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Suitability of thick-core plastic optical fibers to broadband in-home communication

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Plastic Optical Fiber (POF) is an emerging transmission technology for short-haul communication. Especially in-home applications, POF shows a remarkable performance on fiber handling thanks to its do-it-yourself capability. The large core size and the use of visible light make the installation for this type of fiber much easier for average users when compared to the installation using other wired technologies such as glass fiber and copper. Bending performance is one of the key issues for home installation. This paper explores all bending related performance of multi-core, single-core graded, and step index POF.

Introduction

Current home networks are predominantly a mixture of different network technologies, such as, coaxial copper, twisted pair, Cat-5E cables, and WiFi. These networks show bandwidth limitations that prohibit the extension of broadband capabilities of the fiber-to-the-home (FTTH) access network to the end users. Recently, research has started to look into optical fiber for converged indoor network architecture with truly broadband capabilities. In general, an in-home network is privately owned, it should be easy to use, not requiring professionals, and that single household has to bear all the costs. Plastic Optical Fiber (POF), especially 1 mm core diameter polymethylmethacrylate (PMMA) POF, has been demonstrated to meet all these requirements [1]. Over the last decade, industries have shown more and more interests in the step index (SI) POF thanks to its standardization and the transmission speed up to 1 Gbit/s. In the recent years, the interface rates with which consumer electronic devices want to communicate are rising to more than 10 Gbit/s, therefore great interest has been shown for graded index (GI) POF [2].
Next to the transmission performance, an important aspect is the economics, the POF solutions can be already today cost competitive with Cat-5E regarding installation costs [3]. POF offers the opportunity to share the ducts of the power line cables in already existing buildings, on the other hand this provides unpredictable bends and twists of the cable. In recent years, a comprehensive study on POF bending has been carried out to reduce the power losses and improve its bandwidth [1]. To improve the low-pass channel bandwidth and the bending properties of standard SI-POFs, the step-index multi-core POF was recently introduced [3].

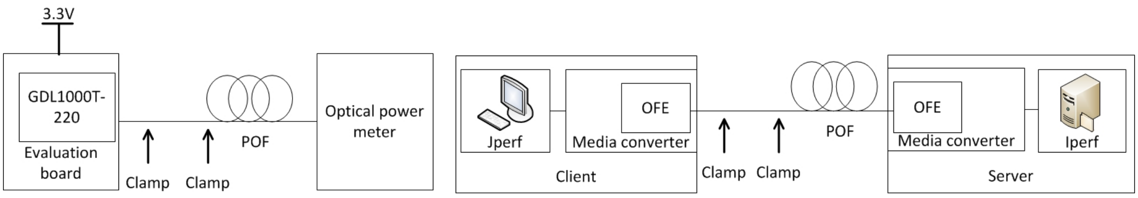
In this paper we compare the bending sensitivity of 1 mm core PMMA MC, SI, and GI POFs. Both power loss and bit rate reduction are considered for bending angles, bending radii, and the number of twists.

POF type	Vendor	Model	Bit rate test cable length (cm)
SI-POF	Mitsubishi Rayon’s	Premier GH4001	212.5
SI-POF	Mitsubishi Rayon’s	Mega MH4002	44 - 141.2
SI-POF	Toray	PFU-UD 1002-22-V	32.6
GI-POF	FiberFin	OM-GIGA	32.3
GI-POF	Optimedia	OM-Giga-SE100	Not performed
MC-POF	Asahi KASEI	SMCK-1000P	176
MC-POF	Asahi KASEI	MC-POF 37 cores	Not performed

Table 1. POFs under test.

Experimental setup

The POFs under test are shown in Table 1, the bends are performed using metallic rings with the following diameters (cm): 0.15, 0.25, 0.6, 1.2, 1.5, 2.5, 3, 4, and 5. In order to ensure the cable follows the bend, a slight tensile force is applied. Two clamps are used to fasten the POF at the curving point, to reduce the movement of the fiber at the receiver. The power loss is calculated as ratio between the received power when the fiber is straight and when it is bent. Two different measurements are performed on the straight POF: before the bends as reference level and after the test to ensure the POF is not damaged.



(a) Experimental setup for power loss vs. bending radius.
(b) Experimental setup for bit rate vs. bending radius.

Fig. 1. Schematic of the setups.

Fig. 1a shows the experimental setup of the bending test in order to study the power loss vs. bending radius. The transmitter is a Firecomms optical transceiver Gigabit OptoLock GDL1000T-220. The optical signal with the wavelength of 650 nm is generated by a resonant-cavity light Emitting Diode. The optical front end is driven by a Firecomms evaluation board,. The receiver is the fiber optic power meter Thorlab PM20A which has been set to the 650 nm wavelength.
The effect of the cable stretching on the connection loss is analyzed. The POF stretching does not affect the coupling loss on the transmitter side, on the other hand, the received optical power is affected by too even small stretching force, proper techniques are applied to minimize the connection loss changes.
Fig. 1b shows the setup of the bit rate vs bending radius test. The server and the client parameters are shown in Table 2. The adaptive bit rate technique is applied. The transmission duration is 10 s and the bit rate measured refers at TCP level.

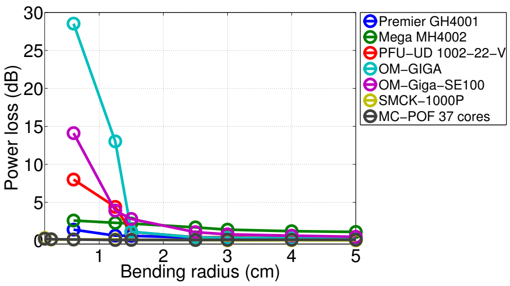
	Server	Client
Software	Iperf 2.0.2	Jperf 2.0.2
OS	Linux server 2.6.32-33	OS X 10.9.4
Network interface	Ethernet 1000Base-T	
Media Converter	KD-EVB 1001-MC	
OFE	Avago transceiver	

Table 2. Server and client parameters.

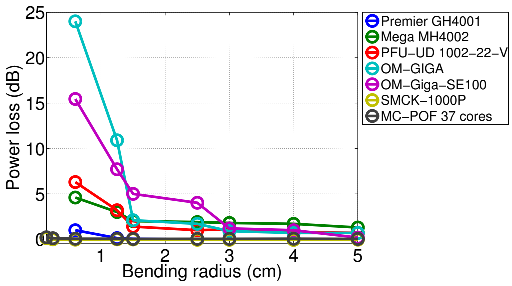
Results and discussion

Fig. 2a-c show the power loss vs. bending radius for 1 twist with different angles: 360° means a full twist, 180° a half twist. For a certain bending radius, it is possible to clearly distinguish the three POF types in accordance with [1]. Both SI-POFs, except MH4002 and GI-POFs show almost exponential growth but with different performance within the same fiber type.

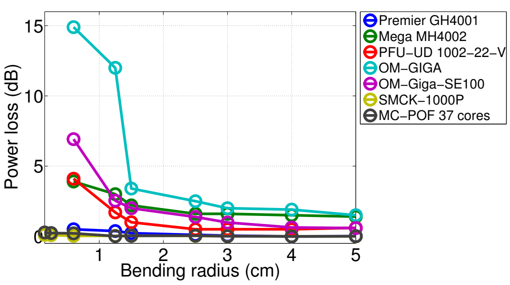
Fig. 2d shows the result of the power loss with respect to the number of bending rounds, with fixed bending angles of 360° and the bending radius of 0.6 cm. The highest loss is given by the first bend. The different behaviors of SI, GI, and MC-POFs are clearly shown.



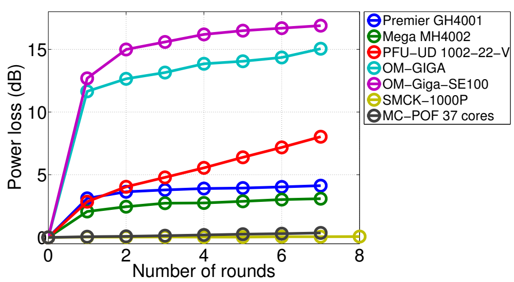
(a) 1 bend of 360° angle.



(b) 1 bend of 180° angle.



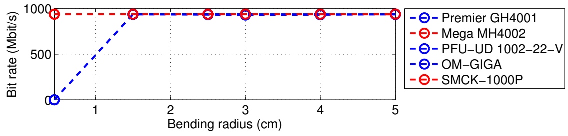
(c) 1 bend of 90° angle.



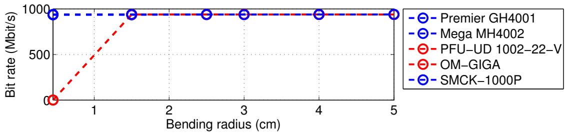
(d) Power loss vs. round numbers.

Fig. 2. Power loss vs. bending radius results.

In Fig. 3a, b are displayed the results of the bit rate vs. bending radius for 1 twist with different angles. Different types of POF have the same bit rate, therefore, for them the same color is used. A step decreasing instead of a continuous trend of the bit rate is observed. The link works either at 940 Mbit/s or 0 Mbit/s, further tests demonstrate that this does not depend on the TCP protocol adopted. The bit rate reduction is still related with the bending angle.



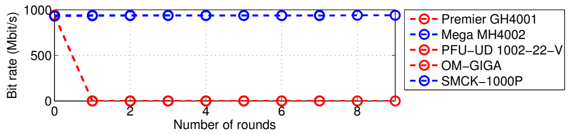
(a) 1 bend of 360° angle.



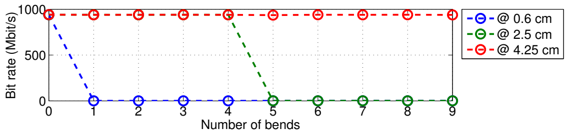
(b) 1 bend of 180° and 90° angles.

Fig. 3. Bit rate vs. bending radius results.

Fig. 4a shows the result of the bit rate vs. number of bending for 360° angles and 0.6 cm radius of bending. Fig. 4b shows the result of the bit rate vs. number of bending, for 360° angle with 0.6, 2.5 and 4.25 cm radii. The first bend is the most effective for the link fault as is also shown during the power loss test. Furthermore, Fig. 4b that shows the bit rate performance of PFU-UD- 1002-22-V is largely influenced by the bending radius. The same results can be shown for OM-GIGA.



(a) Bit rate vs. bending numbers.



(b) PFU-UD 1002-22-V POF bit rate vs. bending numbers and radii.

Fig. 4. Bit rate vs. number of bends.

Conclusion

We have performed an experimental comparison between SI, GI, MC-POF performances when the cable is bent. Both power loss and bit rate tests, for different bending number and angles, were performed. MC-POFs confirm to be the most bend insensitive fiber type, with negligible power loss for any bending radius and angle, as well as no link fault occurs, even for the lower bending radius. During the bit rate tests, an expected step behavior was shown for each POF, which could be provided by the adaptive bit rate technique used by the medium converters KD-POF KD-EVB 1001-MC.

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