	ATLAS SCT Barrel Module FDR/2001				
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SCT BARREL MODULE Document

SCT Barrel Module:
Module Components Section 5.2: Baseboards

Abstract

This document describes the requirements and details of the thermo-mechanical baseboard that forms part of the SCT Barrel Module. The assembly processes are explained and reviews given of the components and product specifications. The methods of achieving both component assurance and baseboard quality assurance are described, and finally the production schedule is presented.

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1. SCOPE OF THE DOCUMENT

The document :

- describes the barrel module baseboards and their fundamental requirements,
- explains their assembly procedures,
- gives the technical specifications of their components
- reviews the preparations for pre-series and subsequent series production
- discusses the details of quality assurance procedures
- briefly considers the role of the baseboard within the construction and performance of a barrel module
- and summarises the future production plans.

2. THE BARREL MODULE BASEBOARD

The baseboard is the central element, sandwiched between two silicon wafers on each of its sides during the module construction. To minimise the overall material within a module the baseboard must have the lowest possible mass, be mechanically rigid, and provide the interface for the module cooling contact. Intrinsically the baseboard must be highly efficient in its thermal transfer capabilities in order to transmit injected heat from both the attached ASIC-hybrid structure and, after some years of running, the leakage currents of the silicon detectors that will arise from radiation damage. The ability to achieve the latter requirement is know as the safety against thermal runaway, as such leakage currents double every 7^{o}C increase in silicon temperature and hence are a potential source of uncontrolled temperature rise. The results of detailed FEA simulations are shown in the documents SCT-BM-FDR-4, and these are compared with experimental data in SCT-BM-FDR-8. The low mass has been achieved by designing a minimal volume baseboard, constructed from customised graphite sheets of very high thermal conductivity, and the overall thermo-mechanical properties and electrical integrity are achieved through the use of new encapsulation processes and graphite-beryllia (BeO) epoxy-fusing techniques that have been developed for this project.

The baseboard substrate is thermalised pyrolytic graphite and is referred to as VHCPG, (very high thermal conductivity pyrolytic graphite), to which are attached BeO facing plates. The VHCPG is an anisotropic material having both mechanical and thermal properties that are basically constant within the plane of a substrate sheet and are significantly different in the orthogonal direction, due to the planar mosaic ordering of the carbon structures. The main features of the 380 ± 15µm thick sheets of VHCPG are: (a) in-plane thermal conductivity typically in the range 1450 W/mK to 1850 W/mK at temperatures around 20°C, and increasing by 0.4% for each degree lower in temperature it is operated, and (b) a transverse thermal conductivity of typically 6 W/mK. Although the VHCPG material is intrinsically extremely friable, electrically conducting, and easily delaminated the encapsulation techniques developed in this project provide a baseboard with the necessary robustness and one which is easily handled in the module construction process. The attached BeO facings have a thermal conductivity greater than 280 W/mK at 20°C and consist of at least 99.5% beryllium oxide with a minimum density of 2.86 gm/cc. They are 250 ± 10µm thick, having precision holes and edges created by laser machining and with metallised electrical contact pads 13 ± 5µm thick.

Following successful prototyping of complete baseboard assemblies, and the appropriate Market Surveys, the tenders for both the VHCPG substrates and the BeO facings have been issued. The Tender document for VHCPG substrates and the Technical Specifications for both items are included as appendices 1, 2 and 3 to this Section 5.2 of the SCT-BM-FDR

3. BASEBOARD ASSEMBLY

A picture of an assembled baseboard is given in Figure 1 showing the dark profiled epoxy-coated VHCPG substrate and the light-coloured BeO facings of the upper-side. Similar BeO facings exist on the lower-side of the baseboard, and are inclined by 40mr with respect to those on the upper surface. The technical drawings of the VHCPG-BeO assembly are also shown in Figure 2. The baseboard fabrication, which is carried out at CERN with customised equipment and facilities in a dedicated laboratory, consists of the following operations:

- Initially a square plate, 100mm by 100mm, of VHCPG is profiled both externally and internally by laser cutting to the shape specified in the technical drawing. A fine matrix of 120µm diameter holes is also made within the body of the substrate as an integral feature of the encapsulation technique. The hole area amounts to less than 2% of the total baseboard surface.

- The relative positioning of the four BeO facing plates and the profiled VHCPG plate is then provided by a set of precision jigs and templates, with the appropriate quantity of epoxy being applied by screen printing to each side of the substrate board. The whole assembly is then cured under an appropriate cycle of temperature, pressure and surrounding vacuum to achieve a bubble-free epoxy coating and graphite-BeO intra-surface junction. The encapsulation is typically 20µm thick.

- Four small disks of epoxy are removed from each side of each baseboard, in a dedicated machining process with a diamond tipped tool, to provide openings for electrical conducting epoxy contacts to be made to the rear side of the silicon detectors in the subsequent stages of module construction. This complements the drilled and filled holes in the upper BeO cooling facing which provide direct high voltage electrical contact from the metallised pad on the upper cooled facing to the conducting graphite of the baseboard substrate.

- The completed baseboards are then checked visually for mechanical integrity, and thermal performance is monitored by a dedicated thermal imaging testing procedure before devices are individually packaged and dispatched to module construction centres.

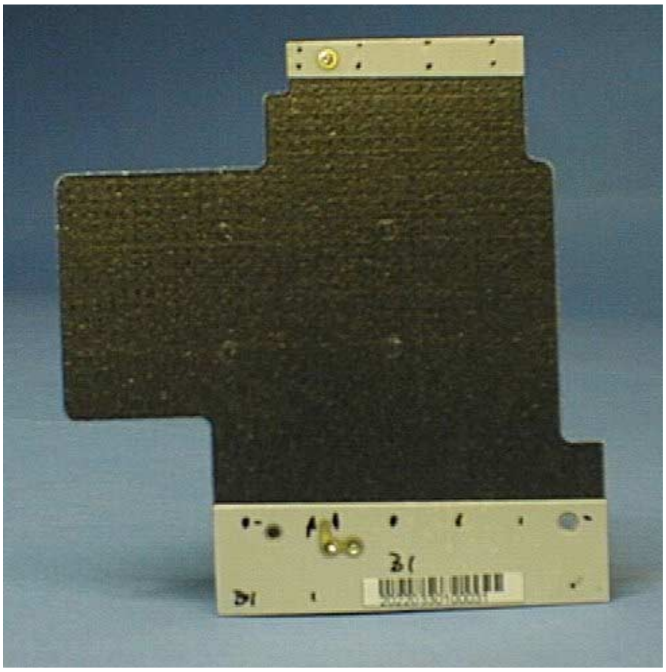

Figure 1. Encapsulated VHCPG baseboard with BeO facing plates

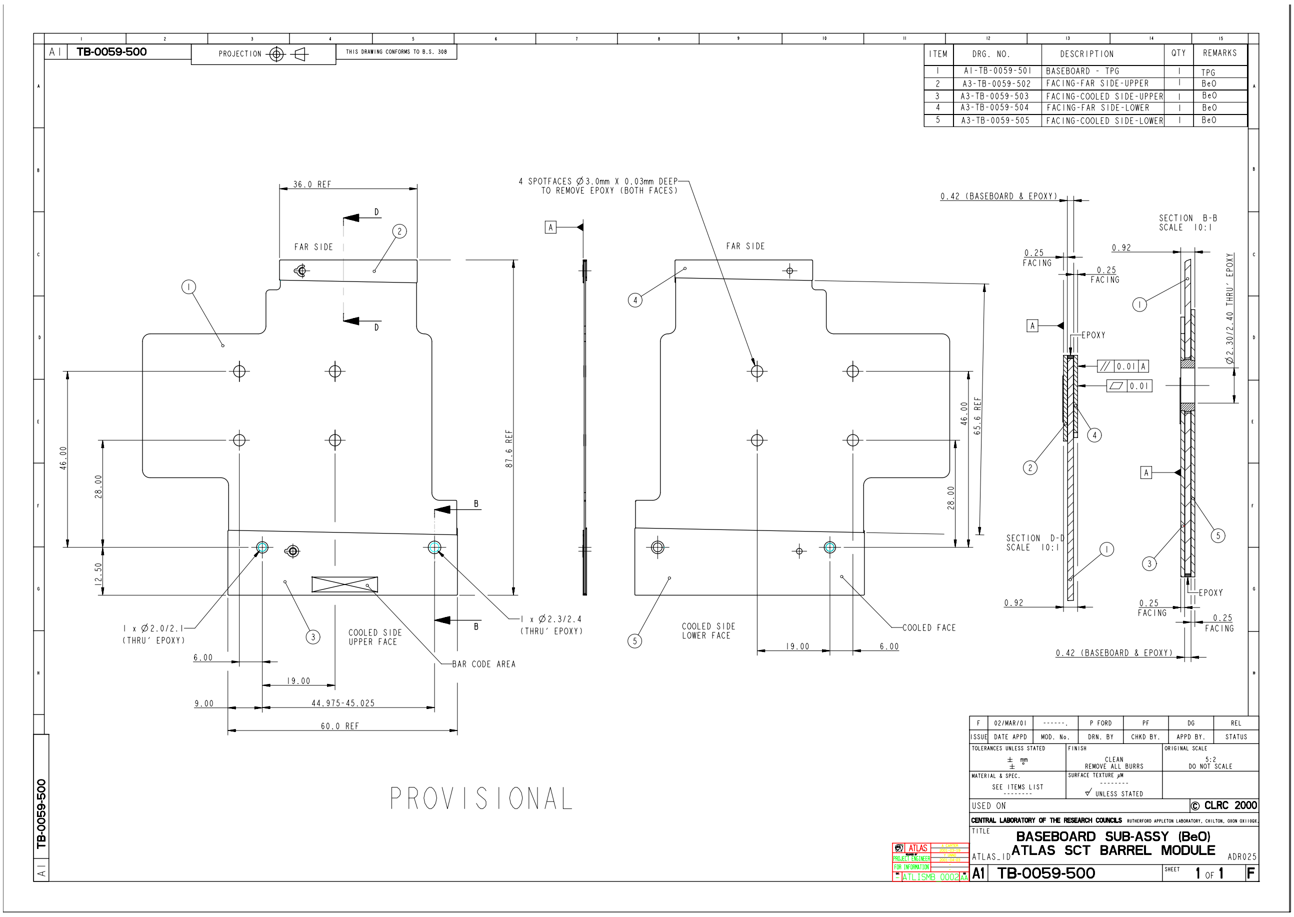

Figure 2. Baseboard Assembly Drawing

4. COMPONENT SPECIFICATIONS AND ASSURANCE

The quality assurance requirements and procedures for the component beryllia facings and for the pyrolytic graphite substrates are addressed in detail in the appended documents that have been prepared within the tendering processes.

4.1 The Beryllia Facing Plates

The geometrical specifications are given in Appendix 3. All the BeO facings are inspected visually and samples are checked for their dimensions by direct measurements before use. Trial insertions will also be made in the high precision fabrication templates. Sample testing of bondability to the gold HV contact pads will also be made from each delivered batch. During the series construction phase sets of the four facings necessary for making an individual assembly will be pre-selected and associated with each VHCPG profiled substrate prior to the fabrication step.

4.2 The VHCPG Substrates

The geometrical and thermal specifications are given in Appendix 2. The thermal and mechanical properties of sample substrates have been extensively studied over the last three years, with the necessary dedicated equipment having been designed and built specially for this project. The thermal conductivity has been measured both in-plane and transverse to verify the material properties, and such measurements, with absolute precision of better than ±3%, will be made on sample sheets from each delivered batch during series production. The mechanical moduli have been measured with a customised tensiometer designed for such anisotropic friable materials. During the R&D and prototyping phases a significant database of geometrical measurements has been acquired for initial VHCPG sheets and fabricated baseboards. This has been used to define the specification of the VHCPG material for use in series module construction. The bare substrates will be 380 ± 15µm in mean thickness and the preferred tender option is for none to have internal thickness variations above 20µm within a given plate. If a 30µm variation for some sheets needs to be accepted on cost grounds a well-defined production technique has been demonstrated to cope with it at the screen printing stage(see section 3). The pre-series will give a further 200 sample of correlated component-baseboard measurements to aid the optimisation of production yield for the series production. The silicon detectors themselves are bowed at the level of 60µm to 80µm and predominantly control and intrinsically limit the module flatness. However, as has been shown in baseboard and module prototyping, the flatness of both the board and the module can be adequately controlled using the accepted component specifications. Full metrology will be carried out on each completed module during SCT Barrel Module production to facilitate initial track reconstruction.

5. THE PRODUCTION PROCESS AND QUALITY ASSURANCE

During the prototyping phase all uncut VHCPG sheets have been measured for thickness and flatness at RAL prior to profiling at CERN. As is shown in the tender documents an option is presented for substrate suppliers to carry out all acceptance measurements at their source, and this is our preferred solution for series production. However, if necessary such acceptance measurements will be carried out at CERN by the SCT, where there is production capability for fabricating at least 16 baseboards per day. This will allow the scheduled production target of 200 baseboards per month to be achieved for the 12 to 15 month series production phase.

Each completed baseboard will be subject to a quality assurance of its thermal performance and electrical contact-continuity at CERN. The electrical continuity will be checked by direct measurements between the contact pads on the beryllia facings and the HV openings on both sides of the central baseboard area. Thermal measurements will be provided be injecting known heat sources at well defined points around the board, and having a controlled heat sink attached to the lower cooling face, while measuring the thermal contours of the structure with an infra-red thermal imaging camera. The form of the necessary equipment, that is now being prototyped, is illustrated in Figure 3, and the nature of the recorded thermal contour data that will be stored for each board is shown in Figure 4. Data for each board will be recorded, and stored in a database for comparison with both standard images and with FEA simulations.

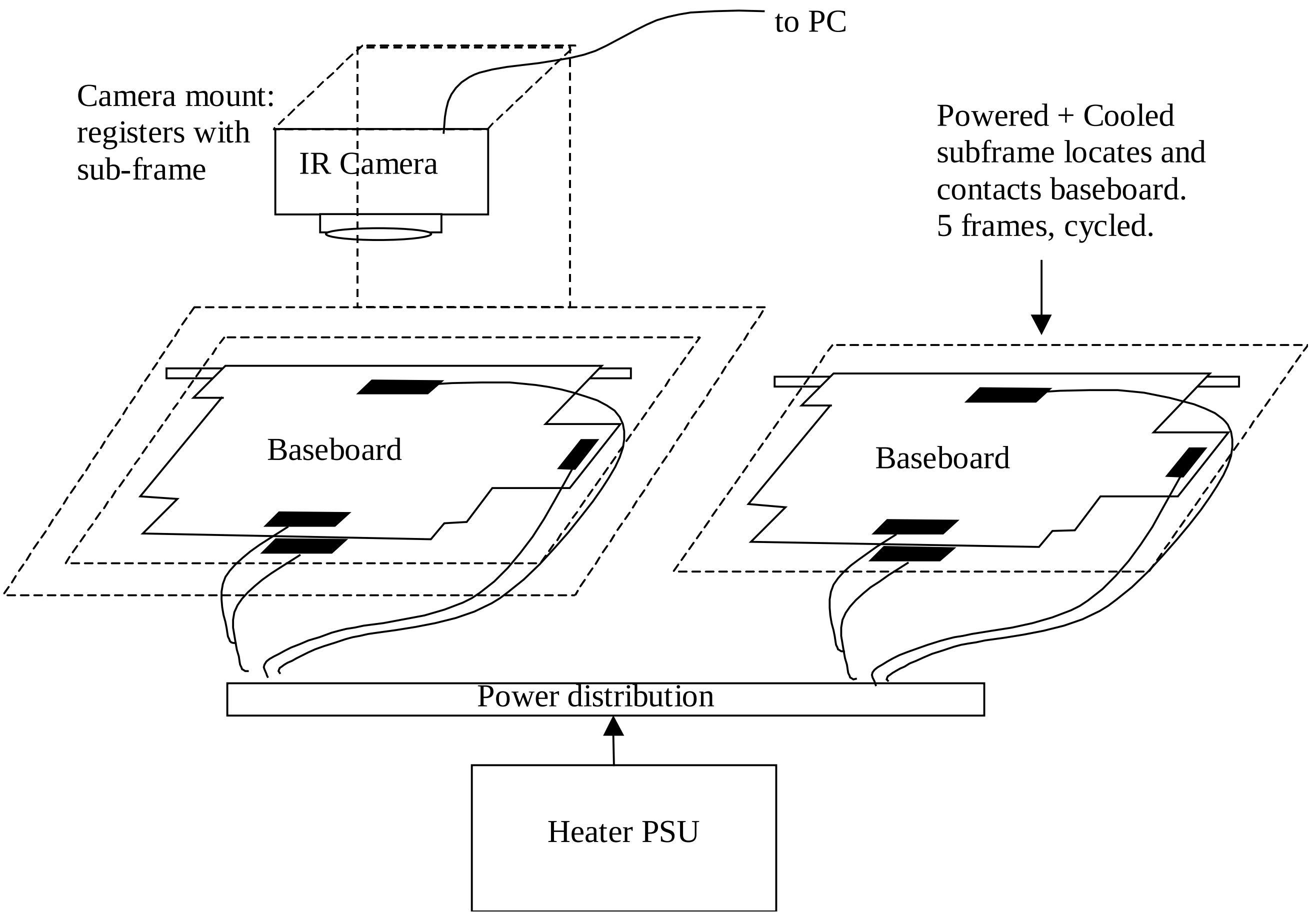

Figure 3. The layout of the IR camera and multi-baseboard support scheme for the thermal QA.

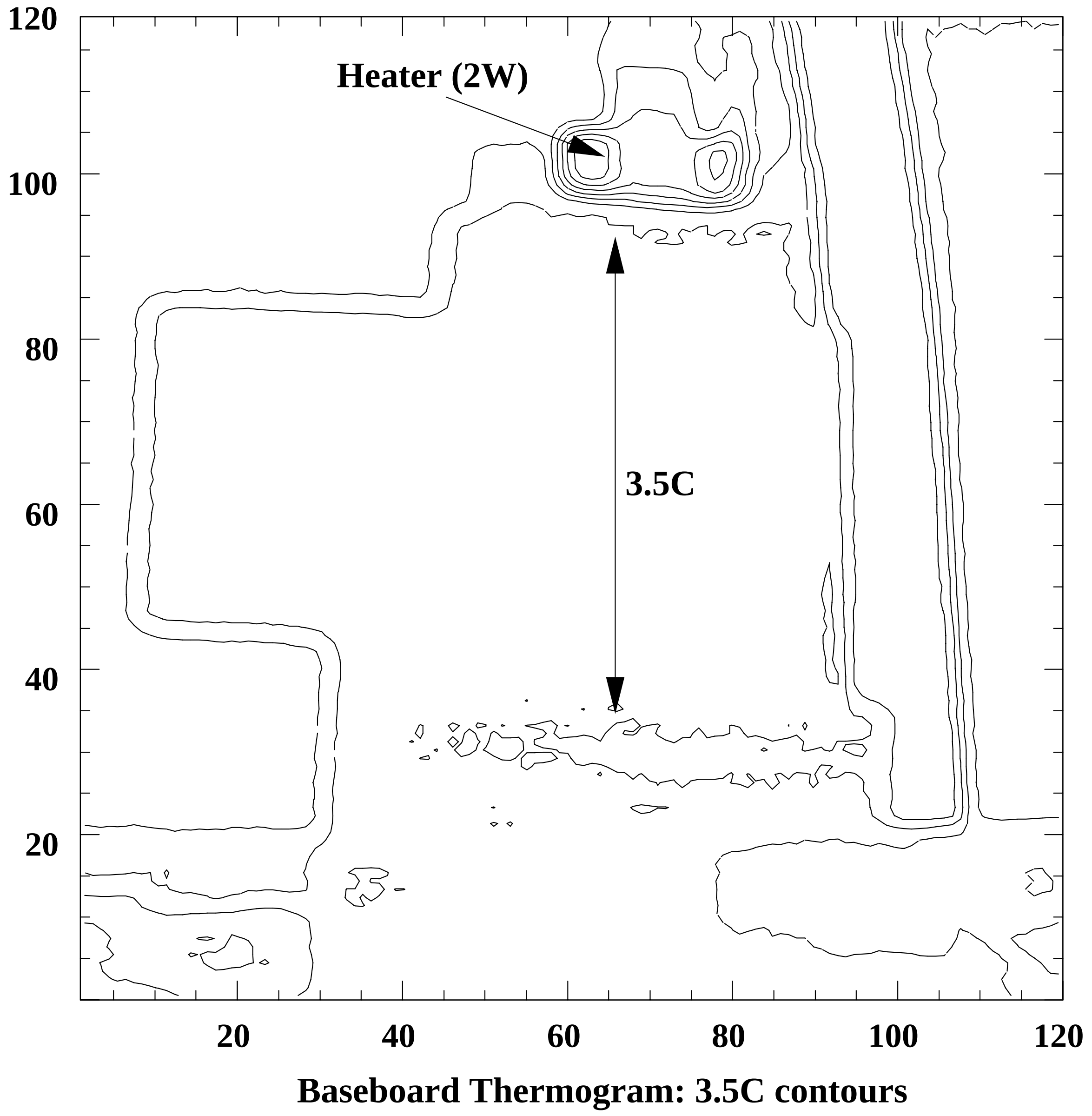

Figure 4. Thermal contour from the IR image of a baseboard.

Each board is given a bar-coded identity from the SCT database and is finally inspected visually before packaging. During the pre-series production each baseboard will be shipped to RAL where a three dimensional profile will be measured with a Smartscope, in order to monitor and record the overall geometrical properties of the baseboards. Figure 5 shows the measured flatness properties of a baseboard that has recently been fabricated.

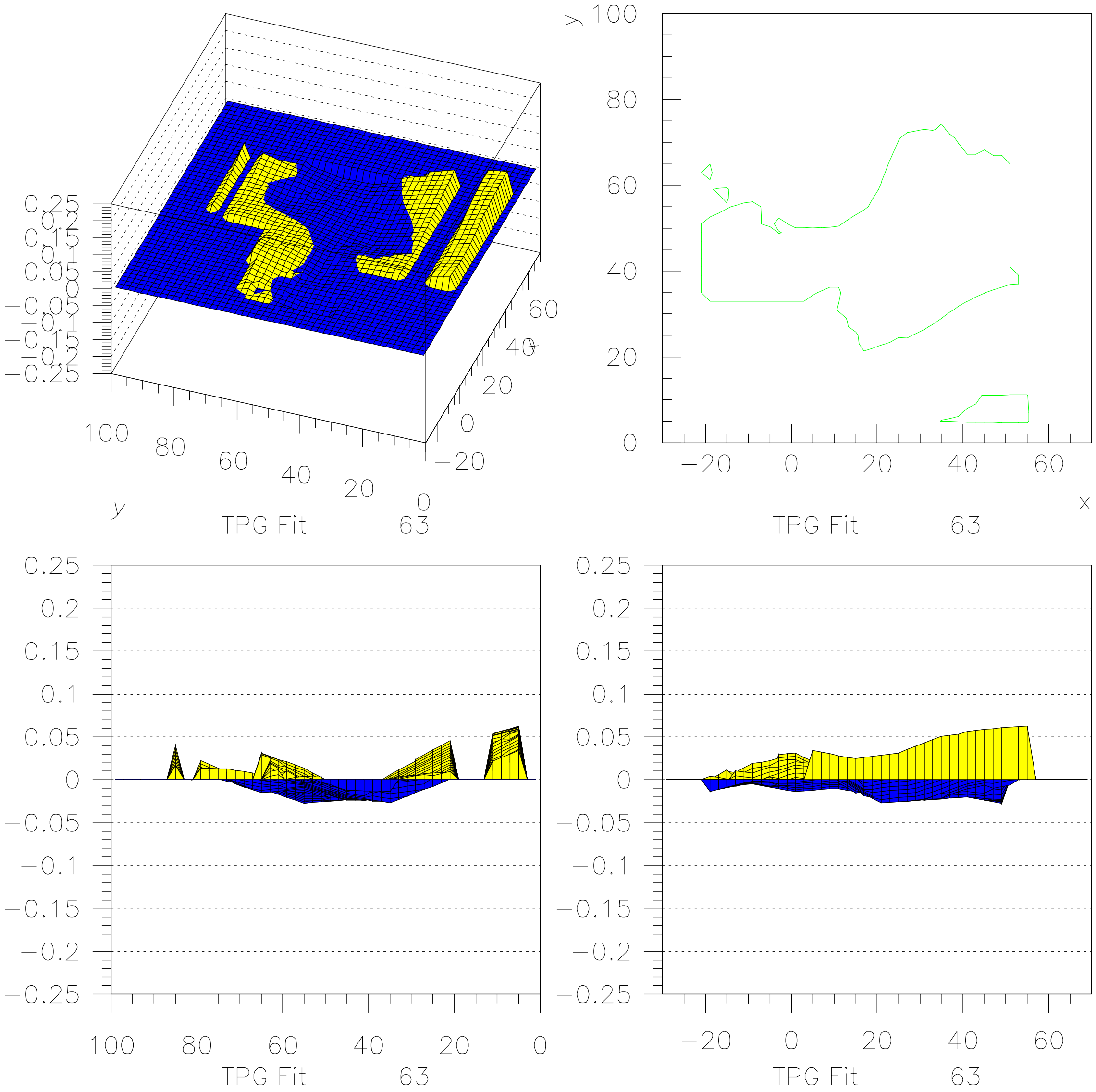

Figure 5 Baseboard flatness profile, contour and orthogonal projections. In-plane dimensions (xy) are cm and out of plane dimensions (z) are mm.

6. THE PRODUCTION SCHEDULE

The fabrication facility is now commissioned and can be brought into full production during the next two months, during which period the final thermal quality assurance instrumentation will be commissioned. The orders for both the beryllia facing plates and the VHCPG substrates are expected to be placed by the beginning of June 2001 and the projected baseboard production schedule is as follows:

- Pre-series fabrication of 200 baseboards begins in August 2001 and following provisional acceptance of the BeO facings and the VHCPG by September 2001 it is aimed to be completed by mid-October 2001
- The initial series batch of 200 baseboards will begin in November 2001 and be completed in December 2001
- The fabrication and dispatch of the 2,400 baseboards will be complete by the end of November 2002.