Herschel – SPIRE

OPTICAL ALIGNMENT PLAN

Alignment Procedure - Sequence

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Liste des abréviations

	Signification	Traduction éventuelle
AC	A Confirmer	
AD	A Déterminer	
ADC	Analog to Digital Converter	Convertisseur analogique numérique
BSM	Beam Steering	Miroir d'orientation du faisceau optique
CCAP	Cahier des Clauses Administratives Particulières	
CCTP	Cahier des Clauses Techniques Particulières	
CEA-Sap	Commissariat à l'Energie Atomique – Service d'Astrophysique	
CNES	Centre National d'Etudes Spatiales	
CNRS	Centre National de la Recherche Scientifique	
DA	Document Applicable	
DAC	Digital to Analog Converter	Convertisseur Numérique Analogique
DIL	Dual In Line	
DSP	Digital Signal Processor	Processeur de Signal Numérique
DPU	Data Process Unit	Unité de traitement des données
EPROM	Erasable Programmable Read-Only Memory	Mémoire effaçable programmable en lecture seule
ESA	European Space Agency	Agence Spatiale Européenne
FDP	Carte Fond De Panier	
FPGA	Field Programmable Gate Array	
IFSI	Inst. Di Fiscia dello Spazia Interplanetario	
IID	Instrument Interface Document	Document d'interface de l'instrument
INSUE	Institut National des Sciences de l'Univers et de l'Environnement	
LAM	Laboratoire d'Astrophysique de Marseille	
LVDT	Linear Voltage Differential Transducer	
MAC	Multi Axis Controller	Contrôleur Multi-Axes
MCU	Mechanisms Control Unit	Unité de Contrôle des Mécanismes
MQ	Modèle de Qualification	
MR	Modèle de Rechange	
MV	Modèle de Vol	
PID	Régulation Proportionnelle Intégrale Dérivée	
PROM	Programmable Read-Only Memory	Mémoire programmable en lecture seule
SMEC	Spectrometer MEChanism subsystem	Sous-système Mécanisme du Spectromètre
SMECm	Spectrometer MEChanism – mechanism	Mécanisme du spectromètre
STBE	Spécification Technique de Besoin d'Essai	
SPIRE	Spectral and Photometric Imaging Receiver	
SVM	SerVice Module	Module de service du satellite
VHDL	Very high speed integrated circuit Hardware Description Language	

Table des matières

1. Introduction:

This document presents the alignment philosophy and gives the procedure to verify and to adjust the Spire optical system, both photometer and spectrometer.
This documents gives details of procedure at ambient and cryogenic conditions.

2. Alignment principle:

Optical alignbment verification of SPIRE aims at:

- Verification of the absolute alignment of the cold stops within the instrument with the telescope stop (secondary mirror, M2)
- Verification of the instrument imaging performance, both of the pupil and of the celestial image.

The absolute alignment has to be checked with respect to a reference external to the instrument, simulating the Herschel telescope axis. This simulator consists of a honeycomb structure with instrument interface points identical to that of the satellite I/F, and a reference mirror and a crosshair to define direction and location of the telescope axis. This simulator, called LAM HOB, defines the direction of the Herschel telescope axis within +/- 0.5arcmin in two orthogonal angles, and the lateral location within +/- 0.02mm.

As two of the instrument's feet are directly attached to the instrument's covers, it is not possible to open the instrument for access to mirrors while the LAM HOB is in place. One of the main concerns of these alignment procedures is therefore to define how to transfer the LAM HOB reference to an external reference system (based on an MAT alignment telescope and theodolites) and to maintain its alignment with the instrument during dismounting of covers and manipulations of mirrors and other components within the instrument.

Imaging performance is verified by a series of tests using LED sources localized in the instrument detector planes, masks located in the instrument's cold stop planes, and various detection equipment external to the instrument, including specially designed equipment (M2 loupe, Hartmann lunette, ...) and an electronic camera.

2.1. Applicable Documents

no.	document name	document number, Iss./Rev.
AD1		

2.2. Reference Documents

no.	document name	document number, Iss./Rev.
RD	N/A	

Chapter 3

PROCEDURE

3. Procedure

3.1. Pre integration

Goal: Assembly of the instrument box, integration of detector box, 3D metrology

3.1.1. Integration of the instrument box

3.1.1.1 Putting together the different elements of the instrument structure according to MSSL procedure to ensure optimum flatness of the bench. Presumably this includes a series of mountings, dismountings as well as low-amplitude vibration to remove strains.

Comments: Following this procedures, lids can be taken off one side at a time without loss of alignment. The validity of this is to be verified by 3D measurement in the following procedure.

3.1.1.2 Mount CS tool in place, without bus bars, so that the top lid is dismountable without need to dismount the box.

3.1.1.3 Mount SOR.

3.2. 3-D metrology

3.2.1. Mounting SPIRE in the rotisserie

3.2.2. 3D metrology of the box, including telescope interface points, and edge of the bench, including SOR.

Comments: Determine instrument coordinate system. Verify the location of the instrument box in these coordinates. Verify coordinates and orientation of SOR.

3.2.3. Remove Photometer panels

3.2.4. 3D metrology of remaining box structure to compare with above measurements

Comments: Detect possible anomalies due to dismounting of the panel.

3.2.5. Remount panels, measure again and compare. Repeat TBD times.

3.2.6. Repeat for spectrometer side.

3.2.7. Remove panels photometer side

3.2.8. Visual inspection of interfaces

Comments: Detect particles or surface defects

3.2.9. 3D metrology of interfaces

Comments: Verification of the coordinates and the orientation of the interface planes with respect to the optical design. Any error detected will be analyze to find its cause and corrected if necessary. A specific, "3 D tool" will be used in place of the mirrors in order to ease the 3-D measurement and to avoid damage of the mirror surface.

3.2.10. Replace photometer panels

3.2.11. Remove Spectrometer panels

3.2.12. Visual inspection of interfaces

Comments: Detect particles or surface defects

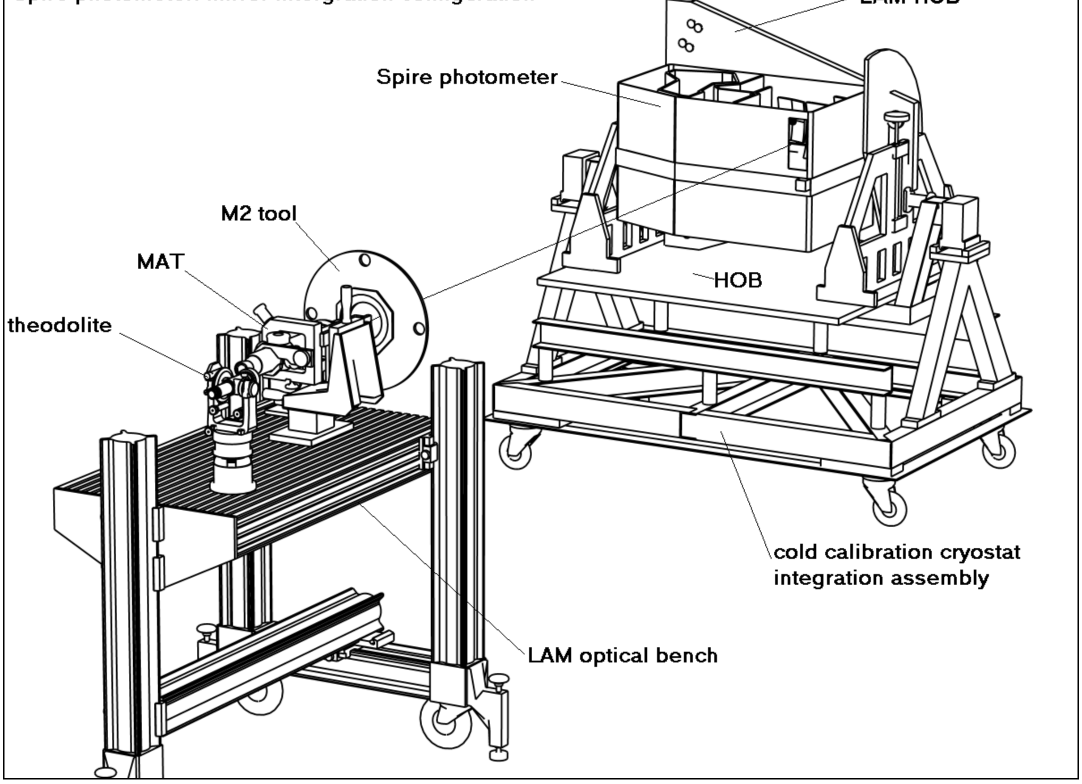
3.2.13. 3D metrology

Comments: Verification of the coordinates and the orientation of the interface planes with respect to the optical design. Any error detected will be analyze to find its cause and corrected if necessary. A specific, "3 D tool" will be used in place of the mirrors in order to ease the 3-D measurement and to avoid damage of the mirror surface.

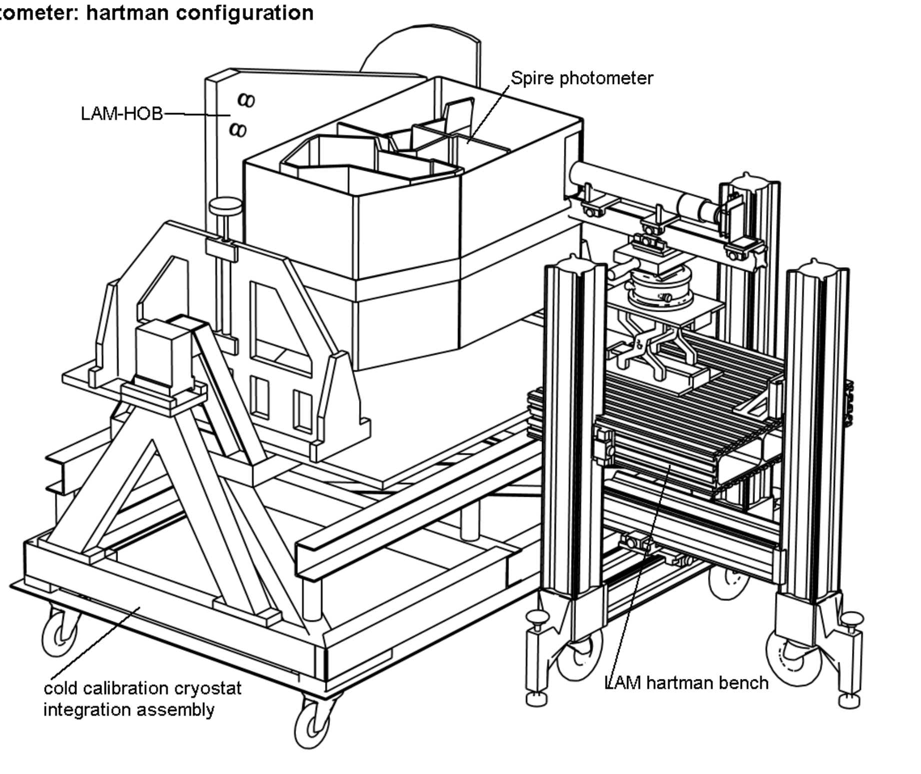
3.2.14. Replace spectrometer panels

3.3. Global views of OGSE at ambient configuration

Spire photometer: mirror intergration configuration



Spire photometer: hartman configuration



Chapter 3.4

Pre-alignments of LAM optical bench

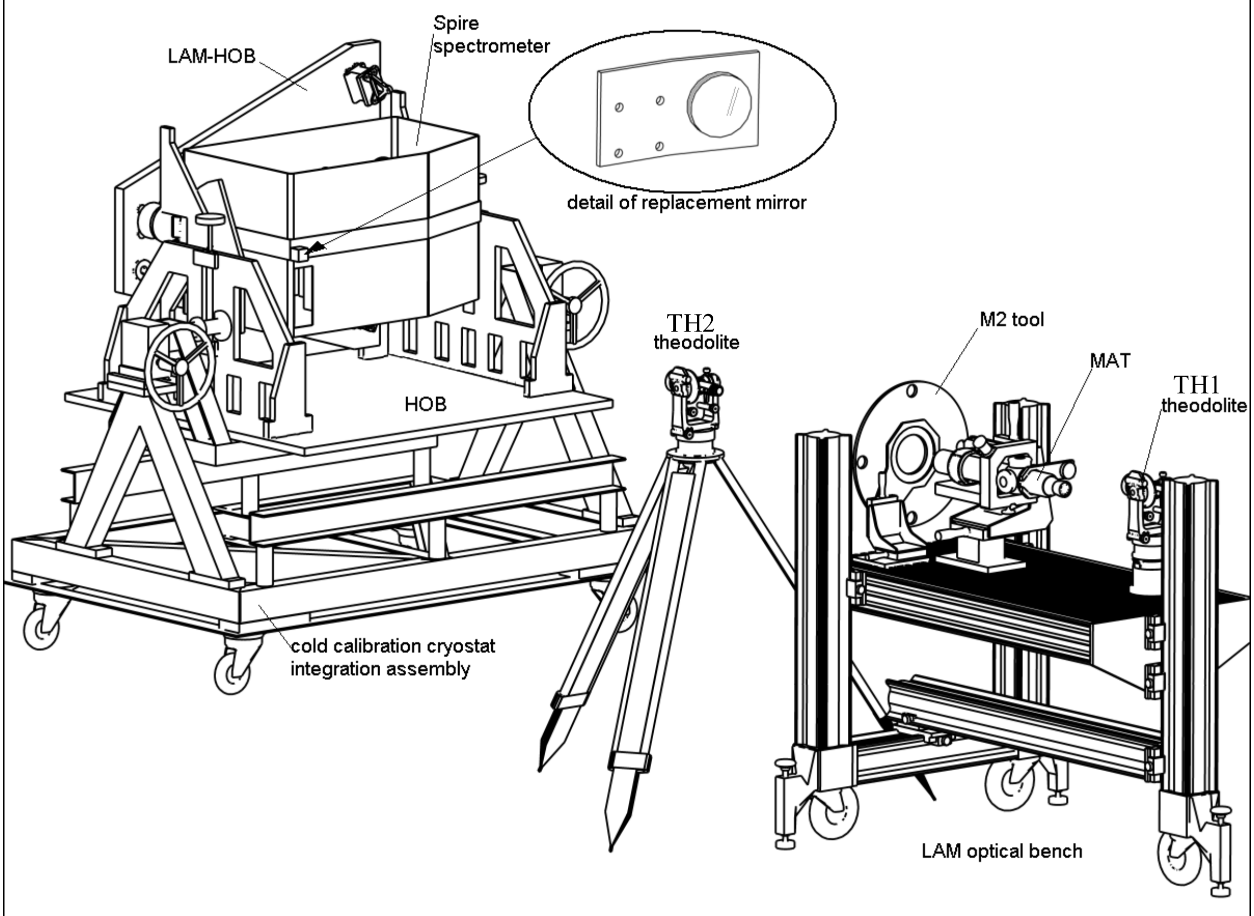
3.4. Pre-alignments of LAM optical bench

<u>Goal:</u> Perform optical alignments of the LAM bench with respect to the LAM-HOB mounted on the feet of Spire which gives the absolute reference (after compensation of some deviations) of the telescope axis.

3.4.1. Set Spire optical bench level

<u>Comment:</u> This procedure is repeated after every displacement of the instrument, in particular changes between photometer and spectrometer side. It is essentially the same for each side.

Spire spectrometer configuration



3.4.1.1 SPIRE mounted in rotisserie, photometer side up, covers on.

3.4.1.2 Remove if necessary the cube fixed on the Spire optical bench.

3.4.1.3 Mount the replacement mirror (glued on a folded aluminium plate) on the I/F cube on Spire optical bench.

3.4.1.4 Install the theodolite (TH2) on its tripod in such a way to allow autocollimation on the flat mirror.

3.4.1.5 Remove photometer panel. Install a precision spirit level on mechanical reference areas of the Spire bench.

3.4.1.6 Adjust Spire optical bench to be horizontal in two perpendicular directions, checked by means of precision spirit level.

Comments: Accuracy required better than ± 10 arcsec. Rotisserie will be finely tilted by means of its three adjustable feet (TBC).

3.4.1.7 Check autocollimation on theodolite (TH2) and note azimuth and elevation values. This is the reference of the horizontal position of the Spire optical bench.

3.4.1.8 Remove spirit level, replace photometer panel.

3.4.1.9 Check autocollimation on theodolite and note azimuth and elevation values. Do not correct the eventual tilt.

3.4.1.10 Mount LAM-HOB on the feet of Spire.

3.4.1.11 Check autocollimation on theodolite and note azimuth and elevation values.

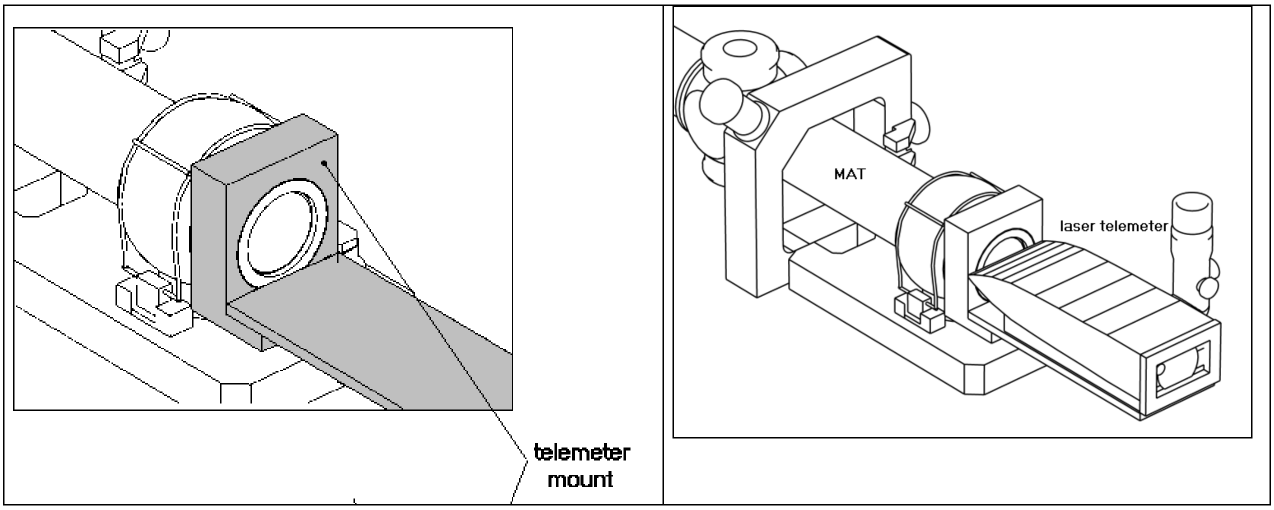
Comments: Differences in TH2 azimuth and elevation values compared with those of 3.4.1.7 are likely to be due to angular instability of the integration assembly ("rotissery"). If this is the case, then applying appropriate counterweights to the HOB plate can restore the original alignment.

3.4.1.12 If original alignment not retrieved using counterweights, then repeat from 3.4.1.5.

3.4.2. Positioning of LAM optical bench

Comment: The distance between the MAT rotation axis and the LAM HOB is measured using a laser telemeter. This measurement is aided by the use of a telemeter mount fixed onto the MAT tube.

3.4.2.1 The telemeter mount is fixed onto the MAT tube such that its rear face is in contact with the MAT mounting sphere and its front face is flush with the MAT tube end, see the following figure.

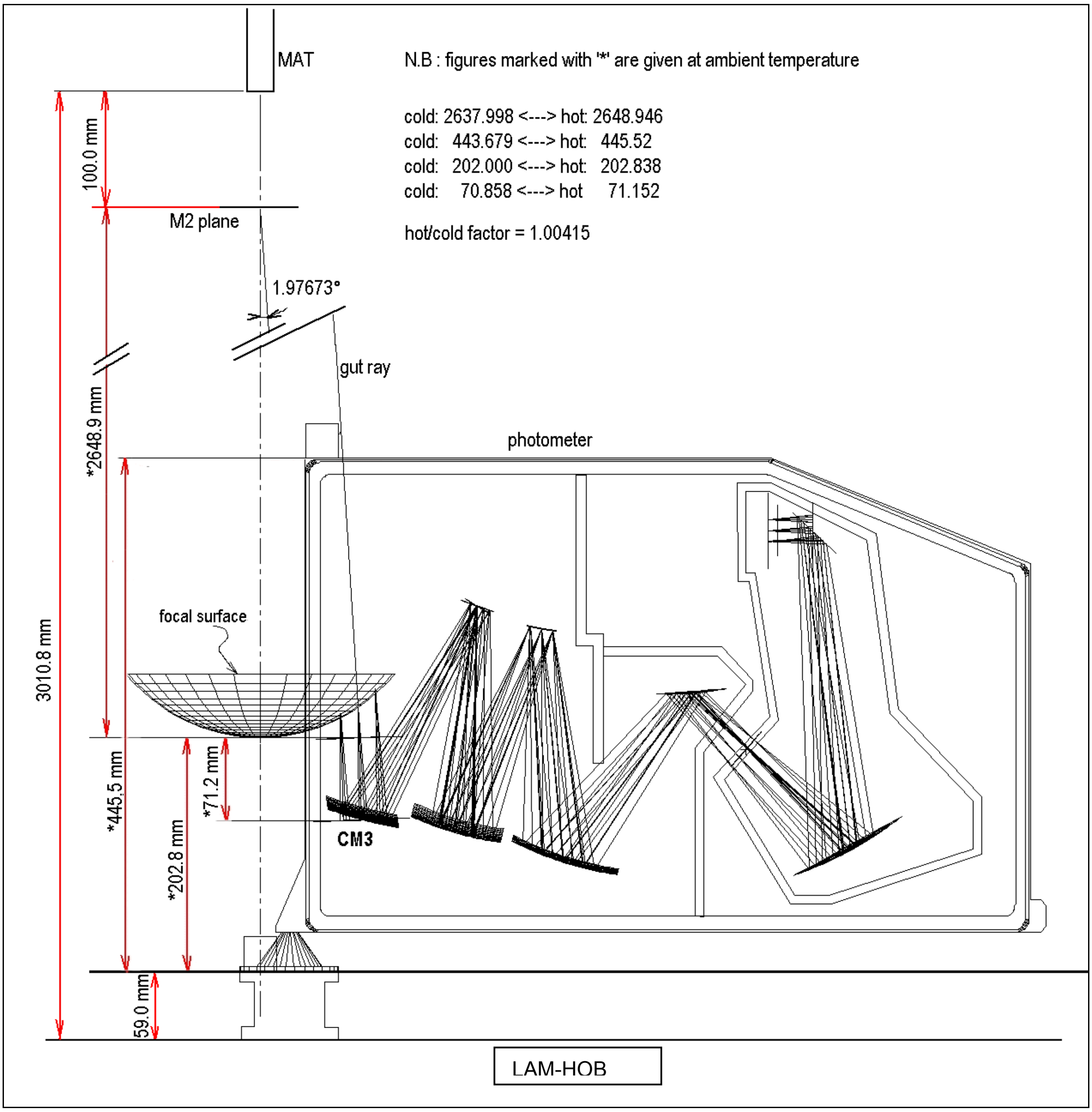


3.4.2.2 The telemeter is placed on its mount and pushed against the MAT tube end. It points (by the aid of its laser beacon) the LAM HOB plate just next to the reference mirror.

3.4.2.3 The telemeter should read 3010.8 mm +/- 1.5mm (see figure on following page).

Comments: Distance is roughly adjusted by axial translation of the whole LAM optical bench. Fine adjustment (< 10 mm) is obtained with translating MAT mount on the bench.

3.4.2.4 Remove the telemeter and its mount from the MAT.



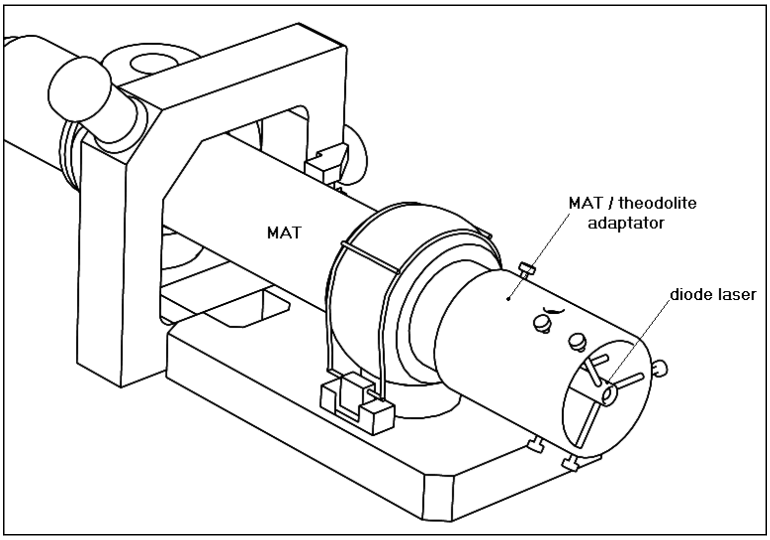
<u>Comment</u>: 3010.8 mm total distance, at room temperature, is equal to the sum of :

(M2-focal plane) + (base plan-focal plane) + (MAT- M2 tool)
= 2648.9 + 202.8 + 100*+59*
= **3010.8 mm**

*MAT is placed at 100mm (TBC) behind the M2 tool plane.
*59 mm height of spacers between LAM HOB and feet of Spire

3.4.3. MAT to LAM-HOB angular and lateral adjustment

3.4.3.1 Mount the tool of collimated laser diode on the MAT end.



3.4.3.2 Verify on a long distance co-alignment of the laser and optical MAT axis.
Comment: use a folding mirror to increase distance, for example aim a wall far away in the clean room.

3.4.3.3 Set the MAT translation plates, vertical and horizontal, at mid-travel. Set the MAT azimuth to its end of travel in such a way to allow 2 degrees or so of rotation when MAT will be aligned on the Spire gut ray.

3.4.3.4 Perform rough autocollimation with laser beam on the reference mirror using adjustable angular knobs of the MAT, and move the whole bench to recenter it laterally on the mirror.
Comment: Several iterations will probably be required to perform this adjustment.

3.4.3.5 When adjustment is close to the autocollimation, remove the tool with laser diode.

3.4.3.6 Connect the power supply of the MAT lamp, and achieve autocollimation with fine adjustment of MAT angular knobs while re-centering laterally the MAT on the reticule of the reference mirror by means of translation plates.

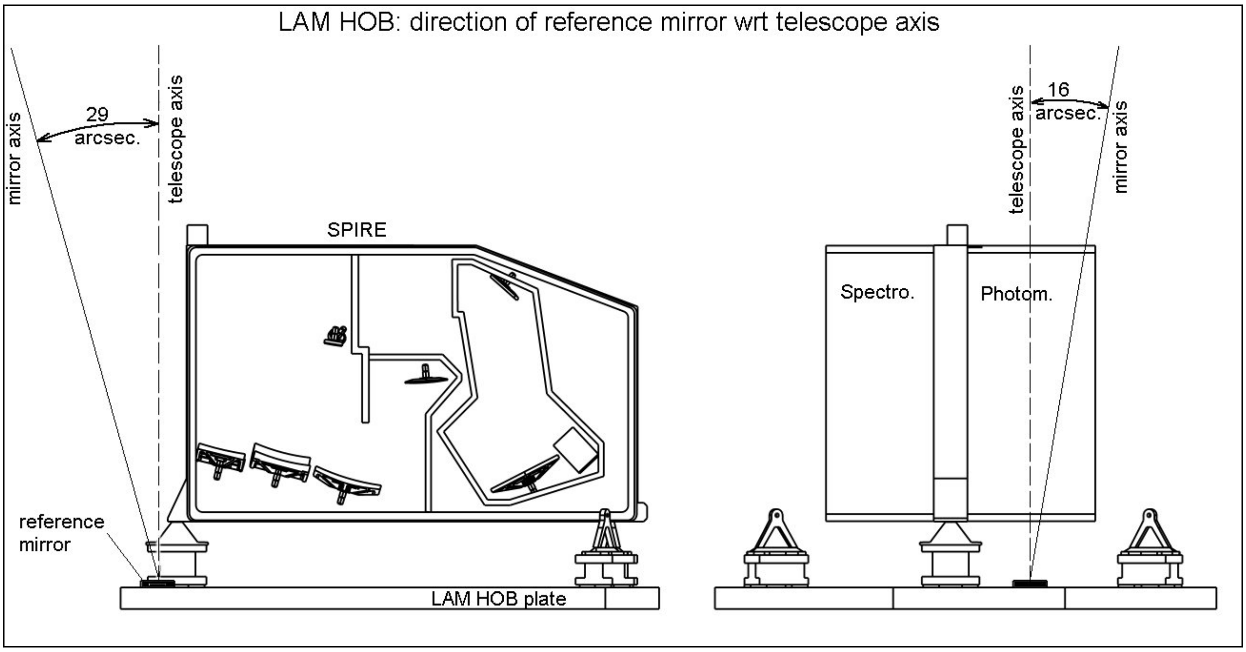
3.4.3.7 When autocollimation is reached, remount the telemeter on its holder at the end of the MAT. Check, adjust and note the distance to the LAM-HOB.

Distance MAT to LAM –HOB must be equal to 3010.8mm +/- 1.5mm

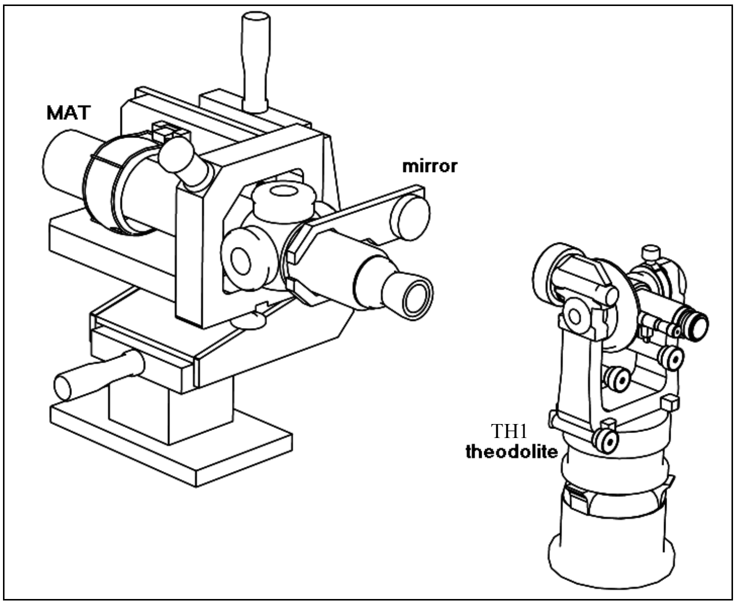
3.4.3.8 Remove the telemeter and its mount.

3.4.4. MAT to telescope axis alignment: angular and lateral correction

Comment: angular deviation between the reference mirror glued on LAM HOB and the theoretical telescope axis is non-zero and must be corrected. Its values, measured during assembly at LAM, are given in the figure below.



3.4.4.1 Install the theodolite (TH1) and its mount behind the MAT roughly aligned with the reference mirror attached to the MAT, see figure.



3.4.4.2 Perform autocollimation on the mirror with the theodolite.

Note the angular values of theodolite reference direction:

$Azimuth_{ref.}$ = . . . ° . . ' . . "

$Elevation_{ref}$ = . . . ° . . ' . . "

3.4.4.3 Applying correction, set elevation and azimuth of the theodolite to "theoretical" telescope axis.

$Azimuth_{tel\ axis.}$ = $Azimuth_{ref.}$ +/- 29 arcsec.

$Elevation_{telt\ axis}$ = $Elevation_{ref}$ +/- 16 arcsec.

(+ or - depends on theodolite compare with figure above)

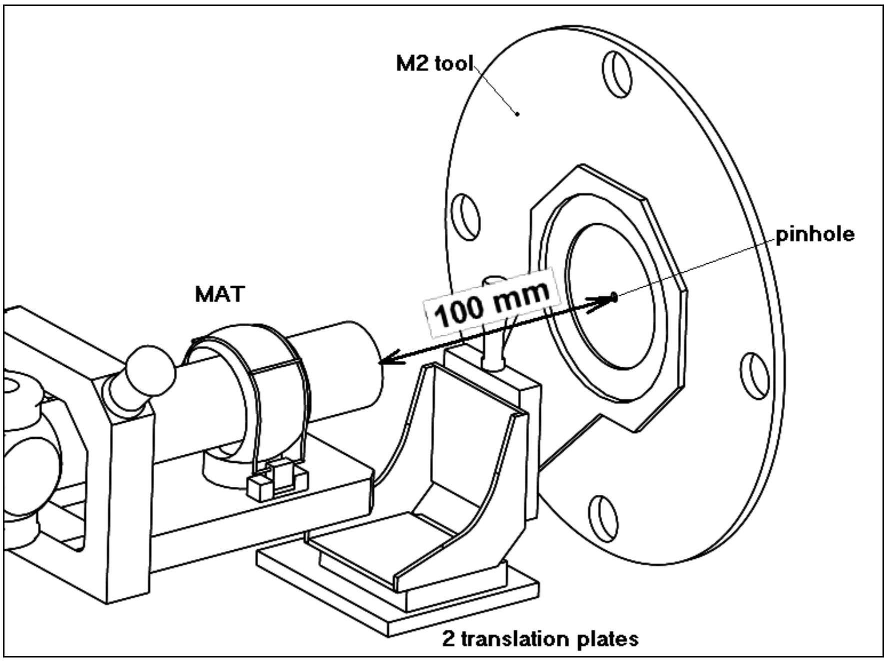
3.4.4.4 Rotate MAT in both directions to be auto collimated again on theodolite.

3.4.4.5 Translate MAT in order to center it on the crosshair in center of reference mirror.

3.4.5. Adjustment of M2 distance to LAM-HOB

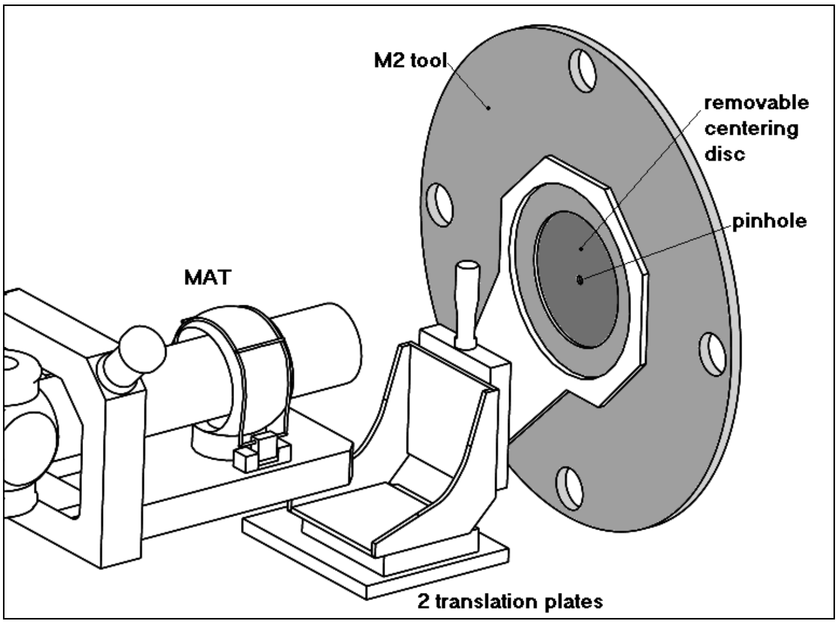
3.4.5.1 Install the M2 tool in front of the MAT on the LAM-HOB. Center roughly the M2 tool manually on MAT. Block the whole tool on the bench with screws.

3.4.5.2 To set the M2 tool distance to LAM-HOB at 2910.8mm (2648.95 + 202.84 + 59), using a steel rule, adjust it to 100 mm with respect to the MAT.



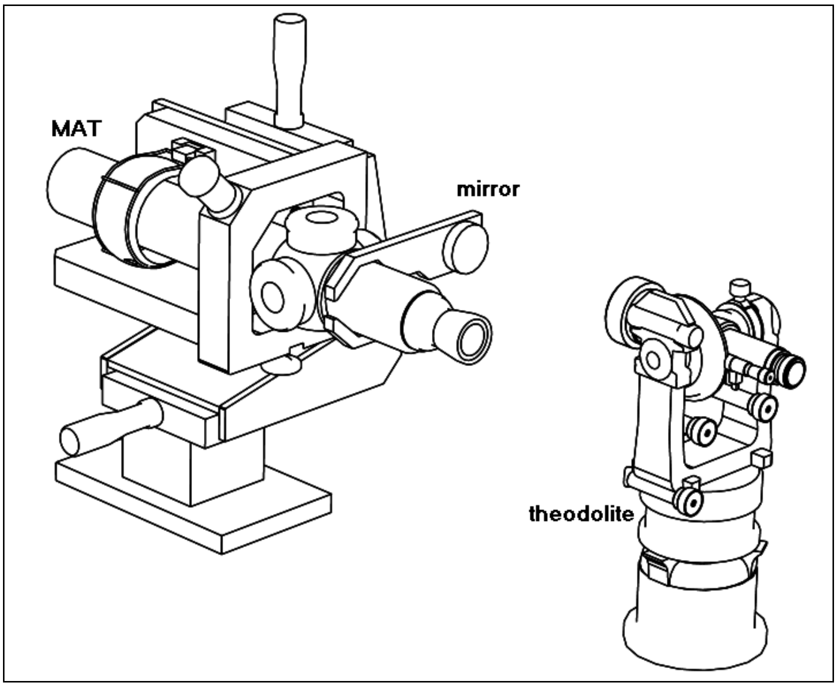
3.4.6. Setting up of the M2 Tool on MAT axis

3.4.6.1 Mount the centering disc equipped with a pinhole on the M2 tool.



3.4.6.2 Using the translation plates adjust finely the centering of the M2 tool on MAT axis.
Comment: during control take into account the little play of the centering disc.
By pushing it in 4 directions (vertical and horizontal) determine the effective M2 tool center.

3.4.7. Angular adjustment of MAT on gut ray



Angular values of theodolite normally same as in 3.1.3.3:

$\text{Azimuth}_{\text{tel axis.}}$ = . . . ° . . ' . . "

$\text{Elevation}_{\text{tel axis}}$ = . . . ° . . ' . . "

3.4.7.1 Set the azimuth direction of the theodolite to “telescope axis” + 1.97673 deg.

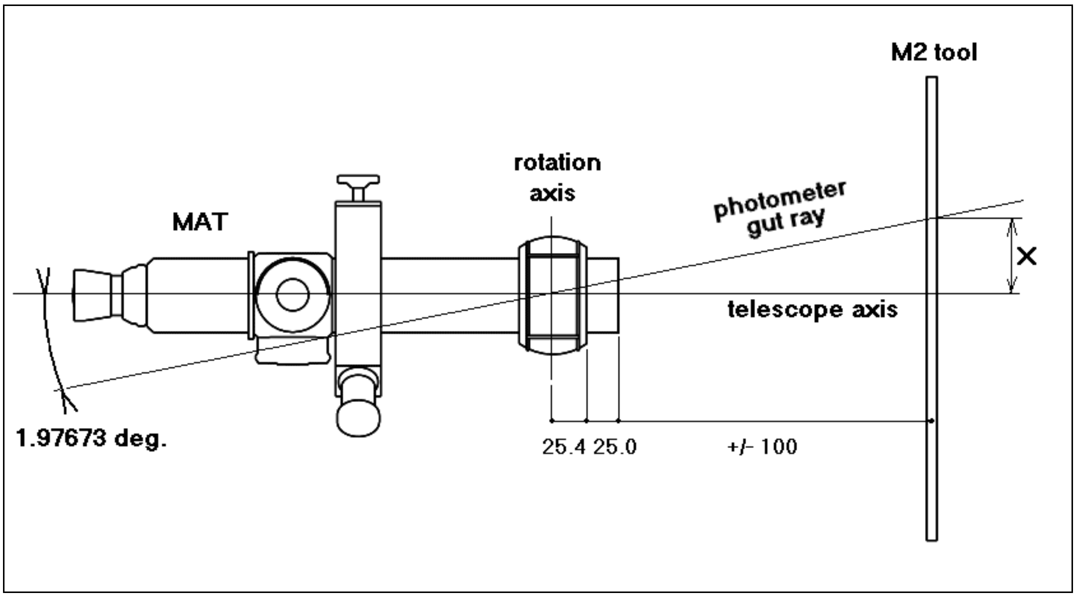
$\text{Azimuth}_{\text{gut ray.}}$ = $\text{Azimuth}_{\text{tel axis.}}$ + 1°58’36”
$\text{Elevation}_{\text{gut ray}}$ = $\text{Elevation}_{\text{tel axis}}$

Comment: The offset value 1.97673 deg.(1°58’36”) corresponds to the theoretical angle between gut ray of the Spire spectrometer and the Herschel telescope axis.

3.4.7.2 Rotate the MAT in horizontal plane using the corresponding control knob in order to realize autocollimation of the mirror with the theodolite.

3.4.8. Lateral compensation of the MAT after rotation on gut ray

After having rotated the MAT in order to align it on the theoretical value of gut ray, that introduces a lateral shift of the MAT axis; this is due to the fact the rotation point is not included in the M2 plane, and also the rotation wasn't made at the end of the MAT. Rotation axis of the MAT is at 50,4mm from its end.



Shift calculation: **X**= tan(1.97673)*(25.4 + 25.0 + 100) = 5.19 mm
In this example, distance between MAT and M2 tool is fixed to 100mm, which could not be exactly the same value during alignments.

3.4.8.1 Mount the pinhole on the M2 Tool.

3.4.8.2 Translate the MAT, by means of horizontal translation plate, in order to aim the pinhole.

3.4.8.3 Verify the translation is close to the calculated value.

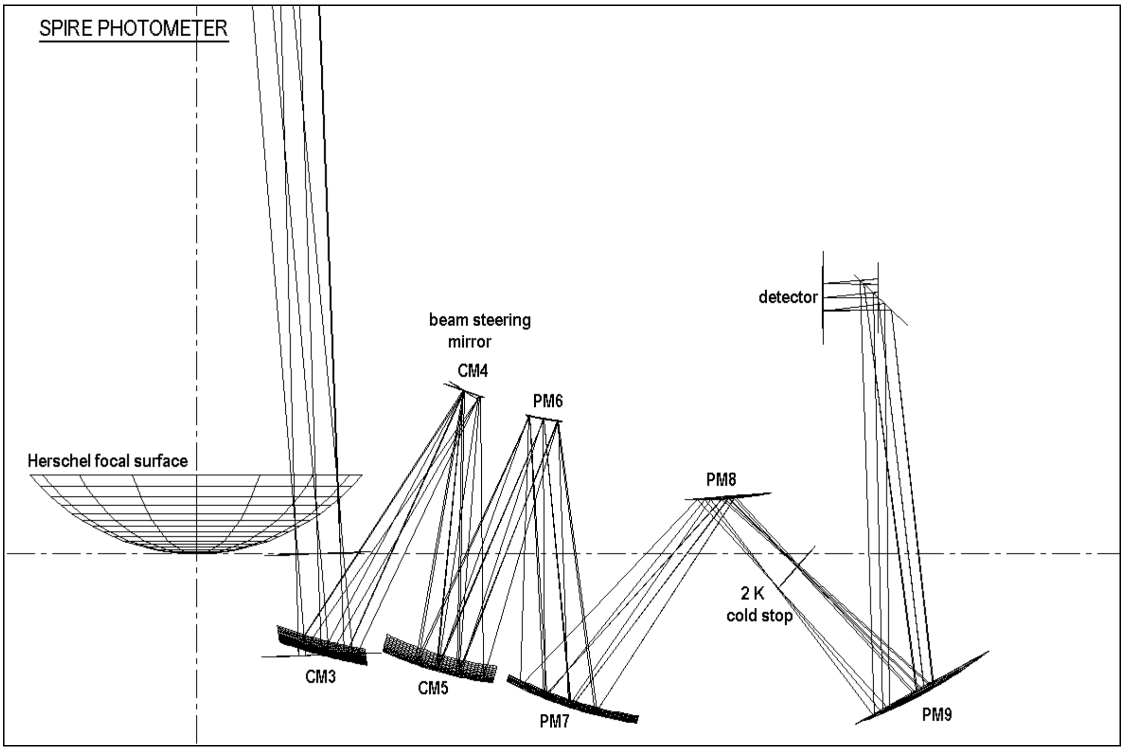
Chapter 3.5

Photometer integration

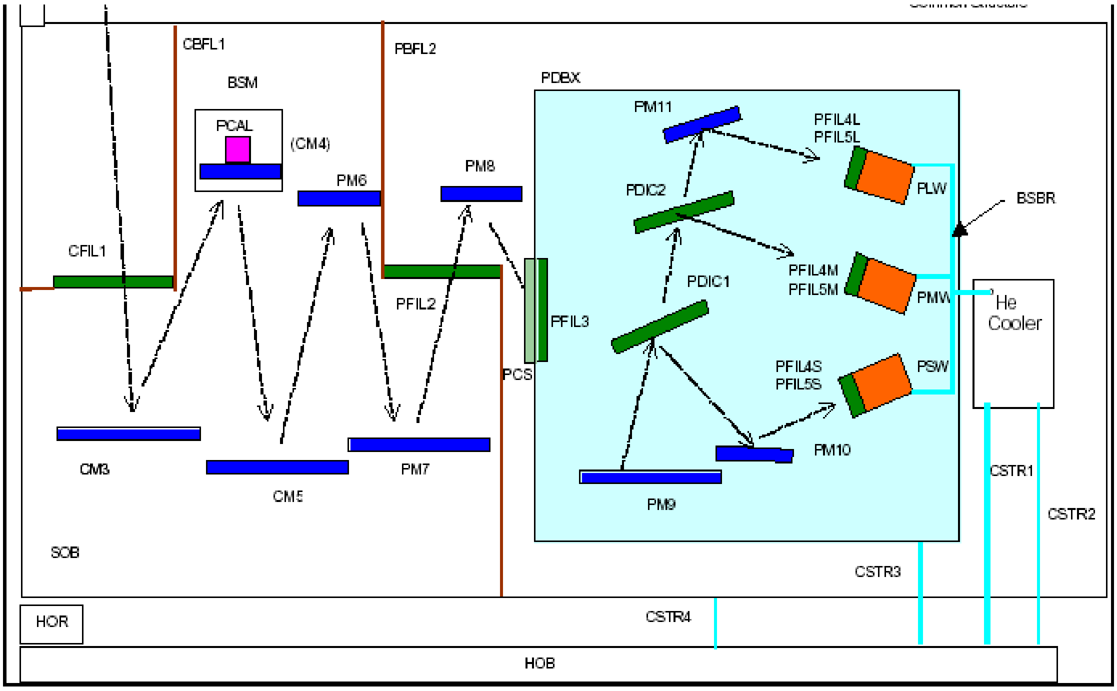
3.5. Photometer integration

Goal: Determination of telescope axis wrt instrument interfaces, integration of mirrors one by one to ensure alignment along gut ray. Deviations are quantified and recorded. Verification of detector centering, deviations are recorded and used in definition of detector interfaces.

3.5.1. Photometer optical scheme

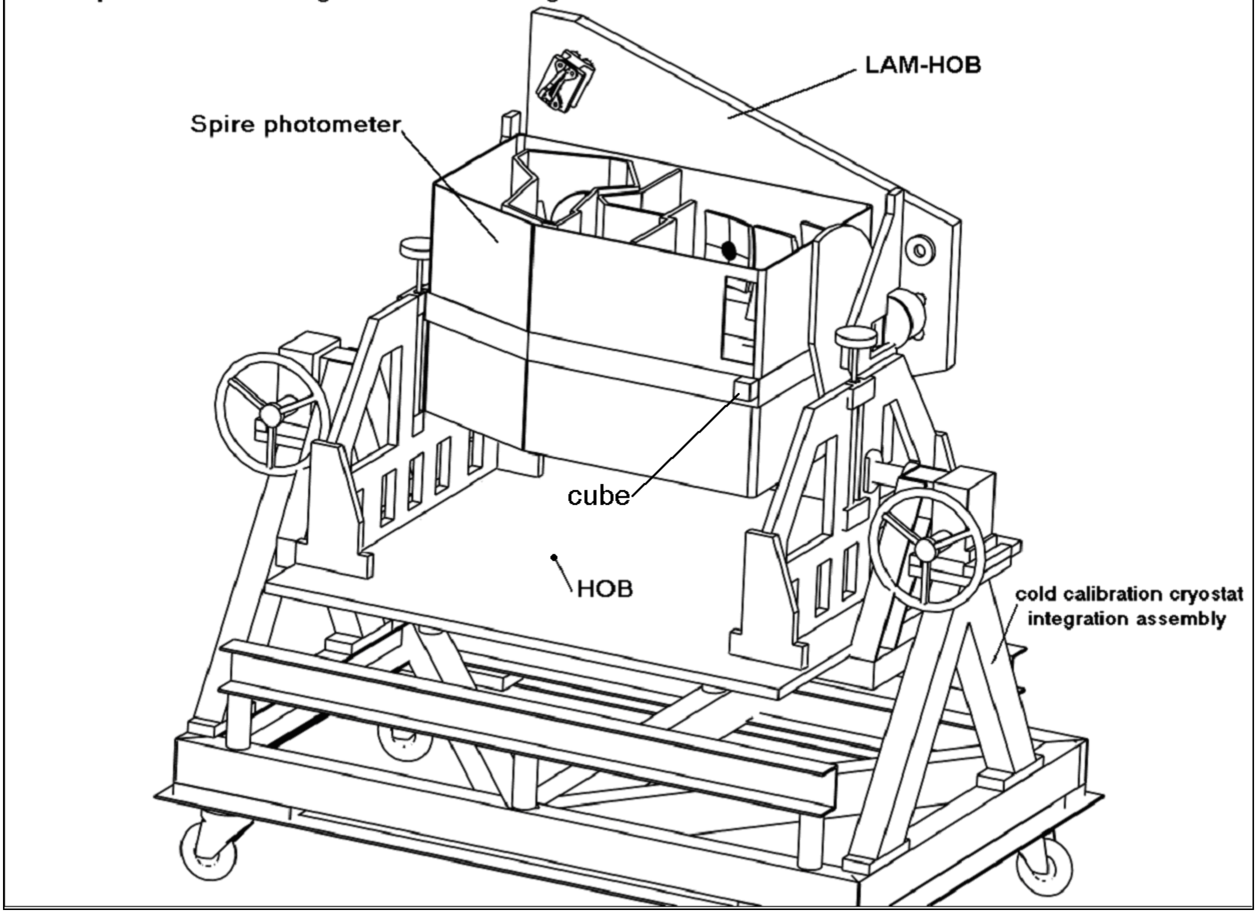


3.5.2. Spire photometer: mirror designation



3.5.3. Set Spire optical bench level

SPIRE photometer in integration mirror configuration



3.5.3.1 SPIRE mounted in rotisserie, photometer side up, covers on.

3.5.3.2 Remove if necessary the cube fixed on the Spire optical bench.

3.5.3.3 Mount the replacement mirror (glued on a folded aluminium plate) on the I/F cube on Spire optical bench.

3.5.3.4 Install the theodolite (TH2) on its tripod in such a way to allow autocollimation on the flat mirror.

3.5.3.5 Remove photometer panel. Install a precision spirit level on mechanical reference areas of the Spire bench.

3.5.3.6 Adjust Spire optical bench to be horizontal in two perpendicular directions, checked by means of precision spirit level.

Comments: Accuracy required better than ± 10 arcsec. Rotisserie will be finely tilted by means of its three adjustable feet (TBC).

3.5.3.7 Check autocollimation on theodolite (TH2) and note azimuth and elevation values. This is the reference of the horizontal position of the Spire optical bench.

3.5.3.8 Remove spirit level, replace photometer panel.

3.5.3.9 Check autocollimation on theodolite and note azimuth and elevation values. Do not correct the eventual tilt.

3.5.3.10 Mount LAM-HOB on the feet of Spire.

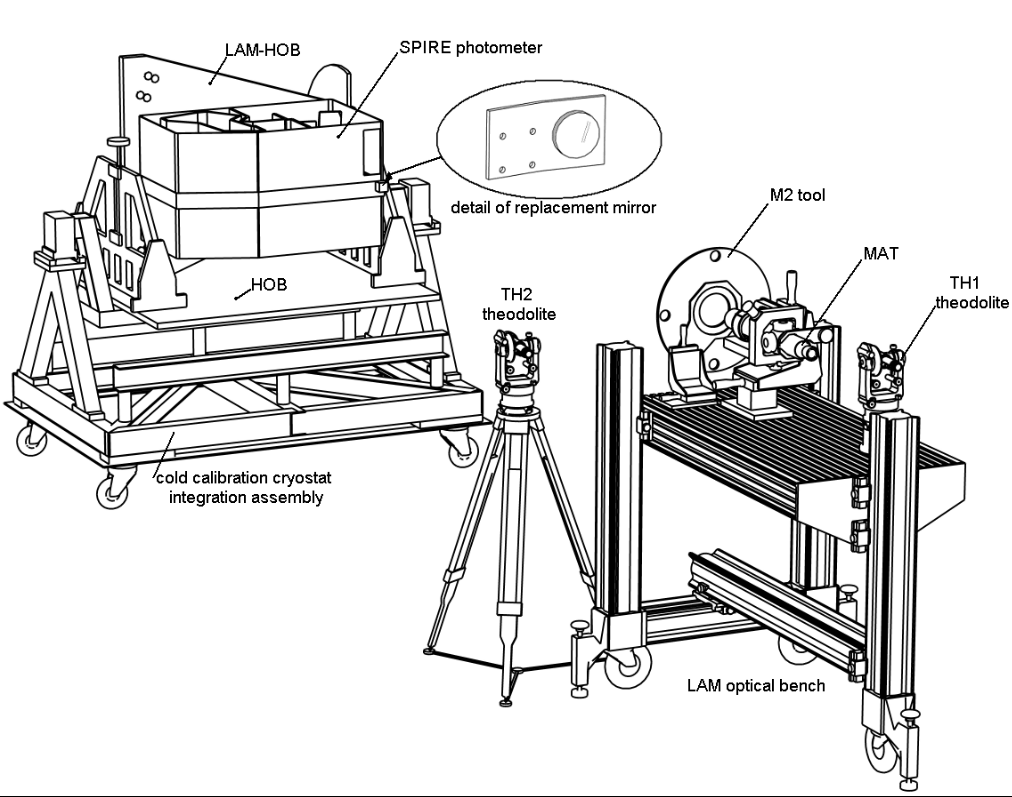
3.5.3.11 Check autocollimation on theodolite and note azimuth and elevation values.

Comments: Differences in TH2 azimuth and elevation values compared with those of 3.5.3.7 are likely to be due to angular instability of the integration assembly ("rotissery"). If this is the case, then applying appropriate counterweights to the HOB plate can restore the original alignment.

3.5.3.12 If original alignment not retrieved using counterweights, then repeat from 3.5.3.5.

3.5.4. MAT alignment with HOR

Spire photometer configuration



3.5.4.1 The LAM-HOB is mounted on the feet.

3.5.4.2 M2 tool equipped with central reticule axially located in plane of M2 by aid of laser distance meter.

3.5.4.3 MAT located behind M2 tool

3.5.4.4 MAT angular position is adjusted for auto-collimation on HOR

3.5.4.5 MAT lateral position is adjusted by observation of the HOR crosshair.

3.5.4.6 MAT angular and lateral position corrected for known HOR angular deviation from telescope axis by the aid of theodolite TH1 (see 3.4.4).

3.5.4.7 M2 tool lateral position adjusted by alignment of its central cross hair on MAT axis

3.5.4.8 Theodolites (TH1 and 2) monitor MAT and SOR angular position respectively
Comments: Detects any spurious movements of the setup. Should be verified regularly (at TBD intervals).

3.5.4.9 Remove HOB simulator, verify TH2-SOR alignment

3.5.4.10 Remount HOB simulator, verify MAT-HOB alignment. Repeat TBD times.

3.5.4.11 Remove HOB simulator

3.5.5. MAT alignment with photometer gut ray

3.5.5.1 MAT is rotated parallel with the photometer gut ray by the aid of Th1, cf 3.4.2.6.

Comments: Orientation of the photometer gut ray is defined by optical calculation:
Δ azimuth = 1.9763º = 1º58'36"
Δ elevation = 0

3.5.5.2 MAT is translated laterally to be realigned with M2 tool cross hair

Comments: Compensation is estimated according to the distance from MAT rotation axis to the M2 plane (100mm + 25mm + 25.4mm = 150.4mm, see 3.4.2.7)
Δ x = 150.4 tan(1.9763º) = 5.19mm
Δy = 0
This value should be taken as indicative, the goal being to have the MAT aligned with the centre of M2.

3.5.5.3 Verify that MAT angular direction is maintained by the aid of TH1. If not, re iterate previous tasks.

Comments: Ensures alignment of MAT axis to gut

3.5.5.4 Remove photometer panels. Verify SOR alignment with TH2

3.5.5.5 Place Apex tool in CM3 position and verify centred on gut ray

3.5.6. Integration of common and photometer optics

Comments: Photometer detector box is pre integrated with PDIC1 & PDIC2 simulators, PM9, PM10, PM11, and PCS tool in place

3.5.6.1 Move Apex tool to CM5 position, mount CM3 and BSM replacement tool, verify gut ray centering.

3.5.6.2 Check autocollimation of the theodolite on the mirror at SOR level, and correct the eventual tilt by adjustment of a counterweight on the large HOB plate. Repeat this check between next following steps.

3.5.6.3 Move Apex tool to PM6 position, mount CM5, verify gut ray centering.

3.5.6.4 Move Apex tool to PM7 position. Mount PM6 and SM6 (in preparation for spectrometer integration, see 3.6.6). Verify photometer gut ray centering.

3.5.6.5 Move Apex tool to PM8 position, mount PM7, verify gut ray centering.

3.5.6.6 Mount PM8, verify gut ray centering on CS tool.

3.5.6.7 Mount D-tool in PSW position, verify gut ray centering on D-tool

Note: Deviations are recorded and used in definition of detector interfaces

3.5.6.8 Mount D-tool in PMW position, verify gut ray centering

Note: Deviations are recorded and used in definition of detector interfaces

3.5.6.9 Mount D tool in PLW position, verify gut ray centering.

Note: Deviations are recorded and used in definition of detector interfaces

3.5.6.10 Remove and remount detector box, verify gut ray centering on D tool and CS tool. Repeat TBD times.

Comments: If changes occur during these operations, improve procedure.

3.5.6.11 Close SPIRE box, verify gut ray centering on D tool and CS tool. Repeat open/close/verification TBD times.

Comments: If changes occur during open/close operations, improve open/close procedure.

3.5.6.12 Mount LAM-HOB, reorient MAT with optical axis, verify alignment with HOR.

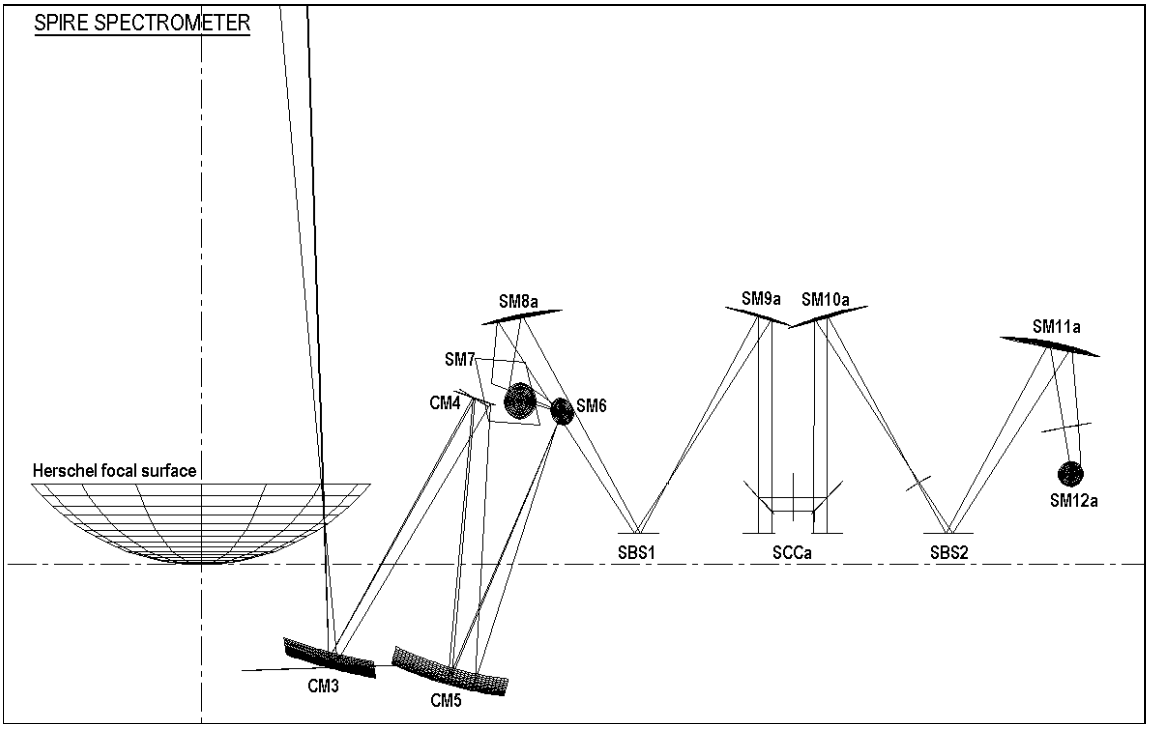
Chapter 3.6

Spectrometer integration

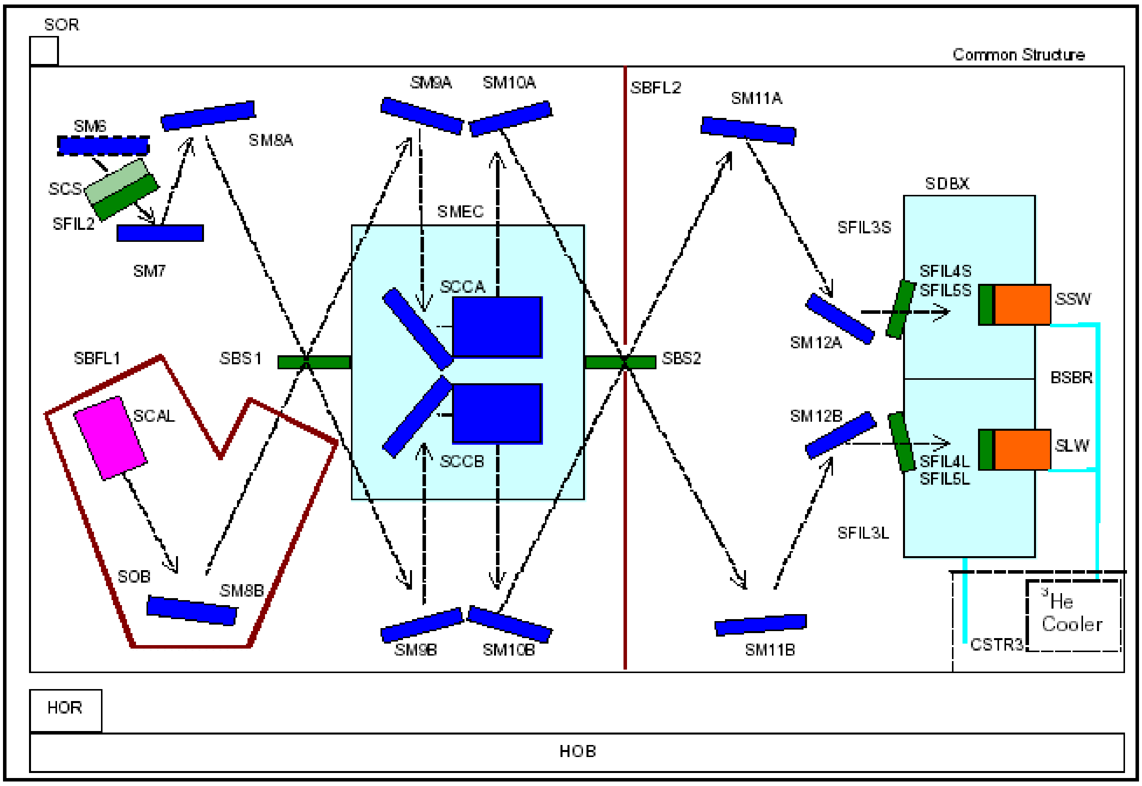
3.6. Spectrometer integration

Goal: Determination of telescope axis wrt instrument interfaces, integration of mirrors one by one to ensure alignment along gut ray. Deviations are quantified and recorded. Verification of detector centering, deviations are recorded and used in definition of detector interfaces.

3.6.1. Spectrometer optical scheme



3.6.2. Spire spectrometer: mirror designation



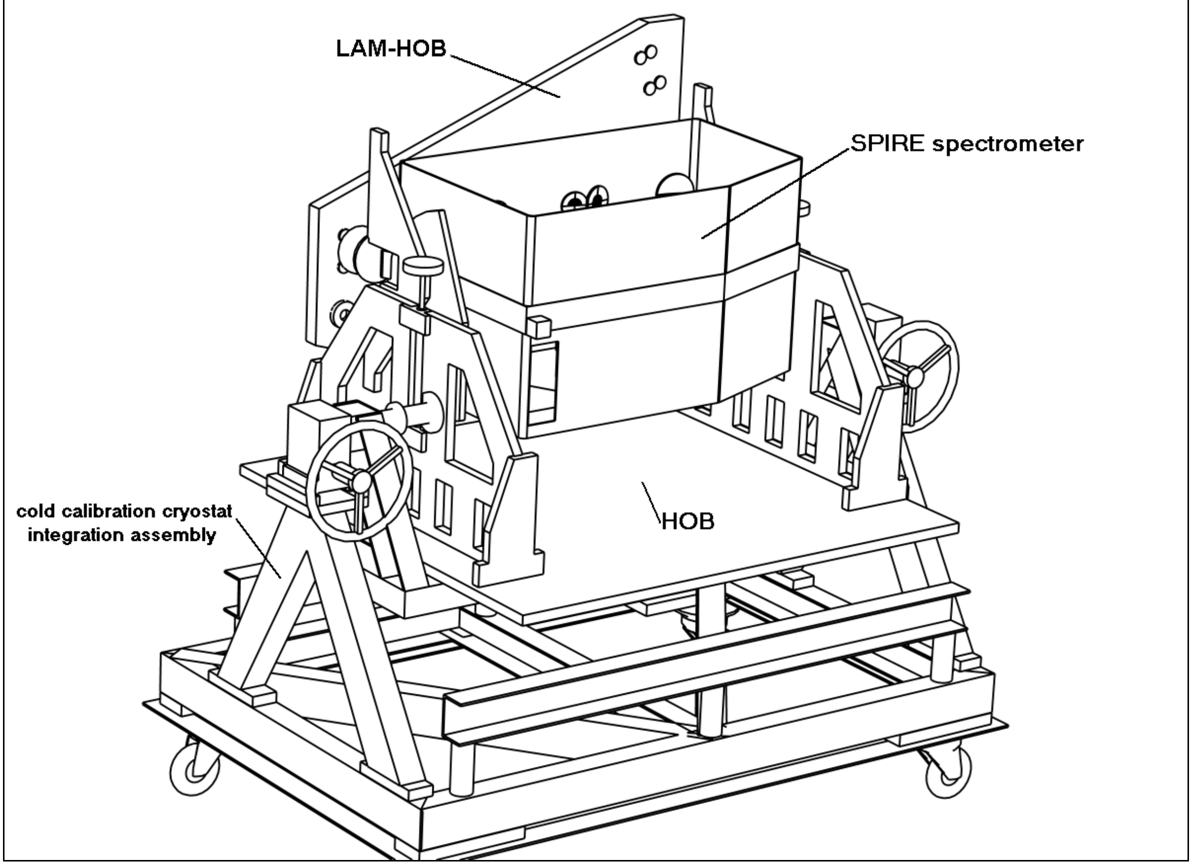
3.6.3. Set Spire optical bench level

3.6.3.1 SPIRE mounted in rotisserie, spectrometer side up, covers on.

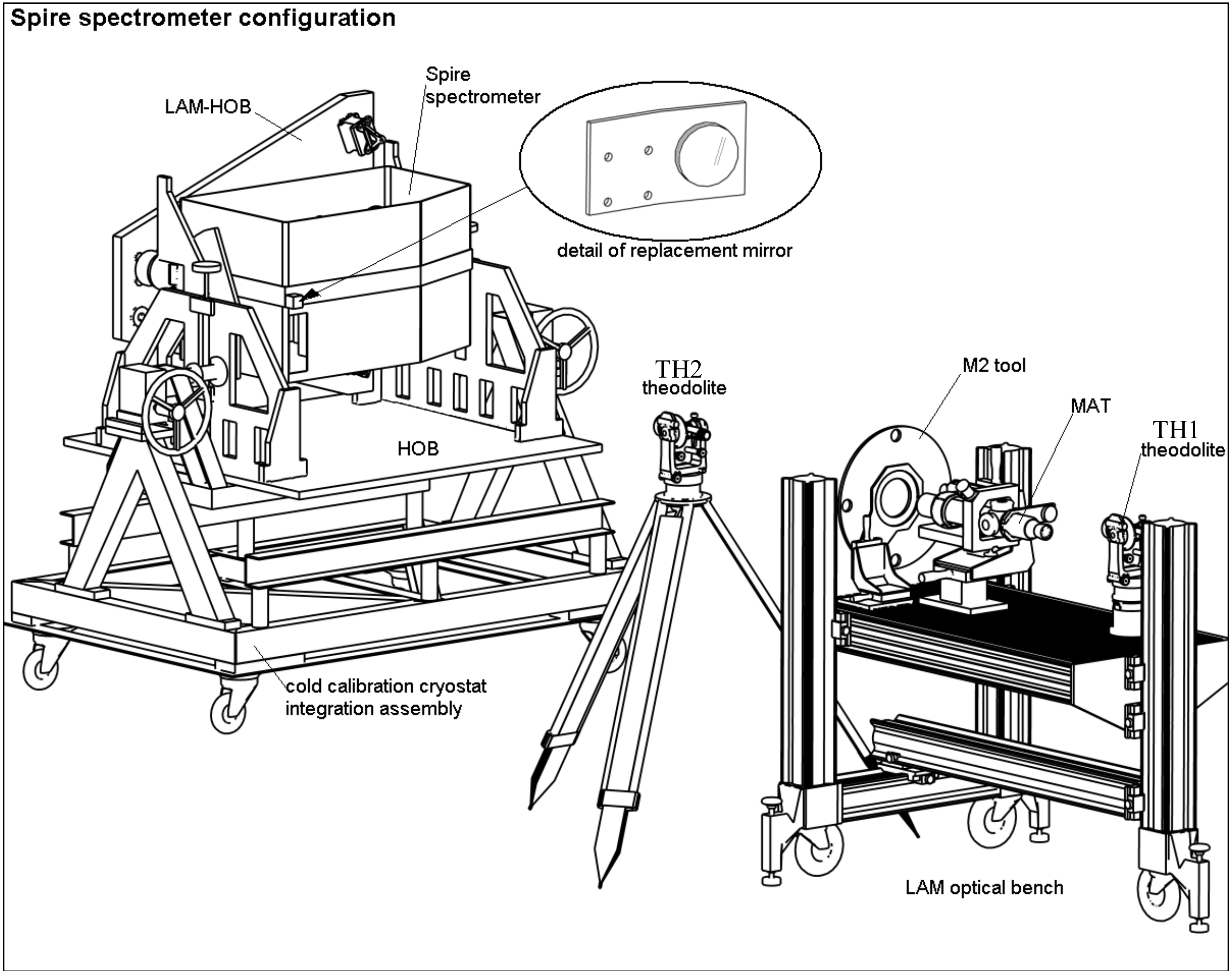
Comments: To change from Photometer to Spectrometer configuration, the instrument is turned 180º around the horizontal rotisserie axis and the entire rotisserie rotated 180º around the vertical axis.

3.6.3.2 Set SPIRE bench level following above procedure (3.5.3).

Spire spectrometer in integration mirror configuration



3.6.4. MAT alignment with HOR



3.6.4.1 Change height of LAM optical bench by about 255mm. Height changes from 1105mm to 850mm.

3.6.4.2 Align MAT with HOR following "MAT alignment with HOR" procedure above (3.5.4).

3.6.5. MAT alignment with spectrometer gut ray

3.6.5.1 Align MAT with spectrometer gut ray following "MAT alignment with photometer gut ray" procedure above (3.5.5), replacing "photometer " with "spectrometer".

Comments: Orientation of the spectrometer gut ray is defined by optical calculation.
Δ azimuth = 1.9775º = 1º58'39"
Δ elevation = 1.32988 = 1º19'48"
Lateral compensation (indicative, for distance MAT axis to M2 plane 150.4mm):
Δx = 5.19mm
Δy = 3.49mm

3.6.6. Integration of spectrometer optics

3.6.6.1 Remove spectrometer panels. Verify SOR alignment (mirror glued on aluminium folded plate)

3.6.6.2 Mount SCS tool in spectrometer cold stop position, verify gut ray centering SCS tool.

3.6.6.3 Mount Apex tool in SM7 position, verify gut ray centering on Apex tool.

3.6.6.4 Move Apex tool to SM8 position, mount SM7, verify gut ray centering.

3.6.6.5 Move Apex tool to SM9B position, mount SM8 and SBS1 simulator, verify gut ray centering (transmission through SBS1).

3.6.6.6 Move Apex tool to SM9A position, verify gut ray centering (reflection at SBS1).

3.6.6.7 Mount SM9 A and B, verify double autocollimation using the internal MAT cross hair.
Comments: Two images of the MAT cross hair should be visible, from beams going through the loop formed by SBS and SM9A and B in opposite directions.

3.6.6.8 Place Apex tool in SM10A position, mount SMEC tool, verify gut ray centering.
Comments: Deviation indicates lateral displacement of RT apex

3.6.6.9 Move Apex tool to SM11A, mount SM10A, SM10B and SBS2 pellicle replacement, verify gut ray centering
Comments: Identify image transmitted through SBS2 to verify alignment of SM10B

3.6.6.10 Move Apex tool to SM11B, verify gut ray centering
Comments: Identify image transmitted through SBS2 to verify alignment of SM10A. Identify image reflected at SBS2 to verify alignment of SBS2.

3.6.6.11 Move Apex tool to SM12A, mount SM11A, verify gut ray centering

3.6.6.12 Move Apex tool to SM12B, mount SM11B, verify gut ray centering

3.6.6.13 Mount SM12A and SM12B, verify gut ray centering on detector tools (SD tools).
Comments: Deviations are recorded and used in definition of detector interfaces

3.6.6.14 Close SPIRE box, verify gut ray centering on D tool and CS tool. Repeat open/close/verification TBD times.
Comments: If changes occur during open/close operations, improve open/close procedure. In particular define tightening order and torque.

3.6.6.15 Mount HOB simulator, reorient MAT with optical axis, verify alignment with HOR.

Chapter 3.7

Post integration verifications

3.7. Post integration verifications

Goal: Final verification of cold stop centering. Verification of pupil image quality. Verification of image quality.

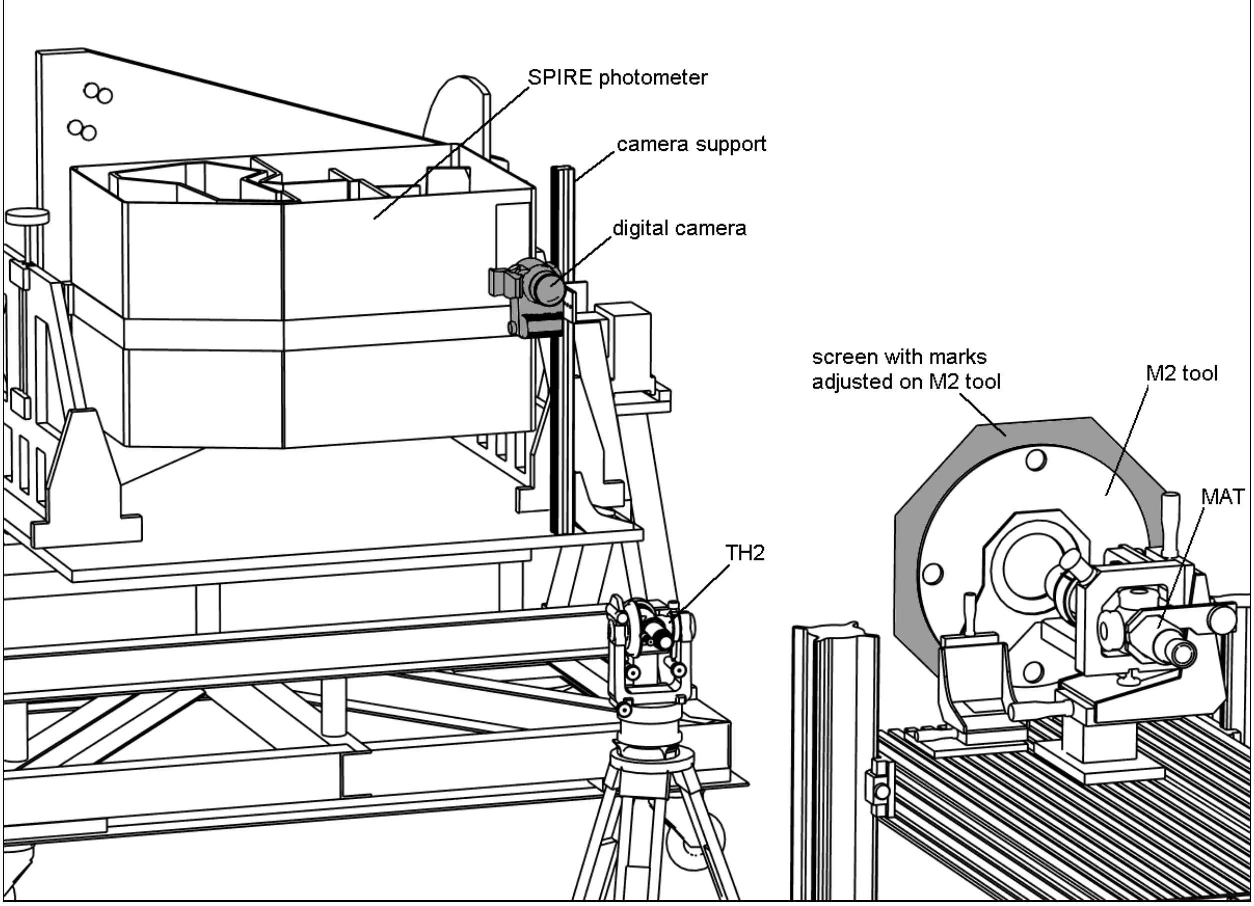
The proposed procedure starts with verification of the spectrometer (3.7.1-3.7.4), but if the previous procedure has not been followed so that photometer side is up, then start with photometer (3.7.5-3.7.8).

SPIRE mounted in rotisserie, spectrometer side up. MAT aligned with gut ray (3.6.4, 3.6.5).

3.7.1. Spectrometer pupil reference map

The following drawing, which corresponds to the photometer configuration, shows the means to record the pupil map on the M2 tool screen with digital camera. Same setup is used to check the spectrometer.

SPIRE : photometer configuration with digital camera



3.7.1.1 Cover off, SCS tool in place.

3.7.1.2 Replace one of SD tools with the Fiber holder.

3.7.1.3 Sanded aluminium screen mounted onto M2 tool.

3.7.1.4 Install the digital camera on its support fixed on the HOB plate with a screw vice.

3.7.1.5 Adjust the camera high in order to be as close as possible to the Spire output beam.

3.7.1.6 Project cold stop onto M2 plane, take picture.

3.7.2. Spectrometer pupil alignment verification

3.7.2.1 Remount SD-tool, remove M2 aluminium plate

3.7.2.2 Observe SD tool diodes through MAT

3.7.2.3 Verify cold stop aligned with gut ray by lighting ~~each~~ SD tool diode ~~in turn~~

<u>Comments:</u> The MAT field is too small to observe the central SCS tool central cross projected on the M2 plane. This verification is therefore made by focalizing on the D-tool projected onto the instrument input plane, then gradually shifting focus towards the M2 plane. The spot will change into a cross, which should stay centred on the MAT cross hair.

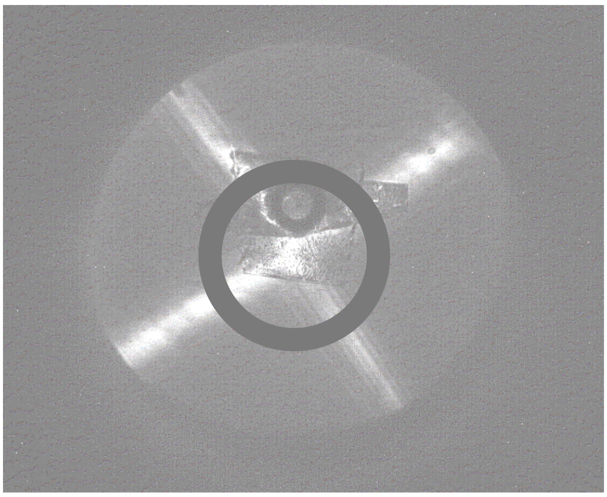
Alternative procedure

3.7.2.4 Place a Plexiglas plate in the M2 plane. Determine the position of the optical axis by the MAT, previously aligned on the telescope axis by aid of the HOR. Mark this position with an opaque ring, Ø5-10mm.

3.7.2.5 Position the M2 loupe equipped with electronic camera behind the Plexiglas plate, approximately centred on the telescope axis.

3.7.2.6 Light ~~each~~ SD tool diode ~~in turn~~ and observe the projection of the SCS tool central cross onto the M2 plane through the M2 loupe. Measure and note decentration.

<u>Comments:</u> The image below shows the central SCS tool central cross projected on the M2 plane as seen through the M2 loupe. A circle has been superpose to indicate the described procedure.



3.7.3. Spectrometer pupil quality verification

3.7.3.1 Locate M2-tool with respect to the SPIRE box

Comments: This will already be the case if above procedure followed.

3.7.3.2 Verify cold stop edge for different field points

Comments: Observe (by the aid of the specially designed M2 loupe) the projected edge of the CS-tool through one of the edge reticules in the M2-tool. Light up sequentially each of the SD tool sources and measure position of the edge for each field point. Repeat for each of the edge reticules in the M2-tool. Deviations are recorded and compared with optical model.

3.7.4. Spectrometer focus and image quality verification

Focus and image quality (Zernike coefficients) are quantitatively deduced from the Hartmann test results using one extra focal and one intra focal image of the Hartmann screen. Best focus position is also qualitatively estimated by observation of through-focus screen images.

Image quality must be measured separately for each of the four optical paths through the instrument to ensure appropriate interferometer functioning.

3.7.4.1 Replace the SCS tool with the S-Hartmann tool (disk with grid of holes).

3.7.4.2 Make Hartmann screen reference map: Replace one of SD tools with fiber holder, mount aluminium plate on M2 tool, project Hartmann screen on M2 plane, take picture.

3.7.4.3 Mount both SD tools with source size reduced by the aid of pinholes.

3.7.4.4 Calibrate Hartmann bench by focussing the detector on a well-defined object (eg knife edge) at a distance FFD = 310mm in front of the front flange of the Hartmann lunette.

Comments: The procedure is described in "SPIRE STM optical alignment campaign, Photometer Hartmann test", KD, 11/9/2003. Drop if already effectuated for Photometer verification.

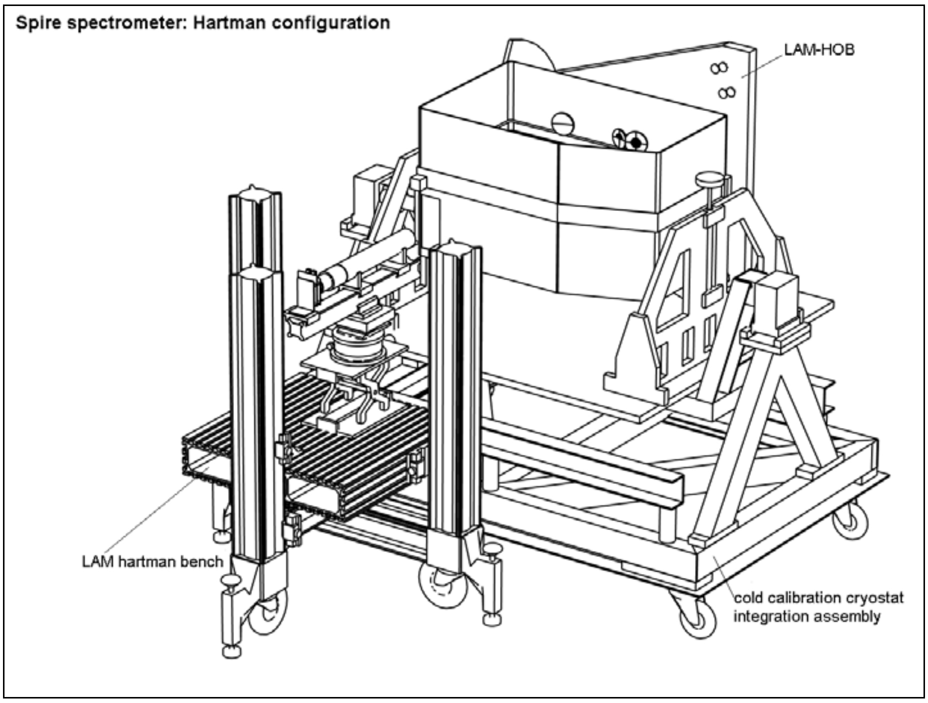
3.7.4.5 Place the Hartmann bench in front of the instrument (see Figure below) with the front flange approximately 106.86mm from the instrument entrance hole.

Comment: The spectrometer best focus lies 203.14mm inside the instrument along the spectrometer gut ray.

3.7.4.6 Align the lunette laterally on the spectrometer gut ray by the aid of the MAT (Hartmann detector block removed).

3.7.4.7 Adjust the axial position of the lunette front flange to 106.86mm from the entrance hole by the aid of a metal ruler.

Comments: This axial adjustment is delicate and a precision of ±1mm may be expected. This corresponds to an RMS wavefront error contribution of 0.8µm.



3.7.4.8 **Path SLW_A:** Light SLW source, block interferometer arm B.

3.7.4.9 Store a series of images in intra and extra focal positions covering ±30mm from the theoretical image position, separated by 5mm. Identify carefully the detector position for each image.

Comments: Two of these images will be chosen for Hartmann test calculations. Nominal defocus distance is ±15mm, but more may be necessary. Intra and extra focal distances can be different The Hartmann test requires that all spots are clearly distinguishable in both intra and extra focal images.

3.7.4.10 Store a series of images in intra and extra focal positions covering ±5mm from the apparent best focus position, separated by 1mm.

3.7.4.11 **Path SLW_B:** Light SLW source, block interferometer arm B. Repeat 3.7.4.9 and 3.7.4.10.

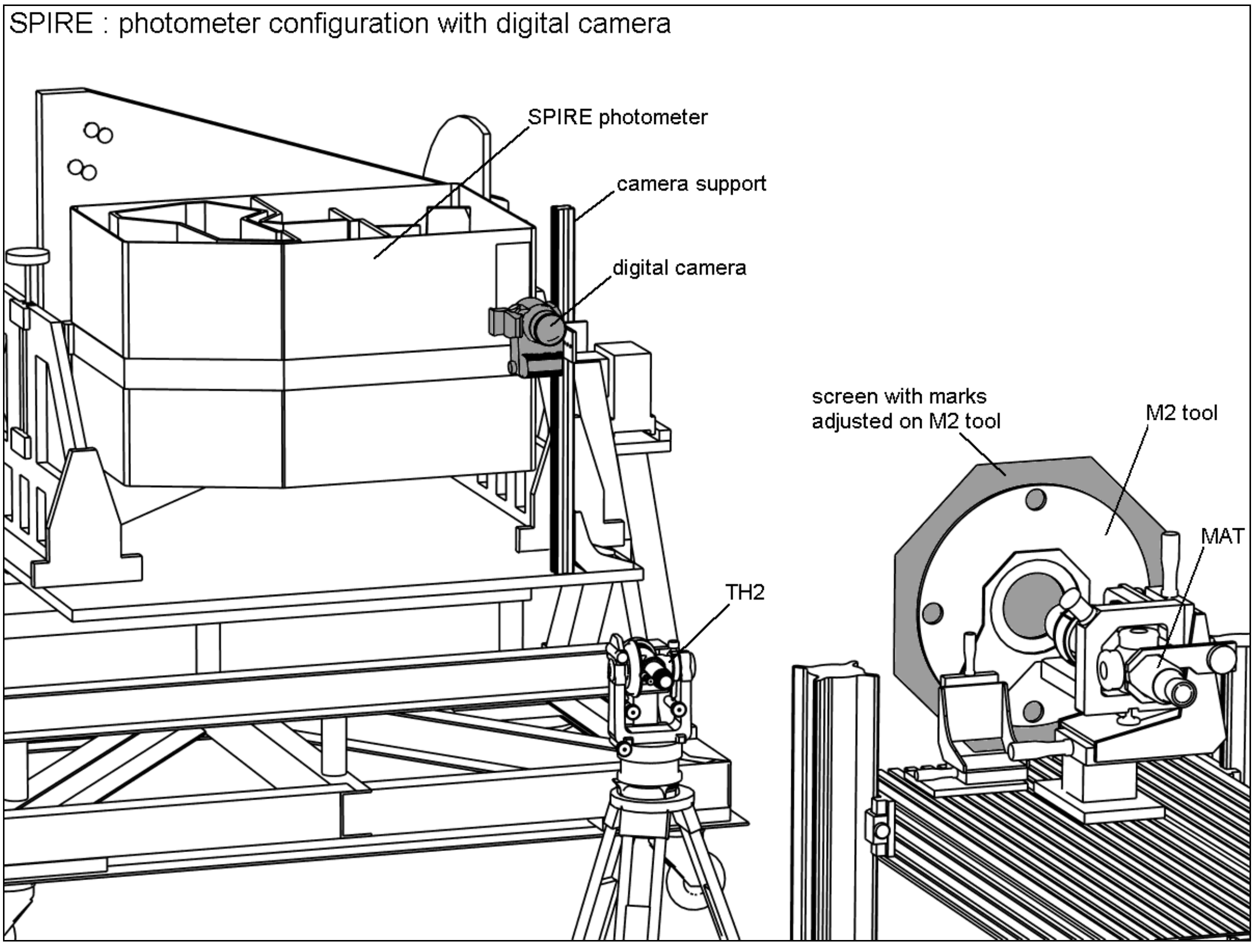
3.7.4.12 **Path SSW_A:** Light SSW source, block interferometer arm A. Repeat 3.7.4.9 and 3.7.4.10.

3.7.4.13 **Path SSW_B:** Light SSW source, block interferometer arm B. Repeat 3.7.4.9 and 3.7.4.10.

Table 1. Procedure for measuring the four paths of the spectrometer.

Path name	SLW	SSW	Upper arm (A)	Lower arm (B)
SLW_A	On	Off	Open	Closed
SLW_B	On	Off	Closed	Open
SSW_A	Off	On	Open	Closed
SSW_B	Off	On	Closed	Open

3.7.5. Photometer pupil reference map



3.7.5.1 Cover off, SCS tool in place.

3.7.5.2 Replace one of SD tools with the Fiber holder.

3.7.5.3 Sanded aluminium screen mounted onto M2 tool.

3.7.5.4 Install the digital camera on its support fixed on the HOB plate with a screw vice.

3.7.5.5 Adjust the camera high in order to be as close as possible to the Spire output beam Project cold stop onto M2 plane, take picture.

3.7.6. Photometer pupil alignment verification

3.7.6.1 Remount PD-tool, remove M2 aluminium plate

3.7.6.2 Observe PD tool diodes through MAT

3.7.6.3 Verify cold stop aligned with gut ray by lighting each PD tool diode in turn.
Comments: The MAT field is too small to observe the central PCS tool central cross projected on the M2 plane. This verification is therefore made by focalizing on the D-tool projected onto the instrument input plane, then gradually shifting focus towards the M2 plane. The spot will change into a cross, which should stay centered on the MAT cross hair.

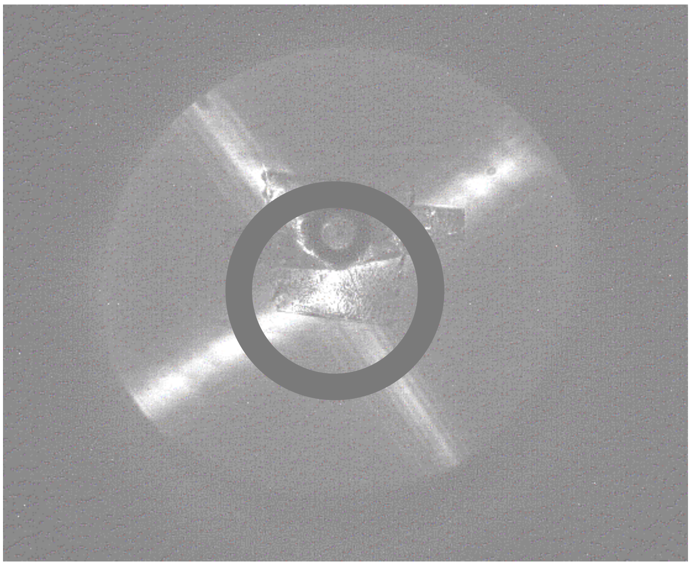
Alternative procedure

3.7.6.4 Place a Plexiglas plate in the M2 plane. Determine the position of the optical axis by the MAT, previously aligned on the telescope axis by aid of the HOR. Mark this position with an opaque ring, Ø5-10mm.

3.7.6.5 Position the M2 loupe equipped with electronic camera behind the Plexiglas plate, approximately centred on the telescope axis.

3.7.6.6 Light each PD tool diode in turn and observe the projection of the PCS tool central cross onto the M2 plane through the M2 loupe. Measure and note decentration.

Comments: The image below shows the central PCS tool central cross projected on the M2 plane as seen through the M2 loupe. A circle has been superpose to indicate the described procedure.



3.7.7. Photometer pupil quality verification

3.7.7.1 Locate M2-tool with respect to the SPIRE box

Comments: This will already be the case if above procedure followed.

3.7.7.2 Verify cold stop position for different field points

Comments: Observe (by the aid of the specially designed loupe) the projected edge of the PCS-tool through one of the edge reticules in the M2-tool. Light up sequentially each of the sources in the D-tool, measure position of the edge for each field point. Repeat for each of the edge reticules in the M2-tool. Deviations are recorded and compared with optical model.

3.7.8. Photometer focus and image quality verification

Focus and image quality (Zernike coefficients) are quantitatively deduced from the Hartmann test results using one extra focal and one intra focal image of the Hartmann screen. Best focus position is also qualitatively estimated by observation of through-focus screen images.

Image quality must be measured separately for each point in the FOV (centre and four corners) for the PLW detector position and (at least) for the FOV centre for each of the PMW and PSW detector positions.

3.7.8.1 Replace the PCS tool with the P-Hartmann tool (disk with grid of holes).

3.7.8.2 Make Hartmann screen reference map: Replace one of PD tools with fiber holder, mount aluminium plate on M2 tool, project Hartmann screen on M2 plane, take picture.

3.7.8.3 Mount both PD tools with source size reduced by the aid of pinholes.

3.7.8.4 Calibrate Hartmann bench by focussing the detector on a well-defined object (eg knife edge) at a distance FFD = 310mm in front of the front flange of the Hartmann lunette.

Comments: The procedure is described in "SPIRE STM optical alignment campaign, Photometer Hartmann test", KD, 11/9/2003. Drop if already effectuated for Spectrometer verification.

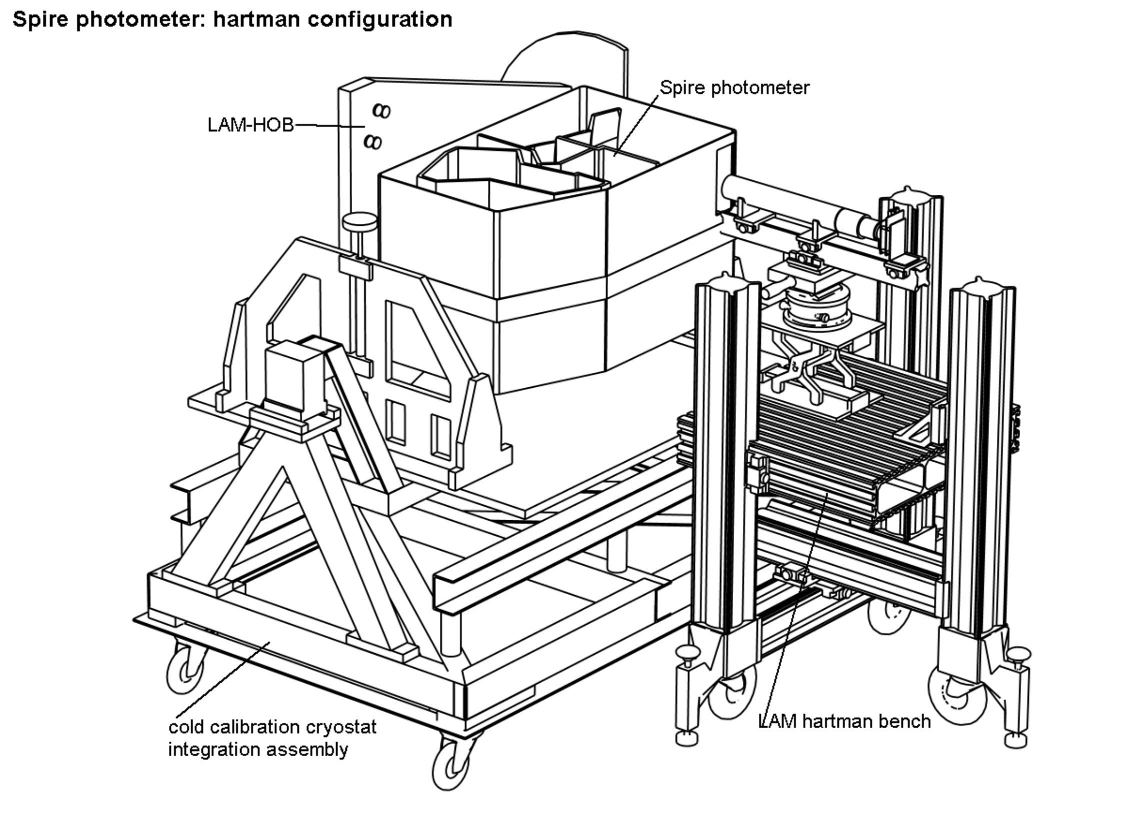
3.7.8.5 Place the Hartmann bench in front of the instrument with the front flange approximately 93.68mm from the instrument entrance hole.

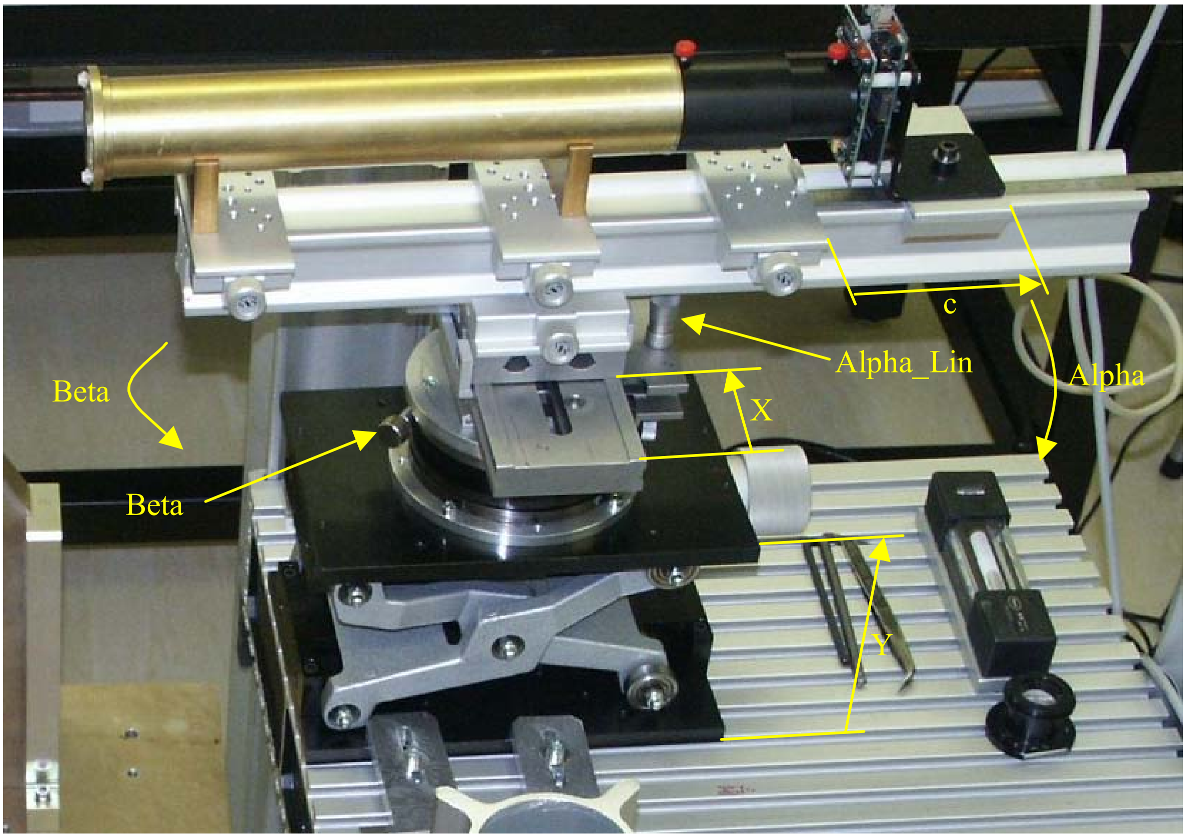
Comment: The photometer best focus lies 216.32mm inside the instrument along the photometer gut ray.

3.7.8.6 Align the lunette laterally and angularly on the photometer gut ray by the aid of the MAT. Note in the table below the four Hartmann bench coordinates corresponding to the central FOV point (E) in the table below: X (horizontal translation), Y (vertical translation), β (azimuth rotation, deg, min, sec scale), α (elevation, linear scale with 100mm arm). Calculate coordinates for the other field points as indicated.

3.7.8.7 Adjust the axial position of the lunette front flange to 93.68mm from the entrance hole by the aid of a metal ruler.

Comments: This axial adjustment is delicate and a precision of ±1mm may be expected. This corresponds to an RMS wavefront error contribution of 0.8µm.





Definition of Hartmann bench adjustment parameters.

3.7.8.8 **PLW point E:** Mount PD tool in PLW position. Light central diode (E).

3.7.8.9 Store a series of images in intra and extra focal positions covering ±30mm from the theoretical image position, separated by 5mm. Identify carefully the detector position for each image.

Comments: Two of these images will be chosen for Hartmann test calculations. Nominal defocus distance is ±15mm, but more may be necessary. Intra and extra focal distances can be different The Hartmann test requires that all spots are clearly distinguishable in both intra and extra focal images.

3.7.8.10 Store a series of images in intra and extra focal positions covering ±5mm from the apparent best focus position, separated by 1mm.

3.7.8.11 **PLW point A:** Adjust Hartmann bench to field point A according to coordinates calculated in the table below. Light diode A. Repeat 3.7.8.9 and 3.7.8.10.

3.7.8.12 **PLW point B:** Adjust Hartmann bench to field point B according to coordinates calculated in the table below. Light diode B. Repeat 3.7.8.9 and 3.7.8.10.

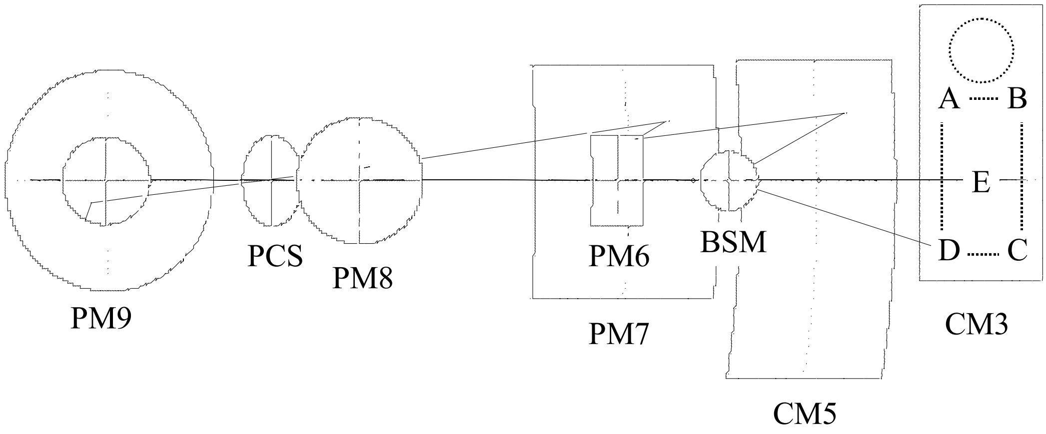
3.7.8.13 **PLW point C:** Adjust Hartmann bench to field point C according to coordinates calculated in the table below. Light diode C. Repeat 3.7.8.9 and 3.7.8.10.

3.7.8.14 **PLW point D:** Adjust Hartmann bench to field point D according to coordinates calculated in the table below. Light diode D. Repeat 3.7.8.9 and 3.7.8.10.

3.7.8.15 **PLW point E:** Adjust Hartmann bench back to field point E according to coordinates calculated in the table below. Light diode E. Verify that alignment is back to original.

3.7.8.16 **PMW point E:** Move PD tool to PMW position. Light diode E. Repeat 3.7.8.9 and 3.7.8.10.

3.7.8.17 **PSW point E:** Move PD tool to PSW position. Light diode E. Repeat 3.7.8.9 and 3.7.8.10.



Defnition of field points as projected onto the SPIRE input plane.

Calculation of Hartmann bench adjustment parameters for each field point.

Parameter	**Unit**	**E**	**A**	**B**	**C**	**D**
Synopsys input						
H	arcmin	0.00	-2.00	2.00	2.00	-2.00
G	arcmin	0.00	-4.00	-4.00	4.00	4.00
Synopsys output						
tan_beta		0.000000	-0.006301	0.006286	0.006286	-0.006301
tan_alpha		0.000000	-0.012575	-0.012573	0.012573	0.012575
Hartmann bench adjustments						
Linear Hartmann bench coordinates						
ΔX	mm	0.00	-12.99	12.96	12.96	-12.99
ΔY	mm	0.00	-25.92	-25.91	25.91	25.92
Angular Hartmann bench coordinates						
$\Delta\beta$	deg:min:sec	-0:0:0	-0:21:40	0:21:37	0:21:37	-0:21:40
$\Delta\alpha$	mm	0.00	-1.26	-1.26	1.26	1.26

Linear Hartmann bech adjustments

$X = X_E \pm \Delta X$ **mm**

$Y = Y_E \pm \Delta Y$ **mm**

Angular Hartmann bench adjustments

$\beta = \beta_E \pm \Delta\beta$ **deg:min:sec**

$\alpha = \alpha_E \pm \Delta\alpha$ **mm**

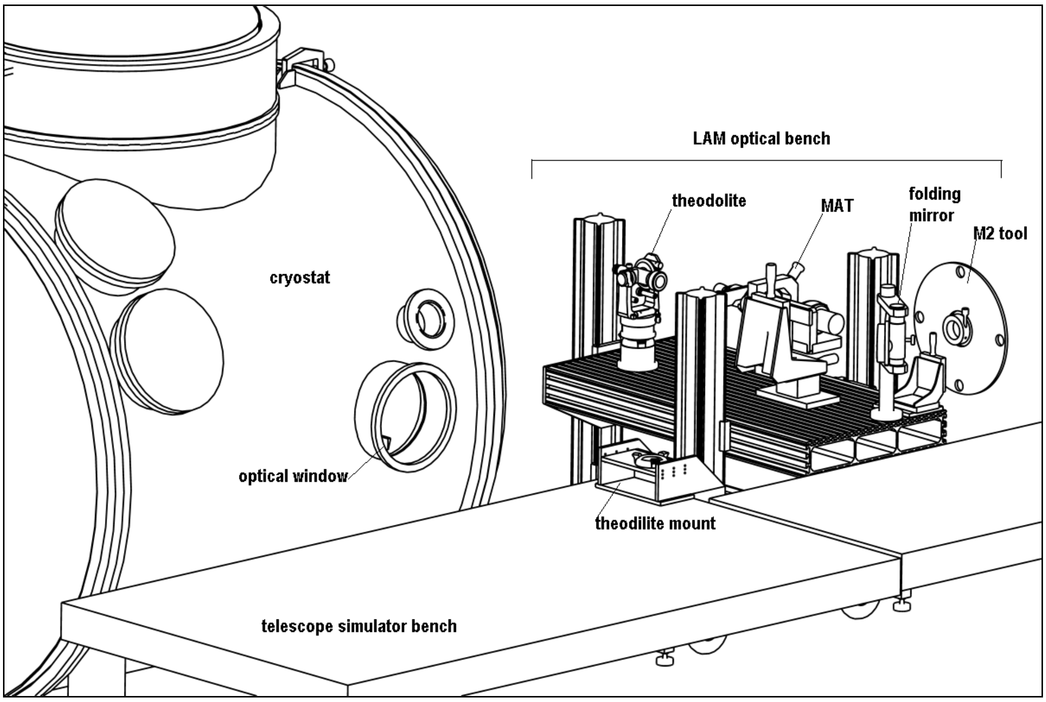
Chapter 3.8

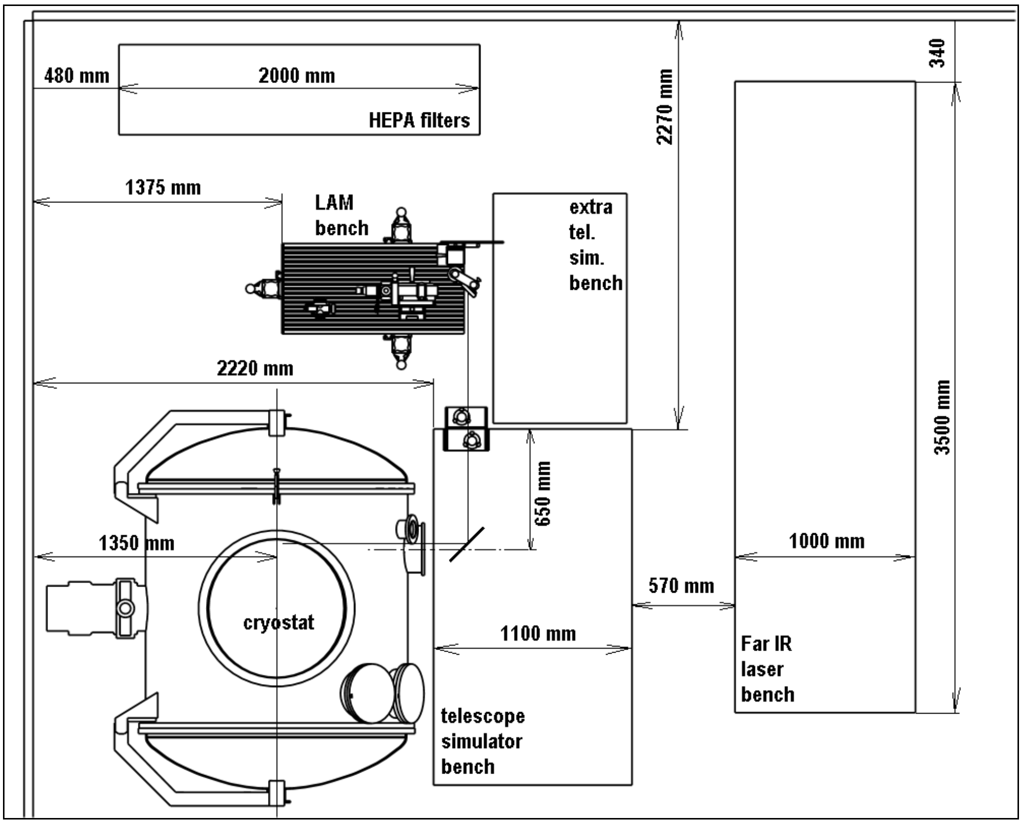
Cryo verification

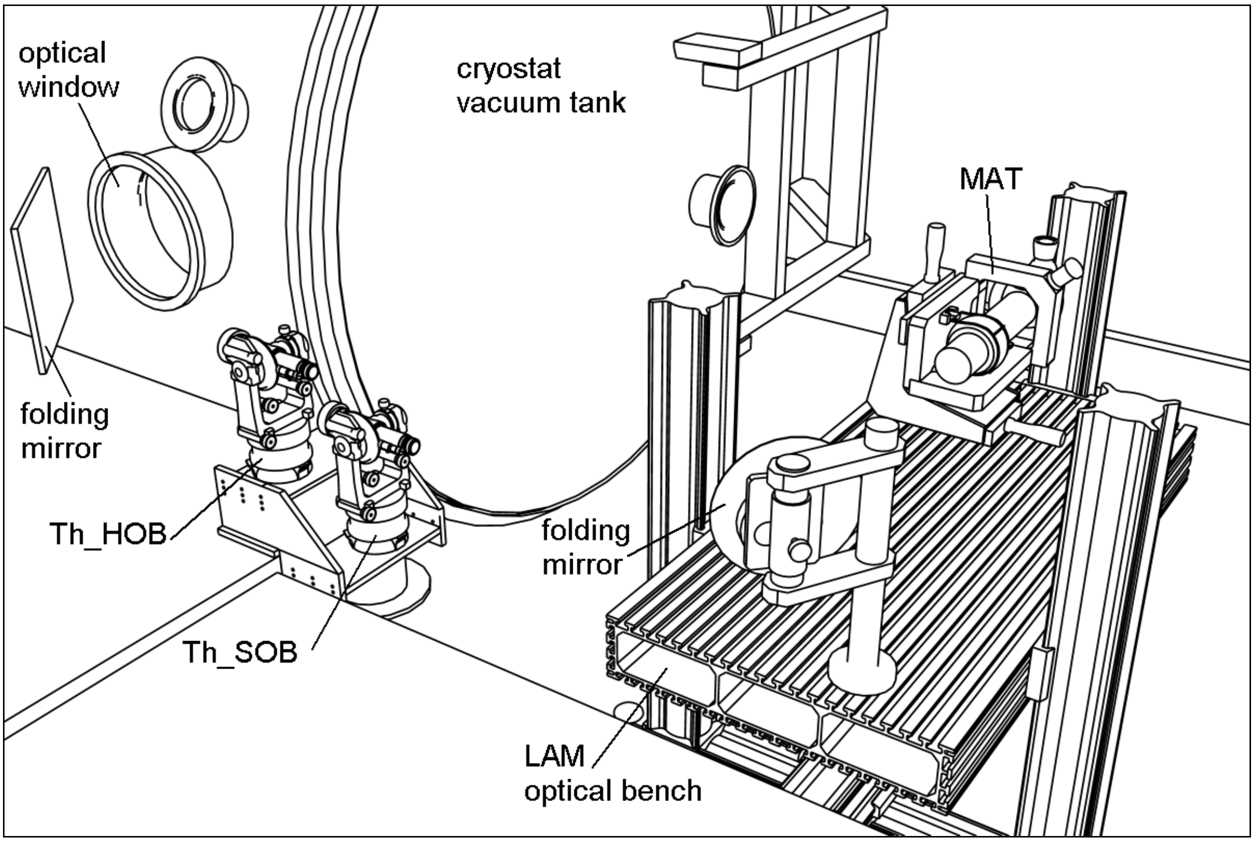
3.8. Cryo verification

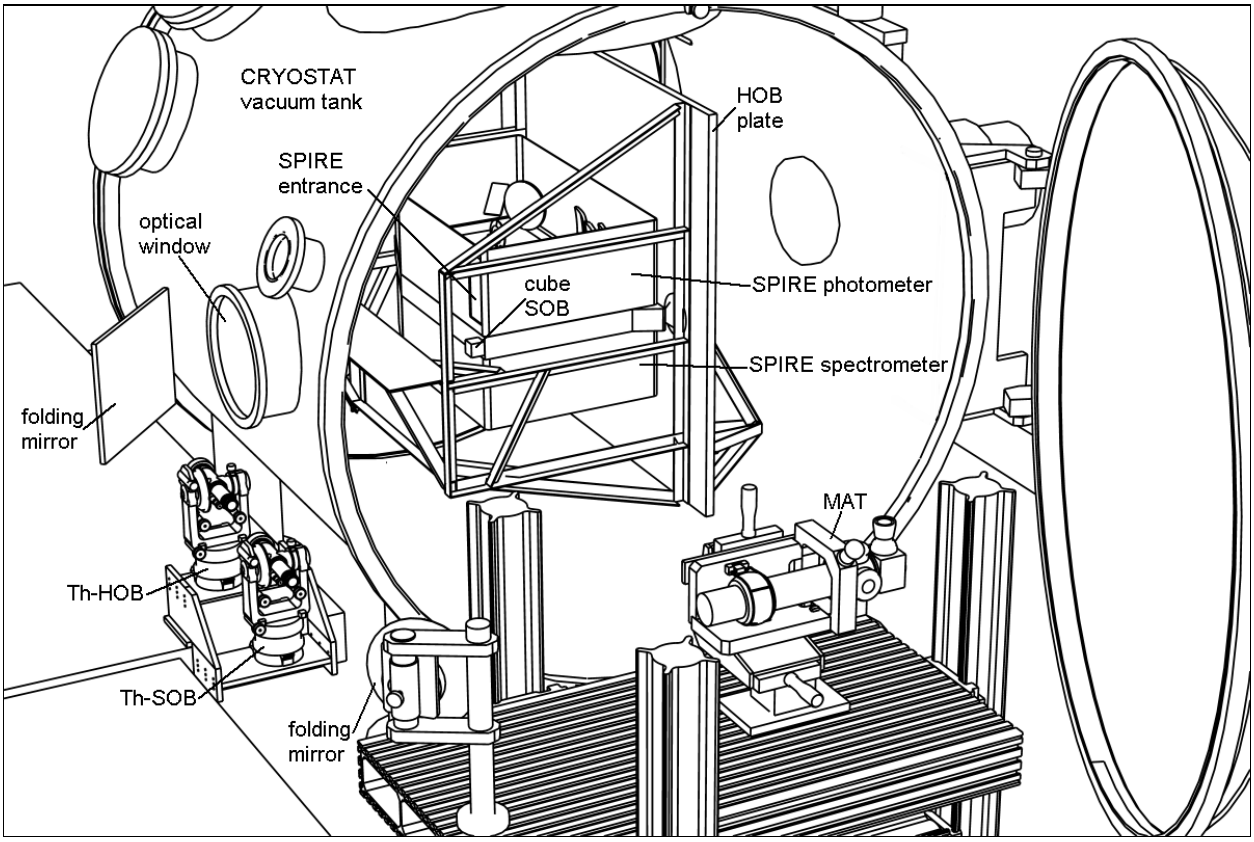
Goal: Series of measurements performed at ambient vacuum, cold vacuum, and again at ambient vacuum. Allows monitoring of changes to the external and internal alignment of the instrument by monitoring of relative orientation of the two alignment cubes HOR and SOR and position of the projected cold stop.

3.8.1. Global views of OGSE at cryo configuration

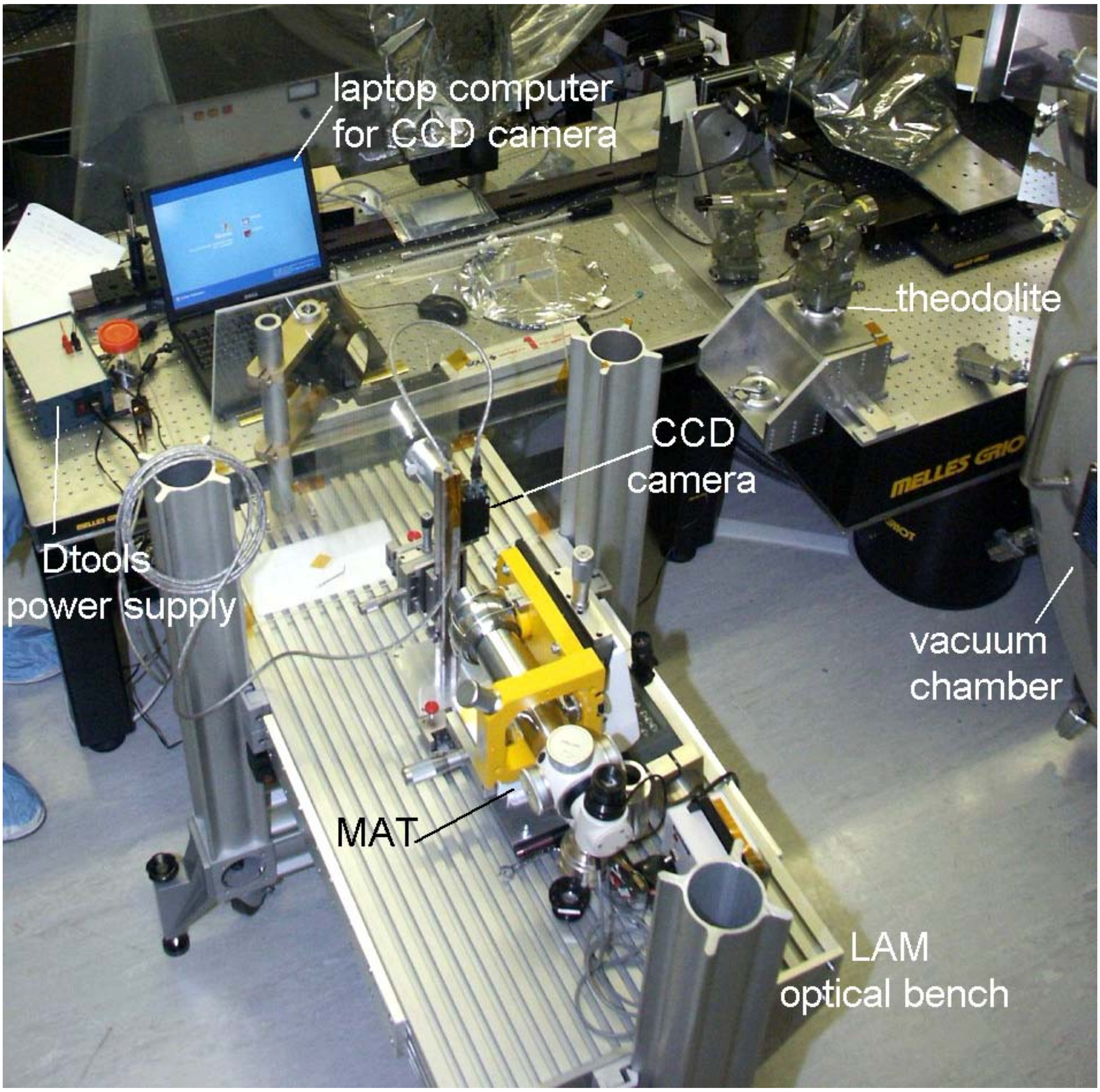





optical window
cryostat vacuum tank
MAT
folding mirror
Th_HOB
folding mirror
Th_SOB
LAM optical bench


CRYOSTAT vacuum tank
HOB plate
SPIRE entrance
optical window
cube SOB
SPIRE photometer
SPIRE spectrometer
folding mirror
MAT
Th-HOB
Th-SOB
folding mirror

LAM OPTICAL SETUP FOR CRYOSTAT



3.8.2. Ambient vacuum reference measurements

3.8.2.1 External alignment stability (HOB to SOB)

3.8.2.1.1 SPIRE mounted inside cryostat with RAL-HOB and HOR on it.

Comments: RAL-HOB and HOR are not made to be absolute references, so only serve as relative references.

3.8.2.1.2 Mount theodolite (TH_HOB) onto telescope simulator bench facing **HOR**. Adjust for autocollimation on HOR. Note site and elevation values.

$Azimuth_{HOB.}$ = . . . ° . . ’ . . ”

$Elevation_{HOB}$ = . . . ° . . ’ . . ”

3.8.2.1.3 Adjust for autocollimation on cryostat window. Note site and elevation values. Record difference in theodolite orientation.

$Azimuth_{windowHOB}$ = . . . ° . . ’ . . ”

$Elevation_{windowHOB}$ = . . . ° . . ’ . . ”

Comments: Although the cryostat window may not be optically flat, it is assumed that it will not change shape between hot and cold conditions under vacuum. It can therefore serve locally as reference surface (reflectivity about 4%). The instrument will move and change orientation on cool-down, because of its own behavior and the behavior of the structure of the whole cold cryostat integration assembly. This test checks the relative orientation of HOR and SOR with respect to the cryostat window. Any change recorded between warm and cold conditions will be a consequence of a structural deformation.

3.8.2.1.4 Mount theodolite (TH_SOB) onto telescope simulator bench facing **SOR**. Adjust for autocollimation on SOR. Note site and elevation values.

$Azimuth_{SOB.}$ = . . . ° . . ’ . . ”

$Elevation_{SOB}$ = . . . ° . . ’ . . ”

3.8.2.1.5 Adjust for autocollimation on cryostat window. Note site and elevation values. Record difference in theodolite orientation

$Azimuth_{windowSOB}$ = . . . ° . . ’ . . ”

$Elevation_{windowSOB}$ = . . . ° . . ’ . . ”

3.8.2.2 Photometer cold stop alignment

3.8.2.2.1 Align MAT to HOR (cf above) laterally and angularly.

3.8.2.2.2 Put the translucent scaled screen, in place of M2 plane, and centre it onto the M2 axis.

3.8.2.2.3 CCD camera equipped with M" loupe will record the projection of the PCS tool on the screen, see pictures (NB invisible to the eye because Dtool diodes are IR).

3.8.2.2.4 Light central D-tool source, record image and measure deviation

Comments: Deviation between CS tool projection and M2 centre represents error in pupil alignment.

3.8.2.2.5 Light sequentially other D tool sources, record images and measure deviations.

Comments: Deviation with respect to result of 3.8.2.2.2 represents pupil aberrations, to be compared with theoretical prediction.

3.8.2.3 Spectrometer cold stop alignment

3.8.2.3.1 Light sequentially spectrometer D-tool sources, record image and measure deviation

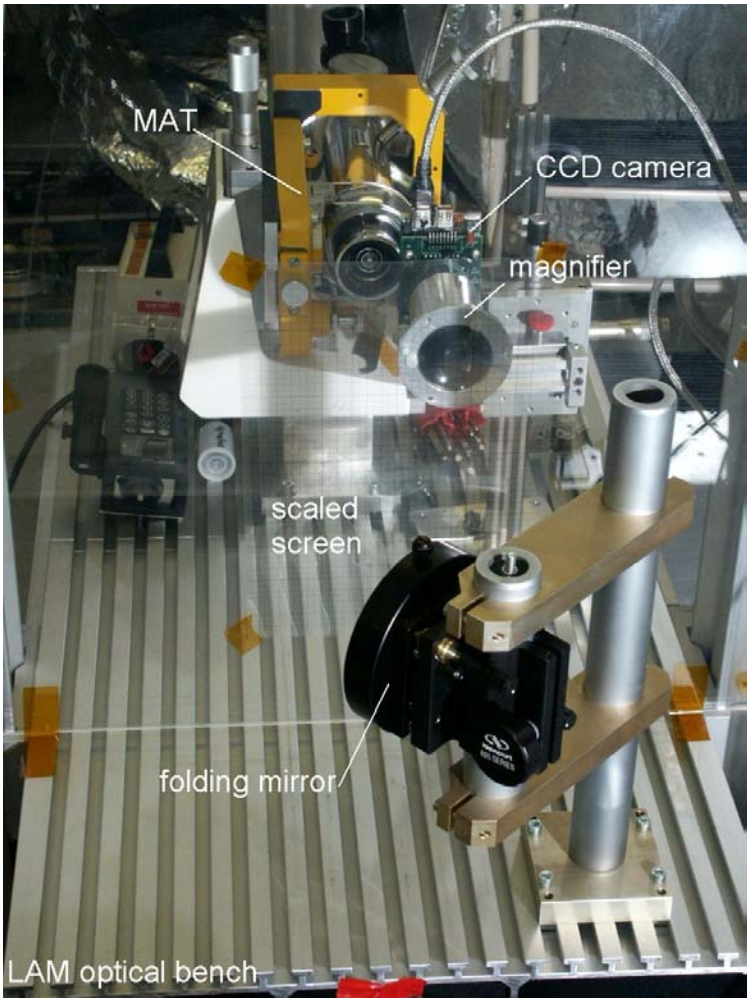
Comments: Deviation between CS tool projection and M2 centre represents error in pupil alignment.

3.8.3. Cold measurements

3.8.3.1 Cool down, repeat above procedures. Compare results.

3.8.4. Ambient re-verification

3.8.4.1 Heat up, repeat, compare.



Translucent scaled screen (plexiglas panel) is used to materialize the M2 plane.

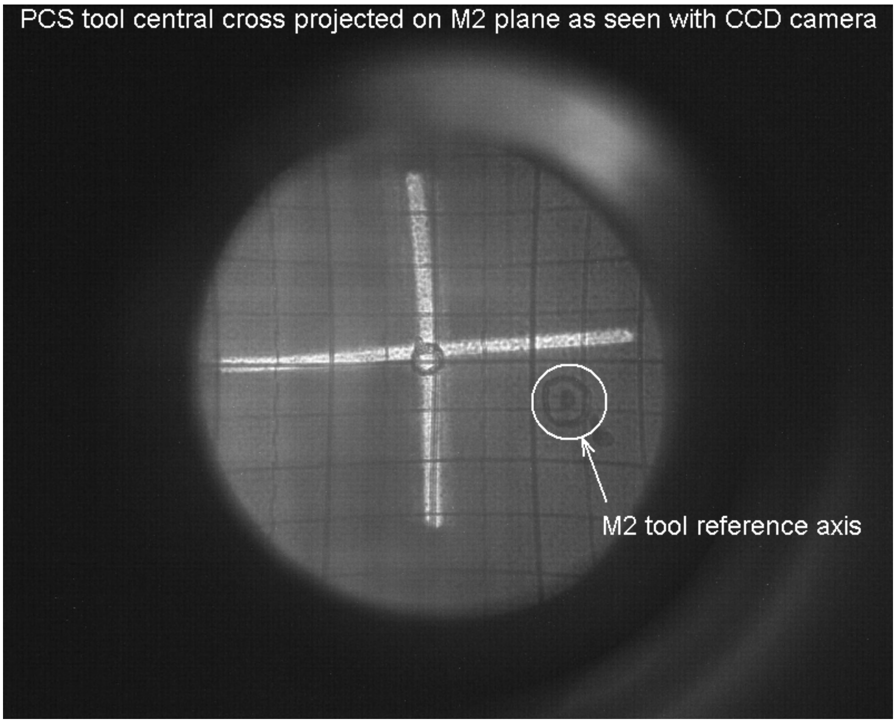


Image taken with the CCD camera of the PCS tool in near IR (Dtool led)

Chapter 4

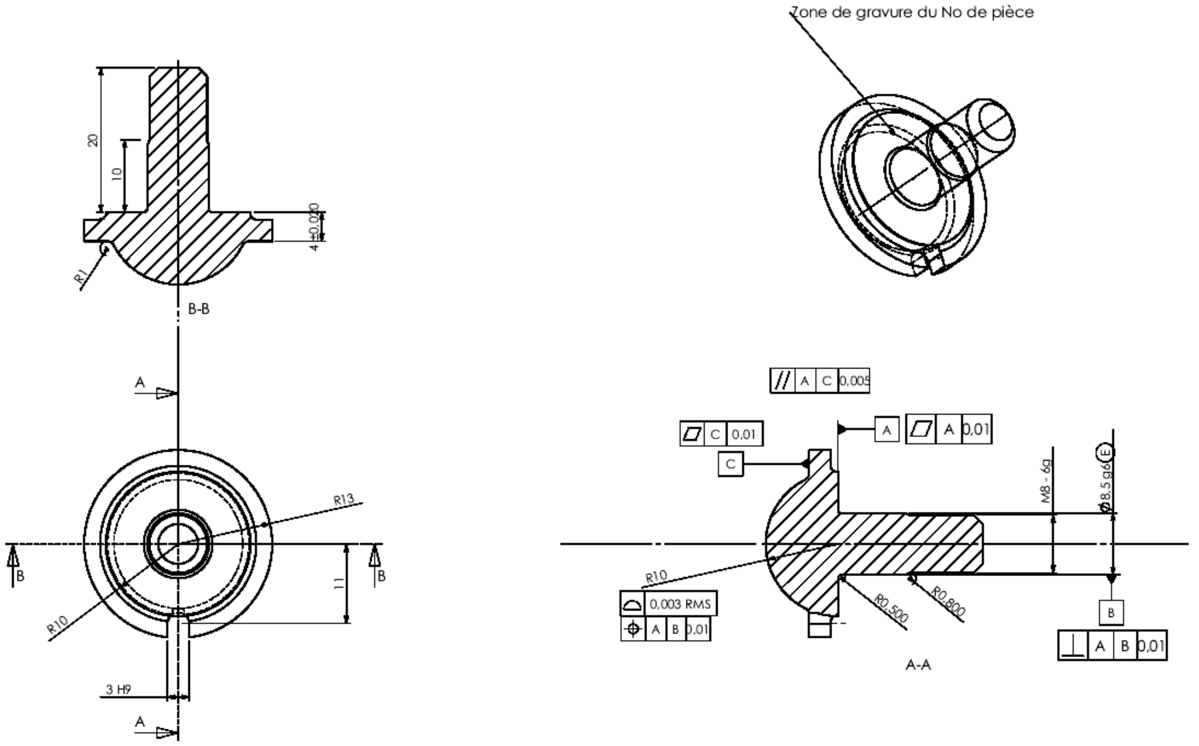
Optical alignment tools

4. Optical alignment tools

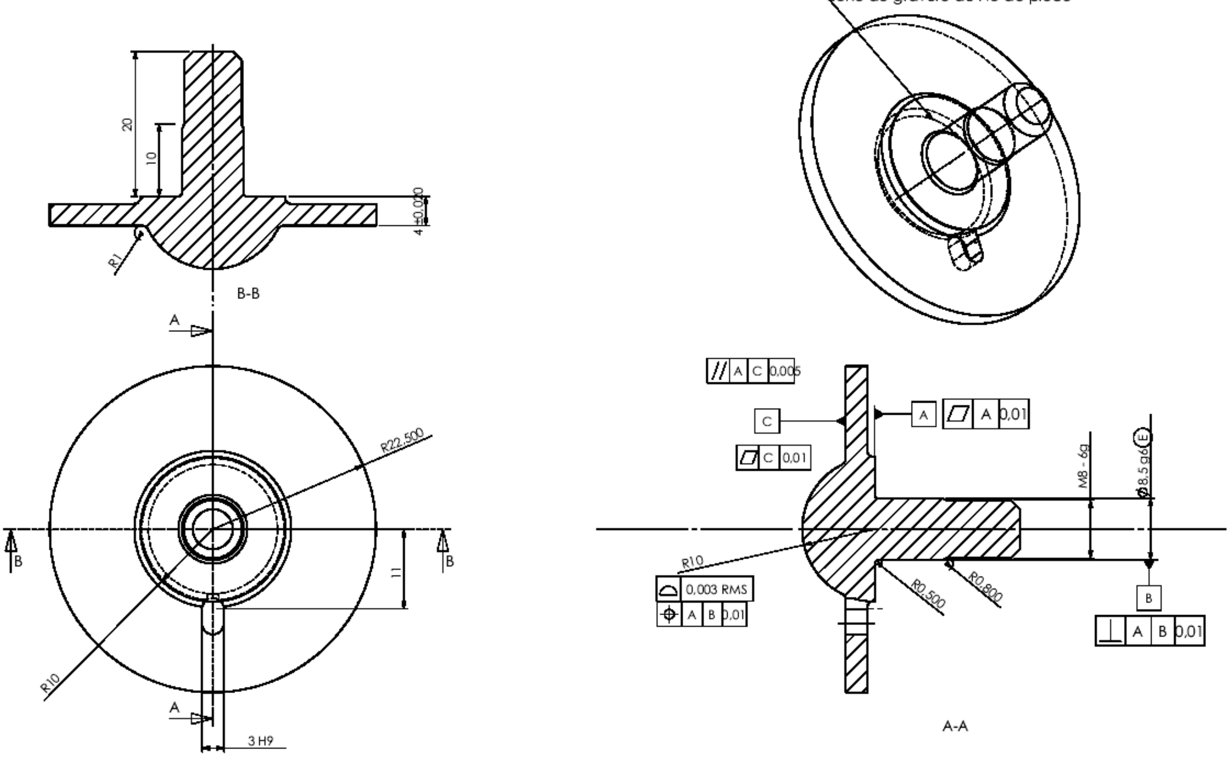
4.1. Mirror interface tools

4.1.1. 3D tools

3D tool 26 mm
Ref: SPI.OAL.20.DD.01.A

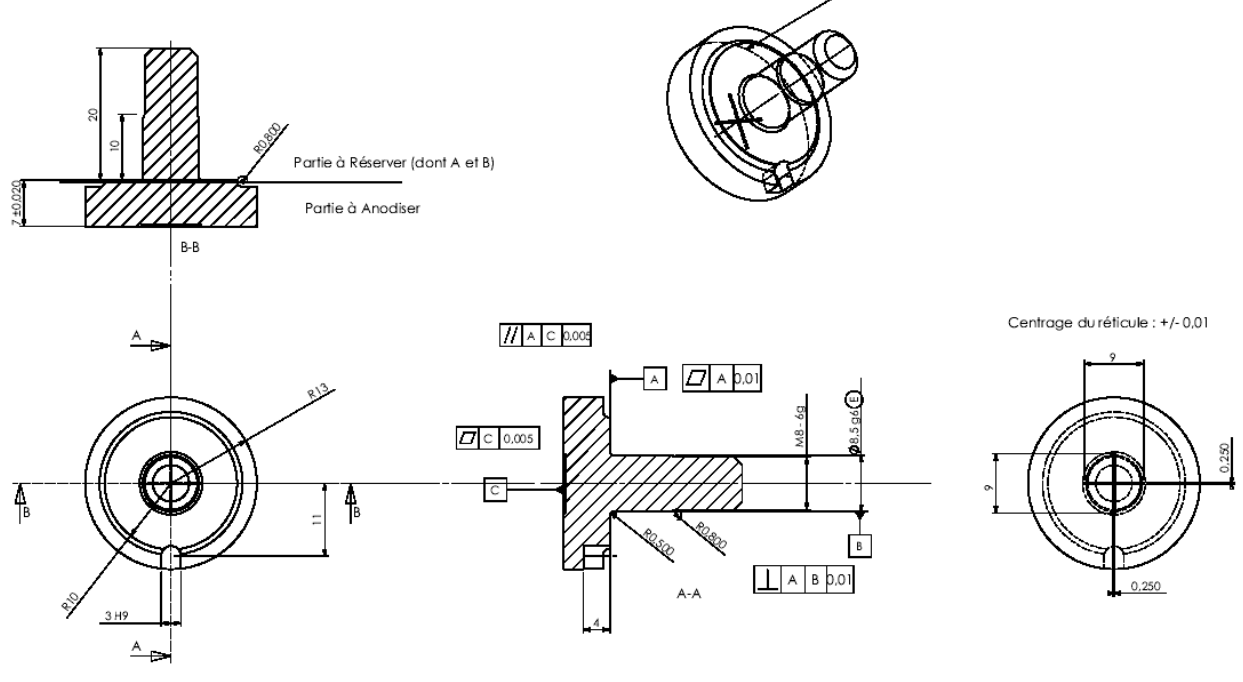


3D tool 45 mm
Ref: SPI.OAL.20.DD.02.A

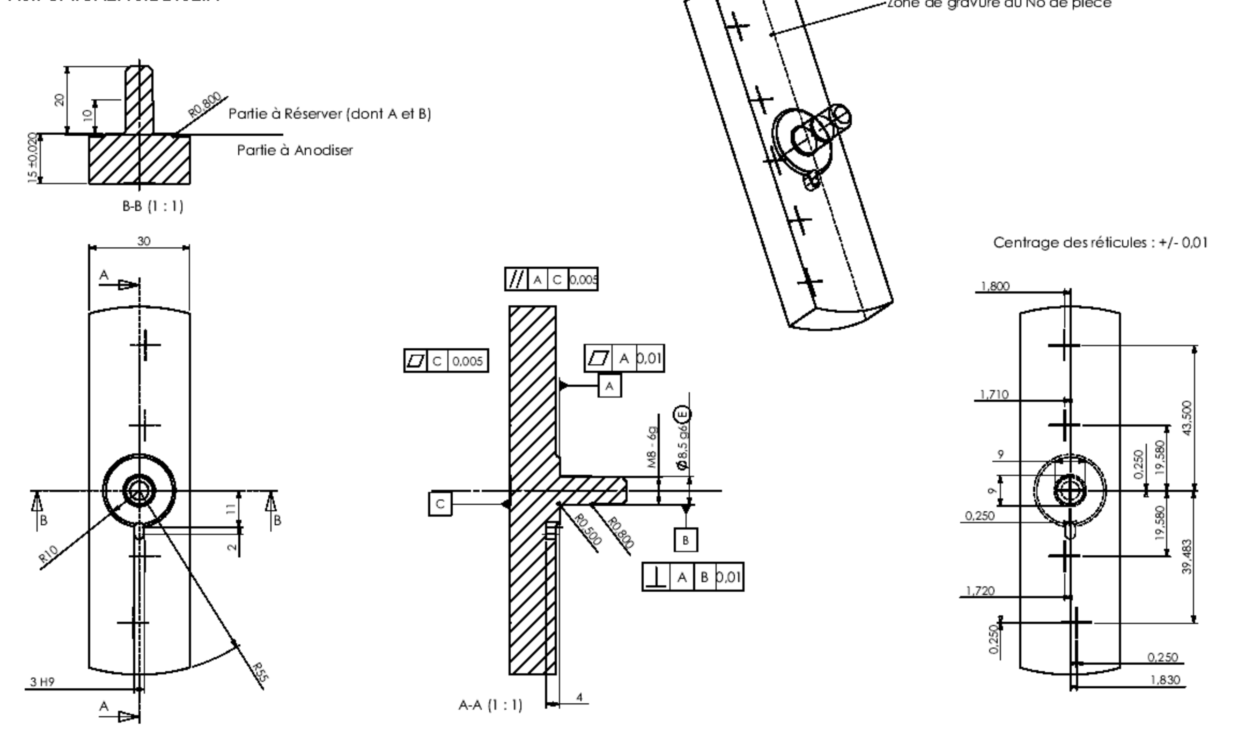


4.1.2. Apex tools

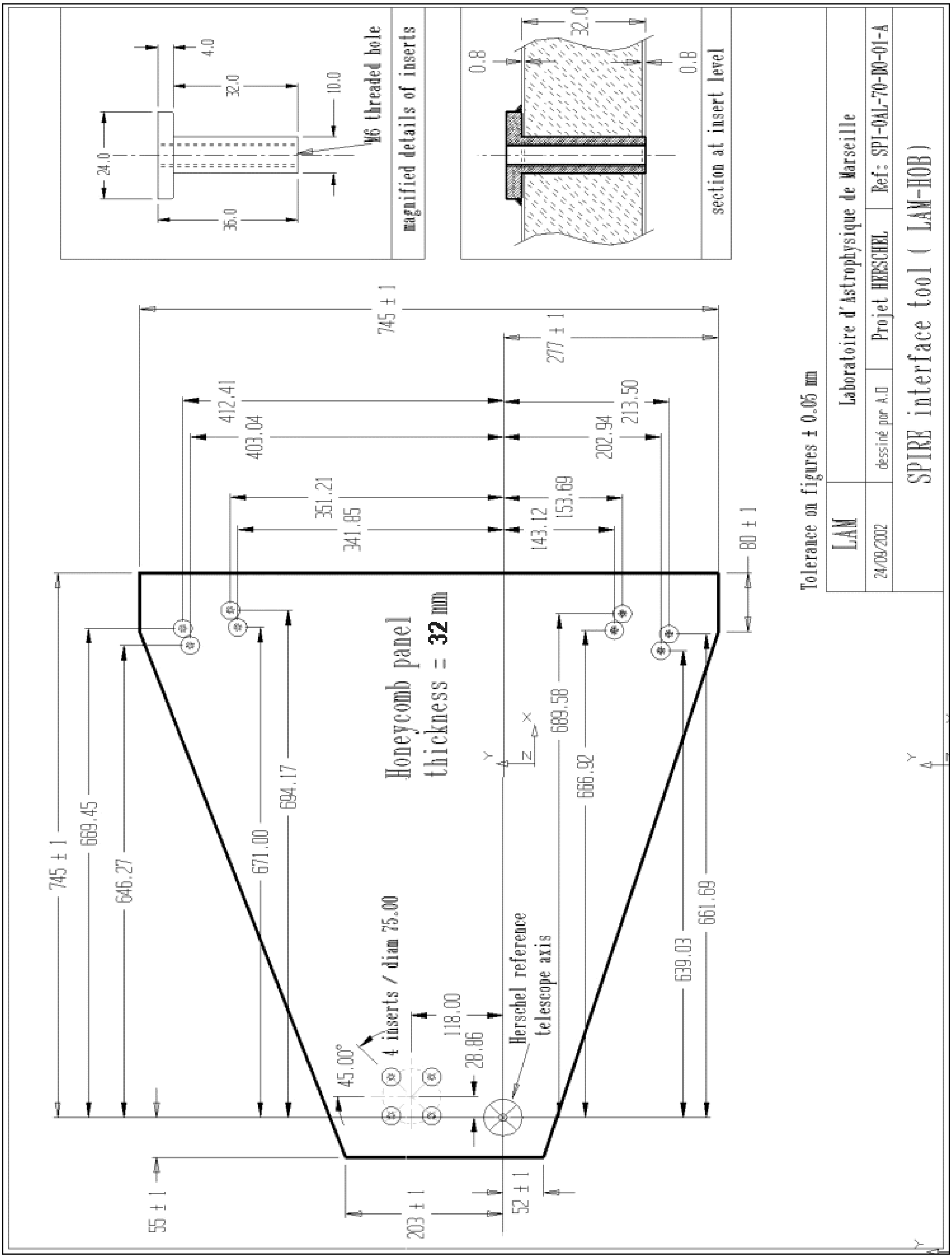
Apex tool 7mm
Ref: SPI.OAL.10.DD.01.A



Apex tool 15mm
Ref: SPI.OAL.10.DD.02.A

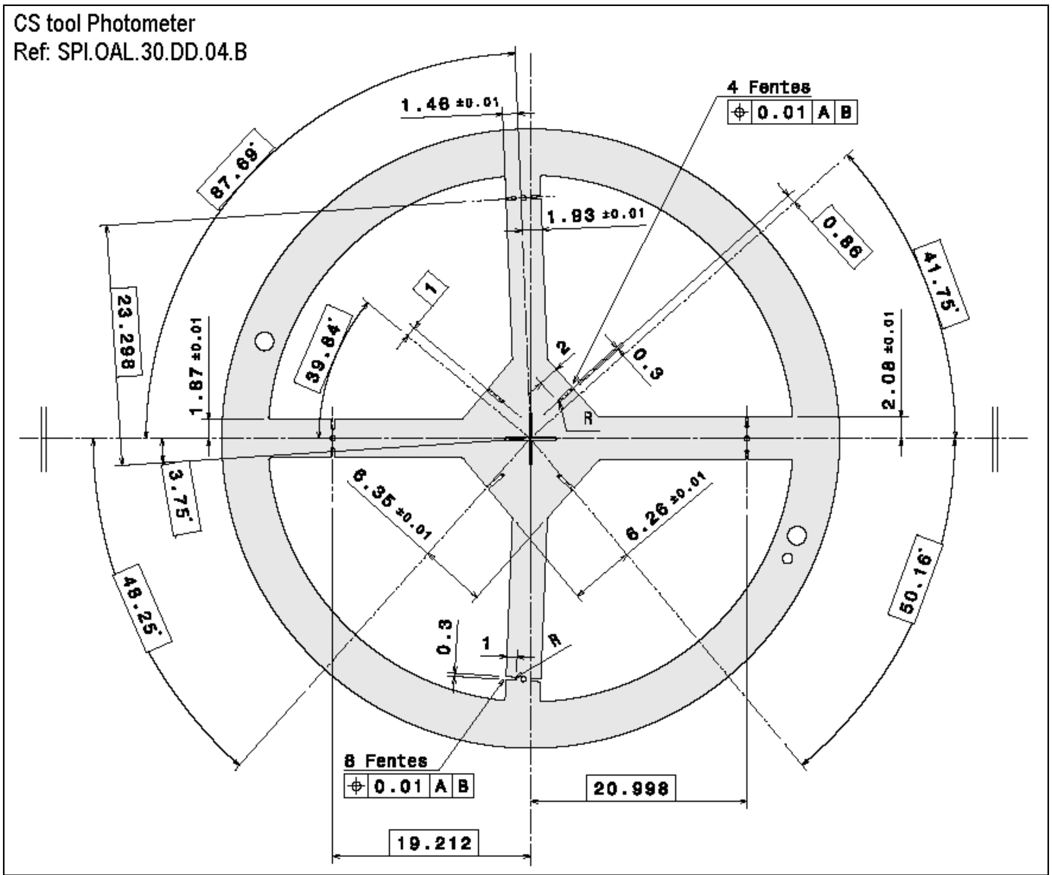


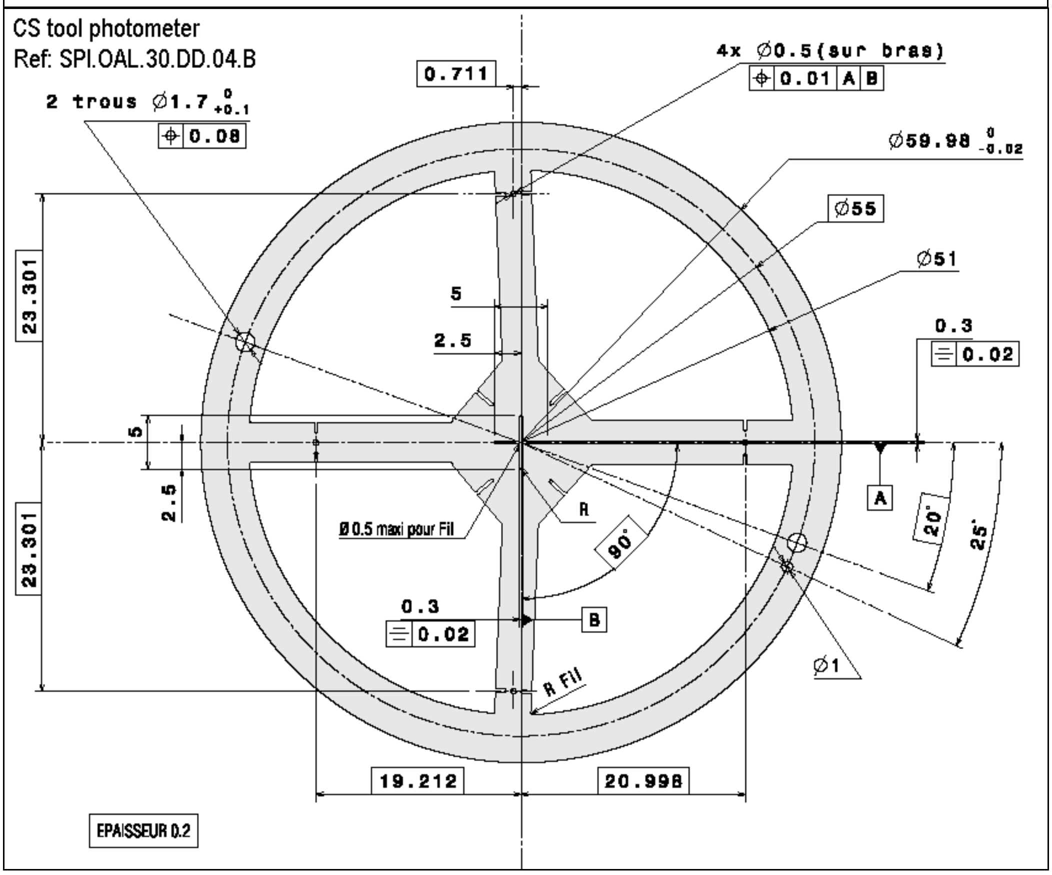
4.2. Spire telescope tool



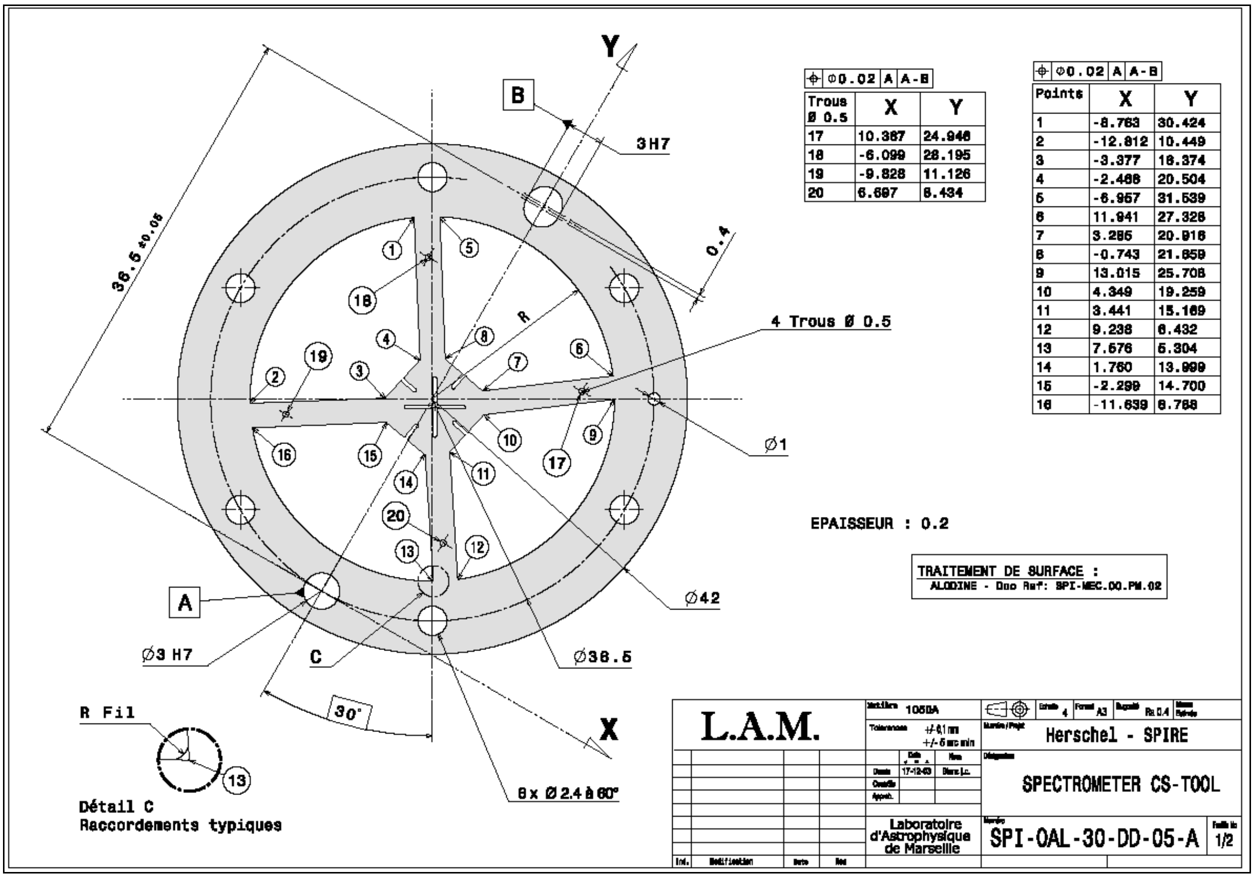
4.3. Cold stop tools

4.3.1. Photometer, PCS tool





4.3.2. Spectrometer, SCS tool

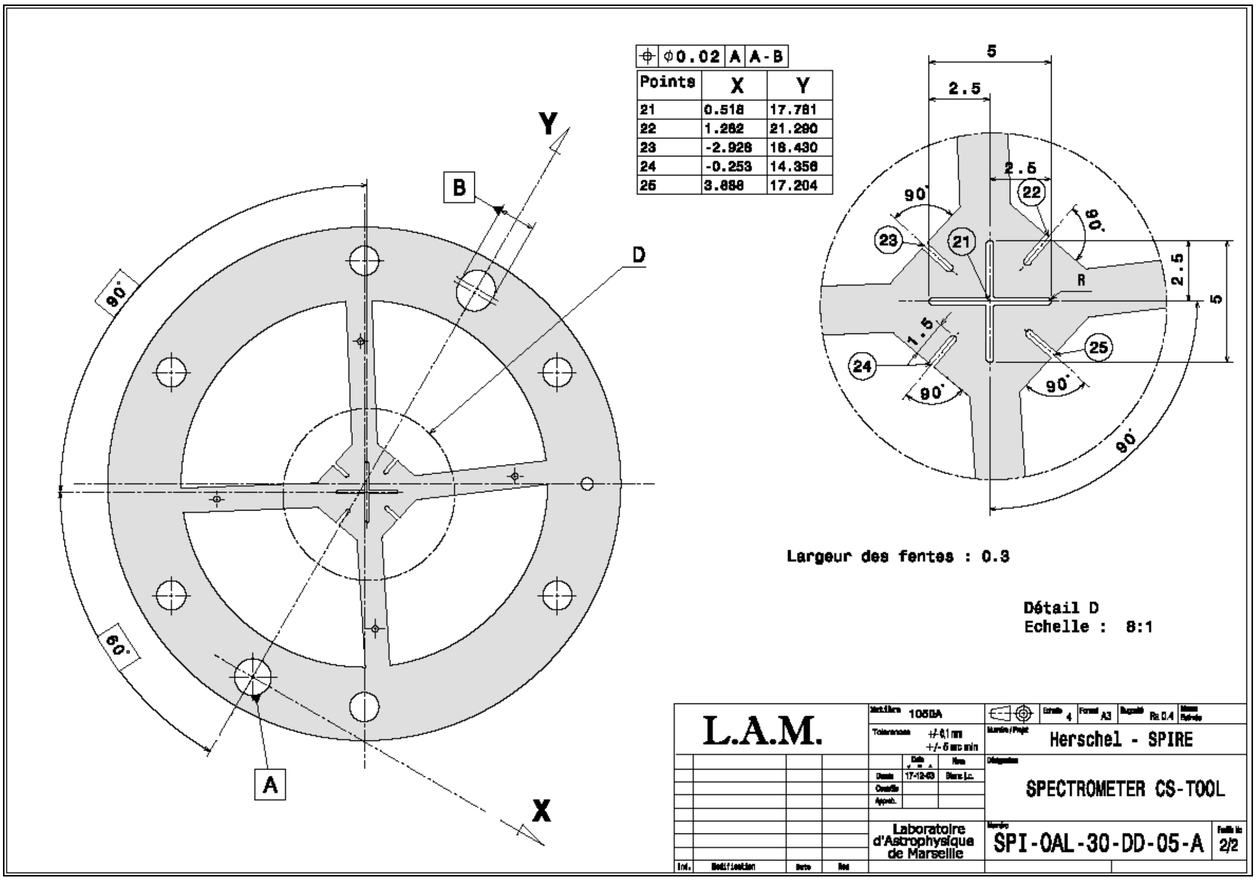


⌖ Φ0.02 | A | A-B

Trous Ø 0.5	X	Y
17	10.387	24.946
18	-6.099	28.195
19	-9.828	11.126
20	6.697	6.434

⌖ Φ0.02 | A | A-B

Points	X	Y
1	-8.763	30.424
2	-12.812	10.449
3	-3.377	18.374
4	-2.466	20.504
5	-6.957	31.539
6	11.941	27.328
7	3.285	20.916
8	-0.743	21.859
9	13.015	25.708
10	4.349	19.259
11	3.441	15.169
12	9.238	6.432
13	7.676	5.304
14	1.760	13.999
15	-2.299	14.700
16	-11.639	8.768

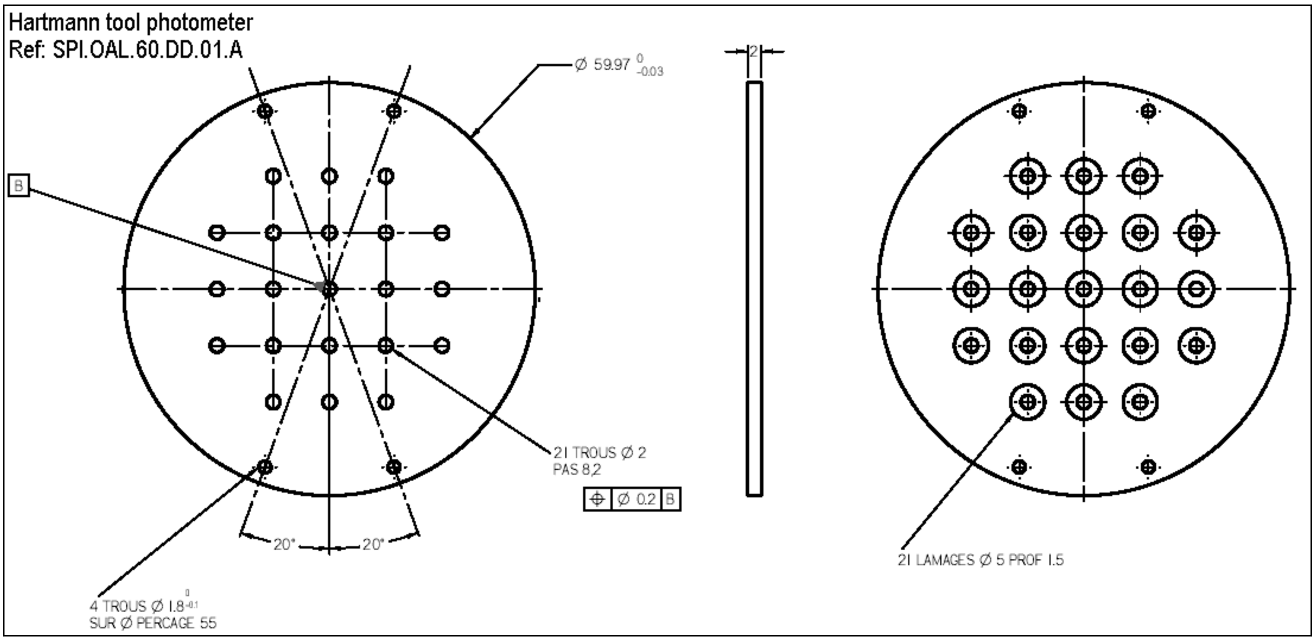


⌖ Φ0.02 | A | A-B

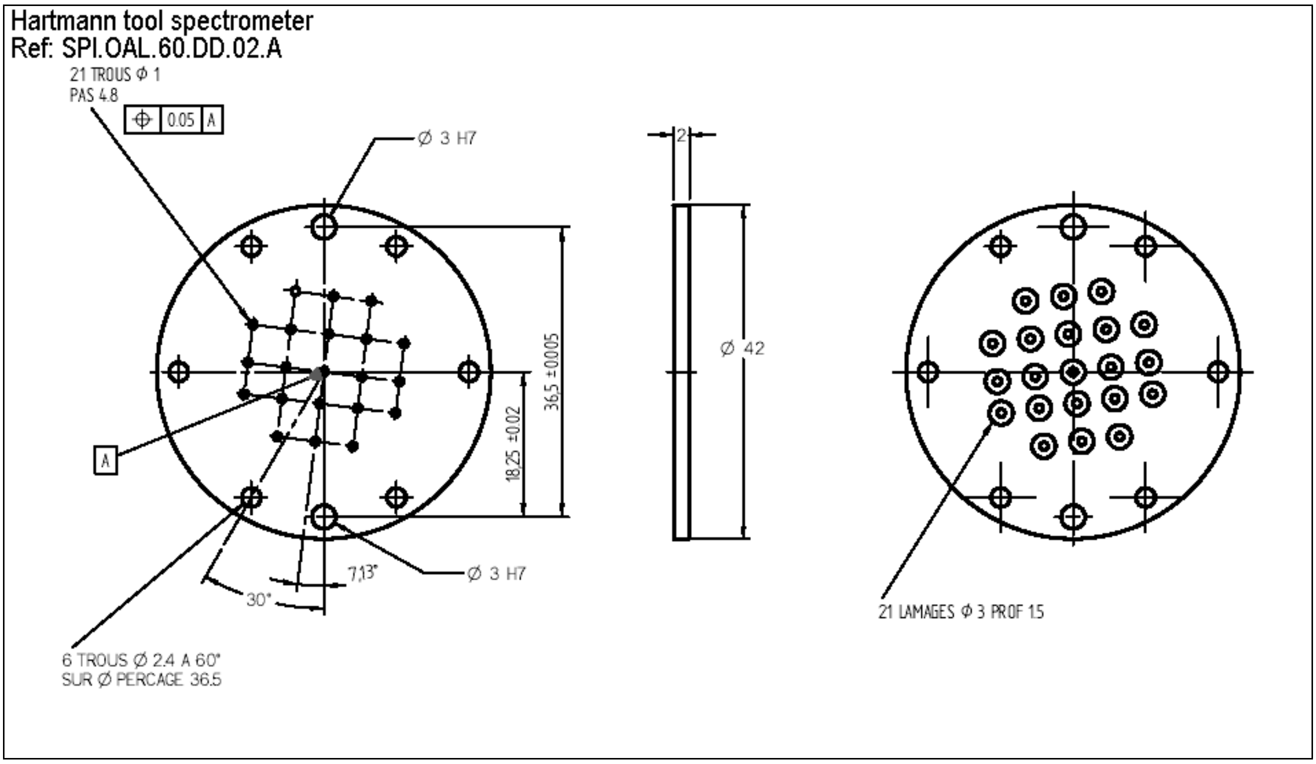
Points	X	Y
21	0.518	17.781
22	1.282	21.290
23	-2.928	18.430
24	-0.253	14.358
25	3.888	17.204

4.4. Hartman tools

4.4.1. Photometer



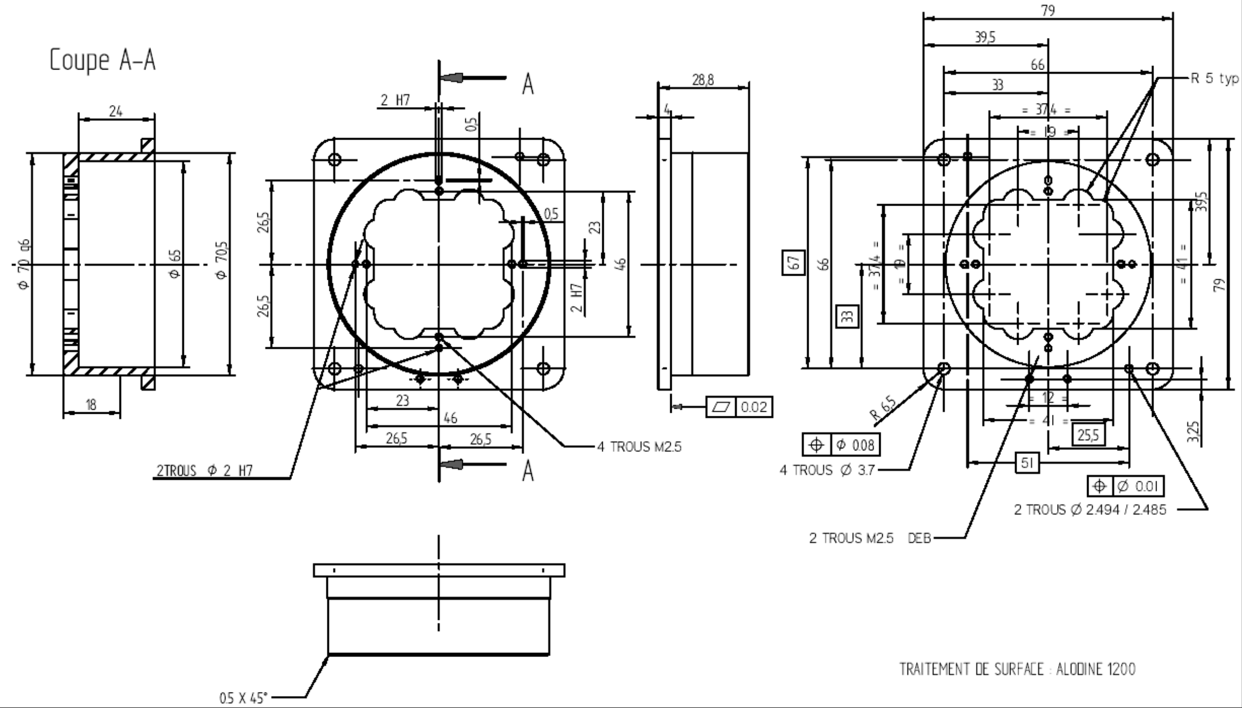
4.4.2. Spectrometer



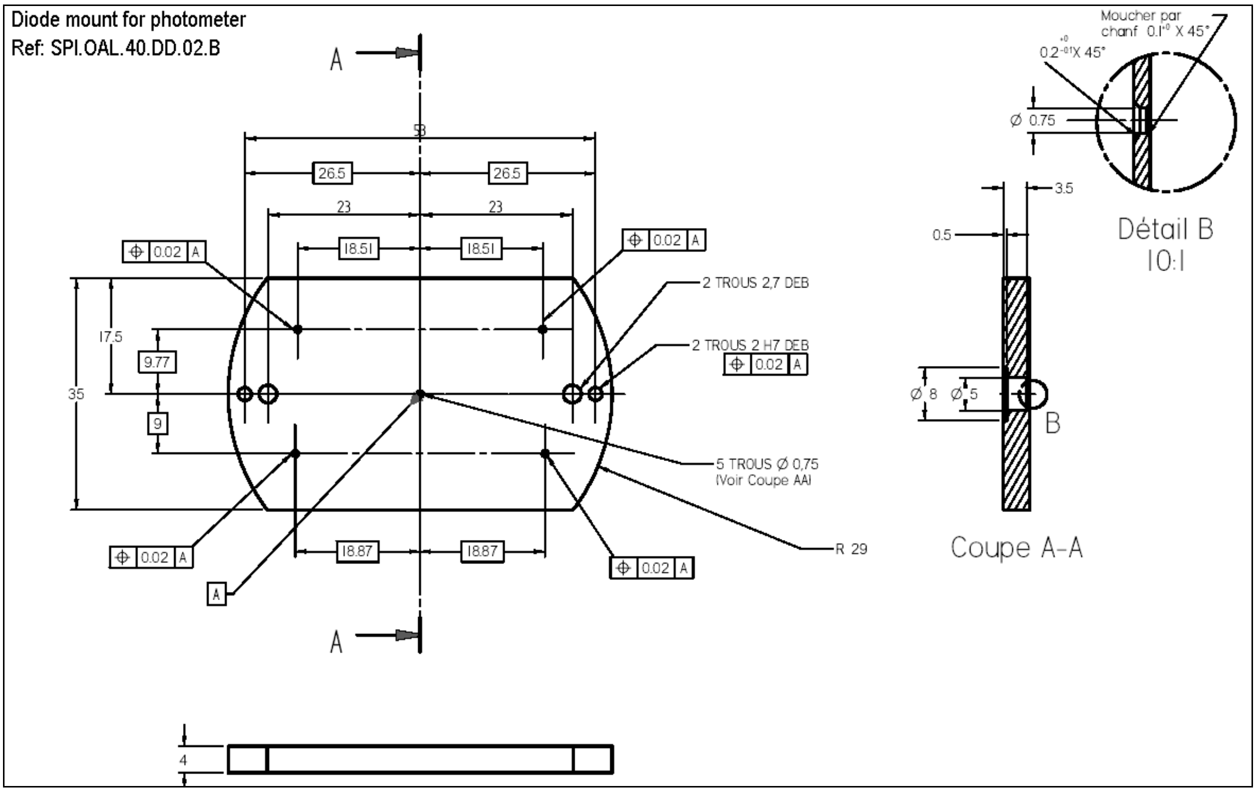
4.5. Detector tools

4.5.1. Photometer

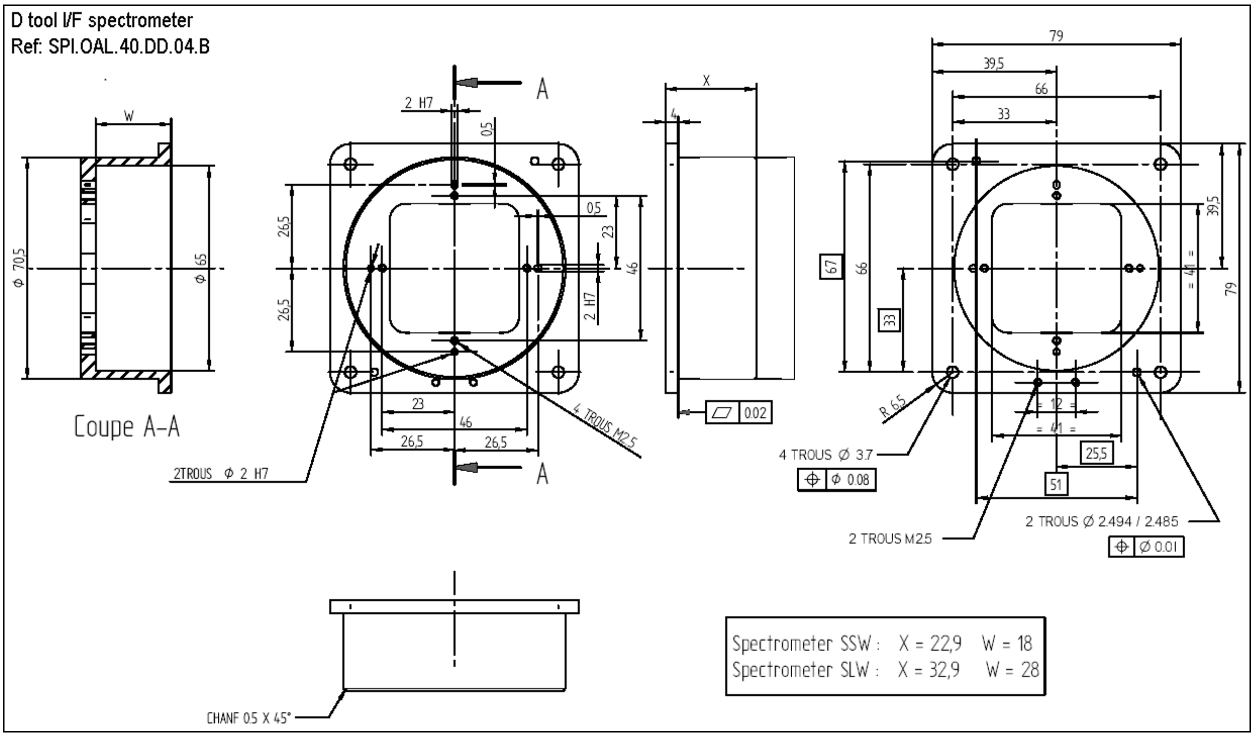
D tool I/F photometer
Ref: SPI.OAL.40.DD.01.B

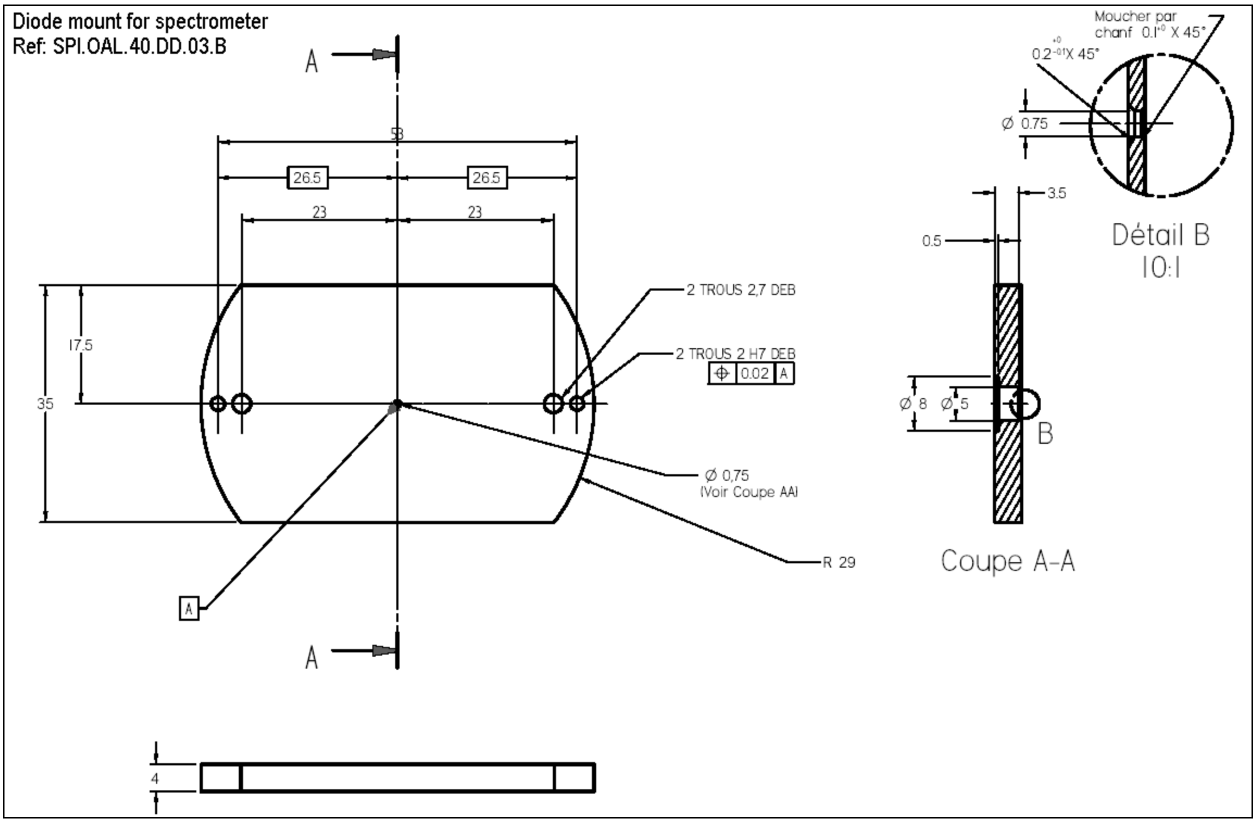


Diode mount for photometer
Ref: SPI.OAL.40.DD.02.B

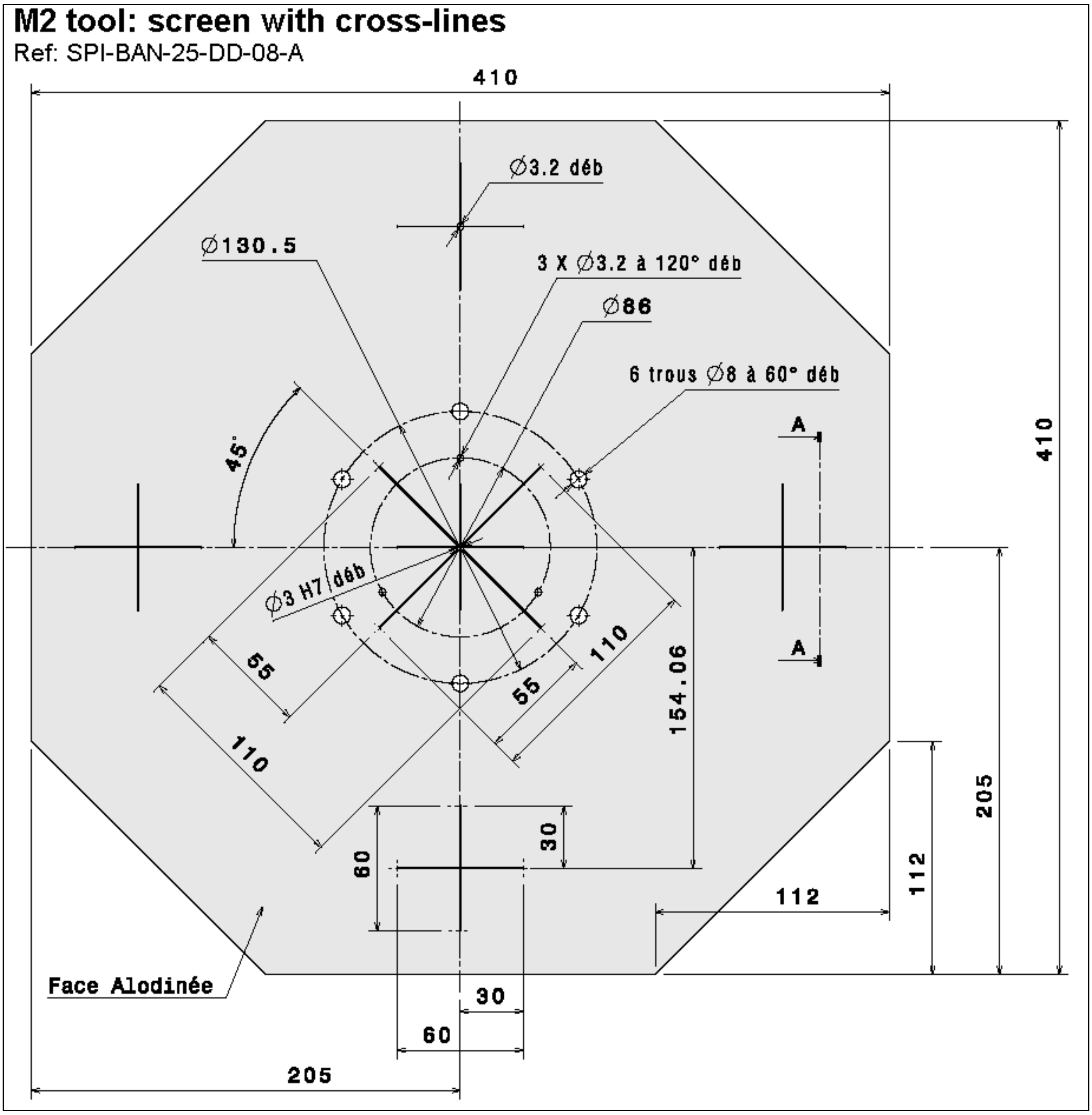


4.5.2. Spectrometer



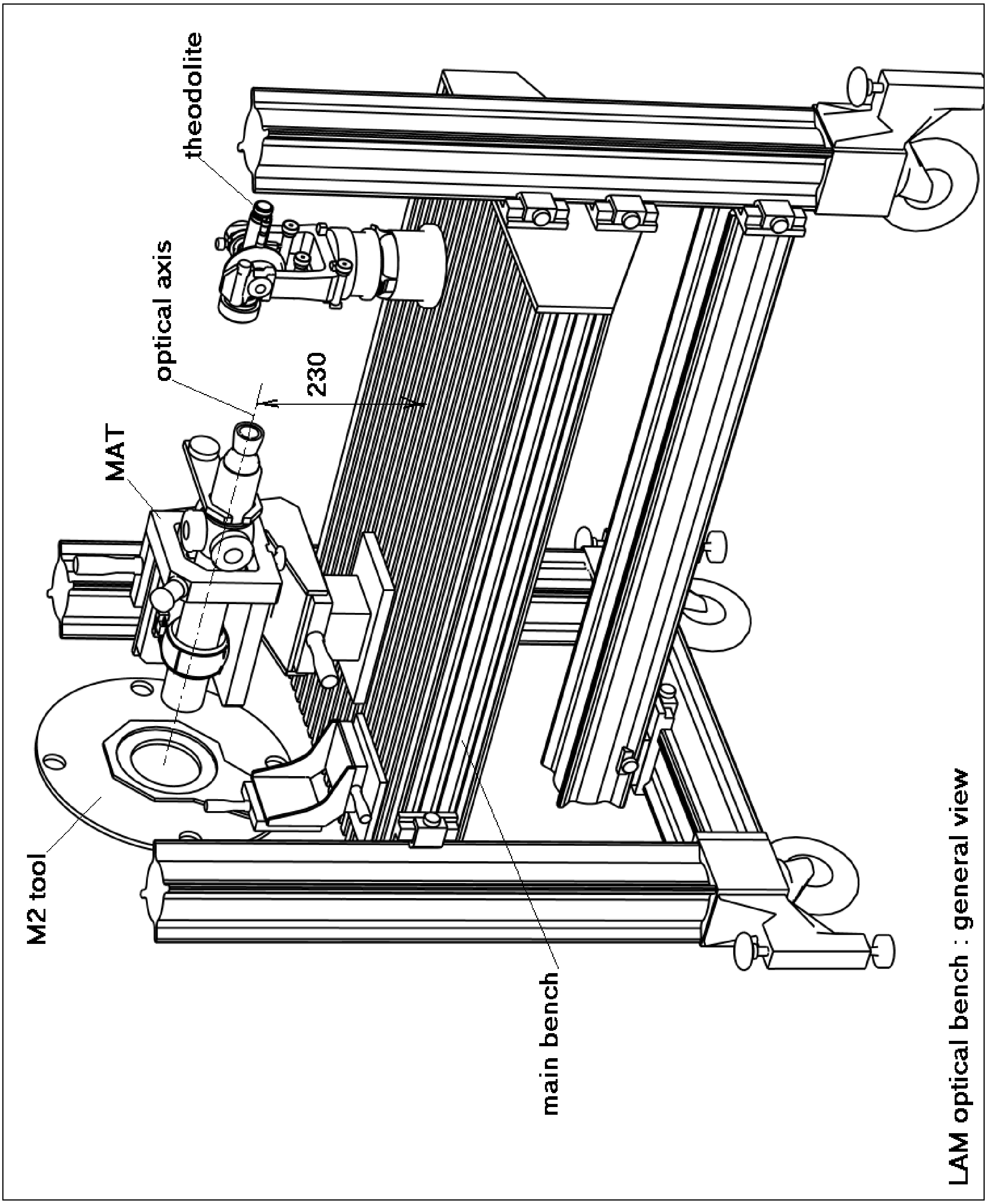


4.6. M2 Tool screen

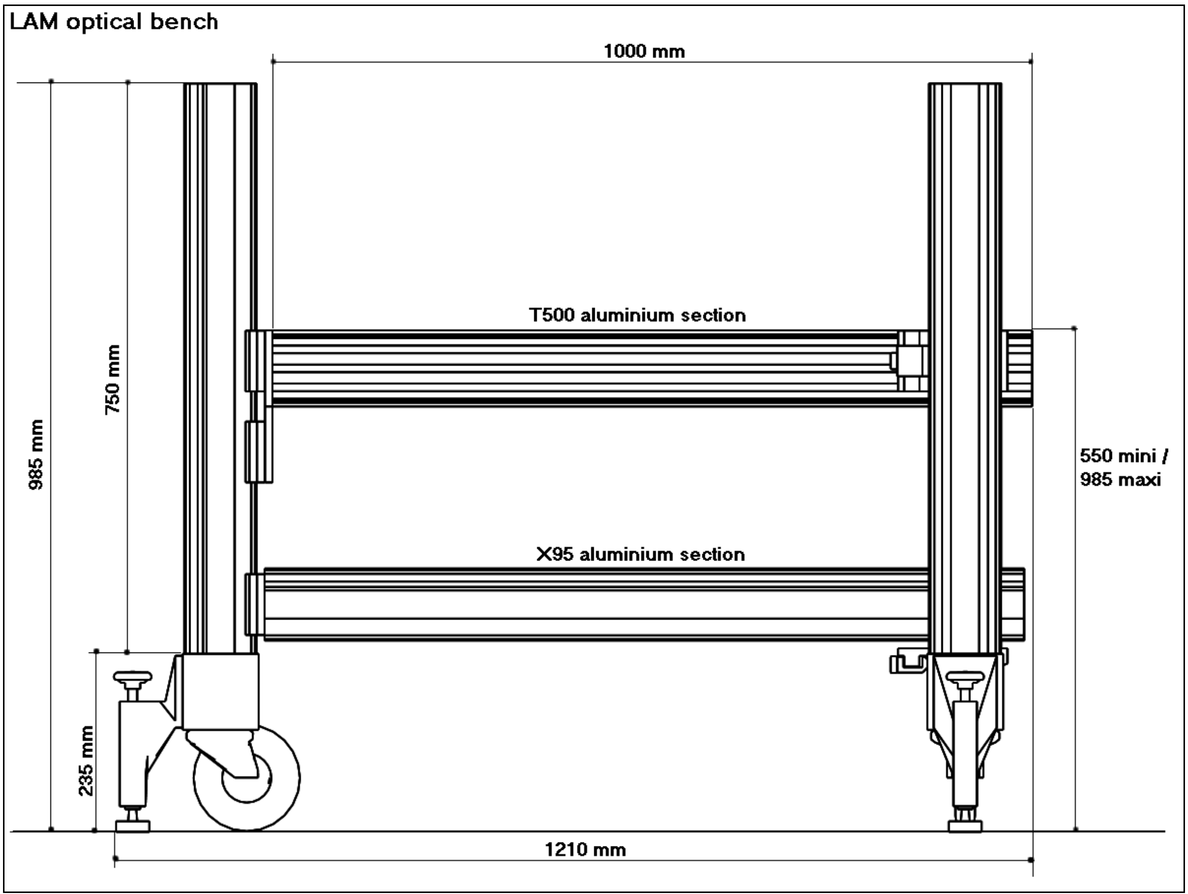


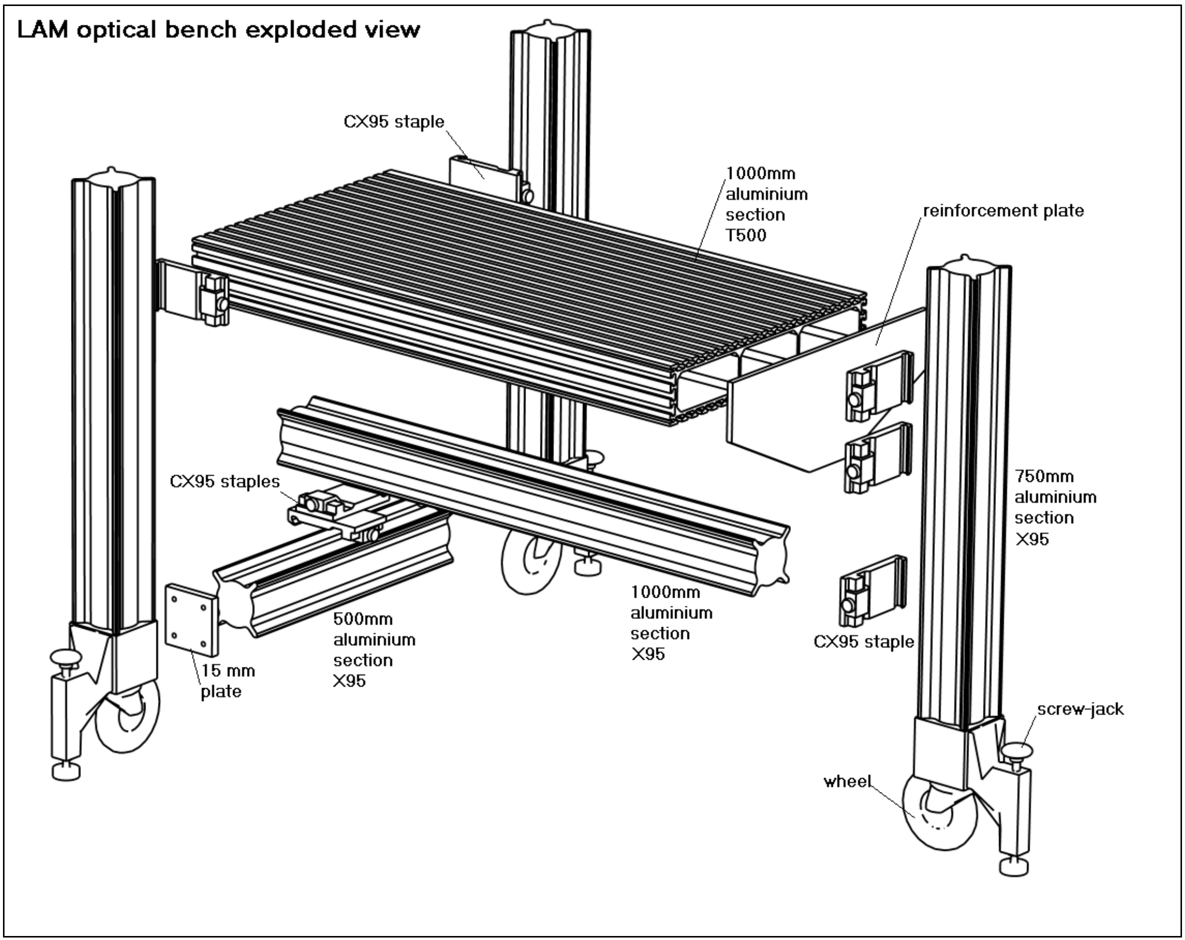
4.7. LAM benches

4.7.1. LAM optical bench for MAT and M2 tool

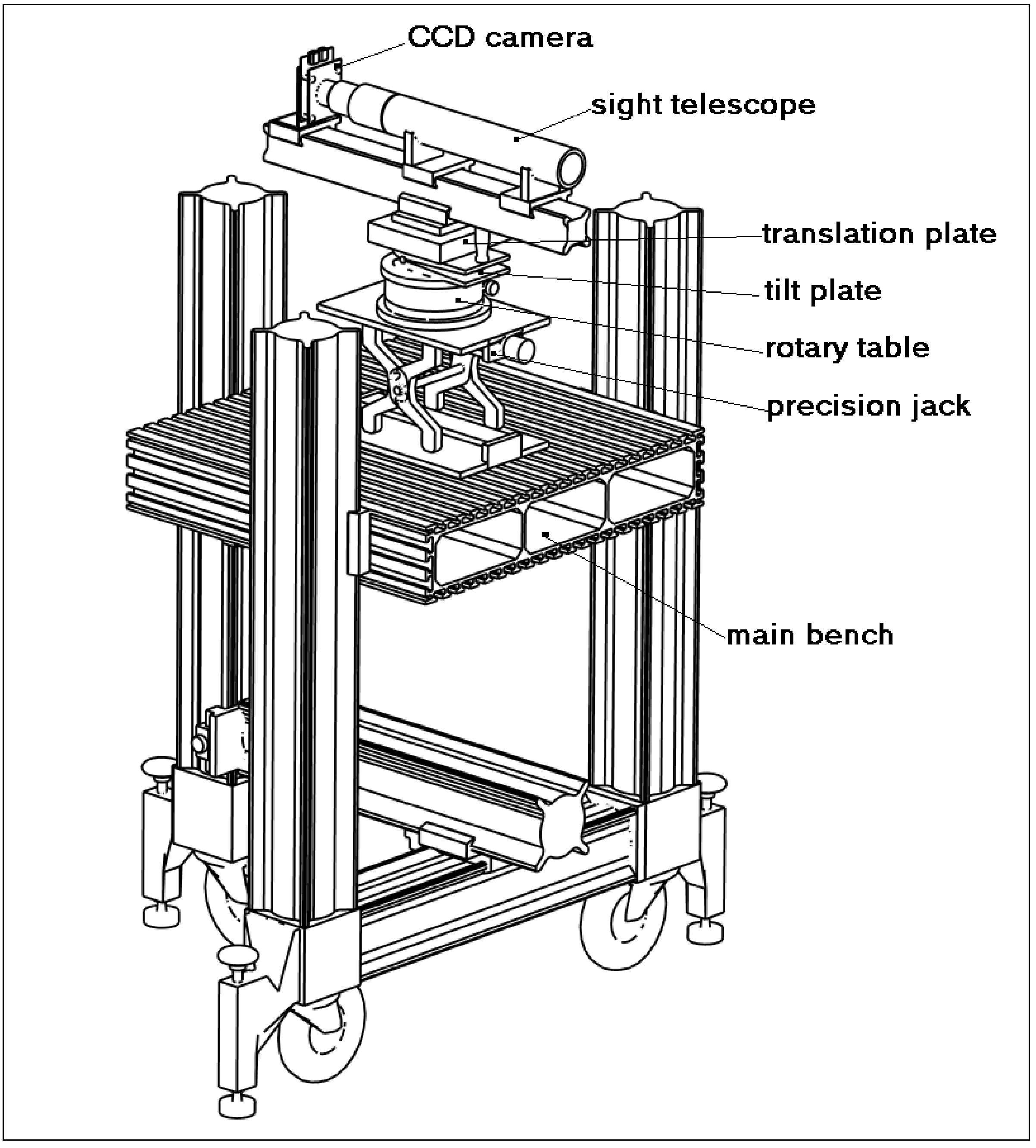


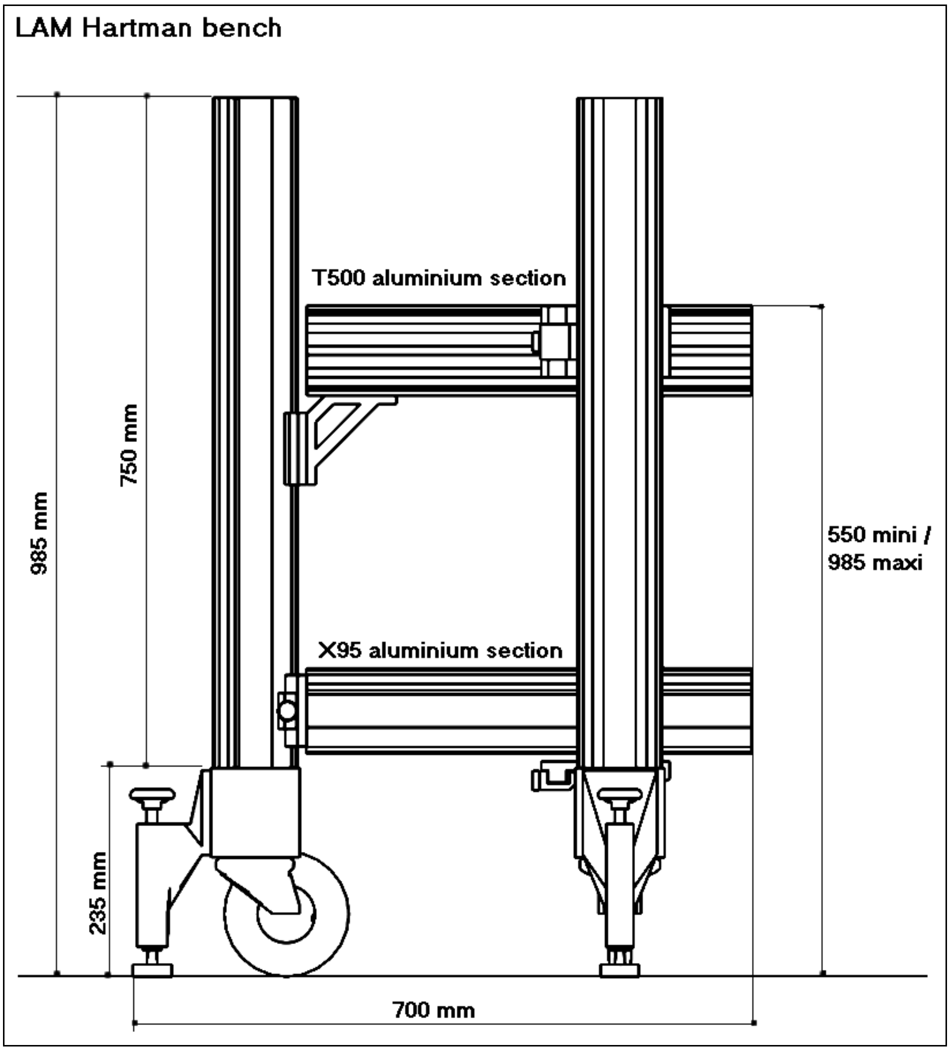
LAM optical bench : general view

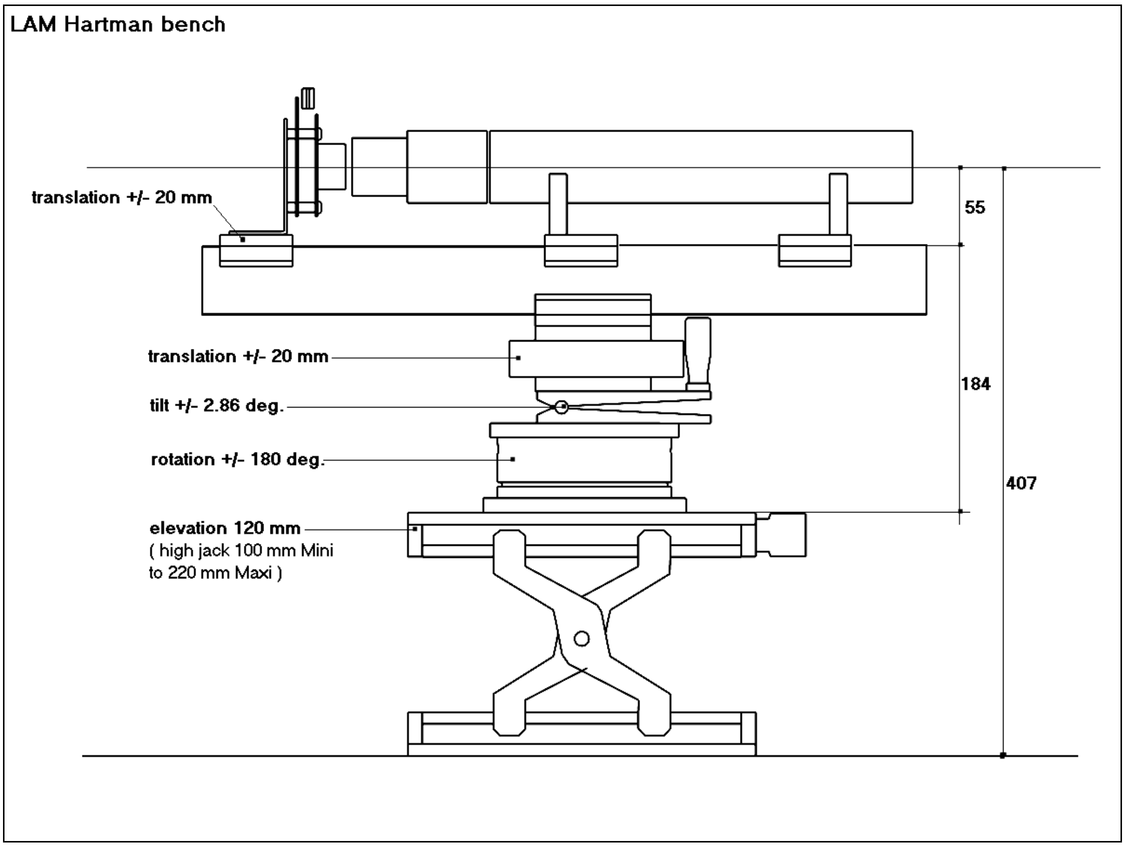

LAM optical bench
1000 mm
T500 aluminium section
750 mm
985 mm
550 mini /
985 maxi
X95 aluminium section
235 mm
1210 mm


LAM optical bench exploded view
CX95 staple
1000mm
aluminium
section
T500
reinforcement plate
CX95 staples
750mm
aluminium
section
X95
1000mm
aluminium
section
X95
500mm
aluminium
section
X95
15 mm
plate
CX95 staple
screw-jack
wheel

4.7.2. LAM Hartman bench




LAM Hartman bench
T500 aluminium section
750 mm
985 mm
550 mini /
985 maxi
X95 aluminium section
235 mm
700 mm


LAM Hartman bench
translation +/- 20 mm
55
translation +/- 20 mm
184
tilt +/- 2.86 deg.
rotation +/- 180 deg.
407
elevation 120 mm
(high jack 100 mm Mini
to 220 mm Maxi)