

# Development of “LFI” (Lead-Frame-Inserted Type) Ferrule for Optoelectronic Interconnection Modules

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With the rapid development of today’s digitally-networked information society, information electronic equipment is increasingly required to process large-volume information at high speed. Recently, the optical interconnection technology is getting a lot of attention as a mean to achieve high-speed transmission. The authors have developed a new type of optoelectronic ferrule called the “LFI” (or Lead Frame Inserted) ferrule for application to optical interconnection modules. The LFI ferrule is fabricated by integrally molding a minute lead frame with the electrode at the end face of a plastic multi-fiber ferrule. After the optical fiber hole position accuracy and electrode position accuracy were checked, it was confirmed that the LFI ferrule is on a practical level without problems. The use of the LFI ferrule allows the parts count to be reduced and eliminates the need for precise core alignment, thus making it possible to manufacture photoelectrical conversion modules at lower costs.

## 1. Introduction

With the rapid expansion of the digitally-networked information society, needs for viewing high-resolution videos on personal digital electronics such as PCs, TVs, cell phones, and home video game console are growing. As a result, there has been increasing demands for devices that can process large amounts of information at higher speeds. However, in the case of electrical wiring based on conventional FR4 printed wiring boards, data transfer rates are approaching their limits, and further improvement of system performance has become difficult.

A means of overcoming this problem is the use of optical interconnection. Optical interconnection is a technology for providing high-speed transmission of large amounts of data by converting electrical signals to optical signals and taking advantage of the broadband properties of optical fibers and optical waveguides. The development of optical interconnections has intensified, as they are the only possible solution to not only the problem of signal delay in electric transmission lines, but also other problems like increases in electromagnetic interference, heat generation, and power consumption as the results of higher transmission speeds.

Yet incorporating optical interconnections into personal digital electronics requires making the photoelectric conversion modules lower in cost and smaller in size. For the application to the next generation of optical interconnection modules, the authors developed a new optoelectrical ferrule (an optical fiber positioning part) and named it the “LFI” (stands for Lead Frame Inserted) ferrule. The LFI ferrule is fabricated by integrally molding a microscopic leadframe onto the connection end-face of a conventional multifiber plastic optical ferrule to form an electrode <sup>(1)</sup>, <sup>(2)</sup>. An optical subassembly is completed simply by positioning and mounting an optical transceiver such as a vertical cavity surface emitting laser (VCSEL) or photodiode (PD) directly onto the end-face of this ferrule and inserting

optical fibers into the ferrule. This enables great cost reductions over the conventional optical interconnection modules. This paper reports on the evaluation results of the advantages, design, fabrication process, and molded part dimensions of the modules that use the LFI ferrule.

## 2. Advantages of optical modules using LFI ferrule

The LFI ferrule is a multifiber plastic optical ferrule that has a leadframe electrode integrally molded onto its end face (the surface with holes into which optical fibers are to be inserted). **Figure 1** shows an external view of the LFI ferrule.

Twelve fiber insertion holes, 0.125 mm-diameter each, were formed at a 0.25 mm pitch. At each fiber insertion hole, two electrodes for the optical transceiver are placed. The electrodes are each 0.05 mm in width and arranged at a 0.125 mm pitch. The surface continuing from the ferrule end face has the cut surface of the integrally-molded leadframe exposed on it to be used as

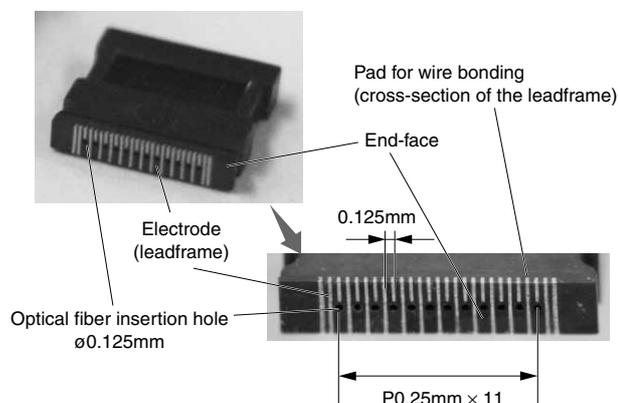


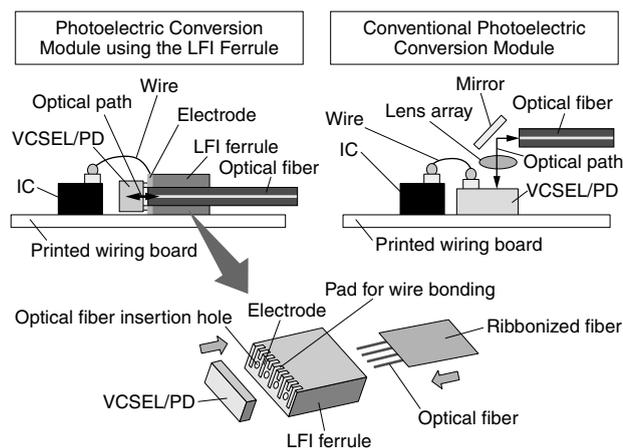
Fig. 1. Structure of LFI ferrule

a wire bonding pad to guide signals from the IC. The surface and cut surface of leadframe at the end-face are plated with nickel and gold.

**Figure 2** provides the schematic illustrations of a photoelectric conversion module using the LFI ferrule and a typical conventional photoelectric conversion module.

In the case of conventional photoelectric conversion modules, a VCSEL/PD is mounted on the printed wiring board. Because the optical path is perpendicular to the wiring board, a mirror is needed to couple the light with the optical fiber that is wired parallel to the board. Also, because the optical fiber cannot be located adjacent to and coupled directly to the VCSEL/PD, a lens array is used to efficiently couple the light from the VCSEL/PD to the fiber. This requires the alignment of three components (the optical transceiver, the lens array, and the optical fiber). Because the conventional structure of this kind requires many components that must be aligned optically with high accuracy, the costs had been high.

By contrast, in the configuration with the LFI module, highly efficient optical coupling of the photoelectric conversion module is achieved simply by positioning and mounting the light receiving/emitting part of the VCSEL/PD to the ferrule's optical fiber insertion holes



**Fig. 2.** Comparison between conventional photoelectric conversion module structure and structure using LFI ferrule

**Table 1.** Comparison between conventional photoelectric conversion module structure and structure using LFI ferrule

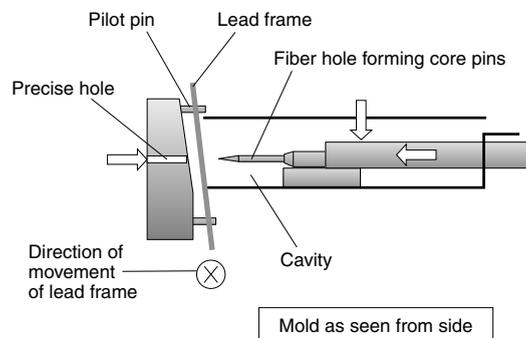
	LFI ferrule	Conventional ferrule
Number of components	Small	Large (lens array and mirror)
Optical alignments	None	2 (between VCSEL and lens array, and between lens array and optical fiber)
Coupling efficiency	High (aligned by the ferrule)	Low (requires high-precision alignment)
Size	Compact	Bulky
Cost	Low	High

using the flip chip (FC) bonding technology, and inserting optical fibers into the optical fiber insertion holes from the opposite side of the ferrule. This structure needs fewer number of parts, requires no precise fiber alignment, and reduces costs. **Table 1** shows a comparison between the conventional photoelectric conversion module structure and the one using the LFI ferrule.

### 3. Fabrication of LFI ferrule

The LFI ferrule is made using the hoop molding method. In the hoop molding method, a hoop material (leadframe) having a lead pattern formed on it in advance is wound on a reel, and then fed into a mold where the plastic molding compound is formed on it. After the formation, the hoop material is moved by a predetermined amount so that continuous molding can be executed. **Figure 3** shows an overview of the fabrication process of the LFI ferrule.

When the hoop material is positioned in the mold, a resin is injected into the mold and left for a predetermined period of time until it solidifies. Then both the leadframe and the ferrule are ejected from the mold. For molding the LFI ferrule, a high filling grade resin for plastic multifiber connectors is used. After the molding process is finished, the excess leadframe is removed from the surface of the ferrule. The LFI ferrule is completed with electroless plating of nickel and gold to the surface and cut surface of the leadframe.



**Fig. 3.** Mold for manufacturing LFI ferrule

### 4. Characteristics of LFI ferrule

In the LFI ferrule, in order to ensure high-efficiency optical coupling between the VCSEL/PD and the optical fiber, it is important that the optical fiber insertion holes be precise. **Figure 4** shows the histogram of the positional accuracy of the optical fiber insertion holes. The positional accuracy of each optical fiber insertion hole is defined as the two-dimensional distance offset from the designed hole position to actual hole position in a coordinate system with the origin at

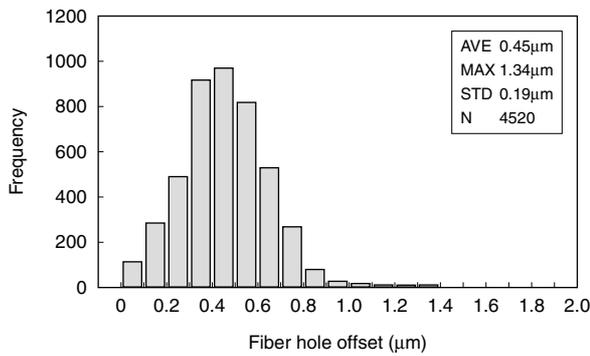


Fig. 4. Positional accuracy of optical fiber insertion holes

the center of the both ends of each optical fiber hole. The positional accuracy of fiber insertion holes is 1.4 μm or less, which is less than 3% of 50 μm, the core diameter of graded index (GI) fiber commonly used in optical interconnections. Because of the good positional accuracy of the fiber insertion holes, high-efficiency

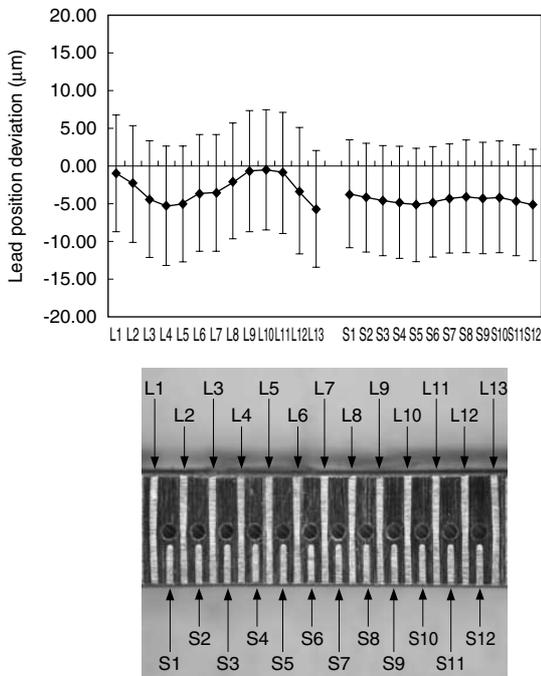


Fig. 5. Positional accuracy of lead frame

optical coupling is expected of the LFI ferrule.

Next, the positional accuracy of the insert-molded electrodes (leadframe) is discussed. Since these insert-molded electrodes are used as the mounting terminals on the ferrule side, it is important to align them with the connection terminal on the VCSEL/PD side. **Figure 5** shows the positional accuracy of the leadframe. **Figure 5** plots the average value and average  $\pm 3\sigma$  value of the deviation in the position of the lead of each electrode taken from  $N = 452$  ferrules. The lead position deviation shown in **Fig. 5** is the distance from the designed position to the actual position of each lead in a coordinate system with the origin at the center of the both ends of the optical fiber insertion hole.

The amount of deviation in the leads including variations is within 15 μm, and should pose no problem for mounting.

## 5. Conclusions

The authors developed an optoelectrical ferrule named the “LFI” ferrule for use in next-generation optical interconnection modules. This new ferrule is fabricated with the hoop molding method that is suitable for mass production, and can be manufactured at low cost. Furthermore, photoelectric conversion modules that use this ferrule have lower parts counts, require no high-precision alignment of fibers, and can be manufactured at lower costs. This paper reports that the LFI ferrule is confirmed to have the optical fiber insertion hole position accuracy and electrode position accuracy that are sufficient for practical application. The authors are currently in the process of making prototype photoelectric conversion modules using the LFI ferrule in order to evaluate in the future the initial characteristics and reliability of the ferrule incorporated into modules.

## References

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