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

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

Prepared by:	*Checked by:*	*Approved by:*
K.K. Gan, R. Kass, J. Myers, J. Moore, D.S. Smith, Y. Yang, M. Ziolkowski		

Distribution List

ATLAS Collaboration for comments

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1	2/12/2012	All	First submission
2	7/1/2013	Assembly steps	

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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.

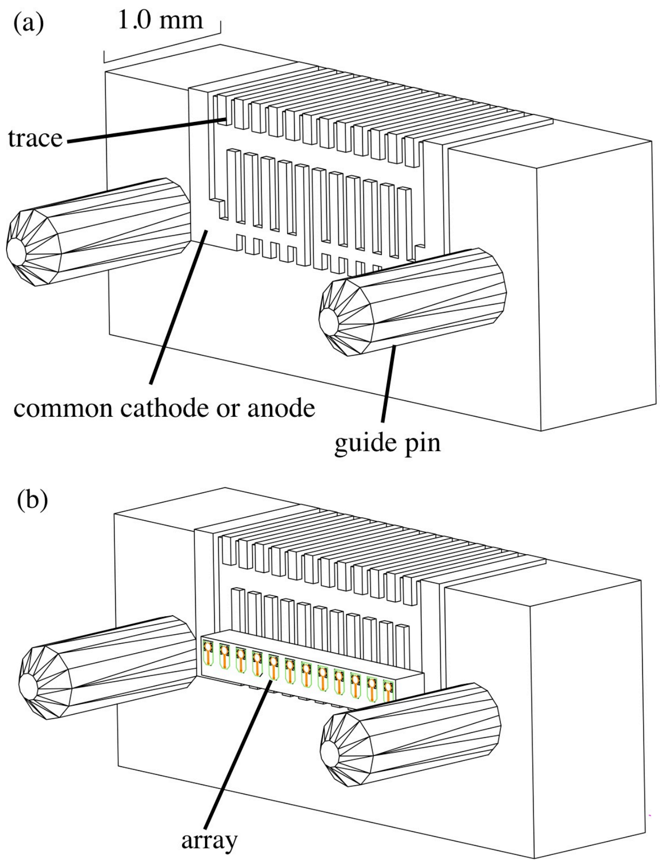

Figure 1: (a) The base of an opto-pack, (b) the base with an array.

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 the same kind of humidity resistant VCSEL array [3] as used in the off-detector optical modules (TX) of Pixel and SCT. We plan to use the PIN arrays fabricated by ULM [4]. These arrays are known to be radiation-hard to the HL-LHC dose and hence are more than adequate for this application [5-6].

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, the guide pins are attached to the BeO base [7] using epoxy [8] with the precise relative location fixed by an MT ferrule. The alignment jig used to glue the pins into a BeO base is shown in Figs. 2 and 3. The BeO bases are held in place using double sticky tape. As shown in Fig. 2 the jig can glue six BeO bases at a time. A small amount of epoxy is deposited into the two holes of the BeO base before the MT ferrule is placed on the jig. Care must be taken to prevent overflow of the epoxy up the guide pins. As can be seen in Fig. 3 (right) the MT ferrule is positioned above the BeO base to prevent the epoxy from reaching the ferrule. The assembly jig is placed in an oven and the epoxy is cured at 100°C for one half hour. The assembly jig is then removed from the oven and disassembled. Each BeO base is now inspected under a microsccope and any glue overflow near the base of a pin is removed. Finally, each BeO base is checked to insure that it mates precisely to an MT ferrule. The ferrule is pushed onto the BeO base with 0.5 kgf and visually inspected to insure that there is a proper fit.

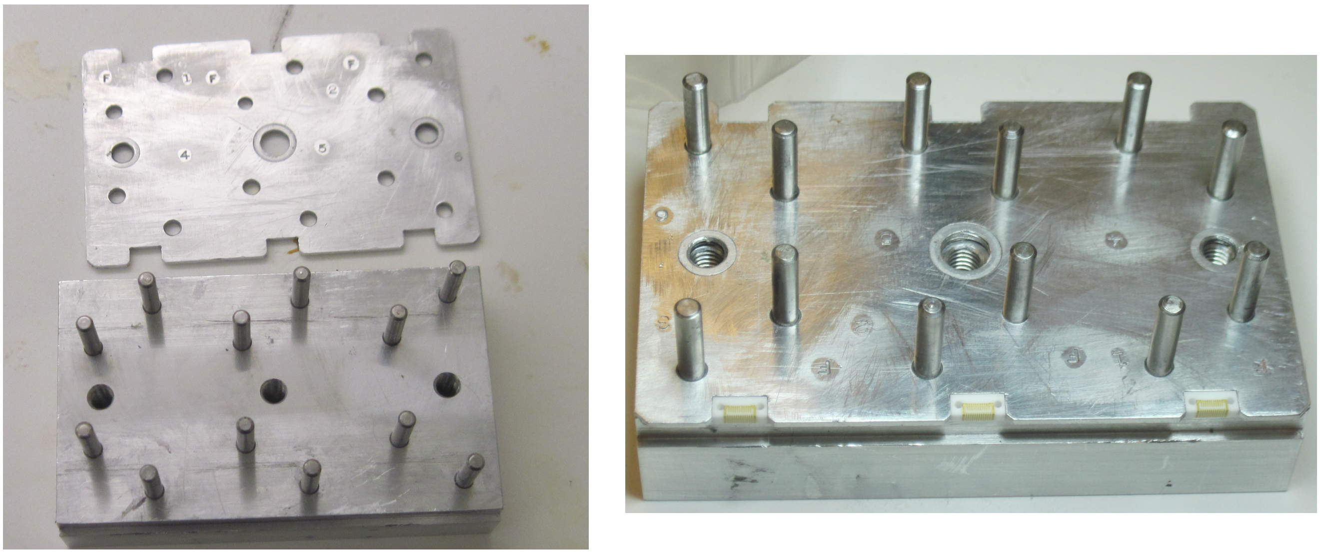

Figure 2: The BeO aligment jig, unassembled (left) and assembled with BeO bases installed.

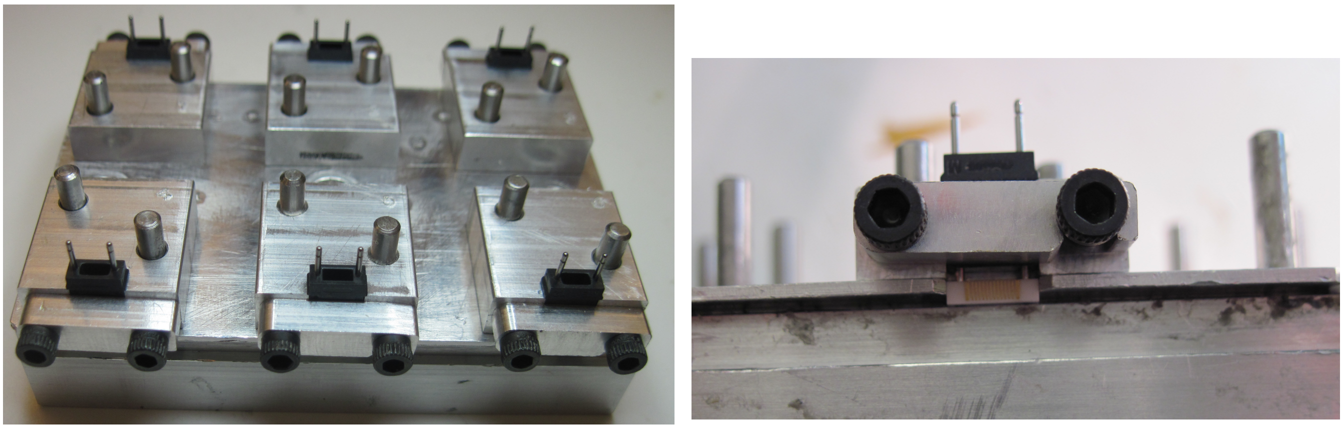

Figure 3: The assembly jig with six MT ferrule alignment guides installed (left). A closeup of an MT ferrule guide showing the BeO base and the guide pins in the glueing position (right).

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 [9]. 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 [10] 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 u-shaped dam (Fig. 2) with two holes for the guide pins is then mounted and secured with some epoxy [8], cured at 100°C for one hour. The thickness of the dam is 254 μm; the thickness is chosen for good light coupling efficiency.

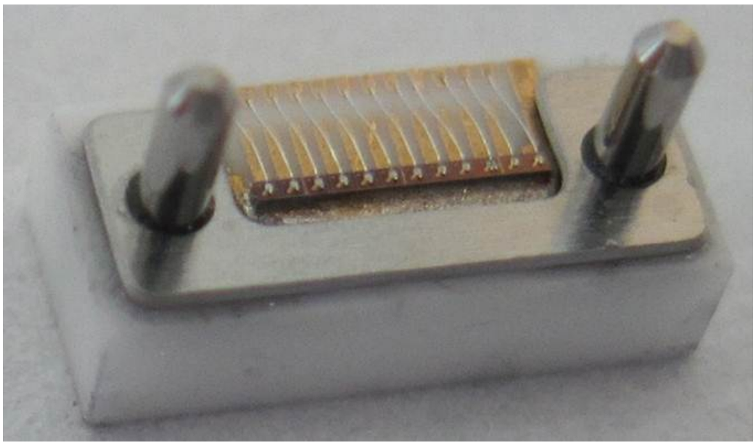

Figure 3: An opto-pack with a u-shaped dam.

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 10 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 V850-2093-001, fabricated by Finisar. The bandwidth of each VCSEL is 5 Gb/s.

[4] The PIN array used is ULMPIN-04-TN-U0112U, fabricated by ULM Photonics. The bandwidth of each PIN is 4.25 Gb/s.

[5] K.K. Gan et al., Radiation-Hard/High-Speed Data Transmission using Optical Links, in the proceedings. of the 11th Topical Seminar on Innovative Particle and Radiation Detectors, Siena, Italy, 2008, Nucl. Phys. B (Proc. Suppl.) 197, 175–179 (2009).

[6] A. Nagarkar et al., in the Proceedings of the 10th International Conference on Large Scale Applications and Radiation Hardness of Semiconductor Detectors, 6-8 July 2011, Florence, Italy, PoS (RD11) 036.

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

[8] The epoxy used is Hysol EA9396.

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

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