Optical Characteristics of Do-It-Yourself Short Optical Links with Multiple Connectors

Kimio Oguchi
Graduate School of Science and Technology
Seikei University
Musashino, Tokyo, Japan
oguchi@st.seikei.ac.jp

Masahiro Watanabe
Faculty of Science and Technology
Seikei University
Musashino, Tokyo, Japan

Abstract— This paper first clarifies Do-It-Yourself optical connector loss characteristics that must be known to design networks that have short optical links. Novices are tasked with using two typical fiber facet finishing methods to create connectors. The packet loss characteristics of optical links constructed with several of these connectors are measured and discussed. Experiments show that amateur optical connectors with about 3 dB loss are feasible if the hot plate is used for finishing the fiber facet. Concatenating connectors will decrease the reachable fiber distance so careful link configuration is needed.

Keywords— short link; MMF; DIY; POF; packet error rate

I. INTRODUCTION

ICT (Information and Communication Technology) is indispensable for current human life and society as witnessed by the dramatic recent increase of network traffic. Optical networks are performing a key role in handling such traffic, especially in core/metro areas. Even the burgeoning wireless networks are being supported by optical networks through the adoption of new technologies e.g. WiFi offloading and mobile backhaul technology in access networks.

Given the pace of broadband network penetration, home/office networks are essential for human life as these locations are occupied for long periods. Research into future broadband home/office networks is internationally active [1, 2], and a standard has been released by ITU-T [3] for realizing the smart and intelligent home network with POF (Polymer Optical Fiber).

Among the several technical issues raised by small area broadband networks, the transmission medium is critical. MMF (Multi Mode Fiber) is seen as the cost effective medium for short range communications. POF offers high bandwidth, excellent flexibility, low-cost, easy handling, and simple plug interconnection. DIY (Do It Yourself) network installation is highly cost-effective. One of the major factors driving the preference of POF over GOF (Glass Optical Fiber) is its large core (e.g. 1 mm). Several DIY kits such as Media Converter (MC), are already commercially available. However, even though commercial products are available and specified, the characteristics of a home assembled network/link have not clearly elucidated.

This paper first clarifies DIY optical connector loss characteristics that must be well understood to design short optical links [4]. In experiments, connectors are assembled by novices using two typical methods for fiber facet finishing. The packet loss characteristics of optical links created with the assembled connectors are measured and discussed.

II. EXPERIMENTAL METHODS

A. DIY based Connector Assembly

Our pre-experiment on connector assembly indicated that connector loss strongly depends fiber facet condition [5]. Therefore, two methods for processing the fiber facet are compared; Hot Plate (HP) and Hot Knife (HK). Each is used to finish the fiber facet that projected slightly from the ferrule. Other tools were the same.

Connectors were assembled using DIY tools: jacket striper, fiber cutter, scissors, pliers, optical cleaner, and hot plate or hot knife. The optical connectors used were SC type and the DIY kit included Al ferrule, metal jacket, plastic housing and boot (FIS SC alloy, Fiber Instrument Sales, Inc. [6]). Optical fiber used was 1 mm SI (Step Index) -POF (NA=0.5, 160 dB/km loss, Super Eska, Mitsubishi Rayon).

Two groups participated in this experiment; one to used the HP method for assembly, the other used the HK method. All other tools were shared. Each group consisted of 6 people (5 undergraduate/master students, and one associate professor all in Computer and Information Department); all were novices at optical connector assembly. Each person assembled 3 connectors.

For the first assembly, all participants were instructed by us as no proper manuals were available. Total time taken to assemble each connector, and connection loss were measured. Comments from participants were gathered upon completion of assembly.

Figure 1 shows the connector loss measurement setup. A 660 nm LED (Anritsu MS9020D) was incident to a master SI-POF cord with SC connectors after traversing 50/125 μm GI-MMF (Graded Index Multi Mode Fiber) and a mode scrambler consisting of 8 m 1 mm SI-POF wrapped around a 30 mmϕ cylinder. This configuration yields stationary mode transmission. The connector loss of each DIY SC connector attached to an SI-POF cord was measured. Here, optical power

difference (P1-P2 in the figure) is considered as connector loss; fiber loss is ignored due to the short length.

B. Transmission Experiment

Figure 2 shows the experimental setup for QoS (Quality of Service) measurements. The 'iperf' application [7] was used to measure QoS between a PC client (PC-CL) and a PC server (PC-S). With 'iperf', the PC-CL sends UDP packets (each 1470 Bytes long) to the PC-S for a given time, and then the PC-S replies with measured QoS values such as packet loss, jitter value, delay and throughput. As the PC sent Ethernet packets and no packets were resent, the UDP long packet was used in the measurements. Between the two PCs we set DIY media converters (MCs) (IEEE802.3u 200Base-FX compatible, Com Science, MC200-OL-JK30 [8]). Between the two MCs (optical section in the figure) we set fiber cords with connectors in W-E direction, and just fiber in E-W direction to eliminate connector effects on the return path. Packet loss rate in terms of the number of cords, connectors was measured.

III. Results and Discussion

A. DIY based Connector Characteristics

Figure 3 shows measured assembly time per connector for the 6 subjects in terms of assembly count; average time and its standard deviation (SD) for HP and HK methods. Clear differences between the two methods are seen for the first assembly; the hot knife is faster than the hot plate. Experience increases the speed of both methods and the learning effect exists even for small total counts. These results suggest that novices can assemble a connector in less than 10 min with some experience.

Figure 4 shows measured connector loss in terms of assembly count; average loss and its SD for HP and HK methods, respectively. HP yields smaller losses than HK and there is no clear dependence on assembly count.

Figures 5 (a) and (b) show histograms of all connector losses (18 = 3 pieces x 6 subjects) for the HP and HK methods, respectively. As shown, HP connectors have better loss characteristics than HK units. This might be due to fiber facet shape; HP yields a slightly convex facet whereas HK facets are quite flat. The convex surface acts like a lens yielding good optical connections.

In interviews, all participants noted that connector assembly was possible, but the DIY tools were difficult to use. Judging the quality of the fiber facet was also difficult and the lack of feed back was also noted.

B. Transmission Experiment Results

Figure 6 shows a screen shot of PC-CL with QoS results sent by PC-S. The information includes; throughput of 78.8 Mb/s, delay of 0.209 ms, and zero packet loss for the 10,005,016 packets sent in 150 sec.

Figure 7 plots optical received power at MC-B versus distance between the two MCs (5, 10, 20, and 50 m fiber cords with SC connectors were used). As seen, if 5 m cords are used, 15 m (5 m x 3) is the maximum distance.

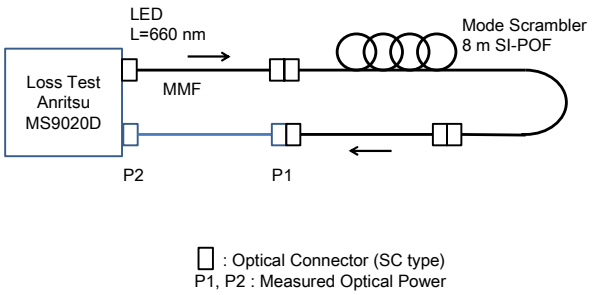


Fig. 1. Experimental setup for connector loss measurement.

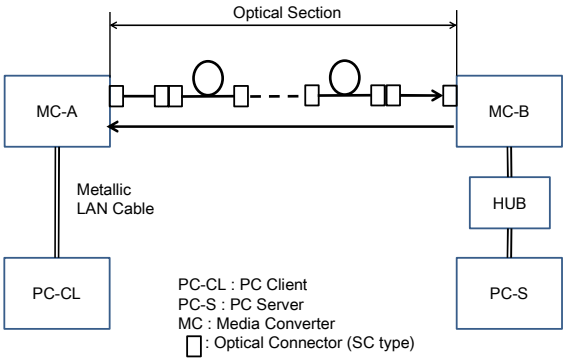


Fig. 2. Experimental setup for QoS measurement.

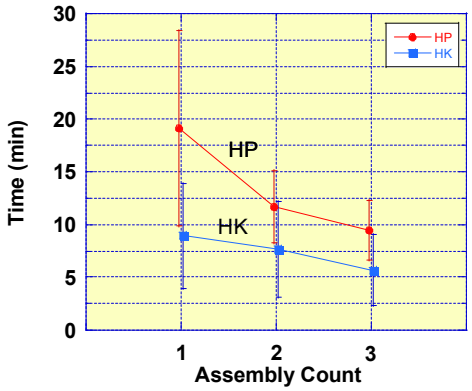


Fig. 3. Measured assembly time per connector: average values for the six subjects and standard deviation (SD).

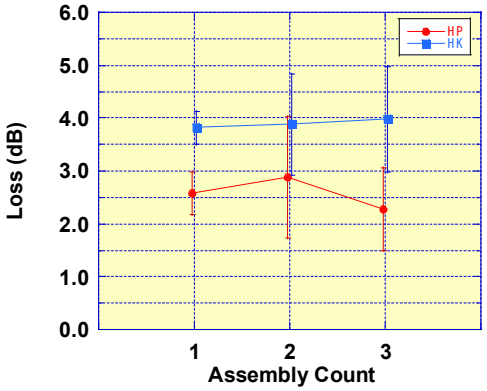
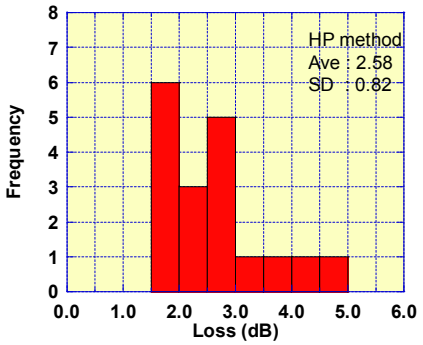
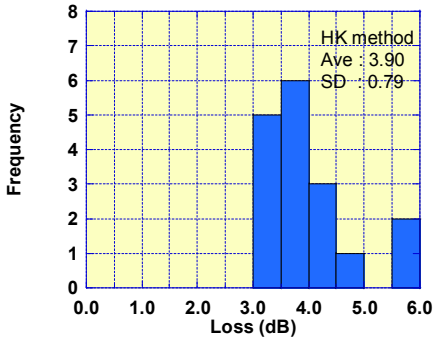


Fig. 4. Measured connector loss vs. assembly count: average losses for the six subjects and SDs.



(a) HP method. Total number is 18.



(b) HK method. Total number is 17 as one broke.

Fig. 5. Measured connector loss histograms.

```
C:\Users\owl\iperf>iperf -c 192.168.11.81 -u -b 100m -t 150
------------------------------------------------------------
Client connecting to 192.168.11.81, UDP port 5001
Sending 1470 byte datagrams
UDP buffer size: 63.0 KByte (default)
------------------------------------------------------------
[  3] local 192.168.11.77 port 56500 connected with 192.168.11.81 port 5001
[ ID] Interval       Transfer     Bandwidth
[  3]  0.0-150.0 sec  1.38 GBytes  78.8 Mbits/sec
[  3] Sent 1005017 datagrams
[  3] Server Report:
[  3]  0.0-150.0 sec  1.38 GBytes  78.8 Mbits/sec   0.209 ms    0/1005016 (0%)
[  3]  0.0-150.0 sec  1 datagrams received out-of-order
```

Fig. 6. A screen shot example on the PC-CL after obtained the result sent by the PC-S.

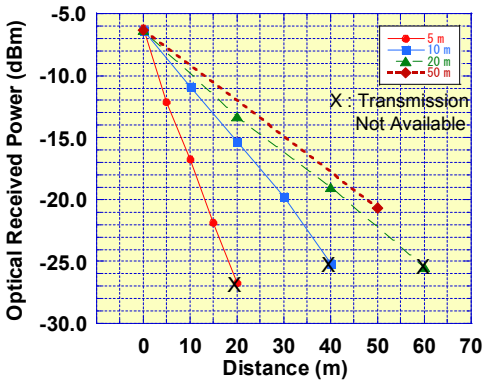


Fig. 7. Reachable distance with different fiber cord lengths and SC connector number. X denotes failure of ACK reception.

At 20 m, the two PCs could not communicate as the optical path loss with 5 optical connectors is excessive. The maximum distances are 30 m, 40 m and 50 m, if 10 m, 20m, and 50 m fiber cords are used, respectively.

The typical Japanese home has a maximum link distance, or cable length of around 35 m if the star type network is used [9]. Therefore, care is needed for installing fiber cables in homes/ small areas.

IV. Conclusions and Future Work

DIY optical connectors can be assembled by novices in for less than 10 min/piece with some experience. Fiber facet finishing with the hot plate yields somewhat smaller loss (about 3 dB connection loss) than with the hot knife. Reachable distance decreases with connector number so each link should use the fewest connectors possible. Future work includes assessing GI-POF use, and checking the feasibility of one-to-multiple configuration even in small networks.

References

[1] S. Terada, Y. Kakishima, D. Hanawa, and K. Oguchi, “Physical Configuration of the Next Generation Home Network”, IEICE Trans. Communications, vol. E91-B, no.7, pp.2169-2177, July 2008.

[2] A.M.J Koonen at el, “A Look into the Future of In-building Networks: Roadmapping the Fiber Invasion”, POF2011, Datacom & Nertworks-I, Sept., 2011.

[3] ITU-T Rec. G.9960 (06/2010), “Unified high-speed wire-line based home networking tranceivers – System architecture and physical layer specification”, June 2010.

[4] K. Oguchi, T. Sakai, and D. Hanawa, “WDM passive network design for small wavelength-count in local area/home applications”, Telecommunication Systems, vol.52, no.3, pp.1517-1523, March 2013.

[5] S. Shimazaki, R. Tsuchiya, K. Mochizuki, D. Hanawa, and K. Oguchi,”Multimode connector loss measurement considering DIY (Do It Yourself) installation”, POF2012, P15 Sept., 2012.

[6] Fiber Instruments Sales, http://www.fiberinstrumentsales.com/.

[7] iperf, http://iperf.fr/.

[8] Com Science, http://www.comscience.jp.

[9] K. Oguchi, T. Okodo, K. Tojo and K. Okada, “Physical network configuration of next generation home network”, OFCNFOEC2006, JThB95, March, 2006.