymer devices for broadband technologies were described focusing on high bandwidth GI-POF [2]. A 250 Mbit/s bi-directional single POF communication system demonstrated using modules with a green light emitted diode (LED) ($\lambda = 495$ mm) and a red LED ($\lambda = 650$ mm) [3].

Polymethiylmethalacrylate (PMMA) based POF has become increasingly popular as a low cost alternative to GOF for application on short haul data transmission systems. In addition, in many application fields, POF offers significant advantages in comparison to conventional data transmission media. It combines the optical transmission properties of glass fiber with the low cost of copper cables. It eliminates the disadvantage associated with the GOF (brittleness, high cost…) and with copper cables (absence of immunity from electromagnetic interference). Conventional PMMA plastic optical filters have a low loss window around 650 nm, where light sources and receivers are still under development [4]. An attempt has been made to substitute a hydrogen atom in PMMA with an atom of fluorine [5] in order to lower the attenuation in longer wavelength (800 nm to 1300 nm).

This led to the development of Cyclic Transparent Optical Polymer (CYTOP) fiber by ASAHI Company in Japan [6]. CYTOP is an amorphous, soluble perfluoropolymer having the outstanding properties of highly fluorinated polymers including temperature and chemical resistance, electrical properties, water and oil repellency and injection formability. It has many applications as Anti-reflective coatings, pellicles used in semiconductor imaging, microelectronic dielectrics, Optical fiber, optical device coatings, and Optical waveguide. The CYTOP fiber has an excellent high transmitance both in the visible and ultraviolet region: 123 dB/km at wavelength of 850 nm and 95 dB/km at a wavelength of 1300 nm.

In this paper, we demonstrate error free digital data transmission at 2 Gb/s over 118 m of CYTOP fiber. This data rate is only limited by the bit error rate measurement system. Also, a subcarrier transmission experiment for two channels of 145 Mb/s each mixed using 1 GHz and 1.4 GHz respectively. Lastly, using the BER test, the fiber dispersion power penalty at 1.3 nm wavelength was measured.

2. Fiber Characterization Results

Figure 1 shows the direct digital modulation transmission setup. A distributed feedback laser source ($\lambda \sim 1310$ nm) was directly modulated from a pulse pattern generator at a rate of 2 Gb/s. The output was coupled to 118 m CYTOP fiber. The other fiber end is focused into a high speed InGaAs detector by a collimating lens. Figure 2 shows the BER vs. modulation index m. An error rate of less than of 10^{-9} was obtained at a modulation index of 1.2 %.

Binary or biphase shift keying (BPSK) is one of the simplest of all the modulation schemes used. It is used extensively for Common Antenna TV (CATV) applications. In this modulation scheme, the phase is shifted 180° between transmission of 0 and 1. The modulation index (or modulation depth) of a modulation scheme describes by how much the modulated variable of the carrier signal varies around its unmodulated level.

Figure 3 shows the multichannel subcarrier transmission setup. Two non-returns to zero (NRZ) data stream channels at 145 Mb/s were mixed using binary shift keying BPSK modulation techniques onto two carriers at 1.0 GHz and 1.4 GHz respectively [7].

A bandpass filter of 300 MHz bandwidth was placed after each mixer (modulator) to remove unwanted higher order harmonics. Different RF amplifiers and attenuators, not shown in the Figure, were added in order to enhance the mixing.

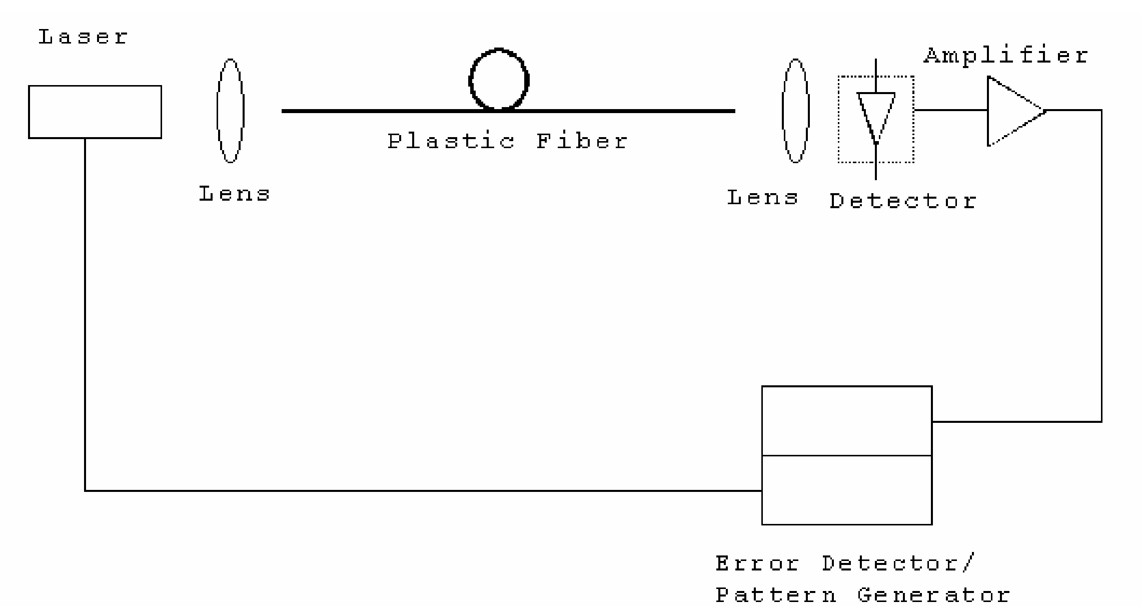

Figure 1. The 2 Gb/s transmission setup.

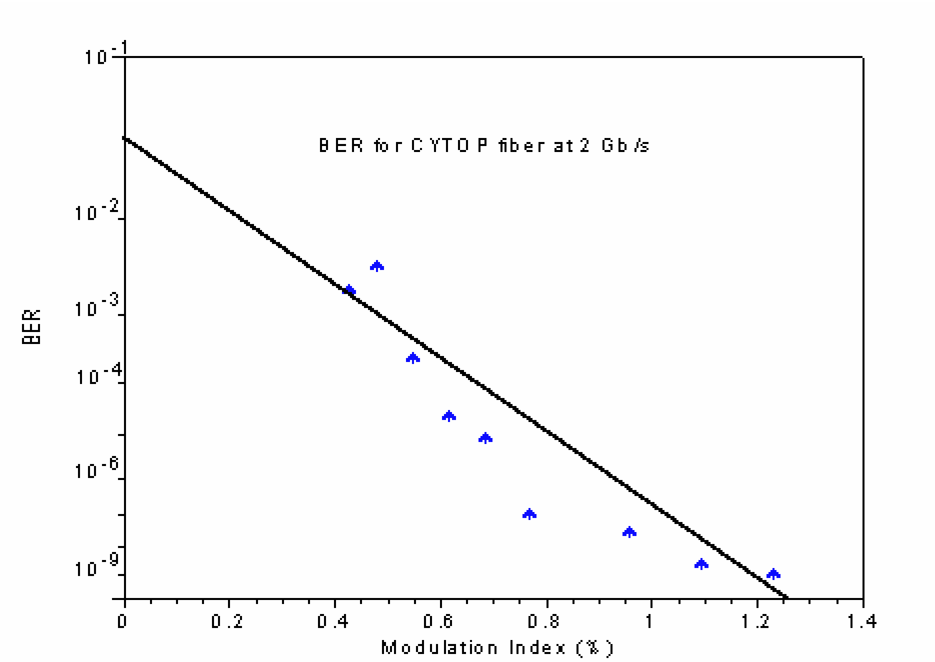

Figure 2. Measured BER vs. modulation index for a 2 Gb/s transmission experiment.

The two-upconverted signals were then combined and used to modulate the laser source that is coupled to the CYTOP fiber. Easy coupling was achieved due to the small emitting region of the DFB laser source and high numerical aperture of the fiber (NA = 1.9). At the receiver, the output photocurrent was amplified then split into two branches for downconversion in order to retrieve the data from the two channels. The signal from the filter in each branch is supplied to the mixer (demodulator). The local oscillator (1 GHz and 1.4 GHz) must be phase locked to the incoming RF carrier.

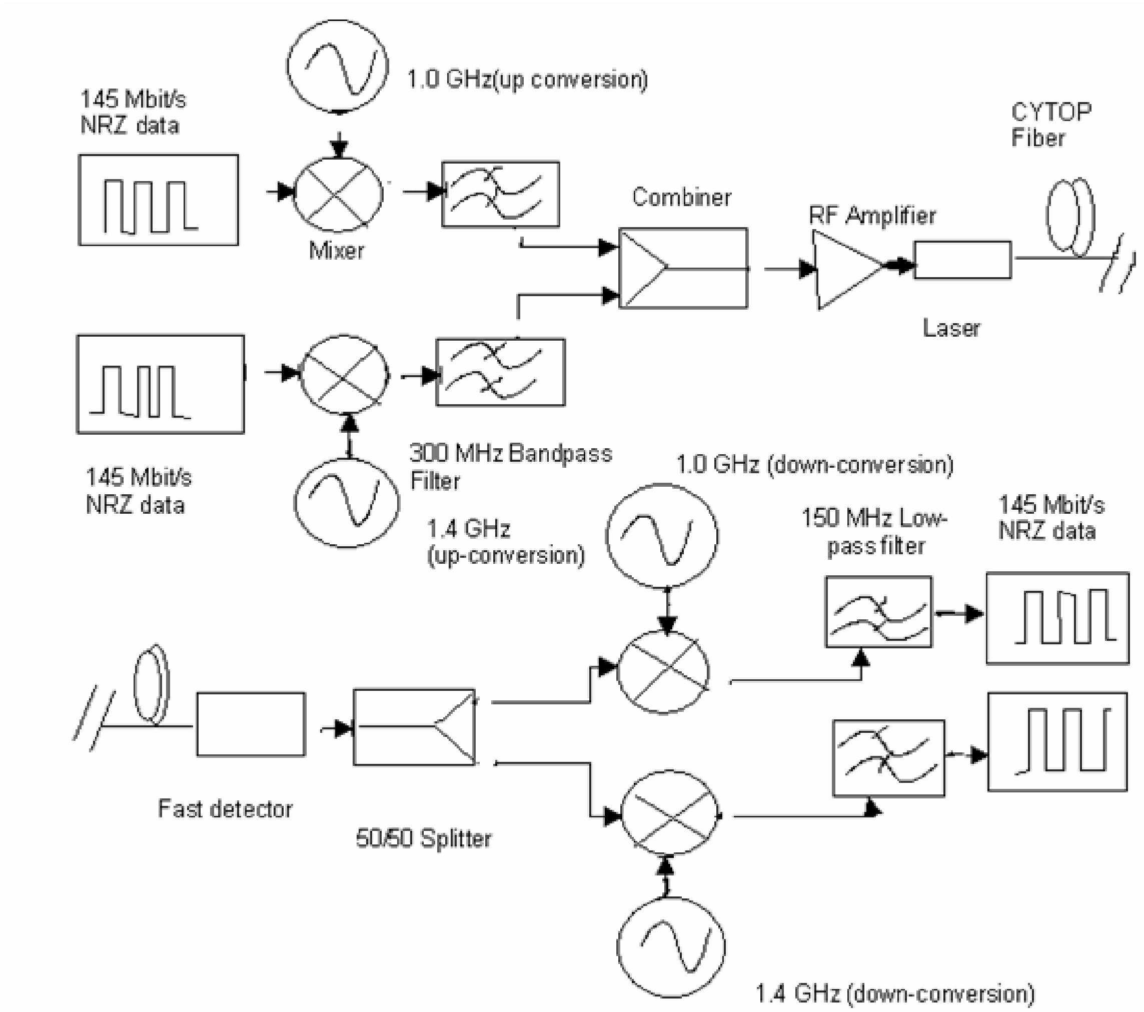

Figure 3. Schematic for subcarrier modulation experiment.

The circuit in Figure 3 utilizes the fact that the second harmonic of the carrier contains no phase shift (when the frequency is doubled, a 180° phase shift becomes a 360° phase shift which is the same as no shift at all.

The bit error rate BER vs. modulation index m_{BPSK} is shown in Figure 4. A bit error rate BER < 10^{-9} was obtained at a modulation index m_{BPSK} of 6.5 %.

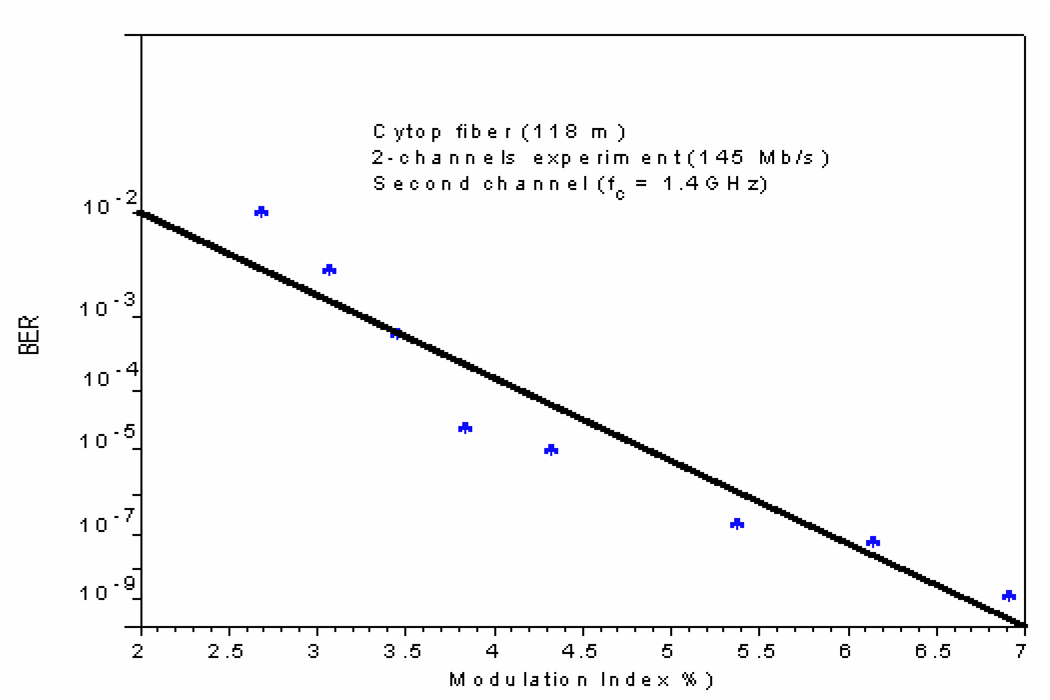

Figure 4. BER vs. the modulation index for one channel of subcarrier modulation experiment.

The test setup to measure the dispersion power penalty of a 118-m CYTOP fiber is shown in Figure 5. Extra care must be taken in doing this experiment [8], since the system has to be calibrated before adding the fiber into the setup. In addition, the system sensitivity must be determined with and without the fiber in place. The measured BER vs. modulation index m without the fiber is used as reference. The calculated dispersion power penalty is determined after inserting the fiber in place and measuring the BER vs. modulation index m. Figure 6 shows the BER vs. the modulation index. The dispersion power penalty is

$$D = P_{fiber} - P_{ref}$$

less than 1 dB for the 118 m of CYTOP fiber. Obviously, this fiber length is not long enough for dispersion manifestation, therefore dispersion measurements are needed using longer CYTOP fibers.

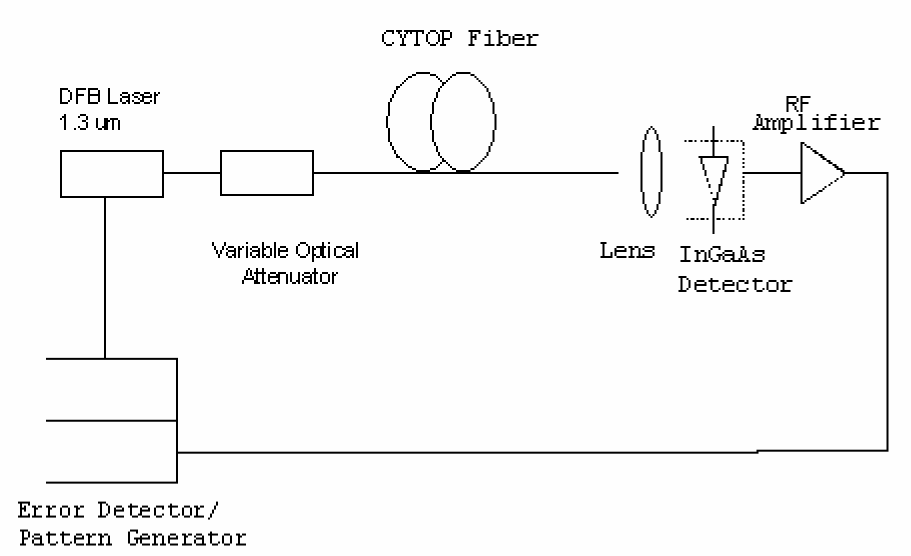

Figure 5 Test set-up for measuring dispersion power penalty.

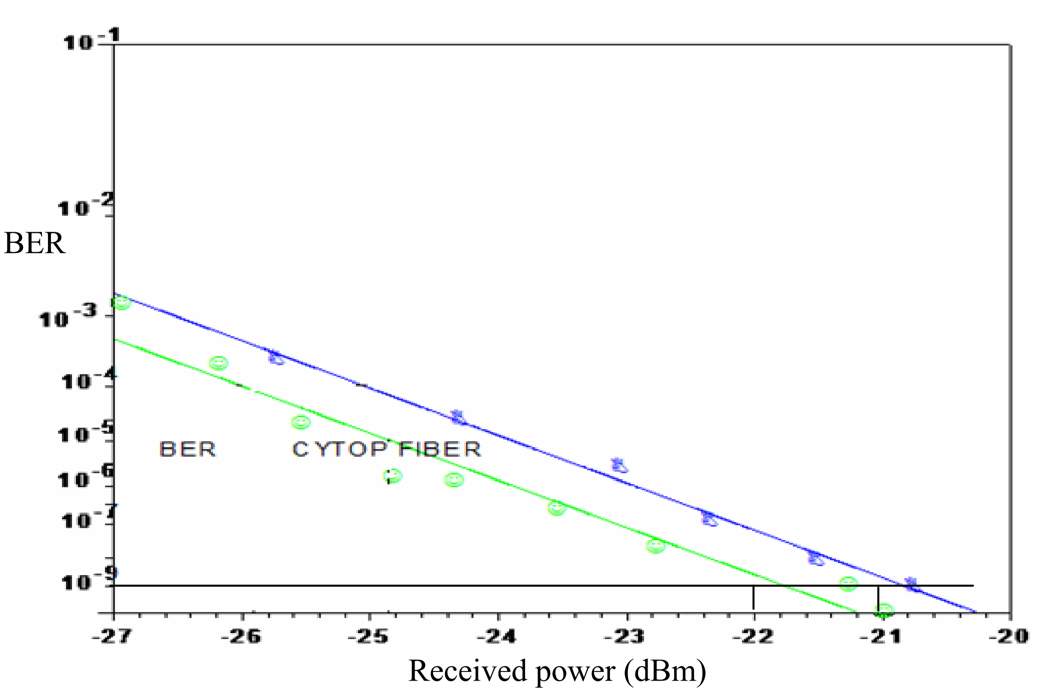

Figure 6. Dispersion power penalty in CYTOP fiber.

3. Conclusion

Results of a digital transmission experiment of 2 Gb/s using CYTOP fiber have been presented. Two BPSK modulated 145Mb/s digital channels are mixed with 1.0 and 1.4 GHz respectively. A bit error rate (BER) $<10^{-9}$ is obtained for subcarrier modulated digital channel after transmission through 118 m of fiber. The results show that dispersion power penalty caused by the laser fiber did not degrade the system, suggesting that the fiber-induced distortion in the transmission system is small. CYTOP POF can be an ideal for very high bandwidth signal transmission over very short distances.

References

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