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SPIRE Alignment Tools Specification

SPIRE-LAM-PRJ-000636

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Table of contents

1. Scope of the document

This specification defines the alignment tools for the SPIRE optical system. It is applicable to the PFM and the FS.

2. Documents

2.1. Applicable documents

	Title	Author	Reference	Date

2.2. Reference documents

	Title	Author	Reference	Date
RD1	FIRST SPIRE: Optical alignment verification plan	A. Origne, K. Dohlen	LOOM. KD. SPIRE. 2000.001-2	16 May 2000
RD2	SPIRE Mirrors and Alignment tools Development Plan	D. Pouliquen	LAM. PJT. SPI. NOT. 2000006 Draft 0	20 May 2000

2.3. Glossary

AD	Applicable Document		
BSM	Beam Steering Mirror	LAM	Laboratoire d'Astrophysique de Marseille
BSMm	BSM cryogenic mechanism		
CEA	Commissariat à l'Energie Atomique	MGSE	Mechanical Ground Support Equipment
CDR	Critical Design Review	MM	Mechanical Model
CNES	Centre National des Etudes Spatiales	MSSL	Mullard Space Science Laboratory
CoG	Center of Gravity	NA	Not Applicable
CQM	Cryogenic Qualification Model	OGSE	Optical Ground Support Equipment
DDR	Detailed Design Review	PDR	Preliminary Design Review
		PFM	Prototype Flight Model
DM	Development Model	RAL	Rutherford Appleton Laboratory
		RD	Reference Document
		SMEC	Spectrometer mirror MEChanism
		SMECm	SMEC cryogenic mechanism
		SMECp	SMEC cold preamplifier
		SPIRE	Spectral and Photometric Imaging REceiver
FIRST	Far InfraRed Submillimeter Telescope	TBC	To Be Confirmed
FPU	Focal Plane Unit	TBD	To Be Defined

FS	Flight Spare model	TBU	To Be Updated
FTS	Fourier Transform Spectrometer	TBW	To Be Written
GSFC	Goddard Space and Flight Center	WE	Warm Electronics

3. Alignment philosophy

The SPIRE alignment verification plan [RD1] defines the procedure to be applied for visible-light verification of the instrument optical system. It also describes the alignment tools required for this work. A concise description is also given in [RD2]. On the basis of the indications given in the reference documents, the present document specifies the tools.

The alignment philosophy consists of
1) precise mechanical measurements of the structure/mirror interfaces prior to mirror integration
2) integration of mirrors one by one with line-of(sight verification after each integration to detect anomalies as early as possible
3) Verify alignment of the instrument pupil and image with respec to the externally defined telescope pupil and image.
4) Verify the stability of the alignment during and/or after environmental testing

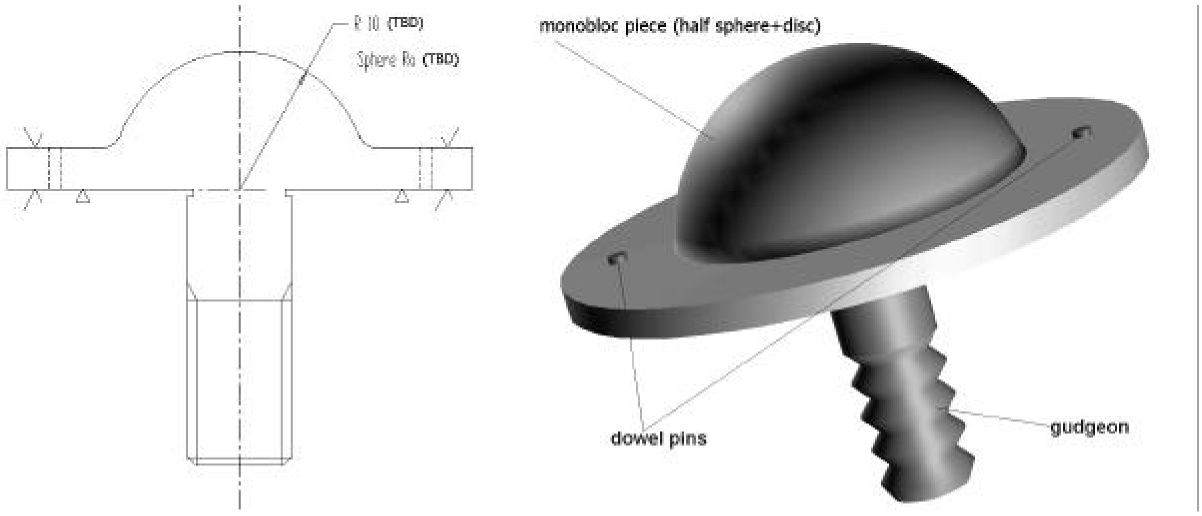
In case of alignment anomalies, it will be possible to adjust interfaces of certain components, see [RD1].

4. Description of the alignment tools

Tool	Functions	Description	Note
MAT	Used to check the position of the reticule on the alignement tools		Used at room temperature only
Apex Tool	Used to check the position of each pirror Apex in the SPIRE structure.	An aluminium flat mirror with a central reticule whose plane is at the real mirror Apex distance from the interface plane with the SPIRE structure.	Used at room temperature only
3D Tool	Used to check the position of each mirror interface with the SPIRE structure.	An auminium monobloc piece associating a disk and a sphere.	Used at room temperature only
D Tool	Acts as a source in the place of the detectors.	A plate containing central and peripheral sources. Each source is individually lightable.	Used at room and croygeni temperature.
CCA Tool	Replaces SMECm during the spectrometer alignment.	Corner cubes mirrors placed at the ZPD position (TBC)	Used at room temperature only.
CS-Tool	Materializes the cold stop location	Plate with apertures marking centre and edges of cold stop	Used at room temperature only
O-Tool	Materializes the SPIRE object plane	Plate with central and peropheral reticules	Used at room temperature only
M2-Tool	Materializes the telescope pupil (M2)	Plate with central and peripheral reticules	Used at room temperature only
PSD-Tool	Used to check the position of the incoming beam on the entrance plane of the detectors.	Plate with PSD at centre of phot and spec FOVs	Used at room and croygenic temperature.
Hart-mann tool	Verify image quality by Hartmann test	Plate with grid of holes	Used at room temperature only

4.1. The "3D Tool"

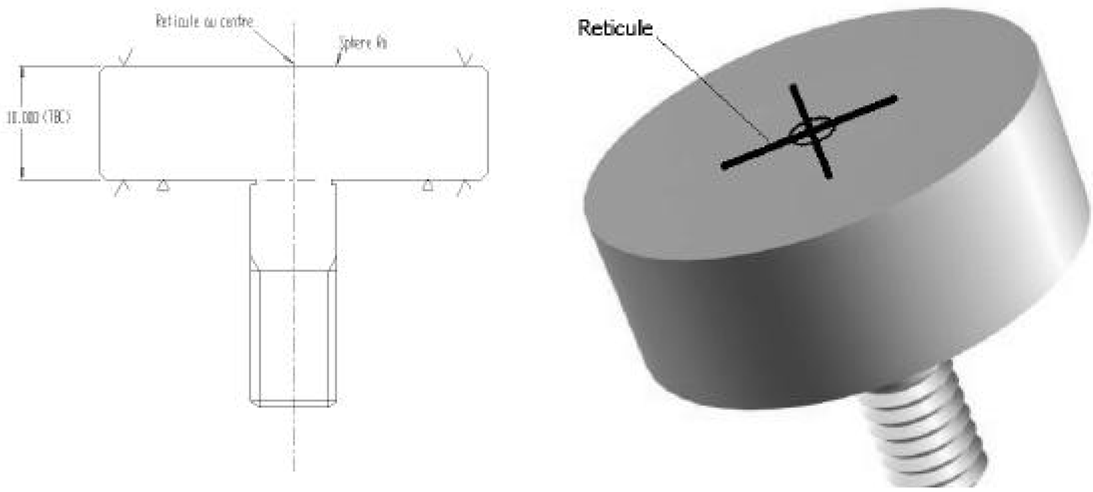
This tool will be used during step 2, 3D metrology of the structure, to facilitate the measurements in 3D-space of the coordinates of the mirror mount interfaces. It will be mounted and tightend on the interface in the place of the mirror.
The interface is defined in 3D-space by the normal to the support plane and a reference point located at the intersection between the support plane and the axis of the bore that receive the mirror tail.
The tool is a monobloc piece with a shape which associates a disc and a sphere. It will be machined with a great accuracy (TBD). The upper surface of the disc provides the orientation of the interface plane and the half sphere provides the position of the reference point.



3D Tool for metrology

4.2. The "Apex tool"

This tool will be used for alignment control during assembly. It has a standard mirror interface. The purpose of this tool is to materialize the apex of the optical surface. The thickness of the tool corresponds to the distance between the interface plane and the apex of the mirror. As far as possible this distance is the same for all mirrors. If some mirrors have a different thickness, several apex tools may be required. The reticule drawn in its center allows to aim each mirror apex using the MAT (Micro Alignment Telescope). When mirror N has been mounted, the tool is mounted in the place of mirror N+1, allowing verification of the alignment of mirror N.



Apex tool

4.3. FOR and SOR, telescope and instrument optical references

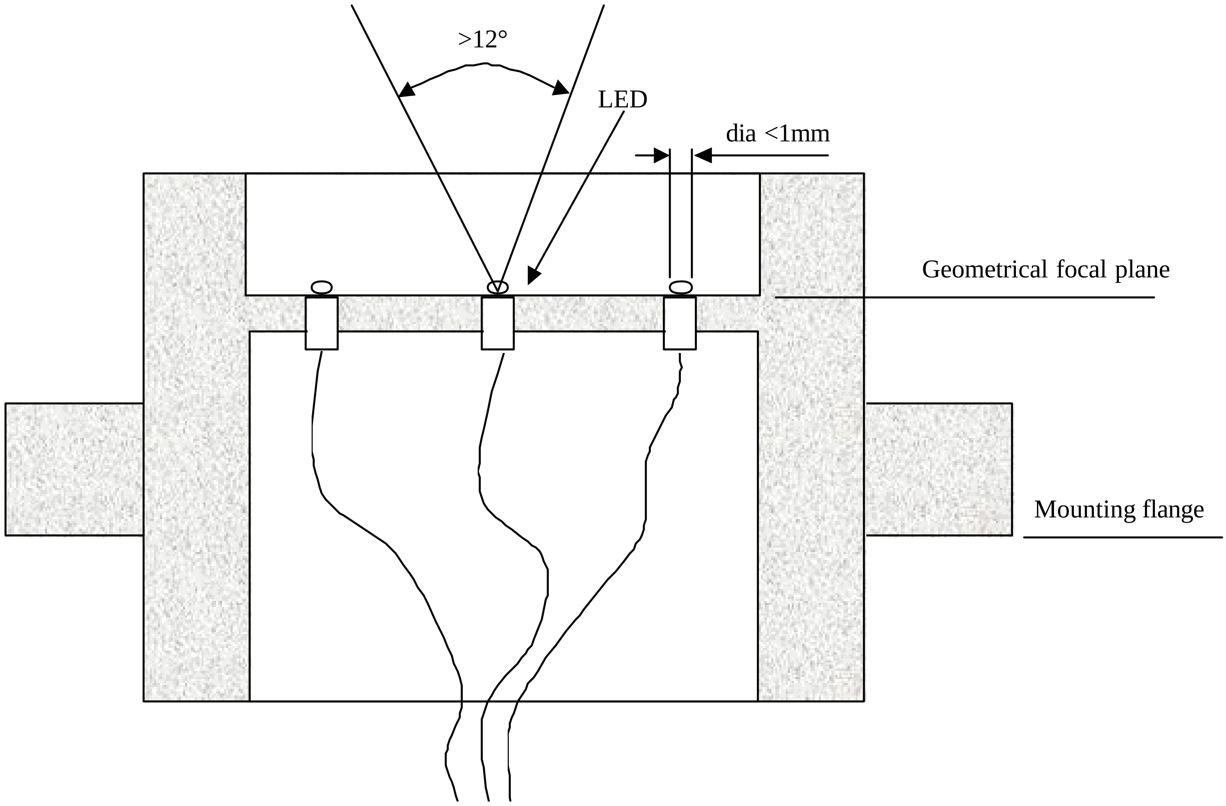
External alignment of the instrument requires knowledge of the telescope reference frame: optical axis and focal point. These are assumed to be materialized by the FIRST optical reference, FOR, mounted on the FIRST optical bench (FOB). The FOR defines the optical interface between instrument and telescope. It must be positioned accurately with respect to the mechanical interfaces. An FOB simulator containing the same interfaces as the actual FOB is used during integration of the instrument. This allows control of the external optical alignment of the instrument.
We assume FOR is a mirror perpendicular to the FIRST optical axis with a reticule engraved et the intersection with the axis.
The back-bone of the SPIRE instrument is the SPIRE optical bench (SOB). It carries the SPIRE optical reference (SOR), assumed to be a mirror parallel with FOR with a reticule at a known distance from the telescope axis. During optical alignment control we verify the alignment of SOR and FOR, allowing control of the alignment of the instrument on the FOB without access to the internal SPIRE optics. This is necessary since the SPIRE instrument is opaque to visible light.

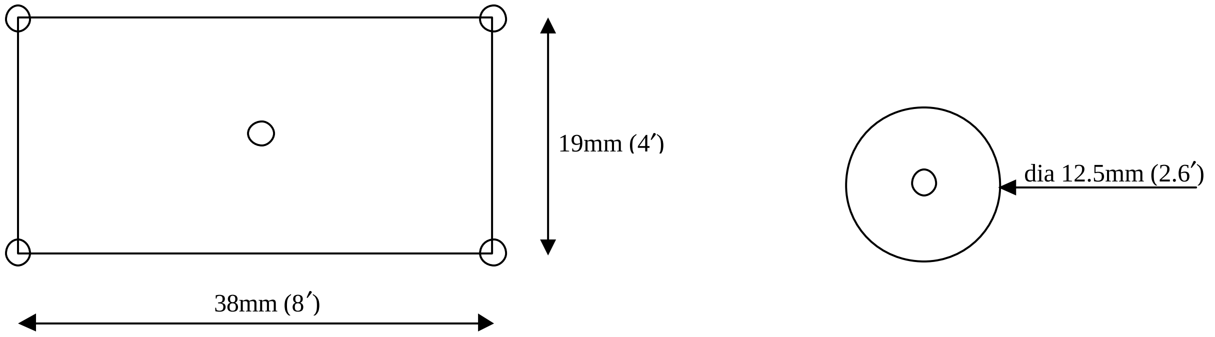
4.4. D-tool

The Detector tool (D-tool) takes the form of a plate containing small sources (LEDs, fibers, …) in strategic points in the FOV: centre and corners for photometer, centre for spectrometer. It is mounted in the position of the long-wavelength detector (PLW) to which visible transmission is assured when dichroics are dismounted. It has a mechanical interface identical to the detector units. Sources can be lit one by one in order to investigate different ray paths through the instrument.

One unit required for photometer, two units required for spectrometer.

To be operated during cold tests.





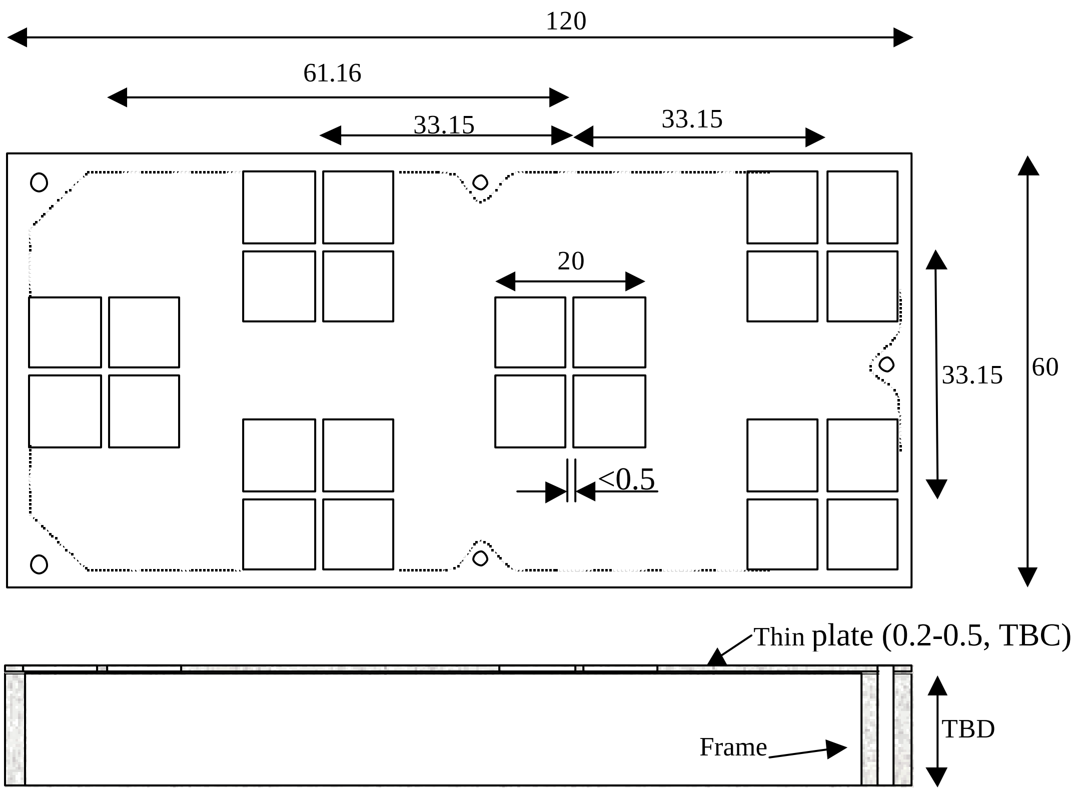
Photometer

Spectrometer

4.5. O-tool

The Object tool (O-tool) is mounted in the SPIRE object plane (ie the SPIRE FOV of the FIRST focal surface). It materializes the same strategic points in the FOV as the D-tools (photometer centre and edges, spectrometer centre). It coincides with the FIRST focal surface, ie not perpendicular to the gut ray. Mechanical interface is TBD.

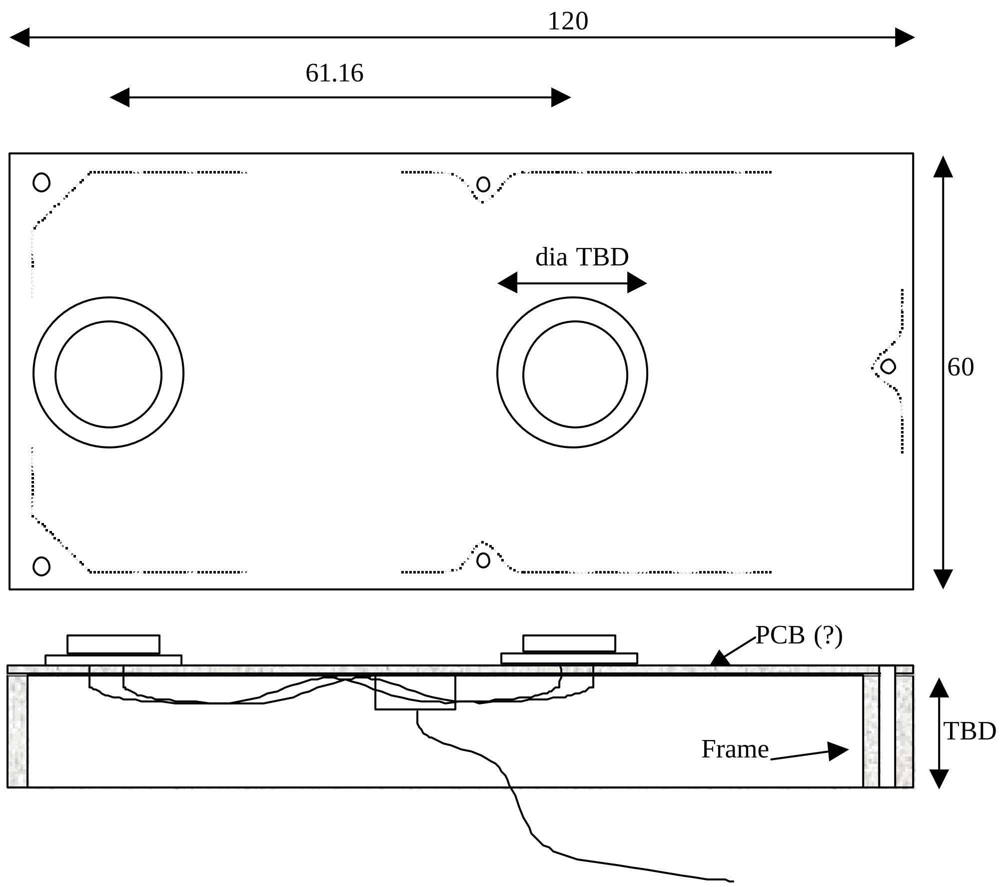
Thin metal plate with laser machined patterns, possibly mounted on a rigid frame, see fig.



4.6. PSD-tool

Tool carrying two (TBC) position sensitive detectors (PSD) located in the SPIRE object plane (telescope focal surface), one in the centre of the photometer FOV, one in the centre of the spectrometer FOV. It permits tracking of the image of the central source of the D-tools.

To be used during thermal tests; the PSD has a simple electrical interface and works well under hard environmental conditions.

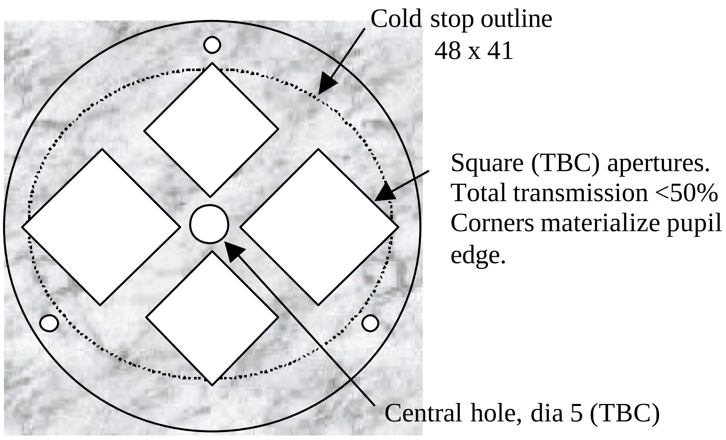


4.7. CS-tools

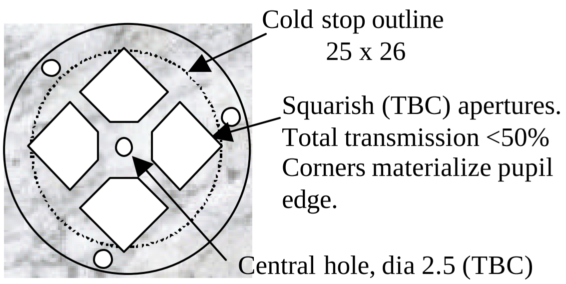
The Cold-stop tools (CS-tool) are mounted in the location of the cold stops (entrance to the 2K box, between PM8 and PM9 for photometer, between SM6 and SM7 for spectrometer). Its function is to materialize the centre of the cold stop and its edges, to control pupil alignment, pupil image quality, and vignetting.

Thin, laser-machined metal plates to be mounted directly onto structure on top of or in place of actual CS masks.

To be used during warm tests only.



Photometer



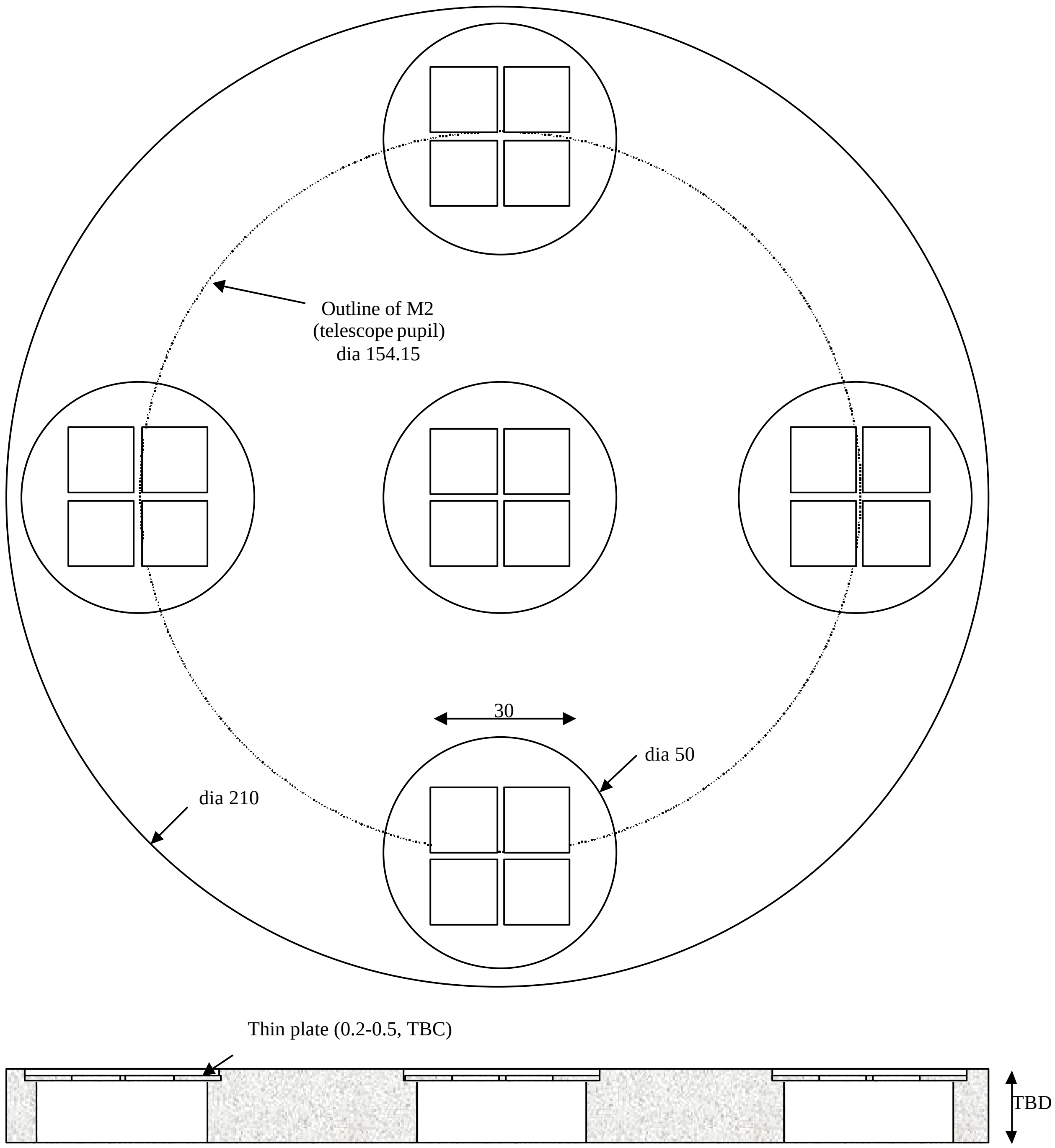
Spectrometer

4.8. M2-tool

This tool materializes the telescope pupil (M2) for control of instrument pupil imaging. Its absolute position with respect to the instrument is not important, as the absolute pupil alignment is controlled using the FOR.

The tool has a diameter of about 300mm, located approximately 2.5m outside the instrument. It has reticules materializing the centre and edges of the pupil, corresponding to points used in CS tools.

Consists of an aluminium plate fitted with thin laser machined metal plates for reticules.

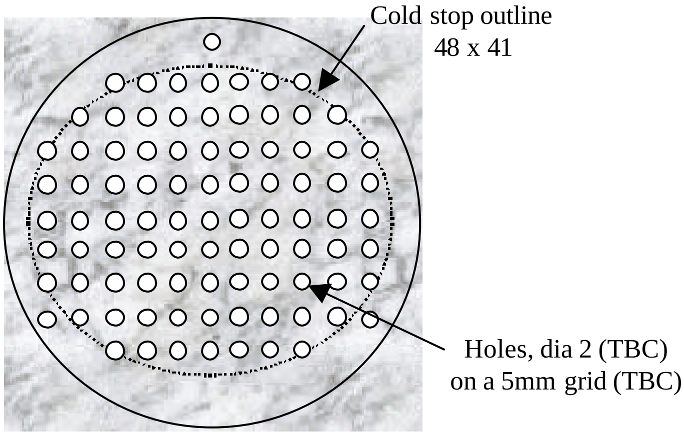


4.9. Hartmann tools

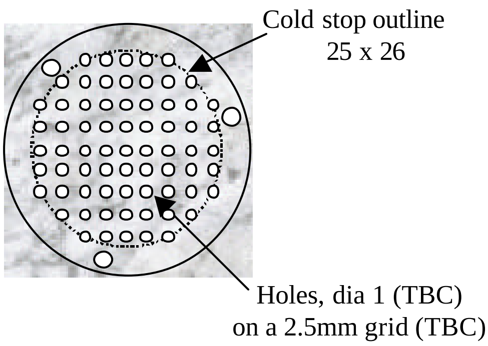
As an option for image quality measurement (see 3.2.6), a Hartmann test will be used. A plate with a rectangular grid of holes is mounted in the cold stop. When lit by one of the sources in the D-tool (typically the central source), the projection of the holes through the system materializes geometrical ray paths. Detection of the grid in two planes above and below the SPIRE object plane, allows reconstruction of the geometrical spot diagram. Comparison with theoretical spot diagram gives an excellent measure of the instrument image quality.

Thin, laser-machined metal plates to be mounted directly onto structure on top of or in place of actual CS masks.

To be used during warm tests only.



Photometer



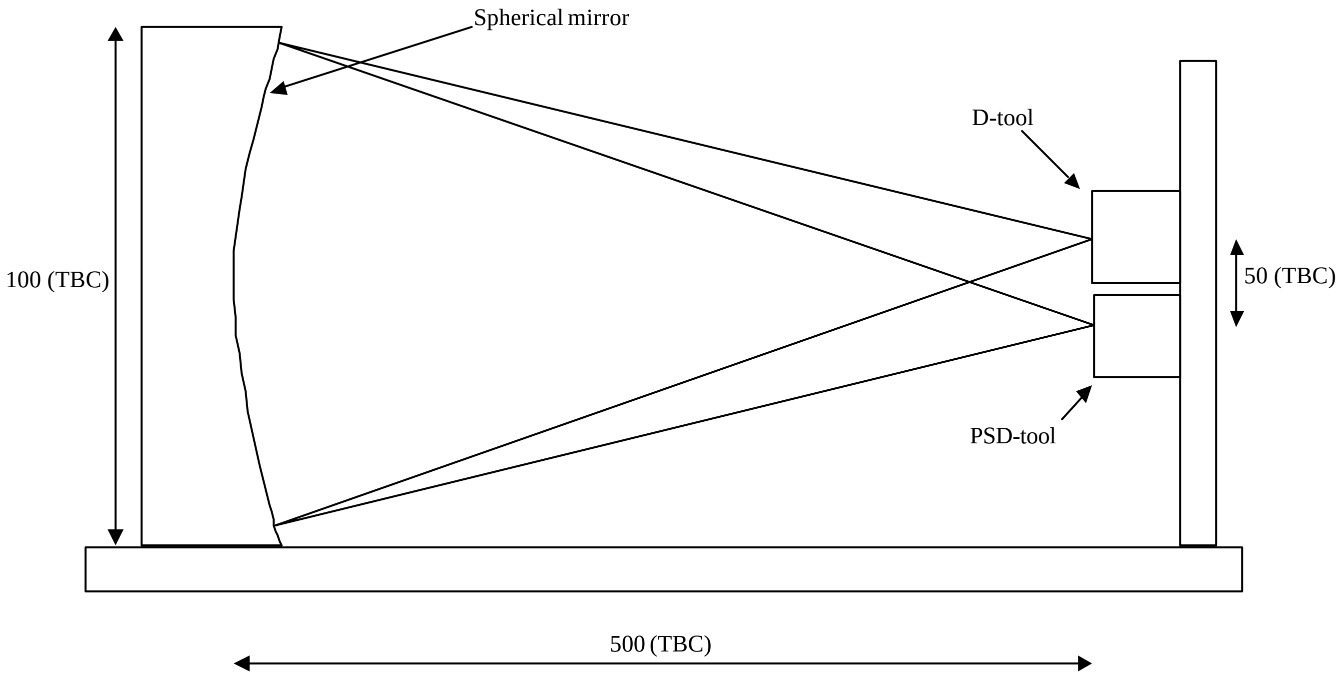
Spectrometer

5. Verification experiments

A series of bench experiments are foreseen to validate the alignment procedure and the proposed tools. These experiments are outlined in the table below.

Bench	Used to…	Note
PSD Control Bench	Verify function and stability of PSD-tool and D-tool at cryogenic temp	
MAT Control Bench **See AO!**	… control the supplementary lens and its mounting on the MAT	The optical mounting consists in a set of lenses which projects the image of a reticule behind the position of the MAT.
Tools Bench	Equivalent optical system simulating SPIRE focal and pupil planes and mechanical interfaces for alignment tools. Permits verification of alignment procedures.	Used at room temp only. Cleen room class TBC (would be most useful as a development bench in normal lab environment).

5.1. PSD control bench

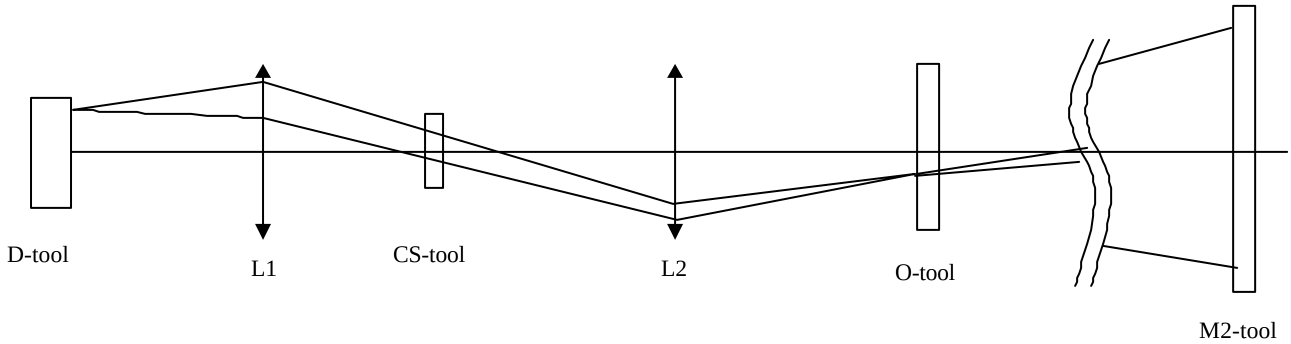


5.2. MAT Control Bench

See AO.

5.3. Tools Bench

Optical design TBD. In principle two lenses is sufficient (see sketch), but more may be necessary to accommodate the large etendue of the instrument.



6. Requirements

6.1. Functional requirements

6.1.1. Performance requirements

The performance requirements are listed in [AD1]

#	Parameter	Value	IRD	Note
P1				
P2				
P3				
P4				
P5				
P6				
P7				
P8				
P9				
P10				

6.1.2. Technical requirements

#	Parameter	Value	IRD	Note
Tm1				
Tm2				
Tm3				
Tm4				
Tm5				
Tm6				

6.2. Operational requirements

6.2.1. Relialibility

6.2.2. Lifetime

#	Parameter	Value	IRD	Note
OL1	Ground Storage lifetime	2 years		A guess
OL2	Ground Integrated lifetime	4 years		About
OL3	Ground operational lifetime	1.5 years		6 months for subsystem acceptance 6 months for SPIRE acceptance 6 months for FIRST acceptance Under 1g conditions
OL4	On orbit operational lifetime	none		

6.2.3. Operating modes

Non applicable

6.2.4. Telemetry

Non Applicable

6.2.5. Telecommands

Non Applicable

6.3. Interface requirements

The interfaces are defined in the relevant applicable documents.

Part	Interface	With	Document
SMECm	Mechanical	SPIRE Structure	SPIRE 1.1/1.5.2
	Thermal	SPIRE Structure	SPIRE 1.1.1/1.5.2
	Optics	SPIRE Optics	SPIRE 1.2 / 1.5.2
SMECp	Mechanical	SPIRE Structure	SPIRE 1.1/1.5.2
	Thermal	SPIRE Structure	SPIRE 1.1.1/1.5.2
SMECe	Mechanical	DRCU	SPIRE 1.5.2 / 2.2
	Thermal	DRCU	SPIRE 1.5.2 / 2.2
	Electronic	DRCU	SPIRE 1.5.2 / 2.2
	Electronic	MCU	TBW
MCU	Mechanical	DRCU	SPIRE 1.5.2 / 2.2
	Thermal	DRCU	SPIRE 1.5.2 / 2.2
	Electronics	DRCU	SPIRE 1.5.2 / 2.2

6.4. Design and manufacture requirements

6.4.1. Design requirements

TBD

6.4.2. Design rules

TBD

6.4.3. Manufacture requirements

These are requirements on accessibility, dismountability, testability and manufacturing processes.

- TBD fluids to be forbidden during manufacture to avoid pollution.
- TO BE COMPLETED

6.5. Logistic requirements

The subsystem wil be transported to and from RAL.
The containers will have to guarantee that:

- no shocks are greater than those defined for the launch.
- no pollution sneaks to the mirrors
- TO BE COMPLETED
-

6.6. Environment requirements

These requirements describe the environement in which the mirrors will live.

6.6.1. Natural environement

This is the description of the natural environment around the mirrors.

#	Parameter	Value	Note

EN1	Vacuum	Less than 10-4 Pa	During tests, launch and in operation
EN2	Operating temperature	during system qualif and on orbit = 4K during subsystem qualification = 300K and 20K	
EN3	Storage and handling temperature Humidity Cleanliness	-20 to +30 °C Less than 45% Class TBD	Overall, on ground In clean room In clean room
EN4	Radiations	Less than 3.5 kRAD	On orbit

6.6.2. Operating environment

This is the description of the environment imposed by the location of the subsystem in SPIRE and in FIRST.

#	Parameter	Value	IRD	Note
ON1	Vibrations	TBD		At 4K
ON2	Shocks	TBD		At 4K
ON3	Microvibrations	TBD		NA
ON4	Acoustic	NA		Launched under vacuum

6.7. Verification requirements

TO BE COMPLETED