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SCT Barrel Module Document

Appendix 2 to SCT-BM-FDR-6

Assembly Jigs & Procedures for the Japanese Cluster

abstract

This document describes the procedures of the barrel module assembly and the jigs as developed for the Japanese Cluster

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Distribution List

Module assembly jigs and assembly steps of the barrel modules

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Abstract

The second version module assembly jigs are developed at KEK by feeding back the experience and issues identified in the first jigs. An overview of the second version jigs, in comparison with the first ones, is presented, followed by descriptions of the assembly station, individual jigs, and step-by-step assembly process.

I. INTRODUCTION

During the fabrication of first version of module assembly jigs and building more than five precision mechanical module, we have gained experience and insights into the jigs and assembly steps. These first version assembly jigs and the precision of assembled mechanical modules were reported in the SCT weeks in Nov. 1998 [1] and Feb. 1999 [2]. Having feedback from these results and experience, we have developed a new set of assembly jigs, the second version. This note describes the new set of module assembly jigs and assembly steps.

Although the full module assembly includes the assembly of hybrid on the baseboard and wire-bondings, this note describes the fabrication jigs which requires precision, i.e, aligning the detectors, in plane and back-to-back, and to the dowel holes in the baseboard. The hybrid alignment and wire-bondings are much less stringent in precision than these detector and dowel alignment.

II. ASSEMBLY JIGS

A. Feedback from the first version assembly jigs

The first version module assembly jigs were developed in the process of evaluating, improving, and simplifying the Rutherford jigs. The first version jigs fabricated the detector-baseboard units with a precision less than about 4μm. Although the precision was within the tolerance of the module [3], the observations were

1. linear bearings-pins introduced 2 to 5 μm errors due to elastic deformation,
2. location of the linear bearings-pins introduced displacement not only in angle but also alignment between the top and the bottom detectors, i.e., back-to-back alignment, due to the lever-arm if there was moment to the top or bottom transfer plates when they were mated,
3. removing the baseboard from the fixed dowel pin was difficult because the dowel pins and holes were made without play,
4. aligning detectors in plane could be made easier if the axis of transfer plates is pre-rotated by 20 mrad, leaving the detectors aligned in one direction, x-axis, which, then requiring small correction in rotation and in the translation in transverse to the strip direction, y-axis.

These issues requested usage of the jigs with great attention. The concept of 1st assembly station is shown in the figure in the appendix.

B. Overview of the second version jigs

Consideration to the issues in the first version jigs has lead to a design of the second version jigs. A conceptual view of the second jigs is shown in Figure 1. The collection of the second version jigs can be seen in Figure 2. The modifications to the first version jigs are

1. location of the linear bearings-pins is moved to the ends of the detectors in the strip direction and in the centre axis of the detectors, in order to have a larger separation of two bearings-pins and a shorter distance to the detector's side-edges, which reduces the influence of the elastic move of the pins,
2. the axis of the linear bearings-pins is rotated 20 mrad to the x-axis of the rotation-translation and the main translation stages,
3. the dowel pins are made movable by using linear bearings-pins, so that the pins can be moved down when the baseboard is taken out of the jig,
4. introducing a master gauge which defines the location of the master pins and the dowel-pins, from which the locations of linear bearings in associated jigs are copied, even to the multiple sets of jigs required for parallel operation of module assembly,
5. introducing a detector pre-alignment fixture, which eases the detector handling in an open space, simplifies the top table of the rotation stage which allows to make the assembly station concise,
6. use of disposable clean-room paper, which is porous enough to transmit vacuum, on the surface of the jigs where a detector touches, which is a common practice in a detector vendor.

The rotation-translation stage of the assembly station is shown in Figure 3, where detectors are vacuum-chucked on the rotation tables. Descriptions of the jigs are given in the next section. Most part of the jigs are made of an aluminium alloy, except the master gauge which is made of a steel alloy.

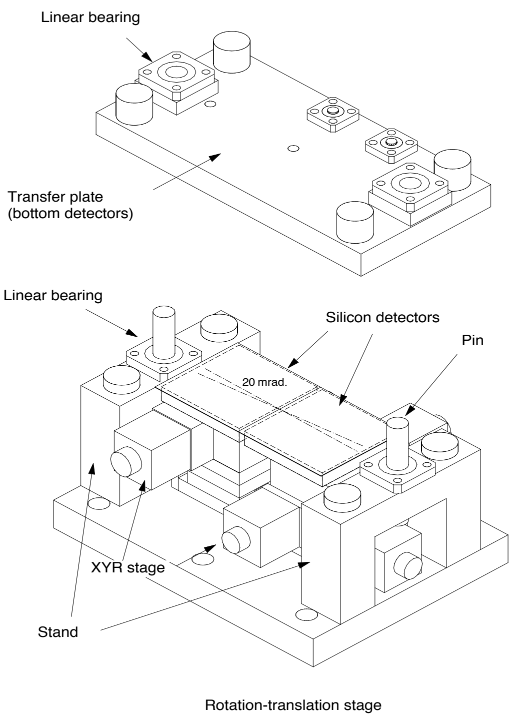

Figure 1: Conceptual view of the second version module assembly jigs

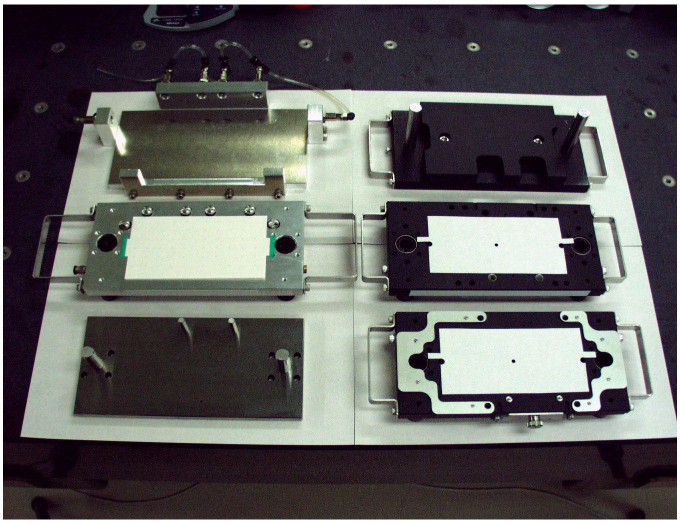

Figure 2: Overview of the second version barrel module assembly jigs: Master gauge (bottom-left), Detector pre-alignment fixture (top-left), Bottom fixture (top-right), Bottom detector transfer plate (bottom-right), and Top detector transfer plate (middle-right)

C. Jig description

1) Assembly station

An overview of the assembly station is shown in Figure 4, where the main components are a microscope-based rotation-translation stage and a video screen to display the view of the microscope. The assembly station is made of two blocks of stages: the main xy stage, X0 and Y0, and a pair of rotation-translation stages, (x1,y1, θ1) and (x2, y2, θ2). The sequence of the motion stages are, from the top,

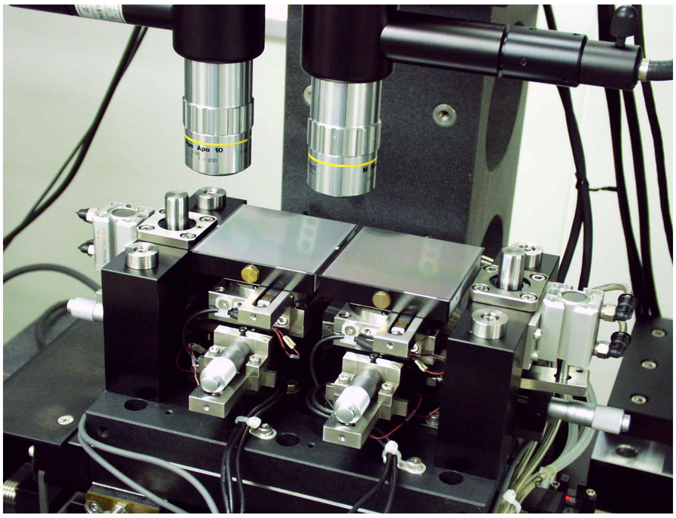

Figure 3: Rotation-translation stage in the assembly station

1. θ1 and θ2 -- rotation stages of two detectors, programme driven,
2. x1 and x2 -- small x-axis translation stage, programme driven,
3. y1 and y2 -- small y-axis translation stage, programme driven,
4. Y0-- main y-axis translation stage, programme driven,
5. X0-- main x-axis translation stage, programme driven.

The main xy stage and the microscope unit can be any of existing equipment as long as the precision fulfils requirement. The small rotation-translation stage is a specific for the detector-baseboard alignment purpose.

The rotation-translation stage of the assembly station has linear bearings for holding master pins for the detector transfer plates. The axis of the linear bearings is rotated 20 mrad to the x-axis of the rotation-translation stage and of the main xy stage. The setting of the 20 mrad axis is described in the section of rotation-translation stage setting.

2) Master gauge

One of the major issue in the assembly jig is to make identical copies. Since the required tolerance is less than an order of 5 μm, it is very costly if all the jigs are machined individually to the accuracy. A simple and economical method is to make a precision master gauge and adjust parts of associated jigs to mate the gauge. This copying of the master gauge is made possible with the use of flange-type linear bearings. The flange of the linear bearing is fixed in the associated jigs after mating the pins of the master gauge.

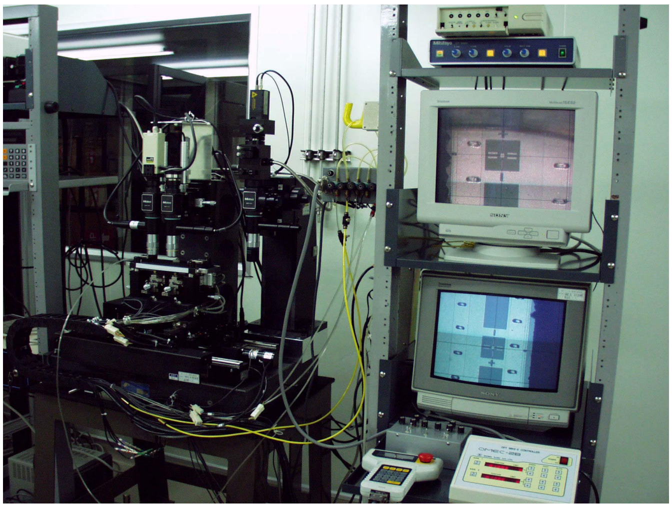

Figure 4: Overview of the barrel module assembly station. The left screen displays the centre fiducial mark of the barrel detector which is being set on the rotation-translation stage of the assembly station.

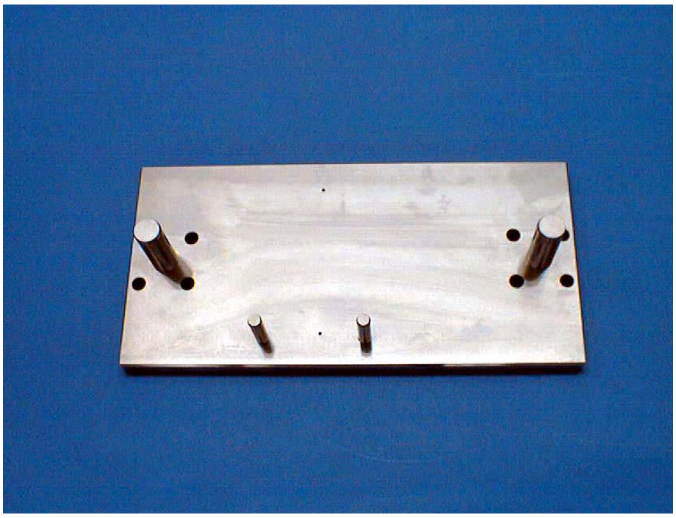

Figure 5: Master gauge. The large two pins are for the detector alignment and the small two pins are for the dowel hole and slot alignment.

The master gauge of the second version jigs is shown in Figure 5. There are two master pins for detector alignment and two small pins for the dowel holes in the baseboard. These master and small pins are made by planting a thicker pins and machining to a diameter a few microns thicker than the diameter of the mating linear bearings. The machining ensures the diameters and the normality of pins. Around the master pins there are four holes so that the screws of the flanges can be fixed through the master gauge when fitted. The gauge is made of a steel-alloy.

Ideally, the axis of the master pins will be the centre line of the module and the module centre will be defined from the location of the dowel pins. Critical dimensions are, as shown in Figure 6,

1. parallelism of the master and the small pins,
2. distance between the axes of the master and dowel pins.

Any offsets from the above can be corrected, but, introduces complexity in the aligning the detectors in the assembly station.

3) Detector pre-alignment fixture

The detector pre-aligning is required so that the centre of the rotation stage is at the centre of the detector in order to separate the movement in translation and in rotation. In the first version jigs, the alignment pins were planted on the rotation table. There were two issues in the step of the pre-alignment:

1. it was possible to work on placing the detectors on the rotation tables in the assembly station, but was awkward because of other objects such as the microscope,
2. the alignment pins chip the detector edge when the detectors are transferred out of the table.

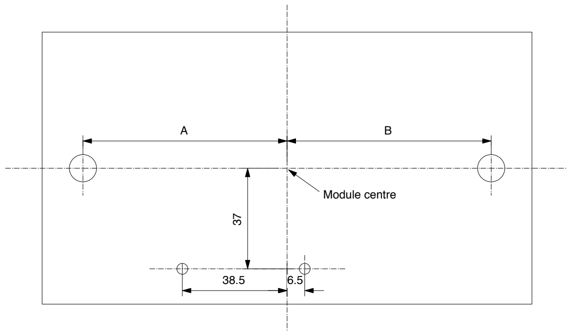

Figure 6: Critical dimensions of the Master gauge. The exact values of "A" and "B" are not critical but the module centre must be known within a required precision.

In order to solve these issues, a detector pre-alignment fixture, shown in Figure 7, is designed, which allows

1. placing the detectors in a separate open space and being able to work simultaneously with precision alignment in the assembly station,
2. alignment pins to be retracted off from the detectors once the detectors are vacuum-chucked to the fixture.

The two master pins in the fixture are pins inserted to linear bearings in the fixture The locations of the linear bearings are copied from the master gauge, although a full precision is not required in these pins.

The surface protection of the detectors and the fixture is made by using a clean-room paper which will be disposed every time when new detectors are placed. The clean-room paper is porous enough to transmit vacuum in order to vacuum-chuck detectors. The use of this clean-room paper for the surface protection is a common practice in testing detectors in a detector vendor.

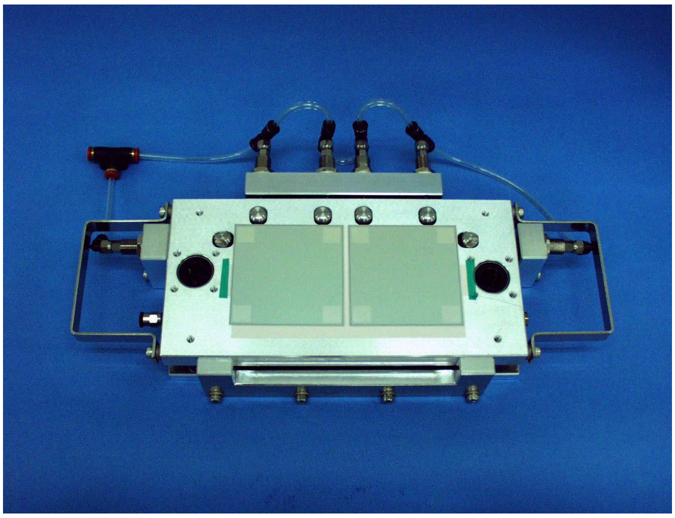

Figure 7: Detectors pre-alignment fixture. The white section is a disposable clean paper. The detector alignment pins will be retracted after the detectors are vacuum-chucked to the fixture.

4) Bottom fixture

Stacking is the concept of the module assembly jigs: from the bottom, the bottom detectors, the baseboard, and the top detectors. The detectors are aligned and vacuum-chucked in transfer plates. In order to stack the transfer plates, a base plate called the Bottom fixture, is designed to hold the master pins and to make clearance for the flanges of the linear bearings of the Bottom-detector transfer plate. The Bottom detector transfer plate itself is described in the next section. The fixture is shown in Figure 8. No critical accuracy is required to the location of the master pins which are being held loosely in the fixture.

5) Bottom detector transfer plate

There are two detector transfer plates. One is for the bottom detectors and the other for the top detectors. The bottom detector transfer plate is shown in Figure 9. The transfer plate carries the master linear bearings which are hidden with the frame-spacer, the dowel pins, with which the baseboard is aligned to the detectors, and a frame-spacer, which defines the thickness of the detector-baseboard unit, surrounding the detector chucking area.

The shiny metal frame is the frame-spacer, which has cutouts for the detectors, the master pins, and the dowel pins. The linear bearings for the master pins are hidden under the frame-spacer. The dowel pins are pins inserted in the linear bearings. The heads of a thicker pins are machined to be the diameter of the dowel screws of the module mounting. The dowel pins are movable, being able to be pushed down, with a metal plate seen in the edge of the jig, connected to the pins. This helps removing the baseboard from the dowel pins since the dowel pins and the dowel holes in the baseboard are designed without play.

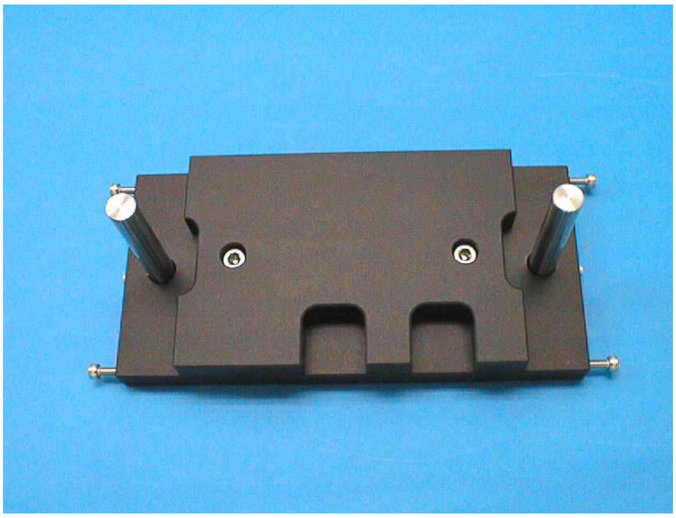

Figure 8: Bottom fixture. A simple pedestal fixture making clearance for the heads of the linear bearings and holding the master pins.

The detector area is covered with the disposable clean-room paper for detector protection. The jig and the clean-room paper have holes along the centre line of the module in order to inspect the location of the fiducial marks from the back after vacuum-chucking the detectors. The thickness uniformity of the clean-room paper is important because the thickness must be counted into the thickness of the frame-spacer. A measurement has shown the uniformity is good. In addition, the thickness can be monitored by sampling the lots.

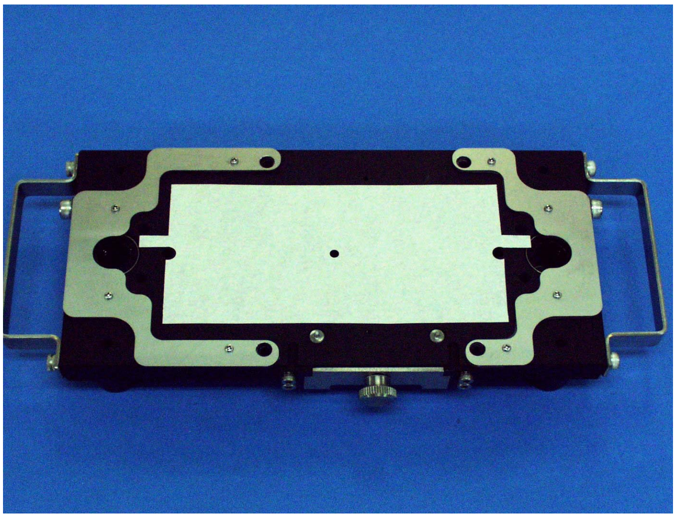

Figure 9: Bottom detector transfer plate. The shiny metal frame is a spacer defining the module thickness, i.e., the distance between the surfaces of the top and the bottom detectors sandwiching the baseboard. The white centre piece is a disposable clean-room paper. The two pins at the bottom-centre is the dowel pins for the dowel holes of the baseboard.

6) Top detectors transfer plate

A pair to the bottom detector transfer plate is the top detector transfer plate, shown in Figure 10. The jig is basically the same as the bottom detector transfer plate, except the dowel pins, for which female holes are machined in the mirror positions. The linear bearings of the master pins are visible in the jig. The frame-spacer can be attached to the top detector transfer plate as well.

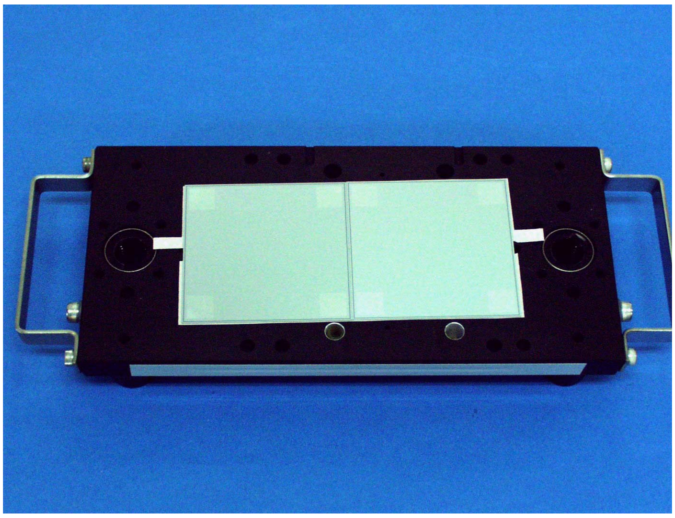

Figure 10: Top detectors transfer plate. The white piece is a disposable clean paper.

7) Glue dispensing machine

The detectors and the baseboard are glued with a room-temperature curing epoxy glue, e.g., Araldite 2011, with a Boron-Nitride filler to help thermal conductivity. The epoxy glue is applied to the both sides of the baseboard with pre-defined amount to ensure the glue thickness. The application is made with a glue dispensing machine which is a combination of a xyz stage and a glue dispensing unit. Use of a glue dispensing machine is a clean way of applying glues, by touching the baseboard only when it is placed and removed from the machine.

Since the glue hardenes in several hours in the room temperature, the viscosity of the glue changes in time, and, in addition, after several hours the glue has to be disposed. An economical glue dispensing is to use a disposable syringe, which is driven by pressure. The change of the viscosity can be compensated by changing the pressure, which is effective for applying dot patterns, and/or changing the speed of head movement, effective for applying line patterns

A machine being used at KEK is shown in Figure 11, which has capability of programming pressure in time [4]. Empirical pressure adjustment curve is shown in Figure 12 for the Araldite 2011 with BN filler in compensating the change of viscosity. The variation of dispensed amount is less than 5% even after one hour from the mixing.

Figure 11: Glue dispensing system which is made of (1) a xyz stage where the baseboard is on the xy stage and a glue-syringe is attached on the z-axis, and (2) a dispensing controller.

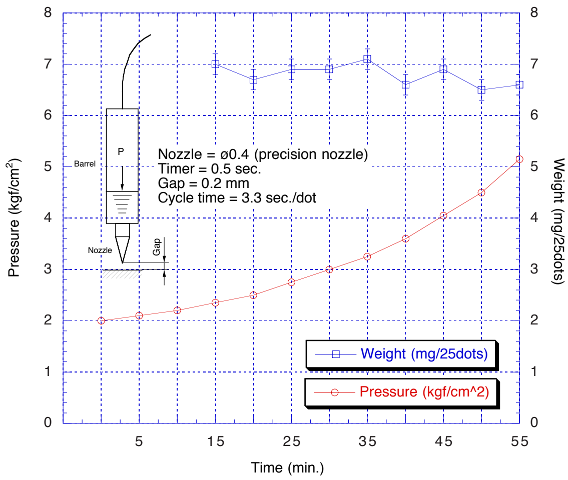

Figure 12: Pressure compensating the change of viscosity of the Araldite 2011 with BN filler (circle) and the weight of dispensed glue in 25 dots (square)

D. Copying the Master gauge

1) Rotation-translation stage

The rotation-translation stage aligning the detectors will have the master pins to which the transfer plates are slided down. The location of the master pins is copied from the master gauge by adjusting the location of the linear bearings of the rotation-translation stage, as shown in Figure 13. Separate master pins, which diameters are measured to match the master pin of the master gauge, are, then, inserted into the linear bearings of the rotation-translation stage.

The location of the linear bearings is at 20 mrad rotation to

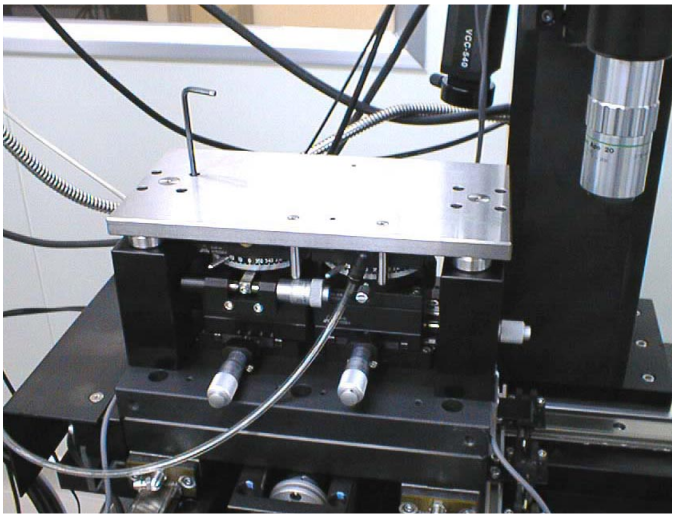

Figure 13: Copying the master pin locations to the linear bearings of the rotation-translation stage from the master gauge

the x-axis, but imperfect because of the required play for the process of copying the master gauge.

2) Transfer plates

The locations of the master (and small) pins of the master gauge are copied to the bottom detector transfer plate by sliding in the transfer plate on to the master gauge and fixing the flanges of the linear bearings. The mating of the master gauge and the bottom detector transfer plate is shown in Figure 14. The similar process is repeated to the top detector transfer plate to copy the master gauge.

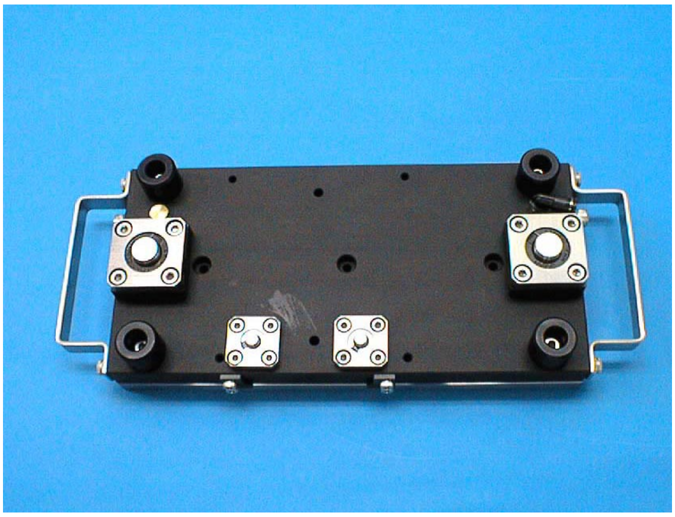

Figure 14: Copying the pin locations from the master gauge to the bottom detectors transfer plate for both the detector and the dowel linear bearings

E. Rotation-translation stage setting

In order to ease the aligning of the detectors, the axis of the master pins of the rotation-translation stage is rotated 20 mrad to the x-axis of the x-translation stages, x1 and x2. With the rotation, if perfect, the detectors, which must be rotated 20 mrad to the module centre line, i.e., the axis of the master pins, is aligned along the x-axis of the stages, as shown in Figure 15. The detectors, then, require only a small correction in the rotation in $\theta 1$ and $\theta 2$ and a small correction in the translation in y2, since the detectors are pre-aligned in the pre-alignment fixture. One remaining relatively large motion is along the x-axis, x2, since a large gap is left between two detectors on the pre-alignment fixture in order to allow a safe operation in the rotation and the y-translation.

The accurate 20 mrad rotation of the axis of the master pins to the x-axis of the main x-translation stage is made by making correction to the unit of rotation-translation stage:

1. the centres of the master pins are obtained by measuring the outer circles of the pins optically,
2. the centres of the pins are referenced to the fiducial marks on the unit of rotation-translation stage,
3. the unit is moved until the fiducial marks are in the preset positions such that the axis of the centres of the master pins is rotated 20 mrad to the x-axis of the main x-translation stage.

The fiducial mark, after setting the rotation-translation stage, is displayed on the video screen in Figure 16. Because of this correction to the rotation-translation stage, there arises a small correlation in the small xy stages, x2 and y2, in the rotation-translation stage, in reality.

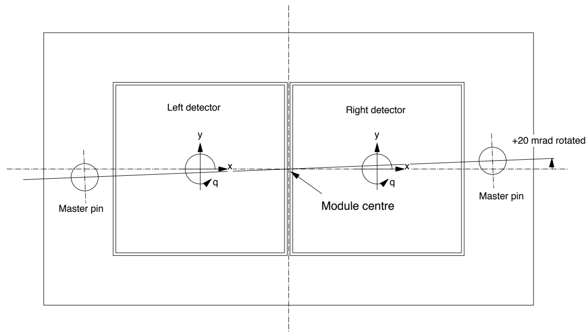

Figure 15: Rotated axis of the master pins in the rotation-translation stage to make the move of the detectors minimum

III. Assembly steps

The detector-baseboard assembly sequence proceeds in the steps of, pre-aligning detectors, transferring detectors to the rotation-translation stage, aligning detectors in precision, transferring detectors to the transfer plates, placing the baseboard on the bottom detector transfer plate with the bottom detectors vacu-

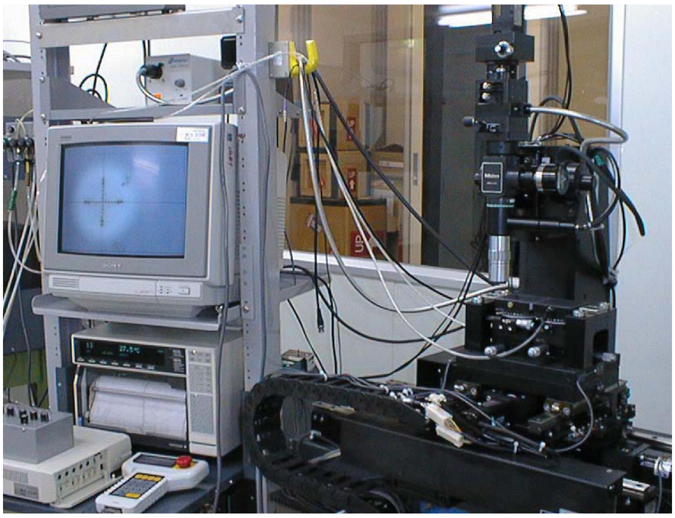

Figure 16: Setting the axis of the master pins of the rotation-translation stage rotated 20 mrad to the x-axis of the main x-stage

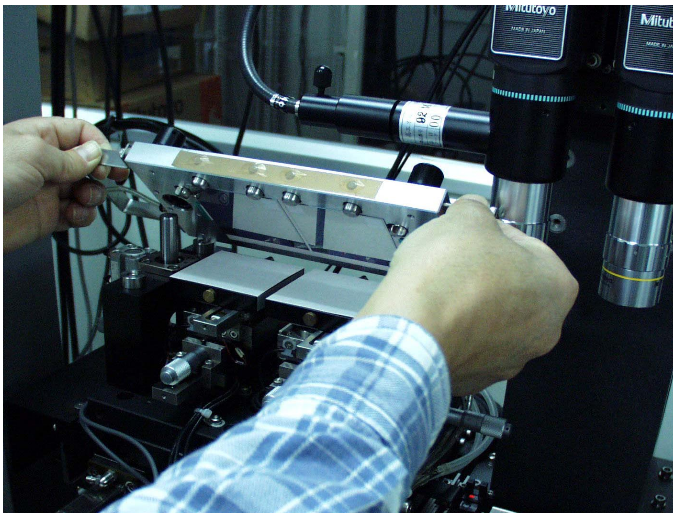

Figure 18: Placing the chucked detectors on the detector pre-alignment fixture to the rotation-translation stage

um-chucked, and mating the top detector transfer plate with top detectors vacuum-chucked.

1) Pre-aligning detectors

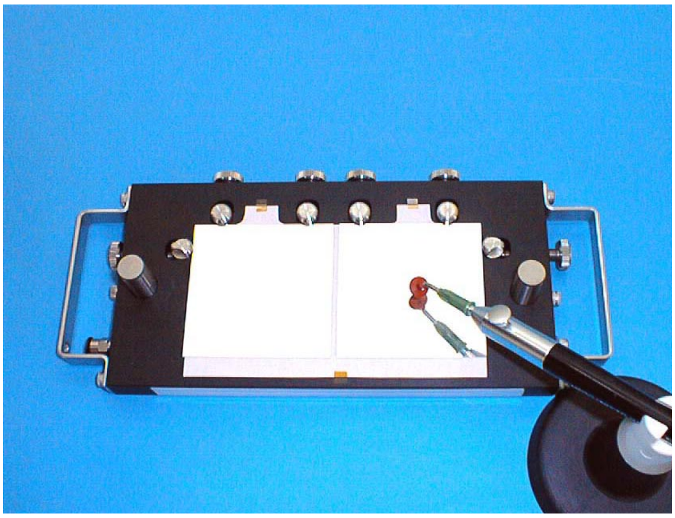

Figure 17: Placing the detectors on the detector pre-alignment fixture. A vacuum picker can be used in holding detectors.

A detector is picked up from the detector envelope with a vacuum picker by chucking the backside of the detector. With the alignment pins pressed to the nominal positions, two detectors are placed to touch the alignment pins at each edge, as shown in Figure 17. Once the detectors are vacuum-chucked to the pre-alignment fixture, the alignment pins are retracted off the detectors to a safe position.

2) Transferring to the rotation-translation stage

The pre-alignment fixture is transferred to the rotation-translation stage while vacuum-chucking the detectors, as shown in Figure 18. A spacer is ensuring such that there is a gap of 10 to 20 μm between the surface of the detectors and the surface of the rotation tables. The detectors are transferred to the rotation table by turning off the vacuum of the pre-alignment fixture and, sequentially, turning on the vacuum of the rotation table. It is not critical in this step, but critical in the precision process, to turn the vacuum off and on sequentially. It is found that when the both vacuum are on, the stages move and there arises random move in the detector position of 5 to 10 μm, due to imperfect flatness or parallelism in the two jigs.

3) Aligning detectors in precision

Two detectors on the rotation-translation stage are aligned in precision by observing the fiducial marks on the detectors, as shown in Figure 19. Since the rotation of the 20 mrad is already taken care of by the axis of the master pins, after small correction in rotation, a move of two detectors in the x-direction with a small correction in y-direction can set the fiducial marks to pre-defined positions, defined from the module centre in the master gauge, relatively in straight-forward way.

4) Transferring to the detector transfer plates

Once the detectors are aligned in precision, the detectors are transferred to the transfer plate. The bottom detector transfer plate being placed on the stage is shown in Figure 20. A gap of 10 to 20 μm is ensured, with a spacer, between the surface of the detectors and the transfer plate. The detectors are transferred by turning the vacuum of the rotation tables off, first, and, then, turning the transfer plate on, sequentially. It is important to confirm the coordinates of the fiducial marks of the detectors, after transferring, viewed through the observation holes, so that there is little move in the transferring.

The bottom detector transfer plate with detectors being vacuum-chucked and placed on the bottom fixture is shown in

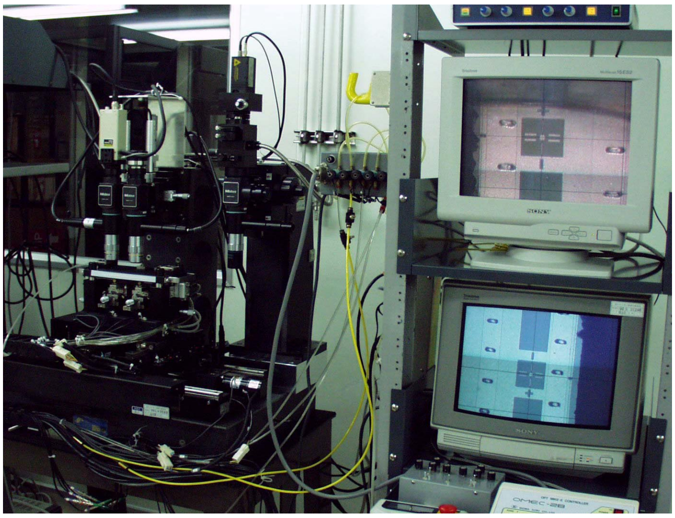

Figure 19: Aligning detectors

Figure 21. The top detectors are also aligned in precision and transferred to the top detector transfer plate

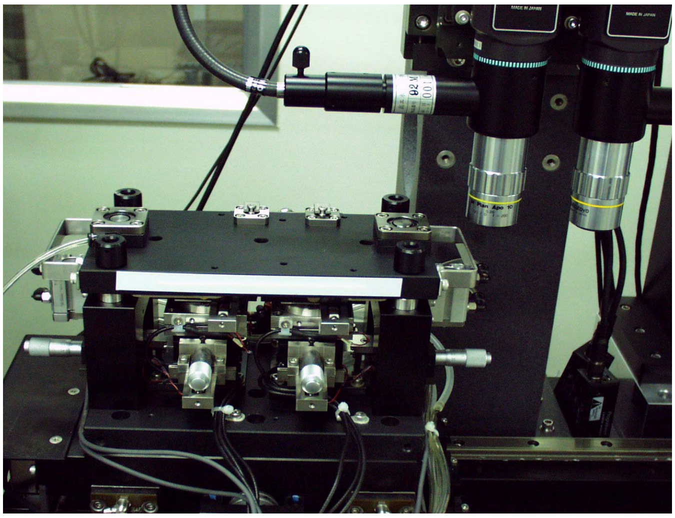

Figure 20: Transferring detectors from the rotation-translation stage to the bottom detector transfer plate. The fiducial marks of the detectors can be seen through the observation holes.

5) Placing baseboard on the bottom detectors transfer plate

In “one-step” gluing, the baseboard is with glues applied in both sides is placed over the bottom detectors on the bottom detector transfer plate, as shown in Figure 22. The alignment of the baseboard is made by using the dowel pins in the transfer plate and the dowel holes in the baseboard.

6) Mating the top and the bottom detectors transfer plates

Immediately after the baseboard is placed on the bottom detector transfer plate, the top detector transfer plate with top detectors being vacuum chucked is slided in, in order to sandwich

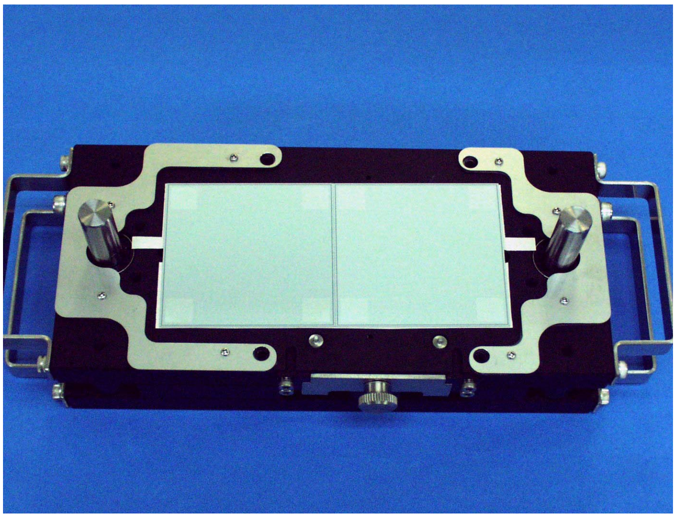

Figure 21: Aligned detectors chucked on the bottom detector transfer plate

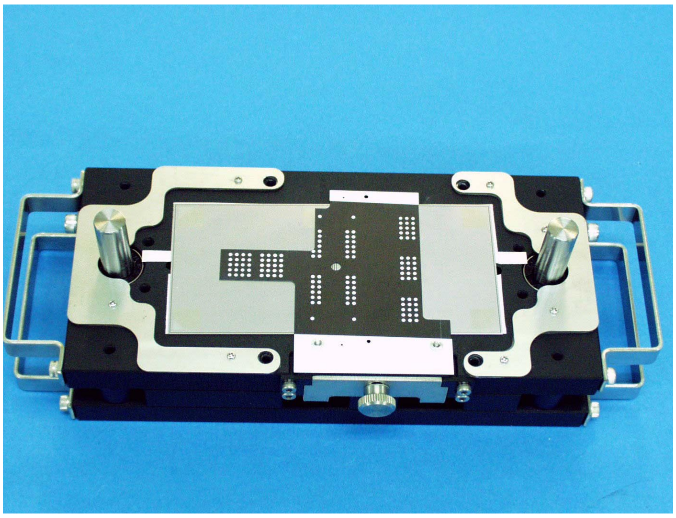

Figure 22: Baseboard is being placed over the bottom detectors. The alignment of the baseboard to the detectors are being made with the use of dowel pins in the bottom detector transfer plate and the dowel holes in the baseboard.. The baseboard and the glue pattern is of the “narrow nose” type. The latest baseboard is of the “wide nose” and the glue pattern has been updated.

the baseboard with the top and the bottom detectors, as shown in Figure 23. The top and the bottom detector transfer plates are, then, pressurized with screws and left in the room temperature for several hours until the glue is cured. The completed detector-baseboard assembly, on the jig, is shown in Fig.xx.

7) Two-step gluing of the assembly

After analysing the assembled modules, the flatness of the module was found to be affected by the deformation in the neck between the facings and the main part. In the “one-step” gluing, the baseboard was constrained, at the facings, so that the loca-

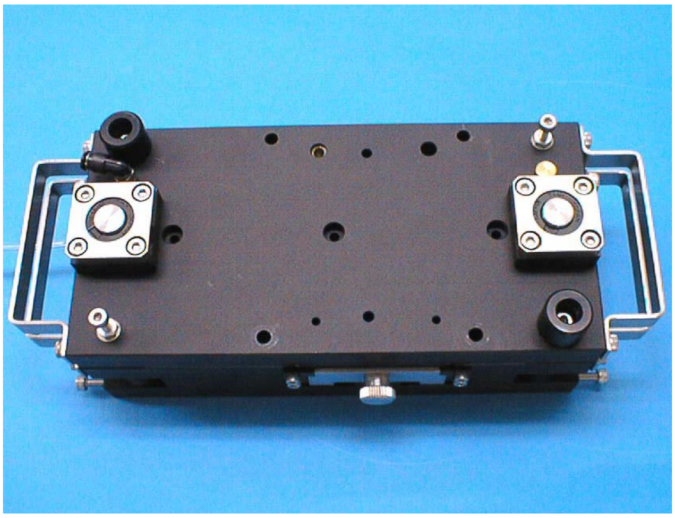

Figure 23: Mating the top detectors and the bottom detectors transfer plates

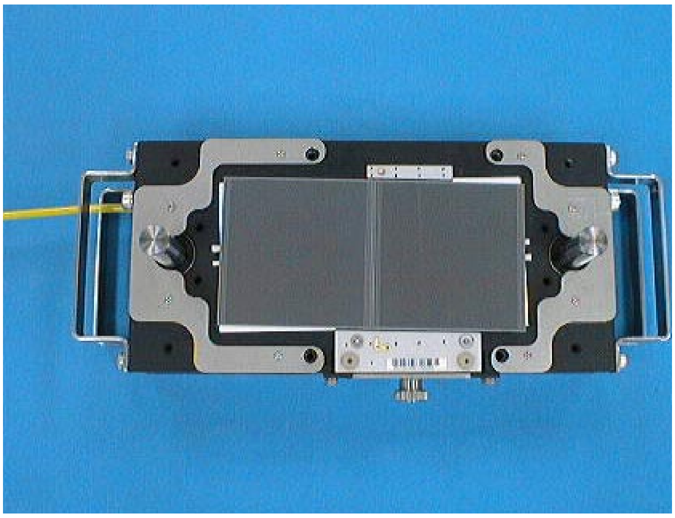

Figure 24: Completed detector-baseboard assembly

tion in height of the baseboard is constrained. This constraint did not work since the viscosity of the glue was much higher than adjusting the glue thickness by the constraint. Instead, the constraint introduced distortion in the neck between the sensor and the facings, which introduced distortions in the flatness of the modules, together.

In order to make the facings free and constrain the baseboard, the baseboard must be held in the main area. This holding the main area of the baseboard with vacuum-chuck transfer plate helps to flatten the baseboard, in addition. Since the glue can not be applied to the vacuum-chucking side, the gluing step is now step-by-step: one side first and then the other side, i.e., "two-step gluing".

In the "two-step gluing", the usage sequence of the transfer plates is reversed. Topside sensors are aligned first, picked up with the top transfer plate, and placed on the bottom fixture. The baseboard is placed on the bottom transfer plate using the dowel pins, vacuum-chucked. Applying the glue on the baseboard, the baseboard is placed over the sensors on top of the top transfer plate and glue is cured. The bottom sensors are aligned and picked up with the bottom transfer plate which is freed from the baseboard, with the dowel pins being recessed. Applying the glue on the baseboard of the baseboard-top sensors assembly still held on the top transfer plate, the bottom transfer plate is mated over the baseboard assembly and the glue is cured.

IV. Summary

A second version of module assembly jigs has been designed and fabricated at KEK by feeding back the experience and the issues found in the first version of the jigs. The major modifications in the second version are the move of the location of the master pins, introduction of the master gauge, the pre-alignment fixture, and the 20 mrad rotation of the axis of the master pins in the rotation-translation stage. Experience of the assembling and the precision of the assembled modules will be reported in a separate document.

V. Appendix

A conceptual view of the first assembly jigs is shown Figure 25

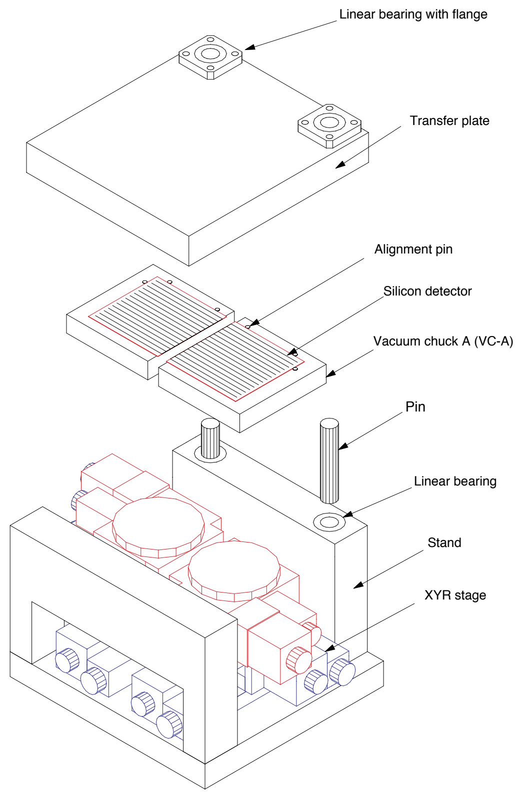

Figure 25: Concept of the first version assembly station and a detector transfer plate

VI. REFERENCES

[1] T. Kohriki et al., "Assembly of precision mechanical modules at KEK", SCT week, Nov., 1998

[2] T. Kohriki et al., "Construction of Barrel Precision Modules", SCT week, Feb., 1999

[3] ATLAS Inner detector technical design report, CERN/LHCC/97-17, ATLAS TDR 5, 30 April 1997, pp 467-470

[4] A pressure-programmable dispenser, ML-808EX, and a xyz stage, SHOTMASTER3, made by MUSASHI engineering, inc. Tokyo, Japan. A similar equipment, ACCURA9 for the dispenser and Ez-ROBO for the xyz stage (an OEM of SONY's ROBOKIDS), is available from IWASHITA engineering, IEI, Tokyo, Japan.