	IBL & nSQP Opto-pack Assembly, Test, and QA Procedure		
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IBL & nSQP Opto-pack Assembly, Test, and QA Procedure

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Distribution List

ATLAS Collaboration for comments

History of Changes			
Rev. No.	*Date*	*Pages*	*Description of changes*
1	2/12/2012	All	First submission
2	7/1/2013	Assembly steps	
3	6/1/2019	Update assembly steps with improved jig	

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1. Introduction

The ATLAS pixel detector has four barrel layers and six disks. This requires a total of 300 opto-boards, the hybrid modules for the optical communication between the pixel detector and the counting room. Each opto-board contains one 12-channel PIN array and two 12-channel VCSEL arrays. Each array is mounted on a small ceramic block with two guide pins and wire bonded. The compact assembly is called an optical package (opto-pack). Due to the simplicity of the design and fabrication, we combine the assembly procedure, test procedure, and quality assurance (QA) requirement into this single document.

2. Design

The design of the optical package [1] is shown in Fig 1. The base is fabricated using beryllium oxide (BeO). With BeO as the substrate, heat produced by a VCSEL array, the major source of heat in an optical link, is efficiently removed. 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 edge of the ceramic block 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.

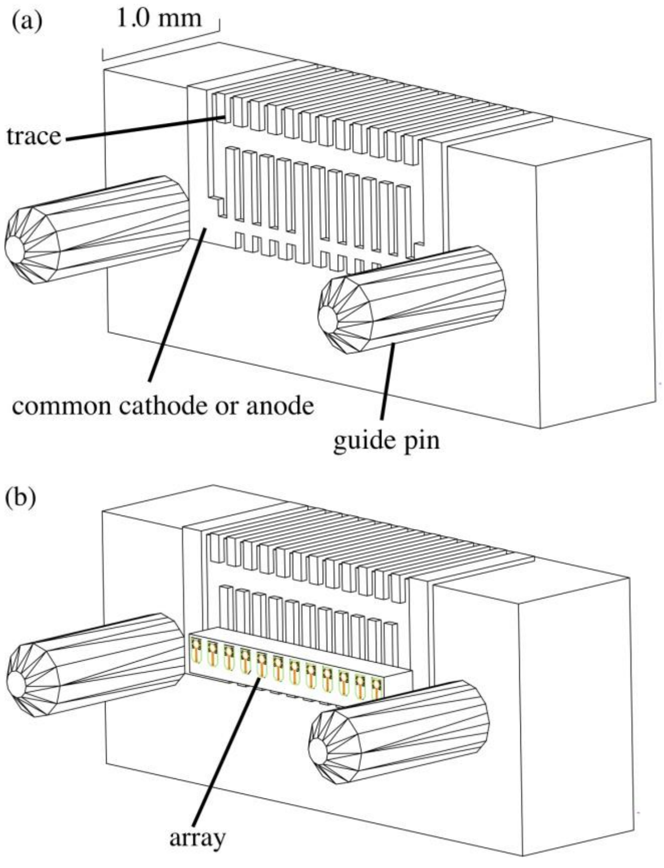

Figure 1: (a) The base of an opto-pack, (b) the base with an array.

There is no solid cathode (or anode) plane under the array. This is to avoid a problem encountered with the opto-packs used [2] in the on-detector optical links of the pixel detector. 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.

There are two holes on the base for the placement of 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 fabricated using non-magnetic stainless steel. Each pin has a ring of groove to ensure good adhesion to the base. The length of the pin is 3.7 mm.

We plan to use humidity-resistant VCSEL annd PIN arrays fabricated by ULM [3,4]. These arrays have been verified to be radiation-hard to thirdteen times the dose expected at the IBL opto-board location for 200 fb^{-1}.

3. Assembly steps

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, two guide pins are attached to an opto-pack base [5] using epoxy [6] with the precise relative location fixed by an MT ferrule. The jig for the placement of guide pins in 10 opto-pack bases is shown in Figs. 2 and 3. First the jig is cleaned with acetone and double-sided sticky tapes are then placed to hold the bases. The faceplate (bottom piece in Fig. 2 (left)) is then mounted and the opto-pack bases are placed with their backs and bottoms flush as in Fig. 2 (right). Lightly press down on the opto-pack bases to ensure good adhesion to the sticky tape. Then a small amount of epoxy is deposited into the two holes of each opto-pack base. Care must be taken not to deposit too much epoxy to prevent overflow of the epoxy when the guide pins are inserted. The epoxy should be given time (~ 10-15 minutes) to pool in the holes. Light reflected off the epoxy under a microscope can be used to assess the amount of epoxy deposited. The MT ferrule holder (Fig. 3 (left)) are then mounted on the faceplate with the top screws tighten by hand. Two short guide pins are then inserted into each MT ferrule followed by two long (standard) guide pins until the bottom of the short guide pins are flush against the MT ferrule. The long guide pins are left in the MT ferrules throughout the fabrication process. The MT ferrules are then placed in the MT ferrule holders and the clamps closed and the screws tighten by hand as shown in Fig. 3 (right). The MT ferrule holders have been designed such that there is a gap (Fig. 4) between each MT ferrule and the opto-pack base to prevent the epoxy from gluing the two pieces together. The guide pins are then pushed all the way down into each opto-pack base. Inspect the opto-pack bases under a microscope to ensure that the two sides and the bottom of each base are parallel to the sides of the enclosure. The sidebar (Fig. 5) on each side is then mounted with the three screws tightened by hand. The alignment jig is placed in an oven to cure the epoxy at 100°C for one half hour.

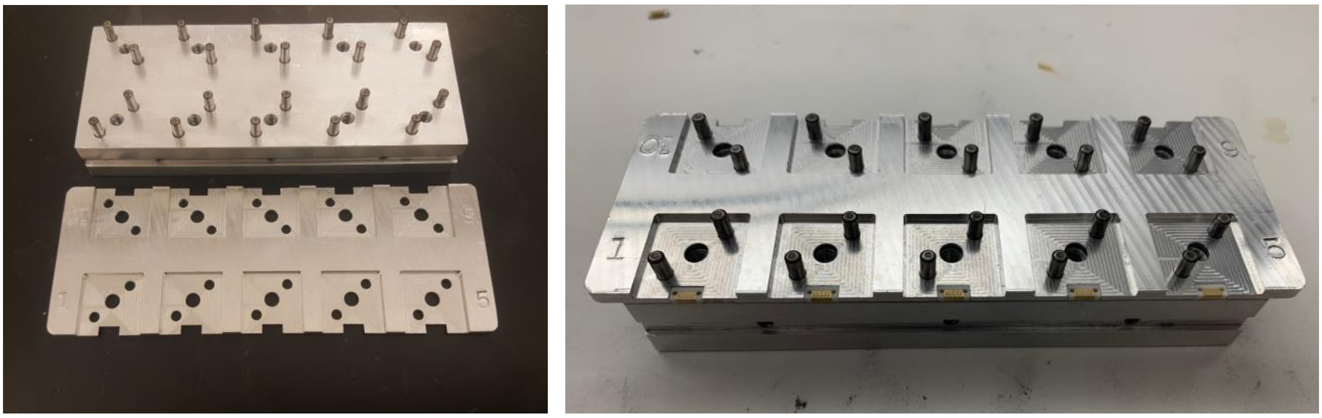

Figure 2: The opto-pack base alignment jig, unassembled (left) and assembled (right) with five BeO bases installed.

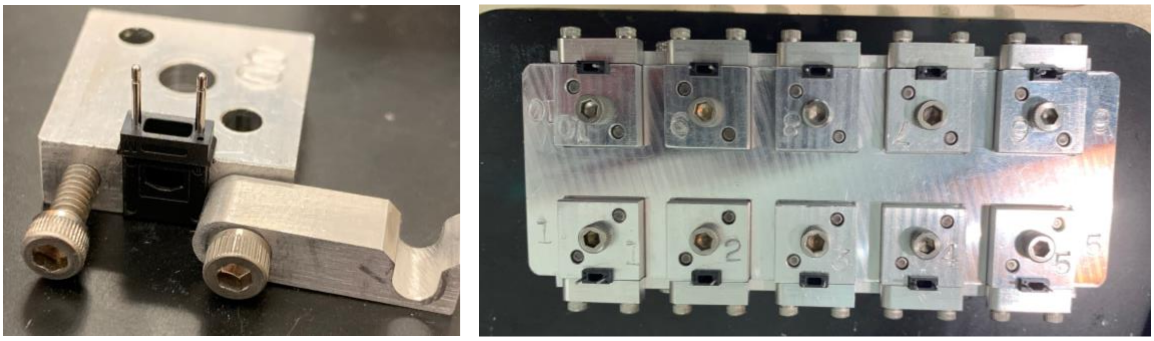

Figure 3: An MT ferrule holder (right) and the alignment jig with ten MT ferrule holders installed (left).

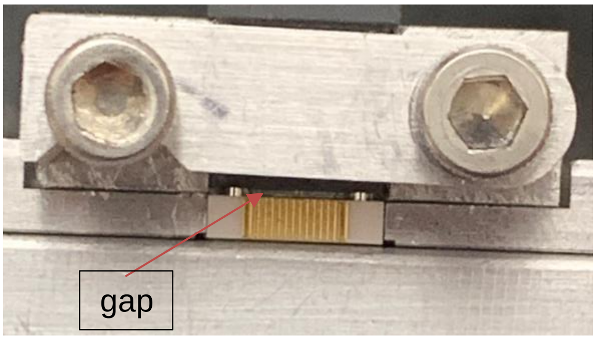

Figure 4: A closeup view of a MT ferrule holder showing the BeO base and the guide pins in the glueing position. A gap is evident between the opto-pack base (gold/white) and the MT ferrule (black) to prevent the ferrule from sticking to the base from excess glue.

Figure 5: The opto-pack base alignment jig with sidebar.

The alignment jig is then removed from the oven and disassembled. Beginning with the removal of the two sidebars, each opto-pack base should be inspected to ensure its placement in the jig is parallel along its base and sides and any outliner noted for further statistical analysis. The ferrule clamps may then be loosened and removed, allowing for an additional placement inspection. Each opto-pack base can now be removed and inspected under a microsccope. Any glue overflow near the base of a guide pin is removed. Finally, each opto-pack base is checked to ensure that it mates properly to an MT ferrule. For the test, a shield is first mounted (temperary) on the opto-pack since a fully assembled opto-pack has a shield attached. Figure 6 shows the picture of a shield together with an opto-pack with guide pins mounted. The opening in the center is where an optical array with wire bonds is located. The shield prevents the MT ferrule from crashing the wire bonds. The shield is made of stainless steel, fabricated with chemical etching. A pocket (indentation) is also etched on the shield so that when mounted on an opto-pack, the metalic shield would not touch the traces that bends over the edge of the base. During the test, a MT ferrule is pushed onto the opto-pack base with 0.5 kgf and the assembly visually inspected to ensure that there is no gap as shown in Fig. 7 or else the opto-pack is rejected.

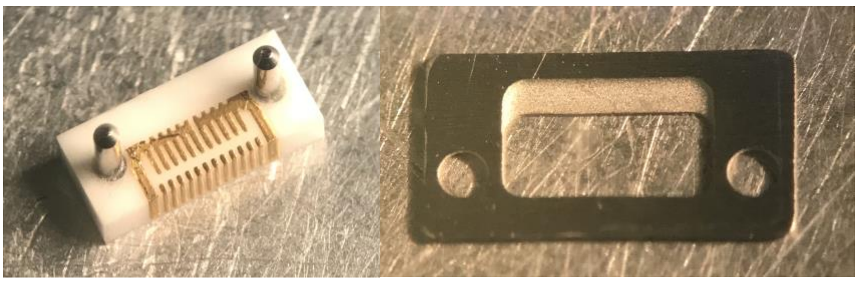

Figure 6: An opto-pack with two guide pins mounted (left) and a shield (right) with an indentation near the top of the opening.

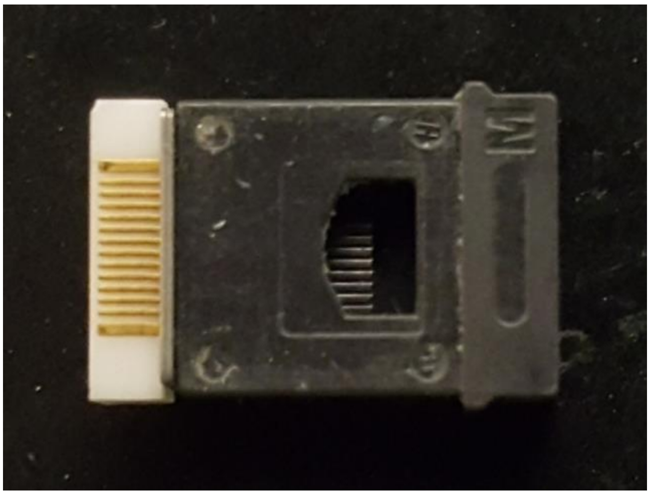

Figure 7: BeO base, shield, and MT ferrule combination for force testing.

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 [7]. 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 [8] 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 at 100°C for one hour, followed by wire bonding (25.4 μm gold wire) of the array.

To prevent the mating MT connector from crushing the wire bonds, a shield is then mounted as shown in Fig. 8 and secured with epoxy [6], cured at 100°C for one hour. The thickness of the shield is 254 μm; the thickness is chosen for good light coupling efficiency. Attach a small piece of Kapton tape to the indentation on the shield with epoxy to seal off the cavity containing the optical array to prevent dust particle from entering (the top opening is sealed off by the MT ferrule in a MPO connector). Cure the epoxy at 100°C for one hour.

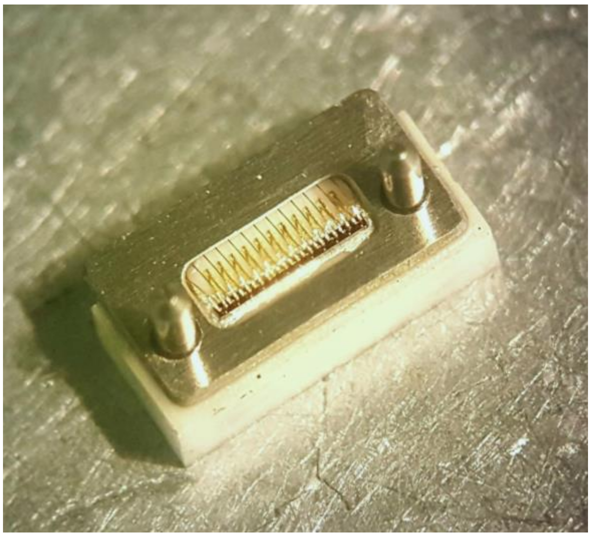

Figure 8: An opto-pack with a shield attached.

4. Quality Assurance

Each VCSEL opto-pack must pass the following QA procedure. First, the opto-pack is inserted into an MT ferrule having a ribbon of twelves 50/125 µm SIMM fibers. Next, using a probe station to make contact with the gold traces on the opto-pack, light, current, and voltage (LIV) curves from 0 to 10 mA are measured for each channel on the VCSEL array. Finally, the VCSEL is checked for possible ESD damage by performing a reverse bias current measurement on each channel. Evidence of likely ESD damage is detected when one or more of the channels in the array has a higher reverse bias current than the other channels or when all of the channels have a higher reverse bias current than expected (the reverse bias current at 4.5 V should be less than 5 to 10 nA). To pass the QA, the measured output power should be larger than 1 mW per channel and have no sign of possible ESD damage.

Each PIN opto-pack must pass the following QA procedure, measured using a fiber and probe station as in the VCSEL QA. An optical power of 1 mW is sent to each channel on the array and the resulting PIN current is measured. This process is repeated at bias voltages ranging from 0 to 5 V. Furthermore, the dark current for each channel is measured at 2 V. To pass QA, each channel must have a responsivity of greater than 0.5 A/W and dark current of less than 3 nA, per the specfication of the ULM datasheet.

There is no plan to do any burn-in/thermal cycle for the opto-packs before mounting on an opto-board. The opto-packs will be burn-in/thermal cycled with the opto-board after the mounting.

References:

[1] K. K. Gan, An MT-Style Optical Package for VCSEL and PIN Arrays, Nucl. Instrum. Methods. A 607, 527 (2009).

[2] M. L. Chu et al., Nucl Instrum. Methods A 530, 293 (2004).

[3] The VCSEL array used is ULM850-14-TT-F0112U, fabricated by ULM Photonics. The bandwidth of each VCSEL is 14 Gb/s.

[4] The PIN array used is ULMPIN-10-TT-N0112U, fabricated by ULM Photonics. The bandwidth of each PIN is 10 Gb/s.

[5] Hybrid-Tek Inc., 1 Hytek Corporate Ctr, Rte. 526, Clarksburg, NJ 08510, USA.

[6] The epoxy used is Hysol EA9396.

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

[8] The epoxy used is Epotek H20E, with 50% resin (part A) by weight.