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Demountable connection for polymer optical fiber grating sensors

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Abstract. The authors fabricated a demountable Ferrule connector/Physical contact connection between silica fiber and a polymer optical fiber (POF) containing a fiber Bragg grating. The use of a connector for POF grating sensors eliminates the limitations of ultraviolet glued connections and increases the ease with which the devices can be applied to real-world measurement tasks. *© 2012 Society of Photo-Optical Instrumentation Engineers (SPIE).* [DOI: 10.1117/1.OE.51.8.080503]

Subject terms: polymer optical fiber; microstructured polymer optical fiber; poly(methyl methacrylate); fiber Bragg grating; polymer connector.

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1 Introduction

Research activity on fiber Bragg grating (FBG) sensors has mainly been focused on silica fiber. However, this established technology is now being transferred to polymer optical fiber (POF), taking advantage of the different material properties of polymer. Most POFs are based on poly(methyl methacrylate) (PMMA), which has a number of potential advantages over its silica counterpart. Polymers are flexible, nonbrittle, and clinically accepted.[1] Polymer has a Young modulus that is 25 times less than that of silica,[2,3] enabling the demonstration of grating tuning by recoverable strains of up to 13%.[4] Multimode POF Bragg gratings (POFBG) have the potential to offer low-cost sensing, since they are compatible with cheaper broad-area emitters and the task of connecting fibers together is simplified.

This latter point has been a significant issue for POFBG. The lack of single-mode POF components means that connection to silica fiber is necessary to interrogate the POFBG. Initially this was done simply by using butt coupling on the optical table, which was fine for basic grating characterization work but did not permit applications research. A significant breakthrough was the development of a permanent glued connection, enabling POFBG to be used away from the optical bench.[5] However, such connections are not particularly robust and of course are not demountable.

We report for the first time the fabrication of a demountable connection between silica fiber and a POFBG. This has been facilitated by the use of a 50-micron-core microstructured POF (mPOF), supporting around 60 modes. The few-moded nature of the fiber results in a sufficiently narrow Bragg response to be utilized in sensing applications, yet the large core size provides tolerance to core misalignment.[6]

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2 Experiments

As described below, a Bragg grating was inscribed in PMMA-based multimode mPOF fiber (Kiriama Pty Ltd.) with an outer diameter of 150 μm and a core diameter of 50 μm. The core is bounded by three rings of holes as shown in Fig. 1. Details of the production process of the mPOF are described by Barton et al.[1] The low average refractive index of the ring of holes effectively provides index guiding in the solid core of the fiber.

A helium-cadmium laser with a wavelength of 325 nm and an ultraviolet (UV) power output of 30 mW was used to inscribe the Bragg grating in the POF. The laser beam was focused vertically downward using a 10-cm focal length cylindrical lens, through a 1034-nm period phase mask and on to the fiber.[6] The multimode POF was laid on a v-groove and taped down using polyimide tape. This type of fiber has a typical inscription time of 40 to 60 min. The Bragg wavelength of the inscribed grating was in the region of 1530 nm with a length of 2 mm, determined by the width of the UV laser beam, and a FWHM bandwidth of 2 nm.

The inscription process was monitored using a 1550-nm Corning multimode 50/125 μm silica fiber (50:50) coupler, a broadband light source (Thorlabs ASE-FL7002-C4), and a Hewlett Packard 70004A optical spectrum analyzer (OSA). For the inscription, a temporary connection was made using a Ferrule connector/Angled Physical contact (FC/APC) connector on the 50/125 μm silica fiber which was then butt coupled to the bare POF using an x-y-z translation stage. A small amount of index matching gel was used in the coupling to reduce Fresnel reflections.

2.1 *Fiber Etching*

Chemical solvents such as acetone can be used to dissolve PMMA. This serves as an easy and efficient way to reduce the diameter of POF to a desired value.[7] Acetone etching was applied to one end of the 150-μm-diameter multimode mPOF for 3 min to reduce its size and enable it to fit into the 140-μm ceramic ferrule connector. The final diameter of the end of the mPOF after etching was 120 μm. The etched part of the fiber was inserted into the ferrule of a FC/PC connector and pulled out gently from the other side until it jammed in the ferrule connector. Norland 76 UV curing adhesive was applied on the fiber, and the fiber was pulled back and forth so that the glue got into the ferrule [Fig. 2(a)].

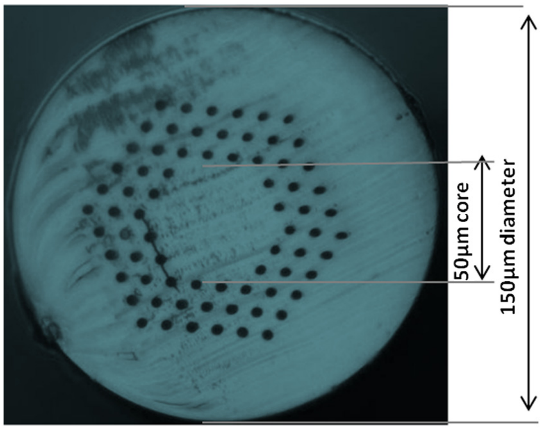

Fig. 1 Microscope image of end face of multimode mPOF.

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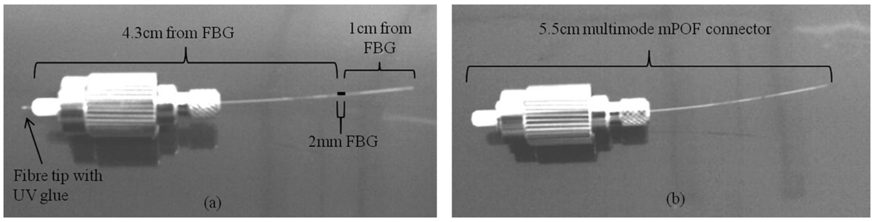

Fig. 2 mPOF in ferrule before and after cleaving.

The protruding end of the fiber was cleaved using a hot (80°C) blade and is shown in Fig. 2(b). The cleaved end was then UV glued with the UV curing lamp for 10 min. The curing lamp had a 2% iris coverage which provided an optical output power of 60 mW. The lamp was positioned 2 cm away from the polished face of the ferrule connector at an approximate angle of 45 deg for effective curing.

2.2 *Polishing mPOF Connector*

Two polishing cycles were carried out on the UV glued end of the ferrule connector using four different aluminium oxide polishing papers of 5, 3, 1, and 0.3 μm in that order. The polishing papers were placed one after the other on a rubber polishing pad (Thorlabs NRS913) which was placed on a glass polishing plate. The glued face of the multimode mPOF ferrule connector was inserted into a polishing disc (Thorlabs D50-FC) and polished slowly in a figure-eight pattern[8] to reduce the heat generated which could melt the polymer fiber [Fig. 3(a)]. The glass plate served as a flat and stable surface for easy polishing, the rubber polishing pad helped to protect the polymer fiber from breaking due to the hardness of the glass plate, and the polishing disc helped to keep the tip of the ferrule normal to the paper while polishing. The glass plate and polishing disc were cleaned between polishing steps with lab tissues soaked in isopropyl alcohol to remove any particle that could damage the face of the fiber. During the two polishing cycles, the face of the connector was inspected repeatedly using a hand-held microscope (Priorspec II). The polished face of the mPOF connector was captured using a Zeiss Axioskop 2 microscope as shown in Fig. 3(b).

After polishing, the multimode mPOF connector with FBG inscribed in it was connected via a bulkhead connector to a 50-micron-core, multimode, step index 1550-nm 50:50 silica coupler. A broadband ASE light source (Thorlabs ASE-FL7002-C4) and an OSA (Hewlett Packard 70004A) were connected to the other two ends of the silica coupler. The reflection of the grating was captured on the OSA as shown in Fig. 4. The mPOF connector was 5.5 cm in length, and the FBG was 4.3 cm away from the polished end. By way of a comparison, Fig. 4 also shows the grating response obtained by interrogating the cleaved distal end of the fiber which was 1 cm away from the FBG, using the butt coupling technique and the same setup described above. In this case, the reflected signal was 5 dB less strong than from the demountable connector.

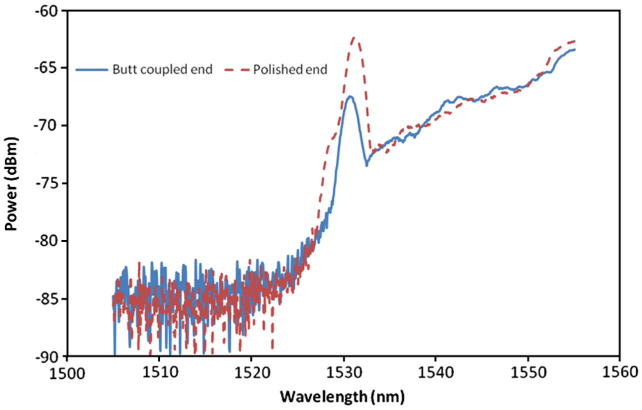

Fig. 4 Reflection spectra of the FBG from the polished (connectorized) and butt coupled ends of the fiber.

3 Discussion and Conclusion

Although the holes in Fig. 3 after the polishing were not as clear as those in Fig. 1, due to the accumulation of polishing debris in the holes, and despite the mPOF not being perfectly

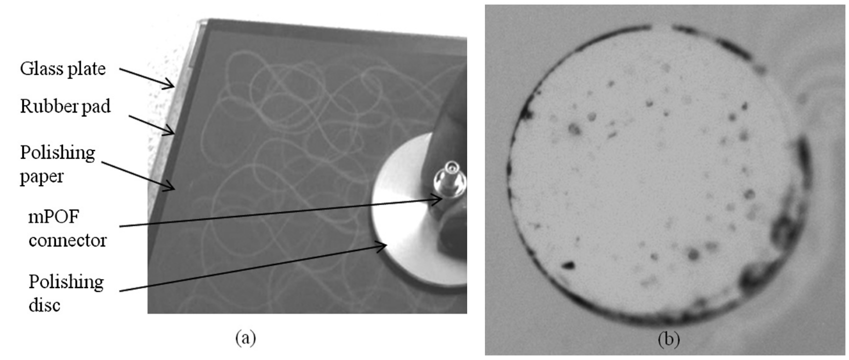

Fig. 3 Fiber polishing process and mPOF in ferrule connector after polishing.

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centered in the ferrule (Fig. 3), the FBG as observed from the connector was 5 dB stronger than that observed with optimized butt coupling, despite the connector being further from the grating than the distal end. We consider this to be a significant improvement in connection capability, based on the known fiber attenuation of around 1 dB/cm in the 1550-nm wavelength range associated with polymer fiber. This attenuation should have made the reflection from the polished end around 6 dB less strong than from the distal end, given equivalent coupling strengths. The result obtained in this work has therefore shown that connectorization of the multimode mPOF FBG gives a stable and much stronger reflection of the FBG than the butt coupling technique.

In summary, we have demonstrated in this work that multimode mPOF can be connectorized, eliminating the limitations of UV glued connections and increasing the ease with which the devices can be applied in real-world sensing tasks.

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