An MT-Style Optical Package for VCSEL and PIN Arrays

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Abstract

A compact optical package for mounting a VCSEL or PIN array has been developed. Each package couples an array to a fiber ribbon terminated with a commercial MT ferrule. The package is fabricated with beryllium oxide (BeO), allowing efficient removal of the heat produced by the array. The package is quite compact as it is significantly smaller than an MT ferrule. The design simplifies testing and assembly of an optical link system because each fiber ribbon can be readily connected/disconnected while preserving good light coupling efficiency.

Key words: optical package, MT ferrule
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1 Introduction

Optical links are now commonly deployed in high energy and nuclear physics experiments to transmit data. The optical fibers used are more compact than traditional copper wires, allowing the construction of more hermetic detector. The fibers also allow the transmission of high speed signals over long distances with small degradation. In addition, the fibers eliminate electromagnetic interference and ground loops.

The optical links typical use Vertical Cavity Surface Emitting Laser (VCSEL) for transmitting the optical signal and PIN diode to convert the optical signal into an electrical current for further processing. The commercial packages for housing the VCSEL and PIN are quite bulky. Space constraints in high energy and nuclear physics detectors necessitate the need to custom design the optical packages. The use of a custom compact optical package is particularly important for a vertex detector located in close proximity to the interaction region. In addition, the use of VCSEL and PIN arrays instead of single channel devices could further reduce the space requirement and simplify the construction. In this paper, we present a compact optical package for housing VCSEL and PIN arrays. Each array couples to a fiber ribbon terminated with a commercial MT ferrule. The package is fabricated with beryllium oxide (BeO), allowing efficient removal of the heat produced by the array. The design simplifies testing and assembly of the optical link system because each fiber ribbon terminated with a MT ferrule can be readily connected/disconnected while preserving good light coupling efficiency. In the next section, we present the design of the package. This is followed by a section on the array alignment, prototype results and then a summary.

2 Optical Package Design

The design of the optical package is shown in Fig. 1. The base [1] is fabricated using BeO. With BeO as the substrate, heat produced by a VCSEL array, the major source of heat in an optical link, is efficiently removed. The base can also be fabricated using alumina for cost saving, however, the thermal conductivity of the alumina is somewhat lower. Each channel of a VCSEL or PIN array is connected via a wire bond to a trace on the optical package. The trace then bends over the package edge and connects via another wire bond to a channel on a driver or receiver chip placed in close proximity. Each trace is 125 μm wide and the separation between traces is 250 μm, the standard spacing between two channels in an array. The traces can be rewire-bonded for diagnostics and rerouting purposes as sometimes needed, especially during the R&D phase of a project.

There is no solid cathode (or anode) plane under the array. This is to avoid a problem encountered with the packages used [2] in the on-detector optical links of the pixel detector of the ATLAS experiment. It was discovered that the conductive epoxy layer between the array and the metallic plane could become too thin when an array was pushed toward the metallic plane during the array placement. We therefore use a group of parallel connected traces. The space between the traces will be filled with epoxy when an array is pushed against the base, thus ensuring an ample ammount of epoxy for connecting the traces to the back side of the array. The two clusters of parallel traces are not connected to ease the fabrication of the mask for the trace deposition. The gap between the two clusters will be filled with conductive epoxy when an array is pushed against the base, producing a continuous cathode (or anode) plane.

The layout of the traces on the optical package are designed to be compatible with several kinds of PIN or VCSEL arrays being evaluated for possible use at the SLHC, an upgrade of the Large Hadron Collider (LHC) at CERN with ten times higher luminosity. In particular, the PIN array by Optowell does not

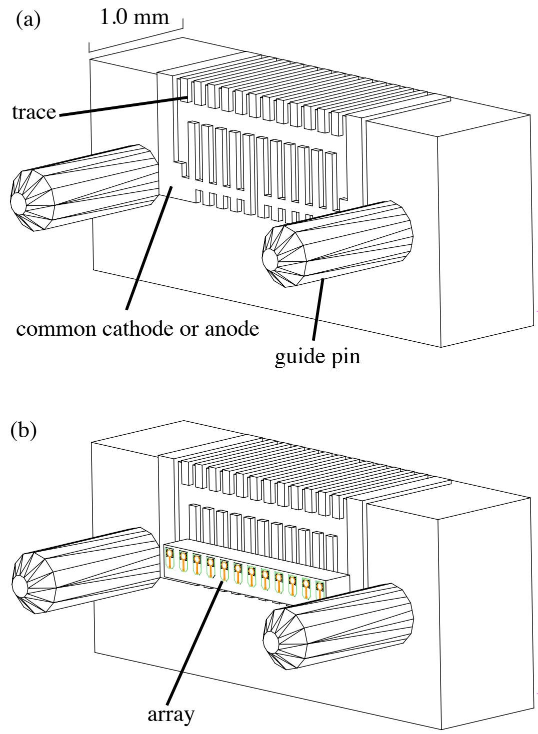

Fig. 1. (a) The base of an MT-style optical package, (b) the base with an array.

have a common anode and hence both the cathode and anode of each channel must be wire bonded. To accomplish this, the common anode traces extend from beneath the array shown in Fig. 1(a) and allow for wire bonding from the PIN anode.

The two holes on the base are for the guide pins. Each guide pin has a diameter of 0.7 mm and the distance between the holes is 4600 μm. We enlarge the holes by 100 μm to ease both the deposition of epoxy in the holes and the production tolerance; the precise separation between the two guide pins will be determined by an MT ferrule during the gluing of the guide pins (see below). The guide pins are available commercially in two materials, stainless steel and ceramic, with the latter material for application in a strong magnetic environment. It is important to use guide pins with a ring of groove to ensure good adhesion to the base. The length of the pin is limited by the bond head of the wire bonding machine and must be as long as possible for mechanical stability. We use a ceramic pin of 3.7 mm in length.

We previously proposed a two-piece MT-style optical package [3], consisting of a rectangular block plus a U-shape piece with two precisely located holes for the guide pins. This one-piece design is much simpler in construction with no precision parts. However, the precise placement of the VCSEL with respect to the guide pins during the fabrication process is critical in both designs.

It is instructive to compare the above design to the package [2] used in the on-detector optical links of the ATLAS pixel detector. Each package for the detector was fabricated using a printed circuit board (PCB) which was a poor heat conductor. In addition, it was quite challenging to solder the fine leads (< 200 μm wide) of the package to a trace on an BeO optical module [4]. It was especially difficult to supply sufficient heat to make a solder joint on the BeO optical module, which efficiently moved the heat from the soldering iron. Moreover, excess heat could loosen and sometimes break the connection on the poorly heat conducting PCB optical package. The package is also not as radiation-hard as the package (ceramic material with traces) described in this article.

3 Array Alignment

The precise alignment of a VCSEL array to the guide pins is critical to achieve good optical power coupling; the alignment of a PIN array is much less critical because of the relatively large light sensitive area. As a first step in the fabrication process, the guide pins are attached to the BeO base using epoxy [5] with the precise relative location fixed by an MT ferrule. A minute amount should is deposited into the two holes to prevent overflow of the epoxy up the guide pins. The MT ferrule used to set the relative location during the epoxy curing should have some material around the guide pins removed so that the ferrule would not be glued to the guide pins should there be an overflow of the epoxy up the guide pins. After the epoxy has cured, any overflow should be removed for proper mating with the MT ferrule.

We use a thin slice of an MT ferrule to aid in the array alignment. Each slice contains two large holes for the guide pins plus an array of 125 μm holes for a fiber ribbon. These holes are precisely located and hence an array aligned precisely to the first and last small holes will have good light coupling efficiency. As a first step of the alignment process, a base mounted with a ferrule slice is securely fixed under a measuring microscope [6]. The microscope then registers the centers of the first and last holes. The ferrule slice is then removed and a fine line of conductive epoxy [7] is deposited at the location where an array will be placed. An array is then placed on top of the epoxy. The array is lightly pushed until the optical centers of the first and last diodes coincide with the first and last small holes. The base is then placed in an oven to cure the epoxy, followed by wire bonding of the array.

To prevent the mating MT connector from crushing the wire bonds, a short wire is placed next to the the array across from the side with wire bonds and secured with some epoxy. The diameter of the wire should be such that the the mating fiber ribbon will be located at ~ 100 μm from the surface of the array for good light coupling efficiency. The wire bonds and the array are then

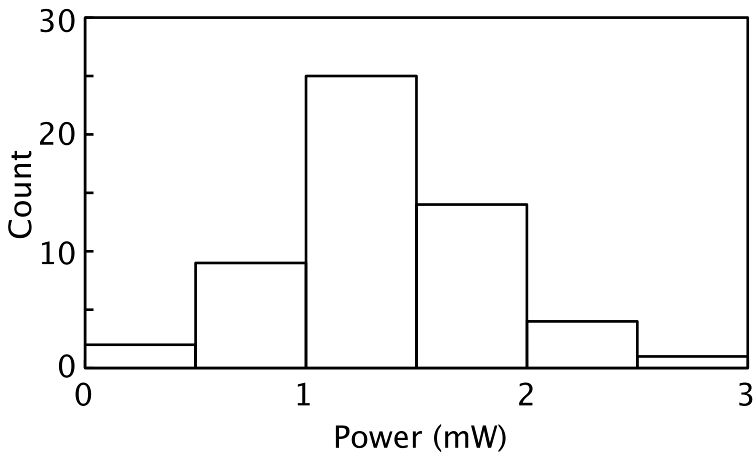

Fig. 2. Minimum coupled optical power of various VCSEL arrays at 7 mA of VCSEL current.

encapsulated [8].

4 Prototype Results

In the past three years, we have fabricated 55 VCSEL and 16 PIN optical packages using various arrays from three vendors, AOC, Optowell, and ULM. We achieve good coupled optical power for the VCSEL arrays. Figure 2 shows the optical power of the arrays at a VCSEL current of 7 mA, approximately the typical current given in the vendor specification sheets. We only show the minimum power of each array as this is usually one of the acceptant criteria of an optical package. The power was measured with a GRIN (50/125 μm) fiber. It is evident that the coupled power is quite adequate for most applicatons.

An indicator of the quality of the alignment is the spread of the coupled optical power within an array. Figure 3 shows the ratio of the maximum to minimum coupled power within a VCSEL array for various arrays at 7 mA of VCSEL current. It is evident that the power spread is small for most of the arrays. The two arrays with large ratios (> 5) correspond to the two arrays with low minimum coupled power ($< 500\ \mu W$) due to poor alignment as shown in Figure 2.

As stated above, the alignment of a PIN array is much less critical because of the relatively large light sensitive area. For the 16 PIN packages we fabricated, all the measured responsivities are consistent with the manufacturer specifications.

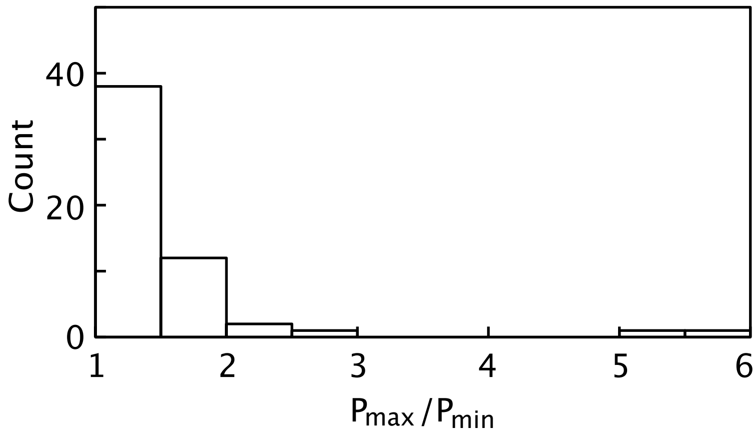

Fig. 3. Ratio of the maximum to minimum coupled optical power within a VCSEL array for various arrays at 7 mA of VCSEL current.

5 High Speed Operation

The traces that bend around the edge of the base could be too long, resulting in too much stray capacitance and inductance for high speed operation. A possible solution is to use an optical module with a hole (or recess) for the base so that a driver or receiver chip placed in close proximity can be wire bonded directly to the array. The disadvantage of such a design is that it is more complicated to test such an optical package before mounting on an optical module, necessitating the use of fine probes to contact the anode and cathode pads for the light-current-voltage (LIV) curve measurement.

6 Summary

In summary, we have developed a compact optical package based on BeO for efficient thermal management. We achieved good coupled power in the large sample of VCSEL and PIN optical packages fabricated. The package is quite compact, significantly smaller than an MT ferrule. The design simplifies the testing and assembly of an optical link system because the fiber ribbon can be connnected/disconnected with ease while preserving good light coupling efficiency.

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References

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[4] K.E. Arms et al., Nucl Instrum. Methods A**554** 458 (2005).

[5] The epoxy used is Hysol EA9396.

[6] The measuring microscope used is Mitutoyo Quick Vision 404 R. The horizontal resolution is a few microns.

[7] The epoxy used is Epotek H20E.

[8] The epoxy used is Epotek 353ND.