Fabrication and Characterization of Customer-Made 1x3 POF-Based Optical Coupler for Home Networking

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Summary
Polymer Optical Fiber (POF) can be and are being used in various field of application, especially for short haul communication application due to the high-speed data transmission, reach up to 100 meter distance data communication and of course have higher bandwidth. Hence, POF here can be seen as one of the best solution for home networking application. Customer-made multimode optical 1x3 fused-taper-twisted POF couplers have been fabricated by a perform technique. There several systems available on the market, which can be split or combine some optical signals to be transmitted into some different channels, which are all afflicted with certain disadvantages. But all these solutions have one main disadvantage; they are all too expensive for most of the applications mentioned above. So the goal of this study is to develop an economical coupler for home networking application over POF. Characterization of the coupler was reported. Red LED with a 650 nm wavelength has been injected into the coupler for the purpose of characterization testing to analyze the level of power efficiency of the coupler. Final analysis shows that efficiency of coupler output able to reach up to 30%. The device performance can be improved gradually through experience and practice. Main point here is the fabrication process is simple, easy and suitable to be used for household.

Key words:
Polymer Optical Fiber, Plastic Optical Fiber, POF, Home-networking, Optical coupler.

1. Introduction

In the past few years, number of applications based on optical fiber so rapidly developed as in the area of optical short-range communication. POFs have attracted much attention in past decades especially in home-network application because POFs have some unique characteristics, such as flexibility, easy to handle, relative low cost in coupling due to their large core diameter [2], heat-proof, immune for noise (external electromagnet disruption), suitable for data communication for long distance up to 100 meter, high speed data transmission (400 Mbps for SI's type and 1 Gbps for GI's type), wider broadband (exceed 4 GHz) and have losses below 25 db / km additional loss once it bent [3,4,6,8]. As a result, increased demands on the architecture of the data connections as well as the transmission media are being made [1,4,5,6].

Other fiber which common be used in home network application, such as glass optical fiber (GOF) was certainly no debate about the fact that the performance characteristics of GOF are far superior to those of POF, but glass tends to be expensive both to acquire and to install [3]. Therefore, POF tend to be able to compete with other transmission medium as one of a good solution due to the issues of fragility and cost [7]. Fig. 1 could explain one of home networking application which is based on POF technology.

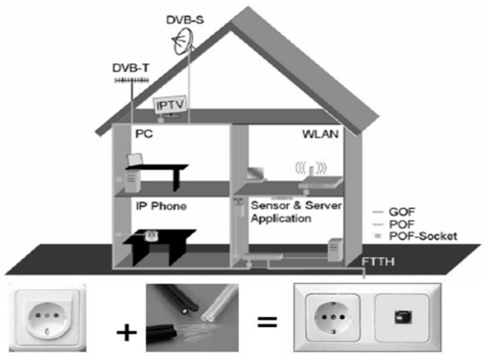

Fig. 1 POF increases the application for use in household, get rid of the bottleneck occurs between the Optical Network Unit and electronic appliances.

Study for characteristics of POFs tends to be one of the requirements to conduct in achieving desired design with some detail modification, and of course meets research's specification requirements. In this case, the proposed fabrication design of real fused-taper-twisted POF coupler is shown schematically in fig. 2.

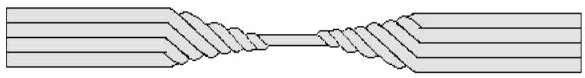

Fig. 2 Schematic of fused-taper-twisted POF-based coupler

For the purposes of practical use of short haul communication application, POF-based technology can be applied on it to connect some nodes. Fig. 3 can explain

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how to connect some users in short haul communication system through a residential gateway.

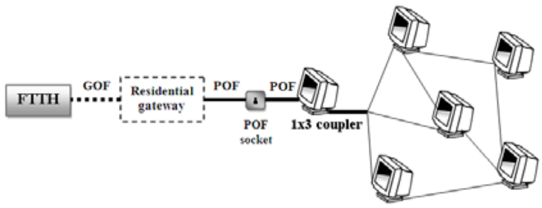


Fig. 3 1x3 POF-based coupler act as a coupler for computer users to connect all the nodes.

In this study, as a preliminary work on the investigation of prototype characterization, it also carried out to design of end part of fused-taper-twisted POF coupler. In prototype characterization, some experiments were conducted to determine optical output power, POFs attenuation characteristics and power losses on the network.

2. Experimental

POF-based coupler is an optical device which ended by N number POFs, while the other port ended by one port. Furthermore, they both work bidirectional. However, they can work from the 1 POF into N POF or vice versa, for home network application we need to apply coupler function which operated from 3 POF combined into 1 POF, based on the objective of the research to ensure N separate optical signals to be linked into one coupled signal by means of data, voice and video in the application of home-networking.

2.1 Material

POF-based couplers were fabricated with 3 ports using standard multimode poly-methylmetacrylate based step-index polymer optical fiber (PMMA SI-POF) with 1 mm of core diameter size.

2.2 Fabrication Method

By overall, prototype development gives a priority in fabrication method due to expectation to produce an optical coupler with the specifications which meet research’s requirement. Development process for the proposed technology can be seen in fig. 4.

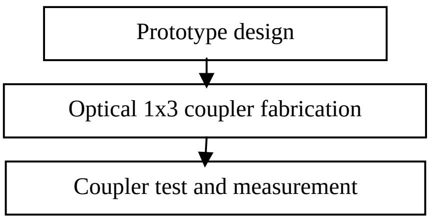


Fig. 4 Flowchart for prototype development process

2.3 Prototype Design

In this study, optical 1x3 coupler developed by the bundling three PMMA POFs. Other specification for the design is that coupler could reach data transmission distance up to 40 cm. therefore, a POF cables (11 to 13 cm length) is required to be linked with each end part of three couplers ports (as an output), also done the same thing to the input side of the coupler which contains 1 port bundle fiber (see fig. 5).

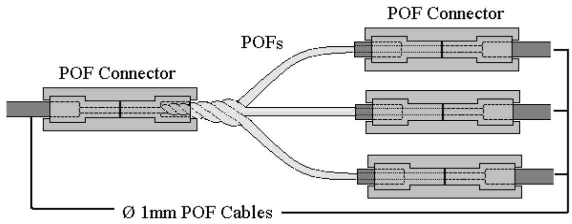


Fig. 5 Optical 1x3 coupler design for home networking.

2.3 Fabrication Method

In fabricating final product of optical 1x3 coupler, some stages has to be done, start from fiber fusion, bundle formation, pulling process and finalized with cable jointing. Fabricated through fusion method by fuses and combine 3 POFs (in bundle form) and fabricate it ends part in a shape of fused-taper-twisted fibers (diameter 1 mm). POFs will be twisted and pulled down while it is fused in a heat of flame. Fusion process was done indirectly, while POFs covered by metal tube. Thus, heat was provided for POFs well-distributed through the metal tube fusion (see Fig. 6).

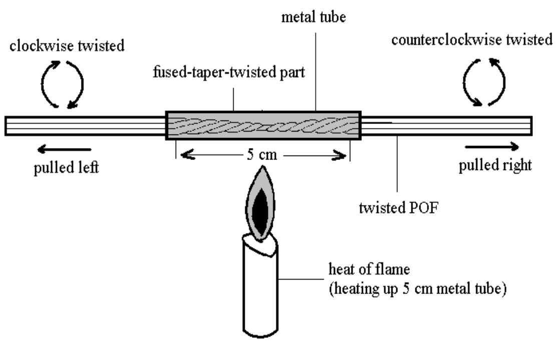
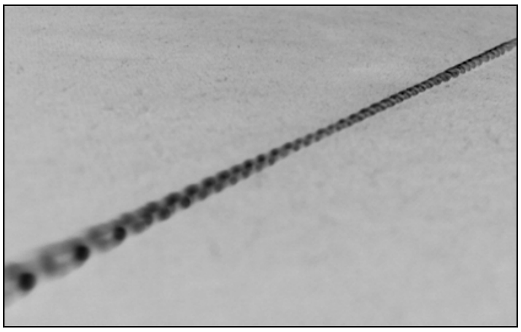


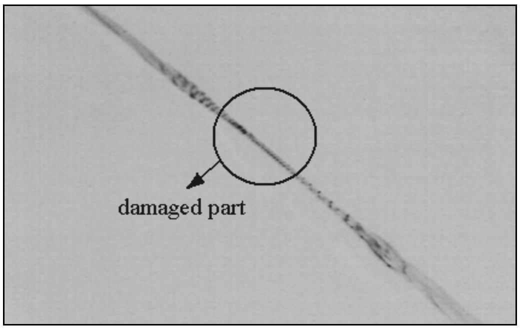
Fig. 6 Fabrication method for fused-taper-twisted POFs

However, some of the POFs trough a well-formed fabrication process, others come out with soma damaged part of body still can be found from the fabrication of it, e.g. deformed shape or damaged cladding. A sample can be called ideal once its diameter uniformly fused-taper-twisted approaching 1 mm.

To assure that samples failed to be used to the nest characterization testing process, these sample will be tested by red-LED injection. It is obtained that red-LED will not efficiently came out from the output port of deformed samples. Thus, the samples cannot be use in characterization testing (see fig. 7).



(a)



(b)

Fig. 7 Final product of (a) well-formed and (b) deformed fused-taper-twisted POFs

To connect bundle fiber with some users and to make sure it could be used in a further distance, it is suggested to use POFs cable (diameter 1 mm, same as bundle fiber core size) with a length around 11-13 cm. Connection between 1x3 couplers and POFs cable, jointed by POFs connector (1 mm core diameter with jacket). POF connector contains two difference socket side, the one with a wide socket pit while other have a narrower. The end part of 1x3 taper-twisted POFs inserted into the socket with a wider slot and glued properly, so that the connection will not be easy to be pulled out. While the other slot side of connector inserted by POFs cable (see fig. 8).

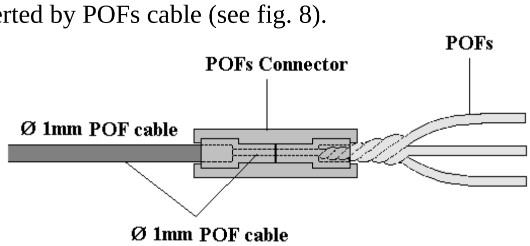


Fig. 8 Connection between optical 1x3 coupler with 1 mm POF cable

After successfully linked the optical 1x3 coupler for 1POF side, fabrication method continue by connecting the other 3POFs side with the same way described before (see fig. 9).

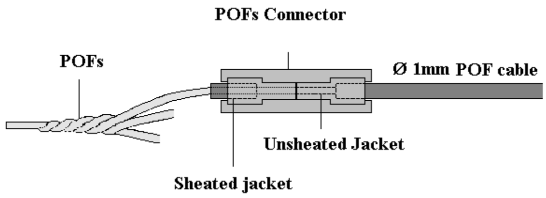


Fig. 9 Connection between 1x3 coupler with 1 mm POF cable.

2.1 Prototype Characterization

In this study, characterization procedure need to be carried out for each fabricated optical coupler. Each of developed coupler must be able to properly couple an optical signal to generate 3 separated signals efficiently, with low power loss.

Furthermore, three characterization stages have been conducted. First, from some fabricated samples obtained, the best three samples have been chosen to be utilized in the research. Second stage need to proceed is choose the best sample continue with measurement of both side of bundle fiber itself, include its power, lost and efficiencies. And the last stage, once the all three side of POF have been linked with Ø1mm POF cable by connecter, measurement could be carried out to the entire system come with the Ø1mm POF cables (see fig. 10).

Characterization process

↓

Characterization of POFs to chose the best sample

↓

Characterization of both end-side of 1x3 coupler without Ø1mm POF cable

↓

Characterization of final design of coupler terminated by Ø1mm POF cable for both 1x3 coupler side

Fig. 10 Characterization stages.

3. Results and Discussion

The analysis of the prototype characterization was carried out, especially for it efficiency percentage of each POFs for all three stages in characterization process. So, the comparison for the all efficiency of optical 1x3 coupler based on POFs has been observed, which the 1 end-POF act as an input and the other port which consist of 3 POFs stated as an output.

Some samples of POFs have been fabricated, red LED with 650 nm wavelength with 3μW input power, have been fully utilized to measure the efficiencies of all fabricated samples. Ten of the fabricated samples have been measured, it power output for each 3port bundle fiber (see fig. 11) and average efficiency of all bundle fiber (see fig. 12). It is clear that, the best 1x3 coupler sample obtained is sample B with high (average) efficiency, although the fact that power output not separated equally from all three POFs output port of sample B.

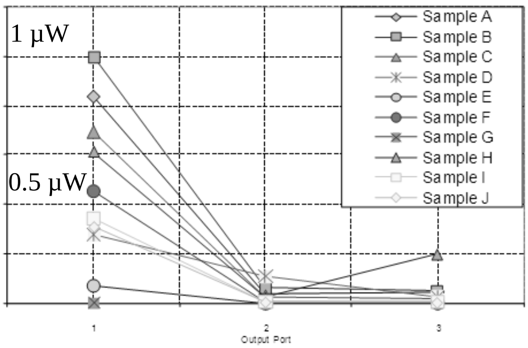


Fig. 11 Power output for all 3port of each bundle fiber

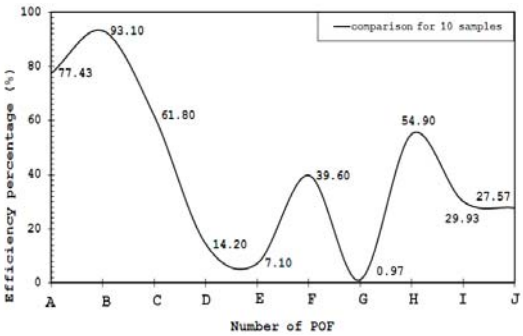


Fig. 12 Efficiency of average power output for all samples

From the observation above, the power efficiency of each output shows a different value. It is true; because error could be happen on it either while fabrication process or characterization test stages imposed on them. Irregularities of controlled heat while fusion process exposed on the POFs become one of the major problem, due to it lower melting point makes core structure of POF could be more sensitive on heating process. Once it is damaged, it is hard to let a light pass through the core, or even not pass at all.

After the best samples have been chosen, the measurement of end-to-end efficiency of sample B need to be conducted to choose the best side of the sample before it connected to Ø1mm POF cable using POF connector. The procedure for this characterization is red LED was injected into the all three input of the POFs and measure for the three output of the other side of POFs, and vice versa. In here, both sides of samples A, B and C have been observed to compare the two side of it (see fig. 13).

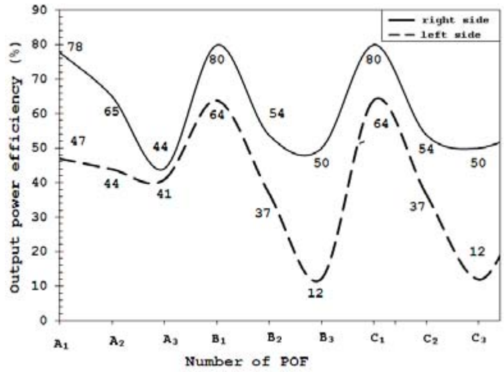


Fig. 13 Output power comparison for two different side of coupler

From the observation showed some imperfection of the shape of POFs if it is seen from the different side. The deviation power efficiency of the different side POFs measurement approximately reaches 30%. From this characterization, the right side of 3POFs have been chosen to be used on the next stage of couplers development, due to it high efficiency.

The research continue by connected the POFs with the Ø1mm POF cable from both input and output side of the coupler, than measurement also conducted for the purpose of analysis whether the POF connector gave some impact on power efficiency of the coupler while it transmits the power, and the result can be seen in fig. 14.

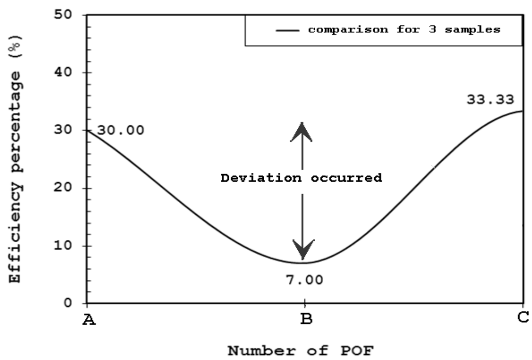


Fig. 14 Efficiency deviation occurred right after the POF connecter jointed with couplers and Ø1mm POF cables

From fig. 14 we can see the average of three output (sample A, B and C) nearly same, but once the POF connector linked with the jointing between POFs and Ø1mm POF it is clearly shown that the efficiency of sample B significantly drop to 7% of it efficiency, while for sample A and C have almost the same efficiency of output power. It is proofed that POF connector also plays a main role on the efficiency of the coupler.

The presence of surrounding light, could be one of the factor cause an error on optical power meter, although have a low intensity they gave a high sensitivity on it. Optical power meter able to reach nanowatt external power, hence, disruption from external source of light ensured to be avoided during the power measurement conducted.

4. Conclusions

In conclusion, a perform technique has been used to fabricate optical 1x3 coupler with based on POFs technology. Multimode SI-POF type with 1 mm core size fully utilized for the base material of the coupler. Some procedures, such as fabrication and characterization stages have been carried out to develop the coupler. Red LED with a 650 nm wavelength has been injected into the coupler for the purpose of characterization testing to analyze the level of power efficiency of the coupler. Final analysis shows that efficiency of coupler output able to reach up to 30%. The device performance can be improved gradually through experience and practice. Main point here is, the fabrication process is simple, easy and suitable to be used for household. The POF-based optical 1x3 coupler have been suggested to be applied in home networking to avoid the bottleneck occurs between ONU and electronic appliances, resulting increase the speed of data communication. Home network deals with transmission triple play signals by means of data, voice and video

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