FIRST-SPIRE

Photometer alignment verification plan

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1. Introduction and scope

This document is a first approach to the photometer alignment plan.

Alignment of the SPIRE phototmeter is based on the principle of "blind" alignment, i.e. integration guided by mechanical rather than optical metrology. The alignment is verified optically (in the visible) after integration at ambient, cooled to 80K (TBC), and after vibration testing (TBC). In the case of an alignment deficiency, correction may be applied by adjustment either of the interface with the FIRST optical bench, or of one or a limited number of components.

2. Reference documents

[RD1] Instrument requirement document, Issue .00 draft 2, 14/5/99

[RD2] FIRST alignment plan, PT-PL-02220, 9/5/96

[RD3] FIRST-SPIRE Photomete pupil alignment budget, SPIRE-LAS-NOT-000279.10, 17/6/99.

Current photometer design is BOLPHT126B.

3. Alignment requirements

3.1. Alignment budget

RD3 shows that the driving performance criterion for photometer alignment is pupil alignment. General alignment tolerances for each mirror of 1 arcminute and 0.1 mm gives a well-balanced overall budget, see Figure 1. It is our opinion that this level of tolerances has a good probability of being met by mechanical metrology.

3.2. Structure and interfaces

Figure 2 shows a schematic drawing of the SPIRE photometer and its internal and external interfaces. It consists of an optical bench (S-bench) at 4K onto which is mounted all mirrors up to the cold stop (CS, internal pupil). The CS is a hole in the 2K cold box (CB) which is suspended from the S-bench. The CB contains further optics whose alignment is uncritical for pupil alignment.

The S-bench is suspended from the FIRST optical bench (F-bench) whose alignment with the telescope is defined in RD2. Figure 3 summarizes the mechanical (vertical, solid arrows) and optical (horizontal, dotted arrows) interfaces to be considered for pupil alignment. The dotted rectangle encloses the interfaces for which SPIRE is responsible.

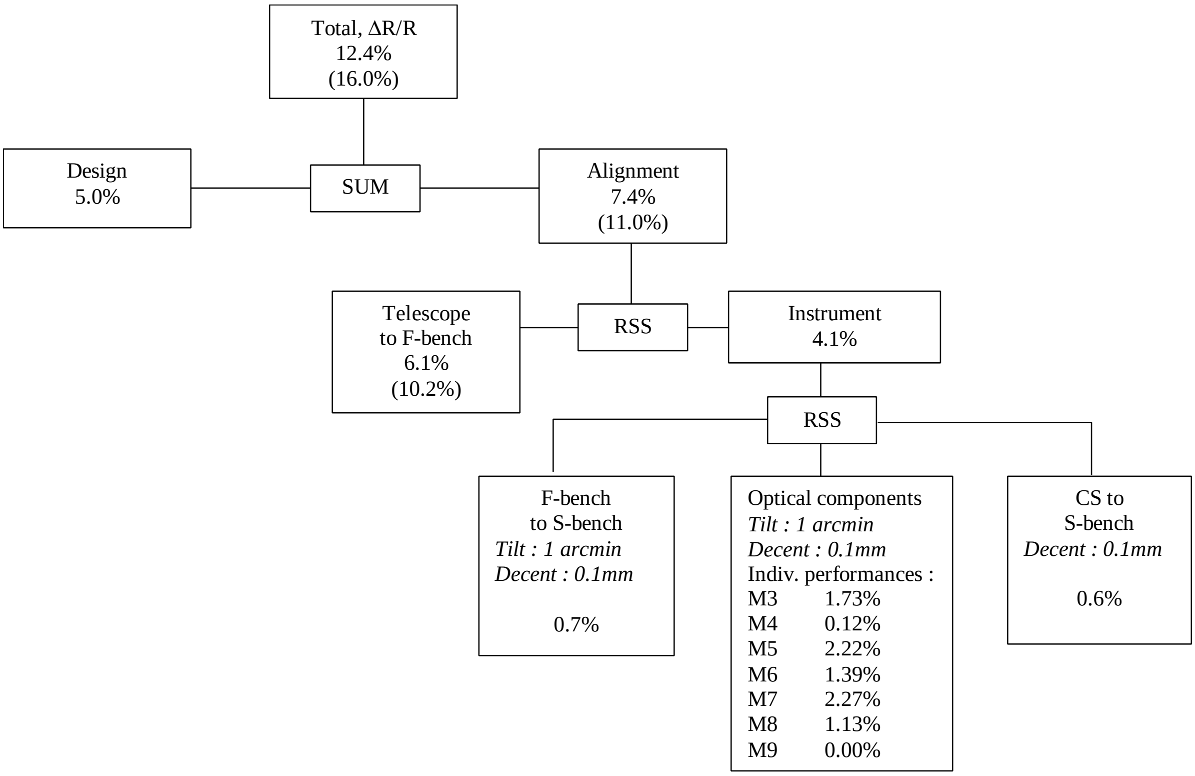

Figure 1. Fractional pupil alignment budget for the SPIRE photometer instrument in terms of ΔR/R. Values in brackets represent an uncertainty in ESA's telescope-instrument alignment specification, see RD3.

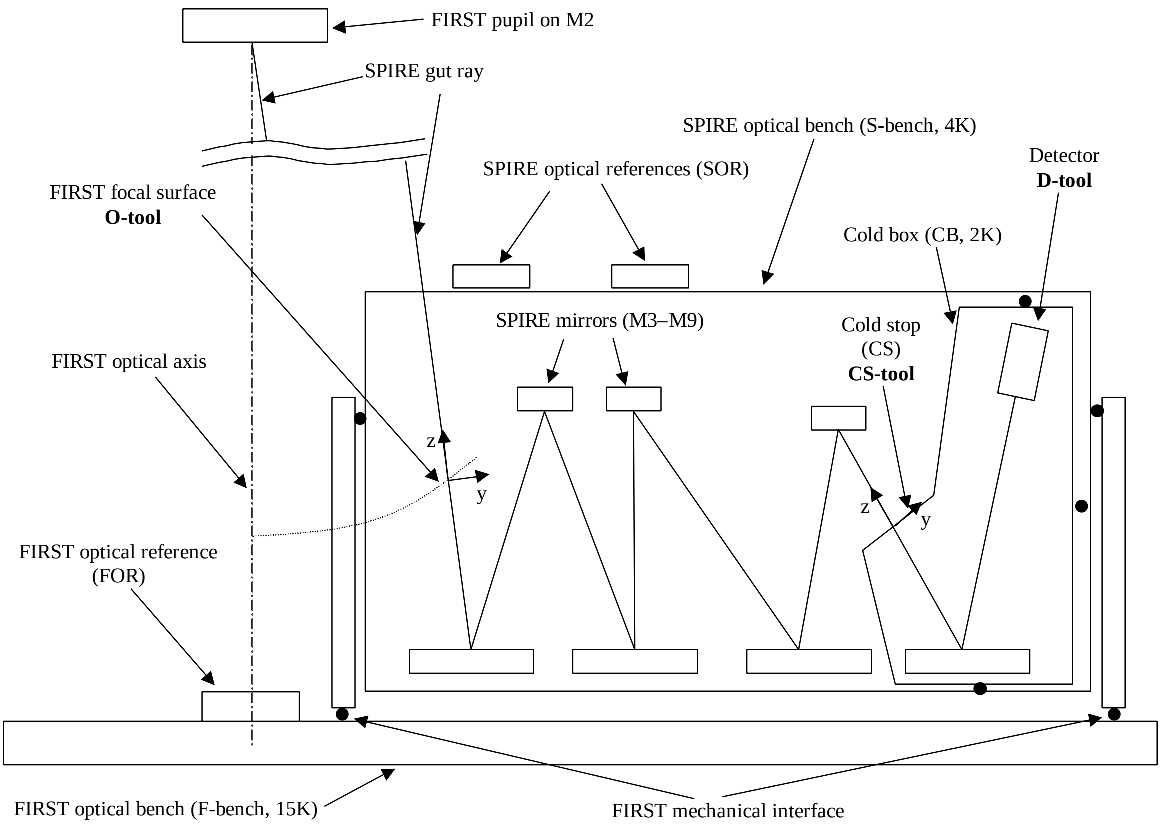

Figure 2. Schematic drawing of the SPIRE photometer and its internal and external interfaces. Alignment tools are indicated in **bold** face.

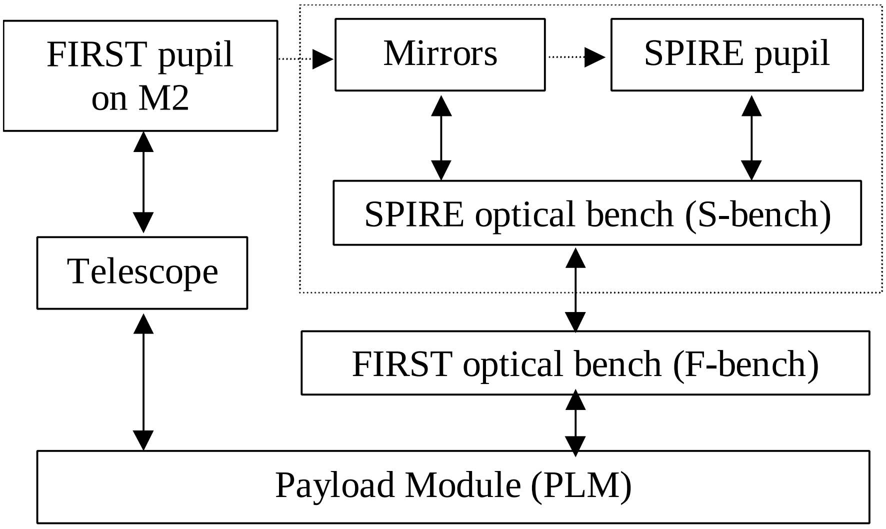

Figure 3. Summary of the mechanical (vertical, solid arrows) and optical (horizontal, dotted arrows) interfaces to be considered for pupil alignment. The dotted rectangle encloses the interfaces for which SPIRE is responsible.

4. Alignment verification

ESA requires instruments to be integrated on the F-bench **without adjustment** [RD2]. However, an optical reference in the form of reticuled mirrors on top of the instruments [RD2] are required to **check** co-alignment of the instruments and alignment of the bench with the telescope.

The aims of the SPIRE optical alignment check are therefore:

• Verify optical performance of the instrument (vignetting, pupil stability across FOV and for chopping, image quality)

• Verify alignment between SPIRE optics and the SPIRE mechanical interface

• Verify alignment between SPIRE optics and the SPIRE optical reference (SOR)

4.1. Preliminary OGSE definition

During alignment check, the instrument must be mounted on a tool representing the F-bench. The tool must be equipped with an optical reference (FOR) representing the optical interface with the FIRST telescope. The FOR may take the form of a reticuled flat mirror so that:

• The reticule represents the position of the FIRST optical axis

• The normal to the mirror represents the direction of the optical axis

• The height of the mirror surface above the bench is known

• The arms of the reticule is aligned with the rectangular cut-out of the unvignetted telescope FOV

The verifications is to be done on the assembled instrument, modified in the following ways

- No filters installed
- Dichroics replaced by pellicle-type (TBC) optical beamsplitters
- Detectors replaced by tools (D-tools) equipped with small sources (see below)
- A tool carrying an engraved glass plate mounted at the CS (CS-tool)
- A tool carrying an engraved glass plate mounted at the FIRST image surface (O-tool)

(Figure 2 indicates the tools in **bold** face.) This implies that the instrument must be disassembled after testing in order for the tools to be removed and filters and detectors to be installed. To avoid any change in alignment due to this process, the tools must mechanically represent the components they replace. Also, it must be verified that the process of disassembling and reassembling does not alter the alignment. This is achieved by repeating the alignment verification after disassembling and reassembling the tools.

4.2. Image alignment and quality

A microscope (equipped with CCD camera) is focalised on the O-tool, a glass plate engraved with reticules or circles corresponding to critical points in the FOV (e.g. centre and corners). The D-tools are projected onto the same surface by the action of the instrument optics. The FOV points are materialized by small (visible) light sources in the D-tools. The sources can consist of individually addressable optical fibres or LEDs. If this is impractical then they could be replaced by diffusely reflecting plots on a black surface, reflecting light incident from a light source within the microscope. This option is less optimal since it imposes simultaneous investigation of the three channels and all FOV points.

Procedure:

1) Verify coincidence between D-tool sources and O-tool marks
2) Verify (by longitudinal translation of the microscope) that D-tool sources and O-tool marks are in the same focal plane.
3) Verify image quality (aberrations) by measuring sizes of the D-tool source images (possibly investigating intra and extra focal images)
4) Verify the position of the O-tool with respect to the SOR and the FOR reticules by performing measured horizontal and vertical translation of the microscope, .

4.3. Pupil vignetting, alignment and quality

An autocollimation telescope (equipped with CCD camera) is focalised on the CS-tool, a glass plate engraved with a pattern as indicated in Figure 4 (TBC). Line thickness should be determined according to surface scatter, possibly experimentally. The central cross allows determination of the centre of the CS, the ring allows determination of vignetting by evaluation of its distance from the edge. If the CS has an elliptical shape, the ring should also be elliptical.

The D-tool as defined above provides back-illumination of the CS-tool. Addressing its light sources one by one allows verification of pupil parameters for each field point separately.

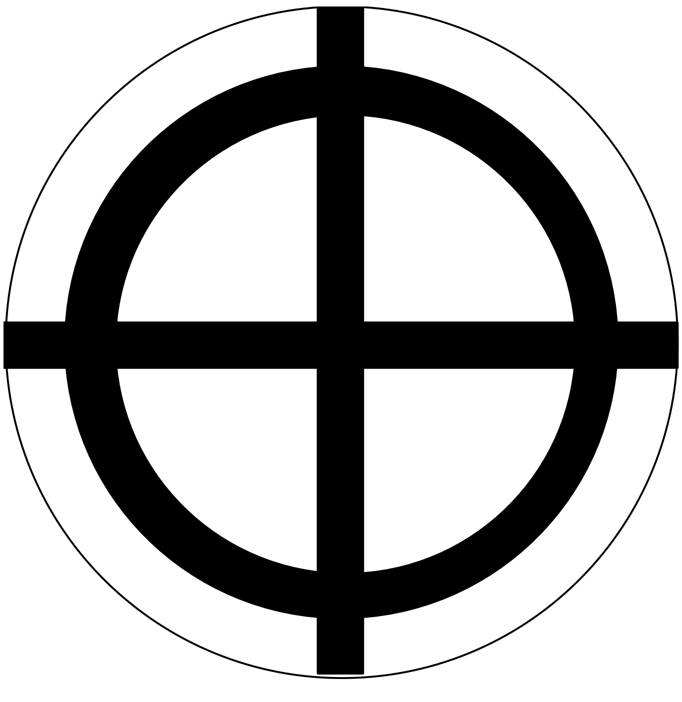

Figure 4. CS-tool pattern.

Procedure:

1) Verify the absence of vignetting (reduction of pupil size due to clipping at components other than the CS) by observing the space between pupil edge and CS-tool mark. Repeat for each D-tool source.

2) Verify across-FOV pupil alignment by recording the position of the central cross for each D-tool source.

3) Verify pupil stability during chopping by recording the position of the central cross for each D-tool source (or only central cource, TBD) in TBD positions of the chopping mirror.

4) Verify gut-ray alignment (i.e. alignment of CS with telescope pupil) by comparing the direction of the projection of the CS-tool central cross with the directions of the SOR and FOR mirrors:

• Align CS-tool cross with autocollimator reticule, record angular position of telescope (corresponding to the direction of the gut ray)

• Move telescope horizontally to point towards SOR mirror

• Perform autocollimation on SOR mirror, record angular position of telescope (corresponding to the direction of the FIRST optical axis)

• Verify angular deviation of the gut ray

• Repeat for the FOR mirror

4.4. Adjustments

In the case of deficiencies detected by the above tests, the following TBC actions may be performed.

• The most likely deficiencies are defocus, image position and gut-ray direction. These may all be corrected by adjusting the mechanical interface with the F-bench, i.e. without adjustment of internal parts.

• Across-FOV pupil misalignment may be corrected by longitudinal adjustment of the CS. This may be done by adjusting the position of the CB on the S-bench. Such adjustment may affect focus.

• Chopped pupil instability may be corrected by longitudinal adjustment of the chopper position. Such adjustment may affect across-FOV pupil alignment and focus.

• Deficiencies of image quality and vignetting are unlikely to occur in the absence of serious deficiencies of the other instrument performances. Action to be taken depends upon the severity of the deficiencies and will most probably depend upon a case-by-case study.