IBL & nSQP Opto-board Assembly Procedure

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IBL & nSQP Opto-board Assembly Procedure

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Distribution List

Atlas Collaboration for comments

History of Changes

Rev. No.	*Date*	*Pages*	*Description of changes*
1	29/11/2012	All	First revision

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1. Introduction

The existing ATLAS pixel detector has three barrel layers and six disks. In transitioning from the present service quarter panels (SQP) to the new SQP (nSQP) no changes will be made to the detector. To service the outer two barrel layers (L1 and L2) and disks, each nSQP opto-board contains seven pairs of data (DTO1 and DTO2) links and seven clock/command links (TTC). Depending on the occupancy of the link in question, DTO1 may be used alone. To achieve a higher bandwidth, both DTO1 and DTO2 may be used. Because of this, fourteen DTO lines are present on each opto-board. For compliance with the connectivity between the SQP opto-boards and the off detector readout, two flavors of nSQP opto-board must be fabricated. The two flavors are called B-Layer and D-Tall.

The insertable B-layer (IBL) detector will be an addition of a single barrel layer inside the innermost barrel layer of the existing pixel detector. To service this new barrel layer, each IBL opto-board contains sixteen DTO and eight TTC links. For the IBL there is only a single DTO line per data link. Unlike nSQP, only one flavor of IBL opto-board will be fabricated.

Each DTO line contains one VDC (VCSEL Driver Chip) channel driving a VCSEL channel. Each TTC link contains one DORIC (Digital Opto-Receiver Integrated Circuit) channel receiving a signal from a PIN channel. The DORIC and VDC are fabricated in 4-channel arrays. The VCSEL and PIN are 12-channel arrays. For integration of the VCSEL and PIN on the opto-board, the arrays are mounted to a custom package called an opto-pack. Therefore each opto-board contains four VDCs, two DORICs, one PIN opto-pack, and two VCSEL opto-packs. All individual components must be certified to meet their own quality assurance (QA) tests before being mounted on an opto-board. The assembled opto-board must then pass a series of QA tests before shipment to CERN.

The nSQP requires 44 opto-boards for the B-layer and 228 opto-boards for L1 and L2 and disk (D-Tall). We plan to order 60 B-Layer and 300 D-Tall copper backed boards from the CERN PCB shop. The IBL requires 28 opto-boards. For production we plan to order 40 copper backed boards from the CERN PCB shop. A photo of a completely assembled IBL opto-board is shown in Fig. 1. Please note that both flavors of nSQP opto-board will have a nearly identical appearance.

2. List of assembly tools

The following is a summary of the tools needed for the assembly:

- Mechanical tester?
- Electrical short tester
- Opto-pack mounting jig
- Tweezers
- 3 MPO connectors with slightly over-polished (100 μm) MT ferrules

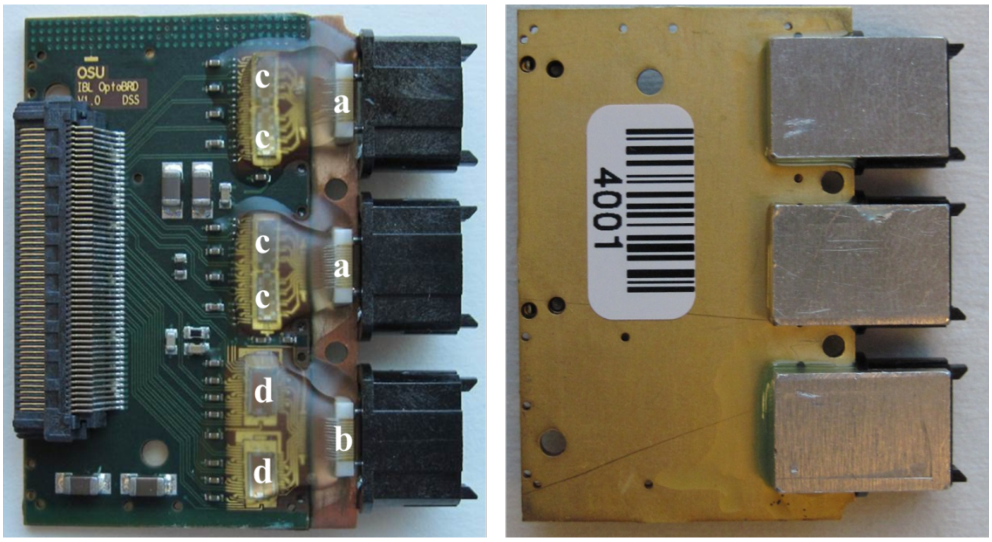


Figure 1: The left image is the top side of a fully assembled IBL opto-board: (a) VCSEL opto-packs, (b) PIN opto-pack, (c) VDC, (d) DORIC. The image on the right is the bottom view of the same opto-board.

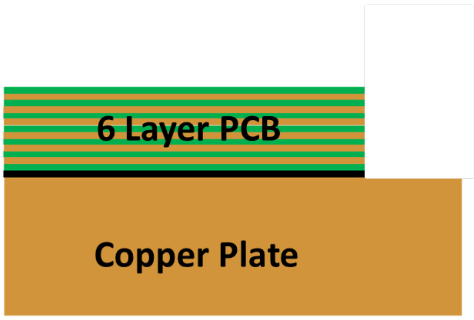
3. Major assembly steps

The following is a summary of the major assembly steps:

- Mounting of passive components
- Mechanical tolerance test?
- Electrical short test
- QA measurements on the VCSEL and PIN opto-packs
- Mounting of the optical connectors
- Mounting of the opto-packs
- Cleaning of the opto-board
- Mounting of VDCs and DORICs
- Wire bonding of VDCs and DORICs
- Wire bonding of opto-packs
- Encapsulation and testing

<u>**Mounting of passive components**</u>

The opto-board PCBs are fabricated by the CERN PCB shop. Each board is comprised of a 6-layer printed circuit board adhered to 1 mm thick copper plate for thermal management. A simplified cross section of an opto-board and a table of the material stack up are shown in Fig. 2. Avcom SMT Inc. populates the blank boards with ~45 passive components: 22 nF, 100 nF, and 1 μF capacitors, 75 and 100 Ω resistors, and an 80-pin (nSQP) or 100-pin (IBL) Samtec LSHM hermaphroditic connector. The solder paste used is AIM NC257-2 SN100C with a maximum reflow temperature of 270°C.



Layer	Thickness (µm)	Product
Soldermask	30	Peters Elpemer AS 2467
Finish	5	ENIG
Top	35	Copper
Prepreg	150	Isola DE 156
Layer2	17	Copper
Prepreg	100	Isola DE 156
Layer3	17	Copper
Prepreg	150	Isola DE 156
Layer3	17	Copper
Prepreg	100	Isola DE 156
Layer4	17	Copper
Prepreg	150	Isola DE 156
Bottom	35	Copper
Glue	25	LF100
Kapton	13	LF7001
Glue	13	LF7001
Copper Plate	1000	Copper
Finish	5	ENIG

Figure 2: Simplified cross section of the opto-board (left). Complete listing of opto-board stack up information (right).

Mechanical tolerance test

So far, there have been no reports of problems with the opto-boards fitting mechanically within opto-boxes. However, should the need arise it will be possible to produce a jig for testing the size of each opto-board and the placement of the 80 and 100 pin connectors prior to mounting the active components.

Electrical short test

The CERN PCB shop performs a netlist verification using a flying probe tester on all opto-boards. We therefore will only check for opens / shorts created during the mounting of the passive components by Avcom SMT Inc. The short tester will be used to measure the resistance between pins on the connector to check for unwanted shorts and to check that the 75 Ω termination resistances on the DTO lines are installed properly. We plan to perform the open / short test upon receiving the populated opto-boards from the assembly vendor before any active components are mounted.

Mounting of optical connectors

To interface with an industry standard MPO optical connector, custom optical connectors are glued to the opto-boards. Each optical connector consists of a standard part from USCONEC called an MTP inner adapter (part #C10196) and a machined aluminium part which are glued together using Loctite Hysol EA 9396. A photo of an optical connector is shown in Fig. 3(a). The machined aluminium part assists in alignment of the MTP inner adapter and the opto-pack and provides a large surface area for glue (Hysol EA 9396) adhesion to the opto-board itself. The attachment of the optical connectors is accomplished using a jig shown in Fig. 3 (b) and (c). The jig holds the optical connectors in their proper locations with respect to the opto-boards in place while the glue (Hysol EA 9396) is cured.

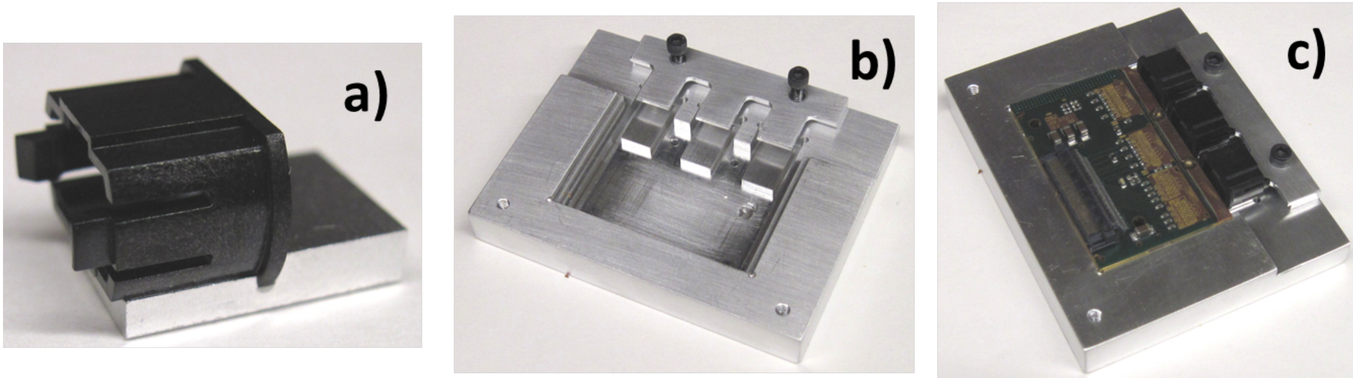


Figure 3: Photographs of the optical connector (a), gluing jig (b), and gluing jig with opto-board (c).

Mounting of opto-packs

Once the optical connectors are securely glued, the opto-packs are glued (Hysol EA 9396) in position on the copper plate. Proper alignment of the opto-packs on the opto-board is critical to ensure good coupling with an industry standard MPO optical connector. This alignment is accomplished by inserting a complete MPO optical connector into the optical connector and then pushing the opto-pack to be glued into this MPO connector. It is important to note that the completed MPO connectors used are made with MT ferrules that have been slightly over polished by 100 µm. The purpose of the over polishing is to ensure that the opto-packs are positioned closer to the edge of the board thus forcing an MPO with a standard polished MT (as will be used during testing and in the detector) to be pressed into the opto-pack completely. Once inserted, small droplets of Hysol EA 9396 are placed at the back corners of the opto-pack as far from the MT ferrule as possible and cured. When this cure is complete, the MPO connectors are removed and more Hysol EA 9396 is placed on the back of the opto-pack to glue it even more securely. The reason for using the two gluing steps is due to the low viscosity of the Hysol. If too much is applied when the MPO connector is mated to the opto-pack, it is possible for the glue to wick up the face of the MT ferrule and permanently glue the MPO connector to the opto-pack. This can ruin both the opto-pack and the MPO connector.

Cleaning of the opto-boards

With the opto-packs securely in place it is easy to swab them clean with acetone and blow them dry. Following this, the other surfaces to be wire bonded on the opto-board are swabbed and dried similarly.

Die attachment of the VDCs and DORICs

The VDCs and DORICs are attached to the opto-board with Epotek H20E, a conducting epoxy. This is a manual process requiring a technician to apply an appropriate amount of glue to the pads where the chips are to be placed. Once this is complete, the die are picked up using ESD safe plastic tweezers and placed into their appropriate positions. The alignment of the die is not critical because the wire bonding machine can easily compensate for varying chip position with respect to the opto-board bond sites. Once the dies are in place, the H20E is cured for at least 1 hour at 100°C.

Wire bonding of VDCs and DORICs

To simplify wire bonding, care was taken in the design of all flavors of opto-board so that the same bonding program works for all boards. For enhanced reliability, all wire bonds are doubled. Since no test pads for wire bonding were designed on the chips, we use unused active pads on the chips to monitor pull strengths. The first step in our wire bonding process is to add these test wire bonds to each chip and then pull them to measure the pull strengths. If the pull strengths are all above 7 gf, the rest of the bonds on the board can be made. If a wire bond fails the pull strength test, the bonding areas must be cleaned and a second set of test bonds attached and pulled. If the new pull strengths are all above 7 gf, the chips can then be fully bonded or else the board is abandoned.

Wire bonding of the opto-packs

The opto-packs are wire bonded to the opto-board using a similar approach to what is used for the ASIC chips. We first put a test bond between each opto-pack and opto-board and then pull them to measure the pull strengths. If the pull strengths are all above 7 gf, the rest of the bonds on the opto-packs can be made. If a wire bond fails the pull strength test, the bonding areas must be cleaned and a second set of test bonds attached and pulled. If the new pull strengths are all above 7 gf, the opto-packs can then be fully bonded or else the board is abandoned. For enhanced reliability, all wire bonds are doubled.

Encapsulation and Testing

With the assembly steps complete, some basic functionality tests will be performed after the wire bonding. If the opto-board passes the tests, the wire bonds will be encapsulated. Following encapsulation, a Kapton bar code serial number label is adhered to the back of the opto-board. All nSQP D-Tall boards will have 4XXX serial numbers, all nSQP B-Layer boards will have 5XXX serial numbers, and all IBL boards will have 6XXX serial numbers. Following the assembly described above, we will perform burn-in, thermal cycling, and QA measurements all to be discussed in a separate document.

4. List of individual opto-board assembly steps

The following is a list of individual assembly steps. Each opto-board has a status sheet that must be updated after each step.

1) Perform a mechanical tolerance test:

   An opto-board satisfies the mechanical tolerance if it can be mounted inside the mechanical tester.

2) Perform the electrical continuity and short test:

   Measure all resistances on the short tester and compare them with the expectations.

3) Clean the opto-board:
   a. Rinse the opto-board with isopropyl alcohol then de-ionized water for 60 seconds.
   b. Blow dry with nitrogen.
   c. Bake in oven for 1 hr. at 100°C
4) Mount the optical connectors
   a. Assemble three optical connectors

   i. Apply a dot (4 mm x 4 mm) of Hysol near the channel on the machined aluminium part
   ii. Press MTP inner adapter into the aluminium channel and the Hysol dot
   iii. Clamp the MTP inner adapter and the machined aluminium part together
   iv. Bake in oven for 1 hr. at 100°C
  b. Insert three assembled opto-connectors into the gluing jig
  c. Bolt down the opto-connector holding clip
  d. Apply a dot (4 mm x 4 mm) of Hysol to the exposed region of the aluminum part of the optical connector away from the plastic part of the optical connector
  e. Place the opto-board into the gluing jig
  f. Screw the opto-board down to the jig using 1-74 screws through the extraction tool holes
  g. Cure for 1 hr. at 100°C
  h. Take the board out of the jig
5) Mount the opto-packs
  a. Re-clean, using acetone and swabs, the surface on the opto-board that will be used for gluing the opto-packs
  b. Select two VCSEL packs and one PIN pack that have passed the QA
  c. Insert 3 complete MPO connectors into the opto-board optical connectors
  d. Clean, using acetone and swabs, the PIN and VCSEL opto-pack surfaces that will be used for gluing
  e. Insert the PIN opto-pack into its associated MPO connector
  f. Insert the VCSEL #1 opto-pack into its associated MPO connector
  g. Insert the VCSEL #2 opto-pack into its associated MPO connector
  h. Apply small dabs of Hysol to the corners of the opto-packs and opto-board
  i. Cure for 1 hr. at 100°C
  j. Remove the three MPO connectors
  k. Apply large dabs of Hysol to the back edge of each opto-pack
  l. Cure for 1 hr. at 100°C
6) Clean the opto-board
  a. Using several swabs, clean the traces on the opto-packs with acetone
  b. Using several swabs, clean the bonding areas on the opto-board
  c. Blow dry the board and opto-packs with nitrogen
7) Attach the DORIC and VDC die
  a. Apply a thin layer of adhesive (Epotek H20E with 50% resin (part A) by weight) on the VDC pads and the DORIC pads on the opto-board
  b. Mount the VDCs on the opto-board
  c. Mount the DORICs on the opto-board
  d. Cure the opto-board at 100^{0}C for 1 hour
8) Wire bond the DORICs and VDCs
  a. Wire bond the test pads on the DORICs and VDCs
  b. Perform pull test on the wire bonds

c. If the pull strengths are all above 7 gf bond all chips. Otherwise repeat the steps on the second set of test pads. If the pull strength of a test bond is below 7gf, abandon the board

9) Wire bond the opto-packs
    a. Wire bond the cathode pads on the opto-packs
    b. Perform a pull test on the wire bonds
    c. If the pull strengths are all above 7 gf bond all opto-packs. Otherwise repeat the steps on the same cathode pads. If the pull strength of a test bond is below 7gf, abandon the board
10) Perform the basic functionality test procedures
11) Encapsulate wire bonds
    a. Apply the encapsulant (Dymax 9001 V.3.1) on all wire bonds
    b. Cure the encapsulant with UV for 60 seconds
    c. Apply encapsulant to any bonds not coated in the first step
    d. Cure the encapsulant with UV for 60 seconds
12) Apply the Kapton serial number label
13) Run the board through burn-in, thermal cycling, and QA