

PLASTIC PLANAR-INTEGRATED FREE-SPACE OPTICAL INTERCONNECTOR

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Abstract: A plastic planar-integrated free-space optical interconnector is demonstrated by a set of imaging and off-axis lenses on a poly(methylmethacrylate) substrate. The interconnector is designed for the standard MT-connector and exhibits an average out-coupling efficiency of -4.4 dB experimentally, while the crosstalk suppression is measured as more than 38dB.

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1. Introduction

Plastic optics draws tremendous attention recently due to its good optical performance, light weight and flexible formation. Especially, its fabrication can be processed by the molding technique, which benefits the mass production much when compared to the conventional fabrication of glass or quartz optics. On the other hand, the planar-integrated free-space optics (PIFSO), or so called the planar optics, has been researched during the past two decades for various applications [1-2]. Since a PIFS system integrates all free-space optical components on the surfaces of substrate, the required longitudinal dimension of an optical system can be reduced sufficiently. Along with the compatible MEMS technique, the PIFS system can have further miniature and, thus, exhibits the superiority of compactness. Although the PIFS system has the potential to be a compact optical platform, the process of profiling optical elements is traditionally carried out by reactive ion etching (RIE) on quartz or glass substrate for every sample, which leads to considerable fabrication expenses and inefficient fabrication time. To make an economic fabrication of PIFS system, a plastic PIFS system is proposed and demonstrated as an optical interconnector in this article.

2. Design of plastic PIFS interconnector

The plastic PIFS interconnector is designed to adapt to a standard MT-type connector with 12 input channels. The proposed interconnector consists of a bottom mirror, a transmissive off-axis lens for the in-/ out-coupling, and a reflective imaging lens for directing each input signal toward the corresponding output channel, as shown in Fig. 1.

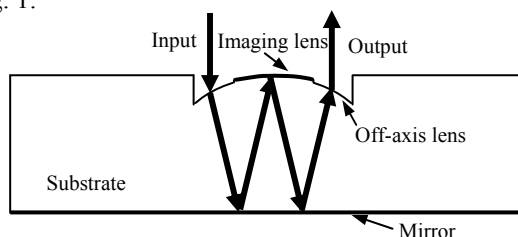


Fig. 1 Schematic of plastic PIFS interconnector

The material of the plastic substrate is designated as poly(methylmethacrylate) (PMMA) with the refractive index of 1.485 and the thickness of 9 mm. The MT-connector is utilized to emanate the input and to receive the output lights at the same plane. To fit the dimensions of MT-connector, the diameters of imaging and off-axis lenses are set as 2 mm and 5.5 mm, respectively. By using optical simulation tools, ZEMAX and ASAP, the curvature radii of these two lenses are optimized as 19.24 mm and 5.88 mm, respectively. The ray-tracing results reveal that the input light can be well imaged to the output channel, as shown in Fig. 2.

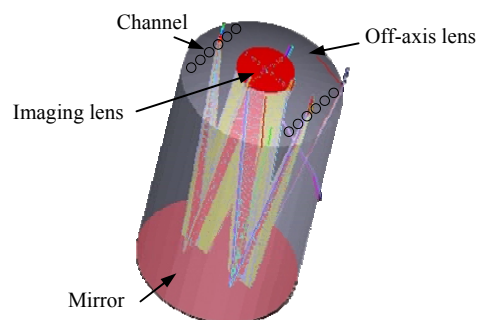


Fig. 2 Ray-tracing plot

3. Fabrication

The fabrication processes of plastic PIFS interconnector include two parts: surface profiling and metal coating. The method exploited herein to carve the plastic is the diamond turning technique. Since the proposed design has two adjacent lenses with different curvature radii, the fabrication of such a non-continuous boundary requires more tolerance, 200 μm wide in our design, while the tolerances for the rest dimensions are 20 μm . The diagnosis of the profiled sample reveals that the average roughness and the profile accuracies of the imaging and the off-axis lenses are 11.5 nm, 213.3 nm and 445.6 nm, respectively.

Finally, the profiled sample is treated with gold sputtering to form the bottom mirror and the reflective imaging lens. By atomic force microscope (AFM), the resultant coating thickness is measured as 430 nm.

4. Experimental results

The characteristics of the plastic PIFSO interconnector are then tested in a laboratory setup, as shown in Fig. 3. The setup consists of a gimbal mount that allows a 6-axis configuration of the interconnector relatively to a metal interface plate where MT-housed fiber-bundles can be inserted. Meanwhile, a light source at a wavelength of $0.85\ \mu\text{m}$ with a fiber pigtail is used in the experiment.

For pre-alignment, the light is coupled into the plastic PIFSO interconnector via an MT-connector with single-mode fibers. During an iterative process, the module is actively adjusted towards the metal interface plate so that the image plane destination and connector plane are identical. The photographs are taken by using a CCD camera, as shown in Fig. 4. The left and right part of this figure represent the out-coupling sections (parts of the metal interface plate) with two active channels, Ch1/12 and Ch6/7, respectively. Expectedly, the outer channels are more distorted than the inner ones.

In the measurement, the destination fiber-connector is inserted and fine adjusted by observing the output power with an optical powermeter. Then, each of the 12 input channels is separately activated, and the absolute power on each output channel is measured. Due to the fiber connection, the repeatability is around 0.5 dB and can also be seen as the accuracy of the measurement. The out-coupling efficiency of each channel of the plastic PIFSO interconnector is then calculated, as shown in Fig. 5. Meanwhile, the crosstalk suppression of the adjacent channel is measured to be larger than 38 dB. From the experimental results, the interconnector exhibits an average out-coupling efficiency of -4.4 dB, which is superior to previous results [3].

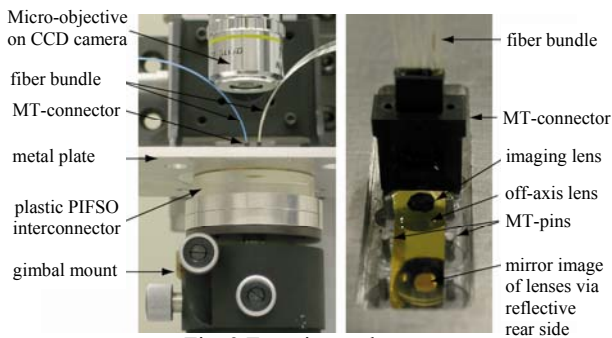


Fig. 3 Experimental setup

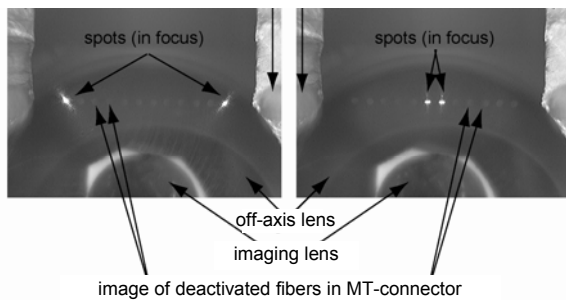


Fig. 4 Photographs of active channels

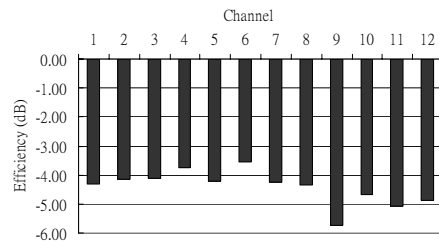


Fig. 5 Experimental out-coupling efficiency

5. Conclusions

In this paper, a plastic planar-integrated free-space optical (PIFSO) system has been proposed to possess merits of both plastic optics and PIFSO systems. We designed a refractive/refractive plastic PIFSO interconnector for a standard MT-connector as a demonstration. The plastic PIFSO interconnector, consisting of a set of imaging and off-axis lenses, has been fabricated by using the diamond turning and the sputtering techniques. According to the experimental results, the designed interconnector exhibits a crosstalk suppression of more than 38dB and an averaged efficiency of -4.4 dB, which is superior to the previous reports [3].

Although the demonstrated sample herein is a refractive system, people can also realize a diffractive type of plastic PIFSO system by either the same technique of diamond turning or the VLSI technique to profile the sample, and by either sputtering or evaporative deposition to fabricate the reflective parts.

By combining with the molding technique, the plastic PIFSO systems can be even replicated massively. Moreover, the interconnector is not the only application of PIFSO system. Since the plastic PIFSO system inherits the superiorities of plastic optics and PIFSO system, such as light weight, low cost, efficient fabrication, and thin volume, its applications to optical sensing, communication, information processing and even light-guiding in display shall be expected in the near future.

6. Acknowledgement

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7. References

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