GOL Opto-Hybrid

Manufacturing Specifications

Version 3.30

Document history:

Rev. 1.00, 21 Dec 02	First released version
Rev. 2.00, 21 Feb 03	Substantial rework, significant additions/revisions to delivery schedule, GOH v.3.1 design, wire-bonding parameters, QA specifications, wire-bond test boards, other minor modifications
Rev. 2.10, 18 Mar 03	GOH v.3.3 design, other minor modifications
Rev. 3.00, 16 Apr 03	GOH v.3.4 design, delivery schedule revised, QA flowchart revised, other minor modifications
Rev. 3.10, 29 Apr 03	Assembly yield defined
Rev. 3.20, 24 Jun 03	Delivery date of Engineering Run modified, QA process revised, definition of accepted GOH added
Rev. 3.30, 24 Jun 03	Typographical error corrected in QA flowchart

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1. Background

The GOL Opto-Hybrid (GOH) is being procured by the CMS Collaboration. It will be the transmitter of the optical data links for the Electromagnetic Calorimeter of the CMS Experiment, located at the CERN laboratory in Geneva, Switzerland. Approximately 10,500 GOH will be required.

The GOH receives parallel 16-bit data plus a 40 MHz clock from a front-end electronics board via a connector. The data are serialized and encoded by a Gigabit Optical Link (GOL) serializer and laser driver ASIC, and transmitted optically at 800 Mb/s via a laser diode and a connected pigtail optical fiber. A block diagram showing the place of the GOH within the optical data link system is shown in Figure 1.

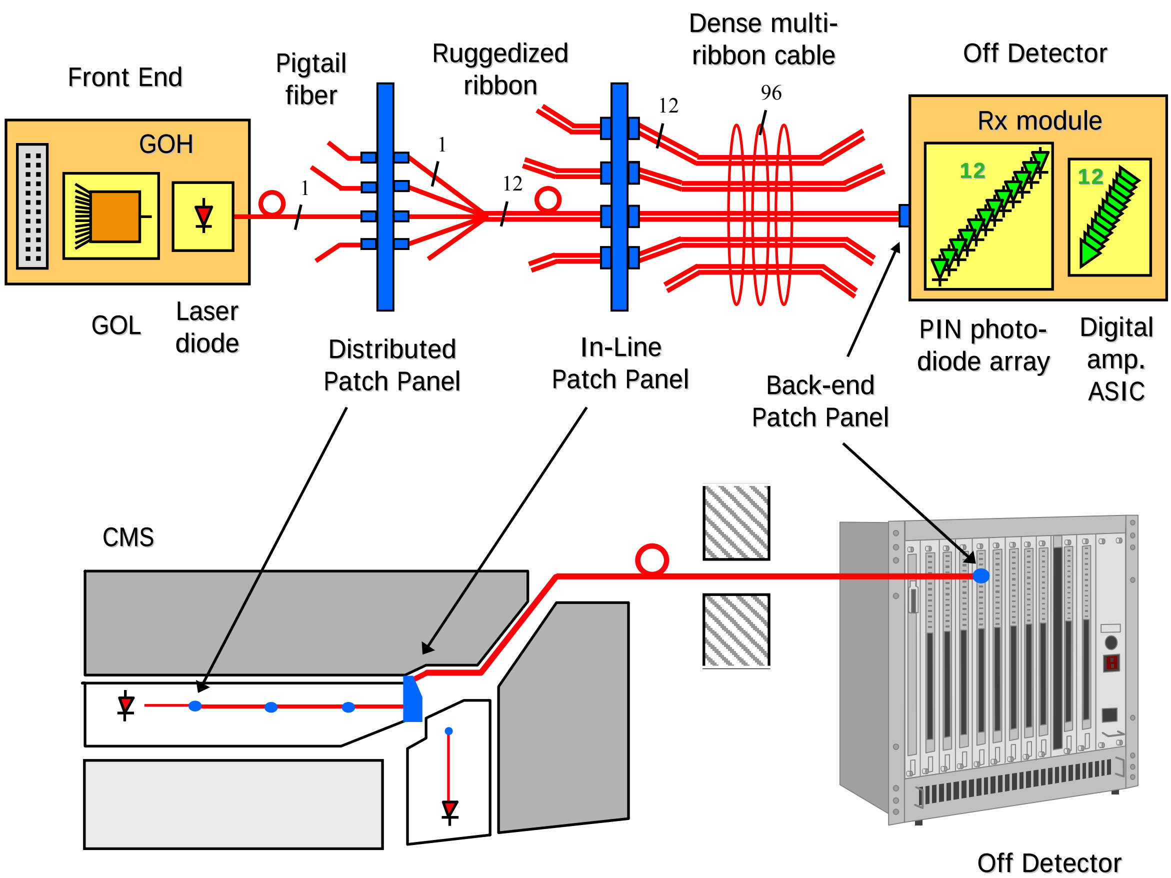

Figure 1. Block diagram of the CMS Electromagnetic Calorimeter optical data link system.

The GOH will be required to operate with perfect reliability throughout its lifetime of approximately 10 years, subjected to a harsh environment of radiation and high magnetic field. Approximately 5,000 GOH will be in an inaccessible location within the Calorimeter; the remainder will be accessible with great difficulty. Approximately 1,400 will operate at –10°C; the rest will operate in a controlled environment where the temperature will be maintained at 18 ± 2°C.

2. Definitions of Completed and Accepted GOH

To be considered "completed", a GOH must have completed the assembly process and the manufacturer's sequence of inspections and tests described in the left column (Inspection, Moderate Tests and Acceptance) of Table 5, including a "pass" result of the pass/fail mask test performed by the manufacturer.

To be considered "accepted", a GOH must additionally have followed the remaining sequence of tests described in the left column, including a "pass" result of the final pass/fail mask test performed at CERN by the CMS Collaboration (except for GOH which are subjected to the strenuous tests; these are considered accepted if they pass the first mask acceptance test).

3. Assembly yield

The minimum acceptable GOH assembly yield of the manufacturer is 100 completed GOH per 110 sets of components (that the CMS Collaboration is responsible to provide) delivered to the manufacturer by the CMS Collaboration. The definition of "completed GOH" is that in Section 2.

4. Delivery schedule

The deliverables by the manufacturer are the wire-bond test boards and the completed GOH.

4.1 Wire-bond test boards

The first deliverable by the manufacturer will be the five wire-bond test boards described in Appendix A. The manufacturer will subject three of the five boards to QA tests as described in the Appendix. The manufacturer will deliver all five boards within one month of the date the GOH assembly contract is signed.

4.2 Completed GOH

The manufacturer will deliver completed GOH according to the schedule listed in Table 1.

The CMS Collaboration will deliver to the manufacturer at least two months in advance of the GOH delivery date sufficient quantities of all components that it is responsible to provide. For example, the CMS Collaboration will deliver no later than Dec 1, 2003 sufficient quantities of all components that it is responsible to provide to produce the 400 GOH of the first month of Production Run 1. In this case "sufficient quantities" is 440 sets of components, according to the minimum acceptable manufacturer assembly yield defined in Section 3.

If there are leftover sets of components at the end of any production month (due for example to better than the minimum acceptable production yield), then these remain the property of the CMS Collaboration, and they are considered as reducing the quantities of components that the CMS Collaboration is responsible to deliver in subsequent months by the same amount.

Stage	Date	Quantity
Engineering Run[1]	Q3 2003	100
Pilot Run[2]	Dec 1, 2003	500
Production Run 1[3]	Feb 1, 2004	400
	Mar 1, 2004	1000
	Apr 1, 2004	1000
	May 1, 2004	1000
	Jun 1, 2004	1000
	Jul 1, 2004	550
	Aug 1, 2004	550
	Sep 1, 2004	500
Production Run 2	Dec 1, 2004	1000
	Jan 1, 2005	1000
	Feb 1, 2005	1000
	Mar 1, 2005	900
	Total	10,500

Table 1. Delivery schedule for completed GOH.

Notes with respect to Table 1:
[1] The delivery date of the Engineering Run will be two months after the CMS Collaboration provides sufficient quantities of all components that it is responsible to provide.
[2]The CMS Collaboration reserves the right to move forward the Pilot Run by one month, such that the delivery date would become Nov 1, 2003. The CMS Collaboration will notify the manufacturer by Sep 1, 2003 whether or not it will exercise this option. The manufacturer will in either case not begin assembly of GOH in the Pilot Run before two months prior to the delivery date, to allow for a possible minor design modification, as noted in Section 5.
[3]The CMS Collaboration reserves the right to move forward Production Run 1 by one month, such that the delivery schedule would become 400/1000/…/550/500 for Jan/Feb/…/Jul/Aug, respectively. The CMS Collaboration will notify the manufacturer by Oct 1, 2003 whether or not it will exercise this option.

5. Design modification option

The CMS Collaboration reserves the right to make minor modifications to the GOH design between each of the four runs listed in Table 1.

6. Components

Each assembled GOH contains:

- One small (2.4 cm × 3.0 cm) 6-layer FR4 PCB with no blind vias
- One GOL ASIC contained in a 144-pin fpBGA 13 mm side package with 1 mm solder-ball pitch, to be mounted on the PCB
- Adhesive
- One “pigtailed” laser diode assembly, comprising:
    - One laser diode to be glued to the PCB

  - o two double-wire-bonds between bond pads on the laser diode housing and bond pads on the PCB
  - o One pigtail optical fiber of type 9/125/250/900 µm glued to the laser diode housing
  - o One 2D QR-code label on a plastic tag pre-attached to the pigtail fiber
  - o One MU connector termination of the pigtail fiber
- One clamp to provide strain relief for the pigtail fiber glue bond to the laser diode housing, to be glued to the substrate
- One cover to protect the laser diode wire-bonds, to be glued to the substrate
- One connector of type NAiS-Matsushita AXN450330S
- Passive surface-mount resistors and capacitors on both sides of the PCB
- One 2D QR-code label on a 5 × 5 mm^2 plastic square to be glued to the substrate

6.1 PCB

The PCB is a small (2.4 cm × 3.0 cm) 6-layer FR4 PCB with no blind vias. It is double-sided with components on both sides. The total PCB thickness is 0.8 mm. The layout of the top of the PCB is shown in Figure 2. The schematic diagram is shown in Figure 3.

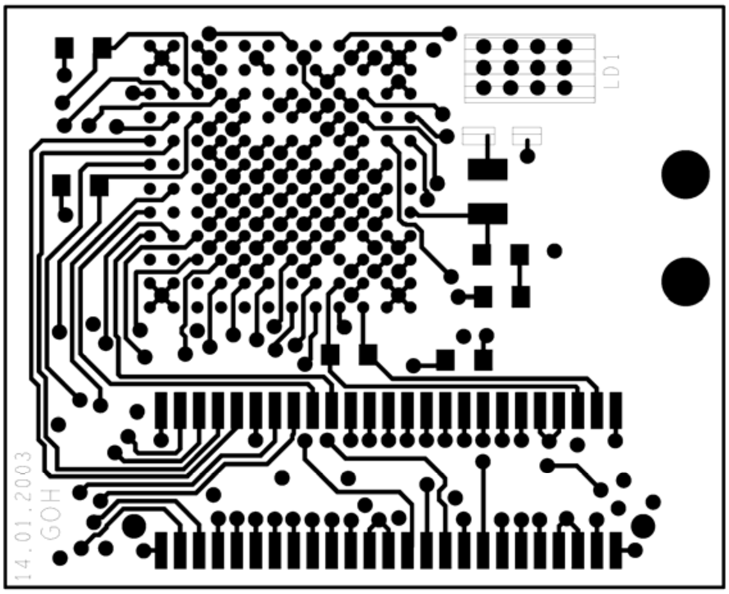

Figure 2. Layout of the top of the GOH PCB.

The manufacturer will provide the PCB's and be responsible for their quality and testing. The company manufacturing the PCB's must be ISO9001 certified.

The metallization of the wire-bond pads is Cu/Ni/Au. The manufacturer will choose the thicknesses of the layers and the Au plating method (e.g., electrolytic, electroless) to optimize the reliability of the wire-bonds, and will use the same thickness and plating method for both the GOH assembly and the wire-bond test boards described in Section 4.1 and Appendix A.

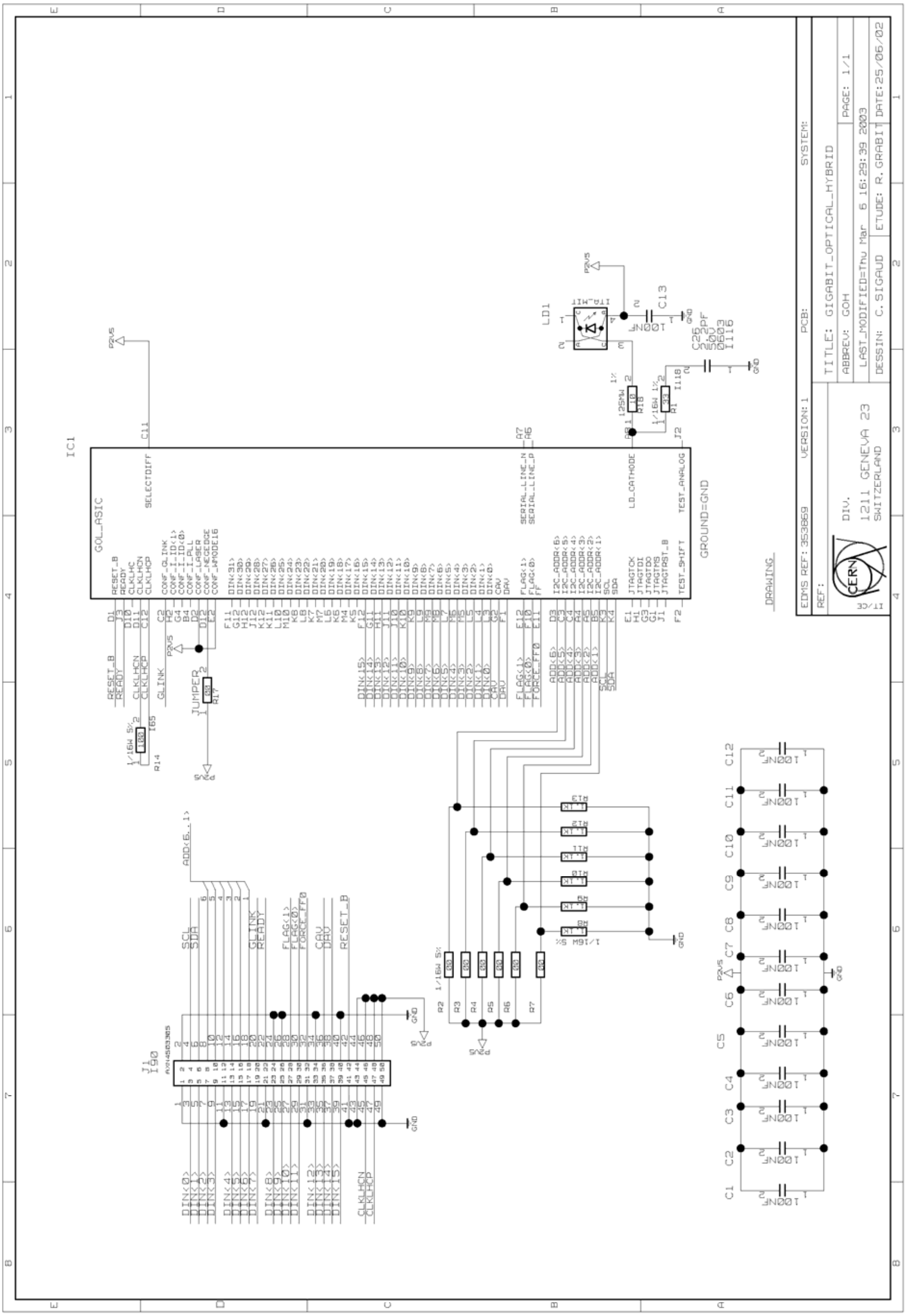

Figure 3. Schematic diagram of the GOH.

The manufacturer will ensure that no "brighteners" are present in the Au plating bath, and that the final Au films contain no measurable thallium and less than 50 ppm total of Ni, Cu, and Pb impurities, for both the wire-bond test boards and the GOH PCB's.

6.2 GOL BGA

The GOL ASIC is contained in a 144-pin fpBGA 13 mm side package with 1 mm solder-ball pitch. The GOL BGA must be baked for 20 hours at 125°C prior to mounting. If it is neither stored in dry nitrogen (≤ 6ppm H_20) nor mounted within 4 hours of baking, then it must be re-baked.

The CMS Collaboration will provide the GOL BGA's and will be responsible for their testing prior to delivery to the manufacturer.

The manufacturer will be responsible for mounting the GOL on the GOH and for verifying the quality and reliability of the mounting.

6.3 Adhesive

Adhesive is required for the gluing of certain components. The requirements for the adhesive are that it must be electrically insulating but thermally conducting, that it must be radiation-hard, that it must cure within a reasonable length of time at a temperature not higher than 65°C and that it must not damage the laser diode (housed in a non-hermetic package) due to outgassing.

The provisional choice of adhesive is Epotek H70E.

The manufacturer will be responsible for providing the adhesive as well as storing and employing the adhesive in a manner consistent with the adhesive manufacturer's specifications.

6.4 "Pigtailed" laser diode assembly

The CMS Collaboration will provide the "pigtailed" laser diode assemblies. Each assembly consists of a laser diode, a pigtail fiber glued to the laser diode housing, a 2D QR-code label on a plastic tag pre-attached to the fiber and a MU connector termination of the fiber.

The metallization of the bond pads on the laser diode is:

- Si
- Ti/TiN/Ti : 0.085 µm
- Pt : 0.2 µm
- Au : 0.5 µm

The engineering drawing of the laser diode and its connection to the fiber is shown in Figure 4.

The CMS Collaboration will be responsible for testing of the laser diode assemblies prior to delivery to the manufacturer. The CMS Collaboration will ensure that the laser diodes are delivered to the manufacturer free from contamination.

The manufacturer will glue the laser diode to the GOH PCB. The provisional choice of adhesive is that described in Section 6.3.

After gluing, the manufacturer will wire-bond the laser diode to bond pads on the GOH PCB. Two pads per laser must be bonded to the PCB. Double-bonds are required for redundancy (thus 4 bonds per laser).

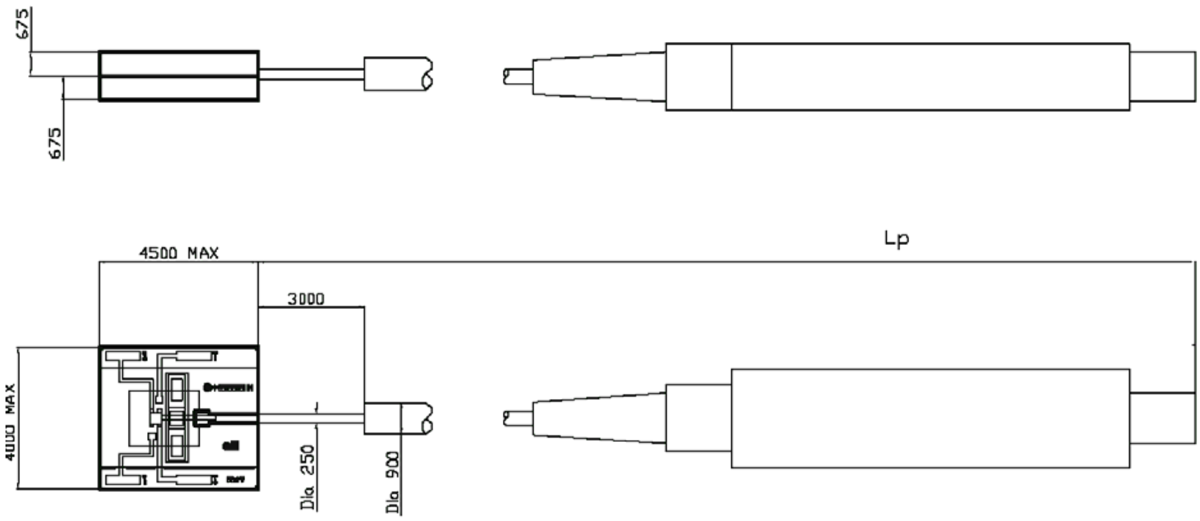

Figure 4. Engineering drawing of the laser diode and pigtail fiber.

The wire-bonding technique to be used is ultrasonic wedge bonding with Al wire.

The manufacturer will choose the wire thickness and wire-bond geometry that maximizes the reliability of the resulting wire-bonds.

The manufacturer will use the same model of bonding wire from the same manufacturer for both the GOH assembly and the wire-bond test boards described in Section 4.1 and Appendix A. The bonding wire will be annealed, 99% Al, 1% Si.

The manufacturer will be responsible for providing the bonding wire as well as storing it in a manner consistent with the bonding wire manufacturer's specifications.

A photograph of a prototype GOH of a previous design, showing the pigtailed laser diode, wire-bonds, the bare and jacketed portions of the pigtail fiber, and the fiber clamp, is shown in Figure 5.

The manufacturer will develop, test and manufacture any jig, clamp or fixture needed to temporarily hold the laser diode during the gluing, glue curing and wire-bonding processes. Special restrictions apply to the handling of the pigtailed laser diodes and to their assembly on the GOH:

- Care must be taken to damage neither the bare fiber near the laser diode nor the delicate attachment between the laser diode and the pigtail. In particular, it is essential never to touch the bare fiber in any way, nor to pull on or rotate the fiber. The maximum allowable pull force between laser diode and pigtail is 3 N.
- The minimum bending radius of 3 cm of the fiber must be respected at all times.
- Extreme care must be taken to avoid electrostatic discharge and contamination.
- The adhesive may not touch the bare fiber. The only part of the fiber that the adhesive may touch is the 900 µm outer jacket.
- Neither the laser diode temperature nor the fiber temperature may exceed 65°C at any time. The maximum allowable rate of change of temperature is 1°C/min.
- The laser diode housing is not hermetic. It therefore must not be subjected to cleaning of any kind, application of glob top material, etc. These same restrictions apply to the entire GOH once the laser diode has been mounted.

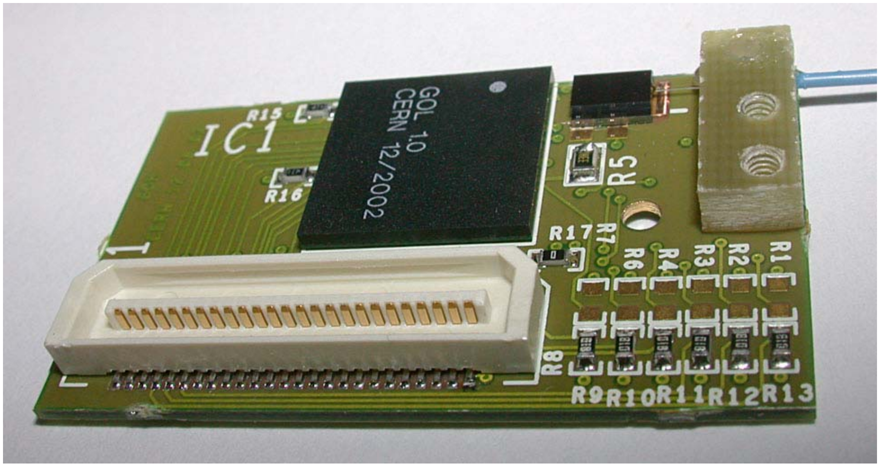

Figure 5. Photograph of a prototype GOH.

6.5 Optical fiber clamp and laser diode protective cover

The optical fiber clamp and the laser diode protective cover will both be made of substrate material. The purpose of the fiber clamp is to provide strain relief for the glue bond between the pigtail fiber and the laser diode. The purpose of the cover is to protect the laser diode wire-bonds.

The CMS Collaboration will provide designs of both objects and specify their orientations on the GOH. The manufacturer may propose alternate designs subject to the approval of the CMS Collaboration. No part of the GOH may extend more than 3.0 mm from the surface of the PCB to allow proper mounting of the GOH on its mate connector. The manufacturer will provide both objects based on the final designs.

The manufacturer will glue the fiber clamp and the protective cover to the GOH substrate. The provisional choice of adhesive is that described in Section 6.3. The same special restrictions described in Section 6.4 apply here.

The manufacturer will develop, test and manufacture any jig, clamp or fixture needed to temporarily hold the fiber clamp and/or the protective cover during the gluing and curing processes.

6.6 Connector

The GOH connector is of type NAiS-Matsushita AXN450330S. The manufacturer will provide the connectors and will be responsible for mounting them on the GOH.

6.7 Passive surface-mount components

The surface-mount capacitors are of type Kemet X7R. The resistors may be of any surface-mount type of the correct size, but must be of the same type for the assembly of all GOH. The numbers and types of surface-mount resistors and capacitors necessary to populate one GOH are listed in Table 2.

The manufacturer will provide the surface-mount resistors and capacitors and will be responsible for mounting them on the GOH.

Type	**Value**	**Unit**	**Tolerance**	**Limit**	**Limit unit**	**Quantity**
resistor	0	Ohms	-	-	-	7
resistor	10	Ohms	1%	125	mW	1
resistor	33	Ohms	1%	1/16	W	1
resistor	100	Ohms	5%	1/16	W	1
resistor	1100	Ohms	5%	1/16	W	6
capacitor	2.2	pF	5%	50	V	1
capacitor	100	nF	20%	16	V	13

Table 2. Surface-mount resistors and capacitors necessary to populate one GOH.

6.8 Labels

The GOH will be identified by a 2D QR-code label on a $5 \times 5\ mm^2$ plastic square to be glued to the GOH substrate and by a 2D QR-code label on a plastic tag pre-attached to the pigtail optical fiber.

The CMS Collaboration will provide the square QR-code labels and specify their orientation on the GOH.

The manufacturer will be responsible for gluing the label to the GOH substrate. The provisional choice of adhesive is that described in Section 6.3. The same special restrictions described in Section 6.4 apply here.

7. Laser diode and GOH consignment packaging

The CMS Collaboration will deliver pigtailed laser diodes in boxes, which will be re-used as the package for the assembled GOH. Diagrams of the box design are shown in Figure 6. The dimensions of the box are approximately 19 cm × 13.5 cm × 3 cm. (This design was originally used for a different three-laser opto-hybrid.)

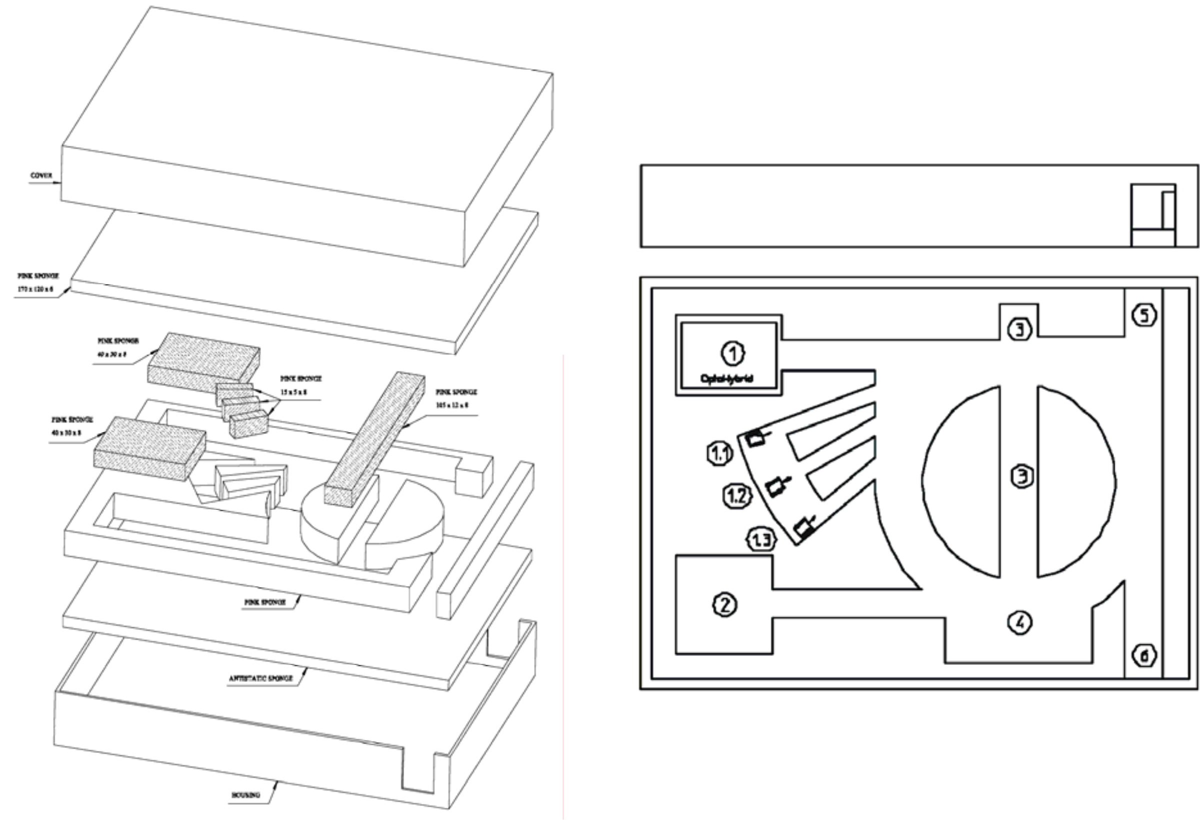

Figure 6. Box for shipment of pigtailed laser diodes and assembled GOH.

The laser diode will lie in slot 1.2. The fiber will be wound in the circular area. The MU connector will lie in slot 2. In principle, the connector and most of the fiber can remain in the box while the laser diode and a short length of fiber are moved to exit the box via hole 5. The laser diode will be glued and wire-bonded to the GOH. The fiber clamp, protective cover and QR-code label will be glued to the GOH, and the GOH will then be placed in slot 1.

The manufacturer will ensure that the completed GOH is re-packaged in such a way that the GOH, pigtail fiber and connector will not be allowed to move significantly within the box during shipment.

8. Special requirements due to operating environment

The GOH must operate in a high magnetic field (approximately 40,000 Gauss) and must neither perturb nor be perturbed by that field. The manufacturer will ensure that no manufacturer-provided part or substance of the assembled GOH is ferromagnetic.

A number of GOH will be required to operate at -10°C. The manufacturer will refrain from using any material or process inconsistent with this restriction.

9. Assembly recommendations to the manufacturer

The manufacturer will receive and store components that it is not responsible to provide, including the GOL BGA's, the pigtailed laser diodes and the QR-code labels.

The manufacturer will procure, receive, test (where relevant) and store components that it is responsible to provide, including the PCB's, connectors, passive surface-mount components, fiber clamps, protective covers, adhesive and bonding wire.

The manufacturer will develop, test and manufacture any jig, clamp or fixture needed to temporarily hold the laser diode, fiber clamp and/or the protective cover during the gluing and curing processes, or needed to temporarily hold the GOH PCB during the wire-bonding process.

The following steps are recommended for each GOH produced:

1. Plasma clean the PCB, the fiber clamp and the protective cover.
2. Surface-mount all passive components by using a stencil dispenser and automatic pick and place process.
3. Mount the GOL BGA.
4. Perform UV-ozone cleaning of the PCB, taking care to control the parameters of the cleaning (exposure time, UV intensity, etc.) such that the FR4 substrate and the BGA package are not attacked. (Plasma cleaning is not allowed at this stage.)
5. Turn the fiber clamp upside-down and fix it with vacuum on the assembly jig.
6. Remove the laser diode from its box with extreme care, as described in Section 6.4, to avoid electrostatic discharge, mechanical damage or contamination, turn the laser diode upside down and fix it with vacuum on the assembly jig. The jig should already provide strain relief (including relief from torsional forces) for the laser diode/pigtail fiber attachment at this point. The fiber should lie in the slot of the fiber clamp.
7. Dispense the chosen adhesive on the bottom of the fiber clamp and the laser diode package, taking care than the adhesive does not touch the bare part of the optical fiber.
8. Fix the PCB on its part of the assembly jig, taking care to avoid contamination, then superpose the PCB on the laser diode and fiber clamp and fix both carefully with clamps. The alignment is to be done by means of precision pins.
9. Remove the GOH from the assembly jig and place it in its box.
10. Cure the adhesive with the techniques relevant for the adhesive chosen (e.g., placement in oven and/or storage for a period of time). Neither the laser diode temperature nor the fiber temperature may exceed 65°C at any time. The maximum allowable rate of change of temperature is 1°C/min.
11. Carefully remove the curing clamps.

12. Remove the GOH from its box, fix it on the wire-bonding jig and wire-bond the laser diode to the bond pads on the PCB.
13. Fix the laser diode protective cover upside-down on the assembly jig and dispense the chosen adhesive on its bottom.
14. Fix the GOH on its part of the assembly jig, taking care to avoid electrostatic discharge, mechanical damage or contamination, then superpose the GOH on the protective cover and fix it carefully with a clamp. The alignment is to be done by means of precision pins.
15. Glue the QR-code label on the PCB with the chosen adhesive and fix it with a clamp.
16. Scan the GOH QR-code label (not the pigtail fiber label), produce a human-readable label with this number and affix it to the outside of the GOH box.
17. Remove the GOH from the assembly jig and place it in its box.
18. Cure the adhesive with the techniques relevant for the adhesive chosen (e.g., placement in oven and/or storage for a period of time). Neither the laser diode temperature nor the fiber temperature may exceed 65°C at any time. The maximum allowable rate of change of temperature is 1°C/min.
19. Carefully remove the curing clamps.
20. Conduct the inspections and tests described in Section 11 and record the results in the database.
21. Pack the completed GOH in its storage box in such a way that the GOH, pigtail fiber and connector will not be allowed to move significantly during shipment.

10. Storage and shipment

The manufacturer will ensure that the storage requirements of the adhesive manufacturer and the bonding wire manufacturer are respected. The manufacturer will ensure that all other GOH components as well as assembled GOH are stored in clean, dry and temperature-controlled rooms.

The manufacturer will take all reasonable precautions (e.g., temperature-controlled rooms, thermal insulation) to ensure that the GOH and the wire-bond test boards are not subjected to temperatures below 0˚C after the wire-bonding step, both in storage and in shipment.

11. QA specifications and manufacturing acceptance test

The chain of inspections and tests for assembled GOH is shown in Table 5. The manufacturer will select at random five percent of the GOH produced from each month and subject them to the entire chain of inspection, tests and recording of results shown in the left column (Inspection, Moderate Tests and Acceptance). The manufacturer will subject the remainder only to the inspection and the acceptance mask test and recording of results.

A number of GOH selected at random from the production of each month will additionally be subjected to the more strenuous chain of tests and recording of results shown in the right column of Table 5. The number of GOH selected from each production month is shown in Table 3. A total of 200 GOH will therefore be subjected to the strenuous tests and recording of results.

Quantity	Production Month
50	Engineering Run[1]
20	Pilot Run
20	First month of Production Run 2
10	All other production months

Table 3. Quantity of GOH selected for strenuous tests from each month of production.

Notes with respect to Table 3:
[1]In the case of the Engineering Run, the acceptance test and recording of results described below and in Table 5 will be performed after each of the three strenuous tests.

All GOH will then be shipped to CERN where the CMS Collaboration will subject them to a burn-in process consisting of operation at 50°C for 72 hours, followed by the mask acceptance test. A GOH will be considered accepted only if it passes this final acceptance test, as described in Section 2 (except for GOH which are subjected to the strenuous tests; these are considered accepted if they pass the first mask acceptance test).

In the case of the Engineering Run, the manufacturer will perform the acceptance test and recording of results after each of the three strenuous tests. In all other months for the strenuous tests, and in all months for the moderate tests, the acceptance test and recording of results need only be performed once after all three tests.

The levels of intensity (essentially the number of G) of the Vibration and Mechanical Shock tests shown in Table 5 are provisional. The final values for the left column will reflect the intensity of shock and vibration expected during shipment, normal handling and mounting/dismounting. The final values for the right column will be proportionally higher to allow an assessment of the margin available.

The information in the shaded box at the bottom of Table 5 is for reference only. Further tests that the CMS Collaboration will perform on the GOH are described.

The setup for the GOH acceptance test mentioned in Table 5 will be provided by the CMS Collaboration. The setup will essentially consist of a GOH evaluation platform, which will drive the GOH, an optical converter, an oscilloscope and a PC running a LabVIEW controlling program. The output optical eye diagram of each GOH will be subjected to a pass/fail mask test. The results will be uploaded and recorded in a database program on the PC. The QR-code labels on both the GOH substrate and the laser diode pigtail will be scanned, uploaded and recorded as well. The entire process should require about one minute per GOH, not including mount and dismount operations.

The acceptance test setup may be used to perform a partial test of the GOH by observing the electronic eye diagram prior to mounting the laser diode, at the discretion of the manufacturer.

The manufacturer will develop, test and manufacture any jig, clamp or fixture needed to temporarily hold the assembled GOH during the tests. In the case of the vibration, mechanical shock and temperature cycling tests, the jig may be constructed in such a way that many GOH may be simultaneously tested.

The CMS Collaboration will develop, test, and deliver the acceptance test setup to the manufacturer, train the manufacturer's staff in its use, and perform on-site service as necessary. The CMS Collaboration will also provide the QR-code label scanner.

12. Warranty

The manufacturer will warrant the GOH for one year following delivery to the CMS Collaboration. The manufacturer will repair or replace any GOH discovered to be defective during this period.

13. Summary of Options

The options reserved by the CMS Collaboration and described in this document are listed in Table 4.

Section in text	Declaration deadline	Option to be declared
4.2	Sep 1, 2003	Delivery date of Pilot Run (either Nov 1 or Dec 1, 2003)
4.2	Oct 1, 2003	Delivery date of first month of Production Run 1 (either Jan 1 or Feb 1, 2004)
5	Two months before first month's delivery date of each production run	Minor design modification

Table 4. Summary of options reserved by the CMS Collaboration.

Test and Test Standard	Inspection, Moderate Tests and Acceptance	Strenuous Tests (for Engineering Run, Acceptance Mask Test is performed after each step)
Inspection, IPC-A-610, Rev. C	Class 2 inspection (100% of GOH) → 5% to vibration; 95% to Acceptance Mask Test	
Vibration, Variable Frequency, JEDEC JESD22-B103-B	Swept sine test, Section 4.2, Table 1, Service Condition 4 (1 G), 4 sweeps/axis, PCB fixed at edges to vibration platform	Swept sine test, Section 4.2, Table 1, Service Condition 3 (3 G), 4 sweeps/axis, PCB fixed at edges to vibration platform
Subassembly Mechanical Shock, JEDEC JESD22-B110	Subassembly free state, Section 4.1, velocity change = 40 cm/s, acceleration peak = 10 G, pulse duration = 6.0 ms, 5 shocks/direction/axis, PCB fixed at edges to shock apparatus	Subassembly free state, Section 4.1, velocity change = 56 cm/s, acceleration peak = 20 G, pulse duration = 4.5 ms, 5 shocks/direction/axis, PCB fixed at edges to shock apparatus
Temperature Cycling, JEDEC JESD22-A104-B	Nominal Ts(min)(°C) with tolerance: -15(+3,-3), Nominal Ts(max)(°C) with tolerance: +45(+3,-3), Soak Mode 2 (5 min), Ramp Rate ≤ 1°C/min, 5 cycles, Test performed in dry nitrogen (≤ 6ppm H_20)	Nominal Ts(min)(°C) with tolerance: -15(+3,-3), Nominal Ts(max)(°C) with tolerance: +45(+3,-3), Soak Mode 2 (5 min), Ramp Rate ≤ 2°C/min, 20 cycles, Test performed in dry nitrogen (≤ 6ppm H_20)
Acceptance Mask Test; Recording of Results	As described in Section 11 of text (100% of GOH) → 10 to 50 / month (see Table 3) to Strenuous Tests → 100% (minus Strenuous sample)	As described in Section 11 of text
Burn-in	Operation under power at 50°C, 72 hours	Operation under power at 50°C, 72 hours
Acceptance Mask Test; Recording of Results	As described in Section 11 of text (100% of GOH, minus Strenuous sample)	As described in Section 11 of text → 50%; → 50%
Separation of Strenuous Test Samples		No further tests (50%)
Accelerated Aging, JEDEC JESD22-A103-B		High temperature storage, Section 3.1, Table 1, Condition E (250°C), 24 hours (50%)
Wire-Bond Pull Strength (Destructive), MIL-STD-883E Method 2011.7		Test Condition D (Wire pull, double bond), Test performed on GOH at ≤ 30°C, One wire of each laser diode double-bond pulled, Pull forces recorded in database for both, Failure category 3.2.1b recorded for all bonds having pull force ≤ 3 grams force

Table 5. Chain of quality assurance tests for assembled GOH.

Appendix A. Wire-bond test boards

A.1 Background

A conceptual drawing of a wire-bond test board and its cover is shown in Figure 7. It will be the first deliverable of the GOH manufacturing project.

The manufacturer will construct five wire-bond test boards and deliver them to the CMS Collaboration by the date specified in Section 4.1. Three of the boards will be subjected to QA tests by the manufacturer before delivery, as listed in Table 6.

The CMS Collaboration will subject the boards to various other tests (e.g., accelerated aging, pulsed currents in a magnetic field, pull tests). The purpose of the boards is to verify the reliability of wire-bonds that are as close as possible to the kind that will be made on the GOH, in terms of materials, machinery and techniques.

A.2 Test board manufacture and assembly

The manufacturer will produce the wire-bond test boards and be responsible for their quality and testing. The company manufacturing the wire-bond test boards will be the same company that will manufacture the GOH PCB's, described in Section 6.1

The method of PCB cleaning, type of adhesive, method of adhesive curing, metallization and purity of bond pads, type of wire, bonding technique, bonding machine, bond geometry, etc., will be as close as possible to those which will be used for GOH assembly, with the exception that *single* bonds are required on the test board.

Each test board and protective cover will be constructed as one unit of two halves that are symmetric in most respects, with perforations between them to allow separation with wire cutters. *The manufacturer will not perform this separation, but will instead deliver each test board and protective cover as a whole.* (The right half of each board will be used for wire-bond reliability tests for a project unrelated to CMS or the GOH.)

The manufacturer will assemble each test board from a PCB and a number of ridges. The PCB will contain the traces, half of the bond pads and all of the surface-mount resistors and test points. The ridges will be constructed from substrate material, ceramic or silicon, at the discretion of the manufacturer. They will contain the other half of the bond pads, but no traces. Their purpose is to provide an elevation for the first bond pad of each wire-bond, to simulate the height of the bond pad on the laser diode package.

The ridges will be precisely aligned and mounted between rows of bond pads on the PCB. Wire-bonds will connect electrically in series the bond pads of each row on the PCB with a row on the adjacent ridge, as shown in Figure 7. The wire-bonds will provide the only electrical connection between the ridges and the PCB. All rows of wire-bonds on a test board will be connected in series via traces on the PCB, with test points between each row.

The ridges may be either surface-mounted or glued, at the discretion of the manufacturer. If adhesive is not used, then the manufacturer will apply two bands of adhesive to each test board, approximately 2 mm wide and 5 cm long. One adhesive band will be applied approximately 1 mm from the top row of ridges; the other will be applied approximately 1 mm from the bottom row of bond pads on the PCB. In either case, the adhesive used will be that mentioned in Section 6.3. The adhesive will be cured with the techniques relevant for the adhesive chosen, before wire-bonding. The purpose of the adhesive is to test the effect of adhesive outgassing on the reliability of the wire bonds.

In the right half of each test board (marked “ATLAS”), the ridge thickness will be as close as reasonably possible to 525 µm. In the left half (marked “CMS”), it will be as close as reasonably possible to 675 µm.

In the right half of each test board, the wire-bond length (measured horizontally) will be 890 µm and the loop height (height above the first bond) will be as close as reasonably possible to 265 µm.

In the left half of each test board, the manufacturer will use the bond length and height that the manufacturer expects to use for GOH assembly (the values which optimize the reliability of the wire-bonds).

The protective cover, shown in dashed outline in Figure 7, will be made from naked substrate material to provide a protective cover for the test board, mounted approximately 1 cm above the test board on spacer posts. Screws or similar devices will attach the PCB, spacers and the protective cover.

The CMS Collaboration will provide the designs of the PCB, the ridges and the protective cover. The total number of ridges on each test board will be 48. The total number of wire-bonds per ridge will be 32. There will therefore be 1,536 wire-bonds per full test board.

A.3 Assembly recommendations to the manufacturer

The following steps are recommended for the assembly of each wire-bond test board. In each step, the materials, techniques, etc., will correspond as closely as possible to those which will be used for GOH assembly, as described at the beginning of Section A.2.

1. Plasma clean the PCB and the ridges.
2. Surface-mount the resistors by using a stencil dispenser and automatic pick and place process.
3. Mount the ridges on the PCB, if the chosen mounting technique is surface-mounting. (If the chosen technique is gluing, delay this until after the UV-ozone cleaning.)
4. Perform UV-ozone cleaning of the PCB, using the same parameters that are expected to be used for the GOH assembly (see Section 9, item 4).
5. Apply two bands of adhesive 2 mm long and 5 cm long to each PCB, if adhesive was not used to mount the ridges.
6. Cure the adhesive with the techniques relevant for the adhesive chosen (e.g., placement in oven and/or storage for a period of time). The temperature should not exceed 65°C at any time, to simulate the identical restriction during GOH assembly.
7. Wire-bond *with single bonds* the bond pads on the ridges with the corresponding bond pads on the PCB.
8. Verify the series connection of all wire-bonds by measuring the resistance between test points at extreme ends of the test board.

9. Install the protective cover.
10. For boards 1 through 3, conduct the test indicated in Table 6, and mark on the back of each board with indelible marker which test was performed on each board.
11. Verify again the series connection of all wire-bonds by measuring the resistance between test points at extreme ends of the test board.

The manufacturer will take all reasonable precautions (e.g., temperature-controlled rooms, thermal insulation) to ensure that the GOH and the wire-bond test boards are not subjected to temperatures below 0˚C after the wire-bonding step, both in storage and in shipment.

A.4 QA tests

The manufacturer will subject three of the wire-bond test boards to one QA test each, as listed in Table 6. The specifications of each test are to be taken from the "Moderate Tests" column of Table 5.

Test board number	**Test to perform**
1	Vibration, Variable Frequency, JEDEC JESD22-B103-B
2	Subassembly Mechanical Shock, JEDEC JESD22-B110
3	Temperature Cycling, JEDEC JESD22-A104-B
4	No test
5	No test

Table 6. QA tests to perform on each wire-bond test board.

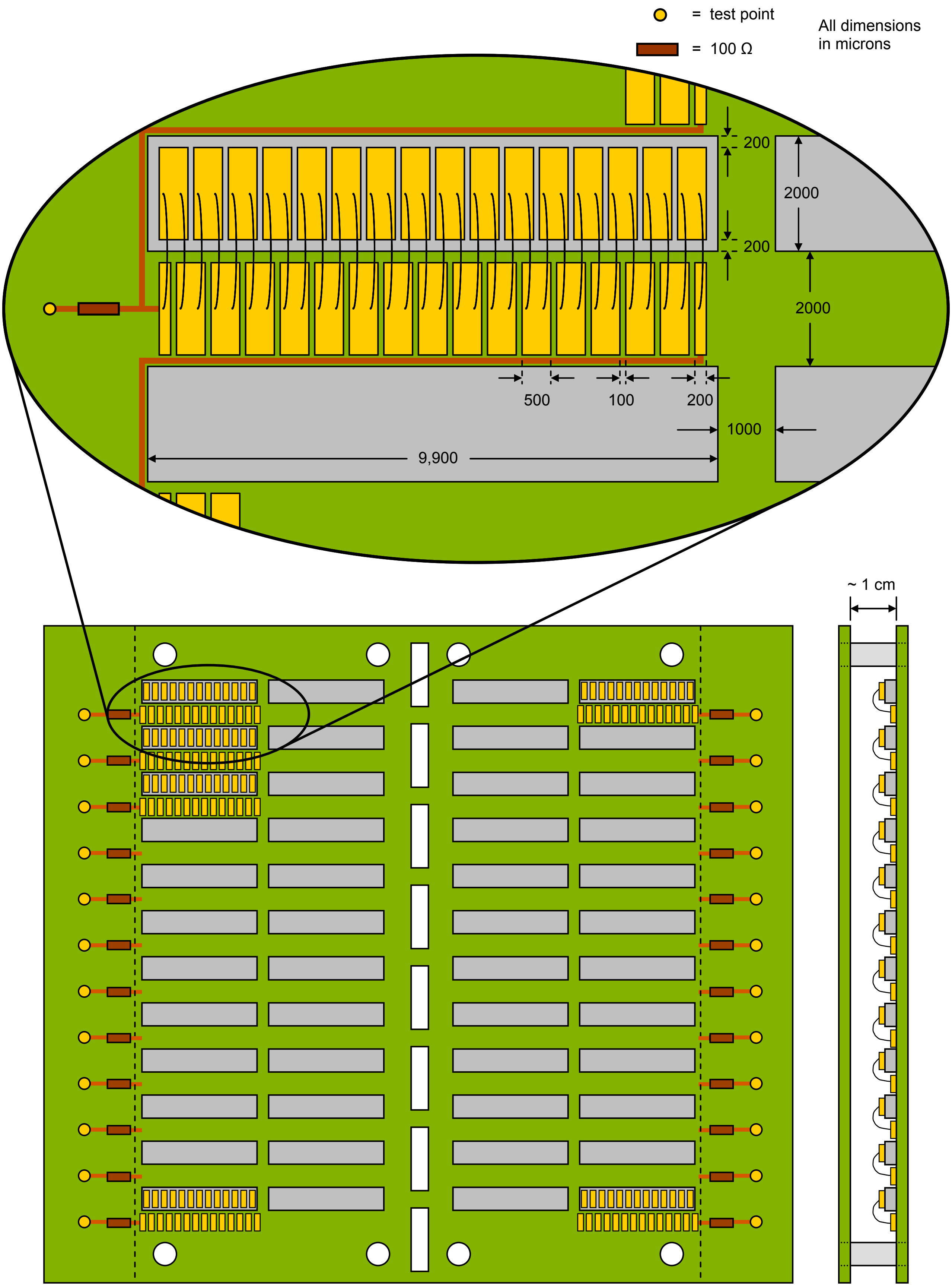

Figure 7. Conceptual diagram of a completed wire-bond test board.

Appendix B. Partial Set of Bid Specifications

This appendix contains a partial set of specifications for the bids of the candidate manufacturers. The purpose is to allow the CMS Collaboration to select among options to be specified by the manufacturer.

1. The candidate manufacturers will itemize their bids at least as specifically as described in the list below. The candidates may itemize their bids more specifically if they desire to do so.

    - Wire-bond test board cost
    - Setup cost of the GOH manufacturing and testing process
    - Per-piece cost of GOH manufacturing, excluding the chain of inspections, tests and recording of results described in Table 5
    - Per-piece cost of the chain of inspections, tests and recording of results described in Table 5, with bids for four options on the percent of GOH which are subjected to the Vibration, Mechanical Shock and Temperature cycling tests shown in the left column (Inspection, Moderate Tests and Acceptance) of Table 5: 1%, 3%, 5%, 10%
    - Per-piece cost of manufacturing up to 2,000 GOH in excess of the quantity listed in Table 1, according to the full specifications as described in this document, including the inspections, tests and recording of results (for the four options listed in the item above), on a schedule to be agreed

2. The manufacturer should specify the per-piece costs taking note of the fact that only GOH which are "accepted" according to the definition of Section 2 will be paid for.

3. The candidate manufacturers will bid for the manufacturing specifications as described in this document. The candidates may offer additional options or options which are substitutions for specifications presented here if they desire to do so, but not in place of bidding for the specifications as described in this document.