A Novel Technique to Fabricate Low Loss POF Tapers

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A NOVEL TECHNIQUE TO FABRICATE LOW LOSS POF TAPERS

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ABSTRACT

A plastic optical fiber (POF) taper would effectively reduce the core area of the step index POF (SI-POF) to values for which the fiber-to-fiber insertion loss can be reduced without a significant increase of the attenuation in the own taper. In this work we present a low cost method to fabricate POF tapers with low attenuation values. The method basically consists on controlled heating while stretching the fiber. This process permits to reduce the core area to diameters down to 300 microns while achieving transition losses below 0.4 dB. The main application for this taper is the efficient coupling of SI-POF or other large area fiber devices to graded index POF (GI-POF).

INTRODUCTION

The emergence of graded index perfluorinated POFs (GI-POF) has given the plastic fiber technology a chance to compete with glass fibers in terms of attenuation and bandwidth [1,2]. One of the advantages of POF is the possibility of using low-cost system components but this advantage is lost for GI-POFs due to their small core diameter of these fibers (core diameters lesser than 200 microns). It makes them impractical in terms of low-cost plastic components, such as LEDs, connectors or couplers designed for large core fibers.

By using a taper, the usual SI-POF 1 mm diameter will be effectively reduced. Thus, the fiber-to-fiber insertion loss can be significantly diminished when coupling the SI-POF to a small diameter GI-POF. This device will be efficient if the taper attenuation is sufficiently small. In this paper we design a low-cost technique to fabricate this device.

POF has very low fusion temperature. This feature can be a disadvantage for some applications. However, we take advantage of it to fabricate tapers by controlled heating and stretching of the fiber.

The proposed technique is a low-cost method, as expensive infrastructures are not needed and the fabrication method can be easily automated. The results presented here are very promising and show the viability of the method.

Potential applications for these tapers are the low-loss SI-POF to GI-POF coupling, the optimal launch of optical power from light emitting diodes (LED) to small area optical fibers, the better coupling of conventional POF to small area detectors, the possibility of reusing low-cost large core designs such as large core based couplers[3] with small core fiber, and also the fabrication of evanescent wave optical sensors.

The organization of the paper is the following: A detailed description of the experimental set-up is given. Then, the fabrication process is thoroughly explained. The tapers characterization results are shown and finally, we present the main conclusions.

EXPERIMENTAL SET-UP

The fabrication set-up consists basically on two sub-systems: a controlled heating system, and a positioning-tensioning system. The former consists on a heater spiral resistance surrounding the fiber controlled by an adjustable current source. The later consists on two XY micropositioners with a holder post each one. Each end of the fiber is attached to each post. The own micropositioner springs are used to tighten the fiber. An additional spring, placed between both holder posts, reduces the tension and permits to regulate it. During the fabrication process, the induced losses are measured in real time using a LED source in conjunction with an optical power meter.

Figure 1 shows a sketch of the arrangement indicating its main components that will be described below. Figure 2 shows a picture of the real set-up used to fabricate the tapers.

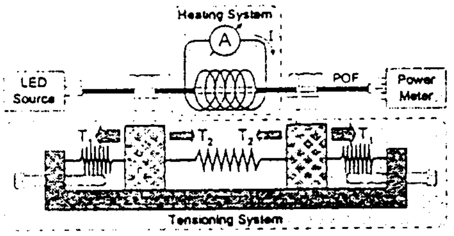

Figure 1. Sketch of the experimental set-up.

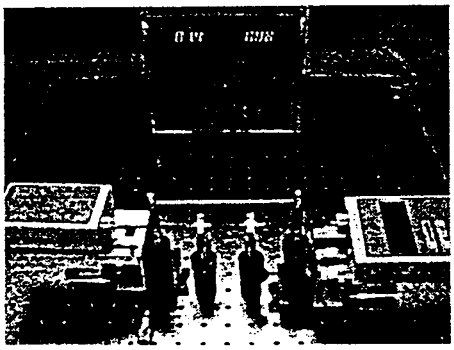

Figure 2. Experimental set-up.

Heating system

A spiral resistive coil forms the heating system. The length of the resistance is about 3 cm, its diameter is 0.6 cm and it has 20 turns. The distance between turns can be designed according to the desired heating profile. The resistance we used is adjusted to have the turns more concentrated at the center and progressively more spaced at both ends. In this way, the heat is reduced smoothly from the fiber center to its ends. A controlled current source is used to heat the wire. The temperature can be adjusted easily by changing this current.

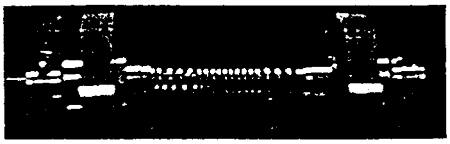

Figure 3. Detailed view of the heater resistance surrounding the fiber.

Figure 3 shows a zoomed view of the heater resistance surrounding the POF. The turn spacing variation can be clearly seen.

Positioning and tensioning system

The fiber is held between two posts fixed to two XY micropositioners. One axis of the positioner is used to center the fiber respect the heating resistance and the other is used to limit the final elongation of the fiber. The micropositioners are placed opposite each other so as their springs stretch out the fiber longitudinally. A third spring is mounted from post to post to reduce the tension applied by the other springs. This configuration permits to reduce progressively the tension applied to the fiber. In this way, when the fiber is more elongated and therefore more fragile, the applied tension is smaller.

Measure system

During the whole process the attenuation is measured by means of a 670 nm. LED source and a calibrated optical power meter. Both devices rest on the same positioners that hold the fiber. Therefore, they move as the fiber does and no additional tensions or curvatures are introduced.

The process can be finished depending on the final attenuation achieved and, most important, the current source can be controlled according to the attenuation progress.

FABRICATION PROCESS

In this section the fabrication process is described dividing it into its different stages. We explain the main details deduced empirically from the best results achieved.

Fiber preparation

We have used a conventional POF of 1 mm of diameter with PVC jacket provided by Hewlett Packard. We start from a fiber segment of 23 cm length. Initially 2 cm of the PVC jacket are stripped from the middle of the fiber segment. Both ends are inserted into two plastic connectors and their extremes are cut and polished as usual.

The fiber is introduced into fixing holes and into the heater resistance. Then the connectors are repositioned and the LED source and the optical power meter are connected. The optical power meter will indicate the quality of the fiber end preparation. In our case, the received optical power must be greater than –8.0 dBm. If the quality is not enough the process must be repeated.

Once the fiber is placed, it is fixed to the posts by two nuts that press the jacket of the fiber slightly. The fiber is fixed at the closer position of the holder posts and the micrometers screws reading zero. Then, the longitudinal micropositioner screws are turned out. Thus, the fiber is tautened and the fiber-posts arrangement is released and centered by two equal opposite tensions. The posts do not move and keep centered by the tensioned fiber. This is shown in Figure 1 where T1 and T2 indicate the spring tensions. Then, both micrometer screws are turned out until the final elongation desired.

Fiber heating

Initially a preheating current (750 mA) is applied and maintained during two minutes to warm up the fiber homogeneously. Then, the current is increased up (850 mA) to reach the fusion point of the fiber. Slowly the posts will move away up to the limit previously selected with the micrometer screws. The current is reduced progressively once the preset elongation is attained or a maximum attenuation is reached. Once the fiber is cold, the nuts are released to extract the fiber carefully.

Characterization

The final attenuation obtained relative to the initial value is registered and the final diameter achieved is measured at the middle of the taper. Taper width has been measured using an Olimpus microscope SZ-CTV coupled with a CCD camera (Electrim). First, the taper was centered manually using a XY micropositioner. Then, the image of the taper was registered and processed. After filtering and edge detection its narrower width is obtained automatically. Figure 4 shows the acquired taper image before and after the processing.

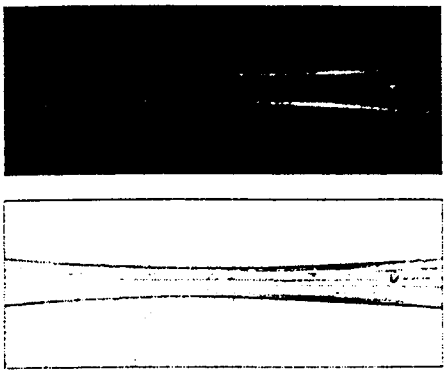

Figure 4. Taper image registered with an Olimpus microscope and a CCD camera. The image above is shown before processing. Below, the image is shown after filtering and edge detection.

Taper termination

Finally, the taper is cut near to its narrower diameter. A good cutting method could obtain two usable half tapers simultaneously. However, obtaining systematically clean cuts is not a trivial task. For this reason, only one usable half taper is obtained as a conservative distance from the optimum cut point is kept. Afterwards, the taper end is polished to remove the excess material.

RESULTS

Several trials have been made to estimate the best values for each procedure variable. The optimum current to heat the resistance, the best distribution of the resistance turns and the tension applied to the fiber during the elongation process were fixed in this way.

To verify the viability and reproducibility of the technique described in this paper, eight tapers were manufactured following a batch process.

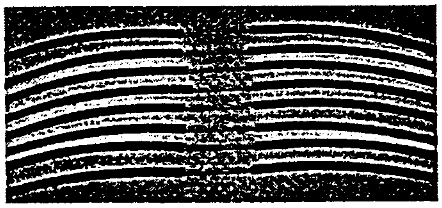

Figure 5. Set of manufactured tapers following a batch process.

Table 1. Diameters and losses of the taper set.

Taper	*Diameter (μm)*	*Losses (dB)*
1	350	0.40
2	273	0.42
3	342	0.45
4	385	0.21
5	350	0.34
6	376	0.29
7	299	0.36
8	325	0.35
Mean	**337.5**	**0.353**
Std	**37.5**	**0.076**

Figure 5 shows the manufactured tapers. Table 1 shows the diameters and induced losses achieved and their mean and standard deviation.

This taper set exhibit very low losses (a mean of 0.35 dB) in conjunction with a notably reduced diameter (a mean of 337 μm). Reproducibility of the diameters size (σ = 37.5 μm) would be increased if a more automated processing were used.

Some tapers with lower diameters have been made but for diameters below of 300 μm, the losses increase quickly without an appreciable diameter reduction counterpart. In the future, we hope to obtain even smaller diameters without increasing the losses significantly.

APLICATIONS

The manufactured tapers have been tested in several readily applications. We have coupled directly a standard 1 mm diameter SI-POF to a 200 μm GI-POF being the relative improvement using the taper about 5 dB. Also, the light injection of a LED source is improved in 2 dB using the taper respect to inject the light directly into the GI-POF. However these results are preliminary, having into account that the process of taper finishing is not yet well achieved. Actually, we are designing special ferrules for the tapers to improve the final centering and the polishing of the narrow end of the tapers.

Also, we are investigating the use of the taper as refractive index sensor and as integrated mode scrambler for conventional 1mm POF.

CONCLUSION

We have presented a low-cost promising fabrication method of POF tapers. The proposed technique permits to obtain a diameter reduction down to 300 μm starting from a conventional 1 mm SI-POF with losses lower than 0.5 dB. This kind of device will allow using the new arriving small diameter GI-POFs while maintaining the easier connectivity of the conventional ones.

ACKNOWLEDGEMENTS

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