SUBJECT: **SPIRE AIV Optics alignment (OGSE)**

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1. INTRODUCTION

1.1 Scope

Before doing the performance test on the CQM, alignment of the optics needs to be done properly. Indeed, a lot of work has occurred in the lab (dry-air enclosure, CQM…) since the optics have been last aligned, and some mirrors are very likely to have moved. Moreover, it seems that the whole bench of the TFTS is not in correct position (13/01/04). It will be clamped in the optical table once in position. The propagation of the FIR laser has been checked in December and the elements on the FIR laser bench (from the beam expander to the focusing system) shall not be moved.

1.2 Structure of Document

One will find in this document:

- A list of all the optical element and their acronym
- A drawing of the optical layout
- The procedures for different bits of the whole system to align
  - Check parallelism of the optical table with the alignment bar
  - Check fold mirrors orientation
  - Move roughly TFTS in position
  - Check internal optics of the TFTS
  - Co-align precisely TFTS and tel-sim
  - Co-align FIR laser and tel-sim
  - Aligning optics on the FIR bench
  - Checking telescope simulator optics
  - Procedure for normal operation during test

1.3 Documents

Applicable Documents

Reference Documents

	Title	Author	Reference	Date
RD 1	Hardware development of the Telescope Simulator	M. Ferlet	SPIRE-RAL-NOT-001258, issue 1.0	03/05/2002
RD 2	Set-up and alignment procedure for the Telescope Simulator imaging mirror	M. Ferlet	SPIRE-RAL-NOT-000734, issue 2.0	03/05/2002
RD 3	Design of the telescope simulator imaging mirror	M. Ferlet	SPIRE-RAL-NOT-000621, issue 4.0	03/12/2001
RD 4	Telescope simulator optical design	M. Ferlet	SPIRE-RAL-NOT-000622, issue 3.0	10/12/2001

2. THE OPTICAL SYSTEM

2.1 List of different optical element

Acronym	Name	Description
In TFTS		
T_M1	TFTS mirror 1	Flat fold mirror
T_M2	TFTS mirror 2	Focusing spherical mirror
T_M3	TFTS mirror 3	Collimating parabola
T_BS	TFTS beam splitter	Michelson Beam splitter
T_MM	TFTS moving mirror	Michelson moving mirror
T_FM	TFTS fix mirror	Michelson fix mirror
D1	Diaphragm 1	Diaphragm for F# control (pupil image)
I1	Iris 1	TFTS focus
Optical bridge		
FM1	Fold mirror 1	Fold mirror just after at TFTS output
FM2	Fold mirror 2	Fold mirror just before pupil mask (PM)
P1	Periscope 1	Upper periscope mirror
P2	Periscope 2	Lower periscope mirror
Telescope simulator		
PM	Pupil mask	Telescope simulator pupil mask
M2	Mirror 2	Telescope simulator focusing mirror
F1	Flat mirror 1	Telescope simulator first flat mirror
F2	Flat mirror 2	Telescope simulator second flat mirror (scanning)
F3	Flat mirror 3	Telescope simulator third flat mirror (scanning)
I3	Iris3	Reference at the end of alignment bar (tel sim focus)
FIR laser bench		
F_M0	FIR bench mirror 0	Mirror for alignment with He-Ne laser
F_BS	FIR bench beam-splitter	Beam-splitter for alignment with He-Ne laser
BE1	Beam expander mirror 1	1st off-axis parabola in beam expander
BE2	Beam expander mirror 2	2nd off-axis parabola in beam expander
F_M1	FIR bench mirror 1	Flat mirror
D2	Diaphragm 2	Diaphragm for F# control (pupil image)
F_M2	FIR bench mirror 2	Flat mirror
F_M3	FIR bench mirror 3	Focusing off-axis parabola, D=4 inches, f=326.7 mm
I2	Iris 2	FIR laser focus

2.2 Optical layout

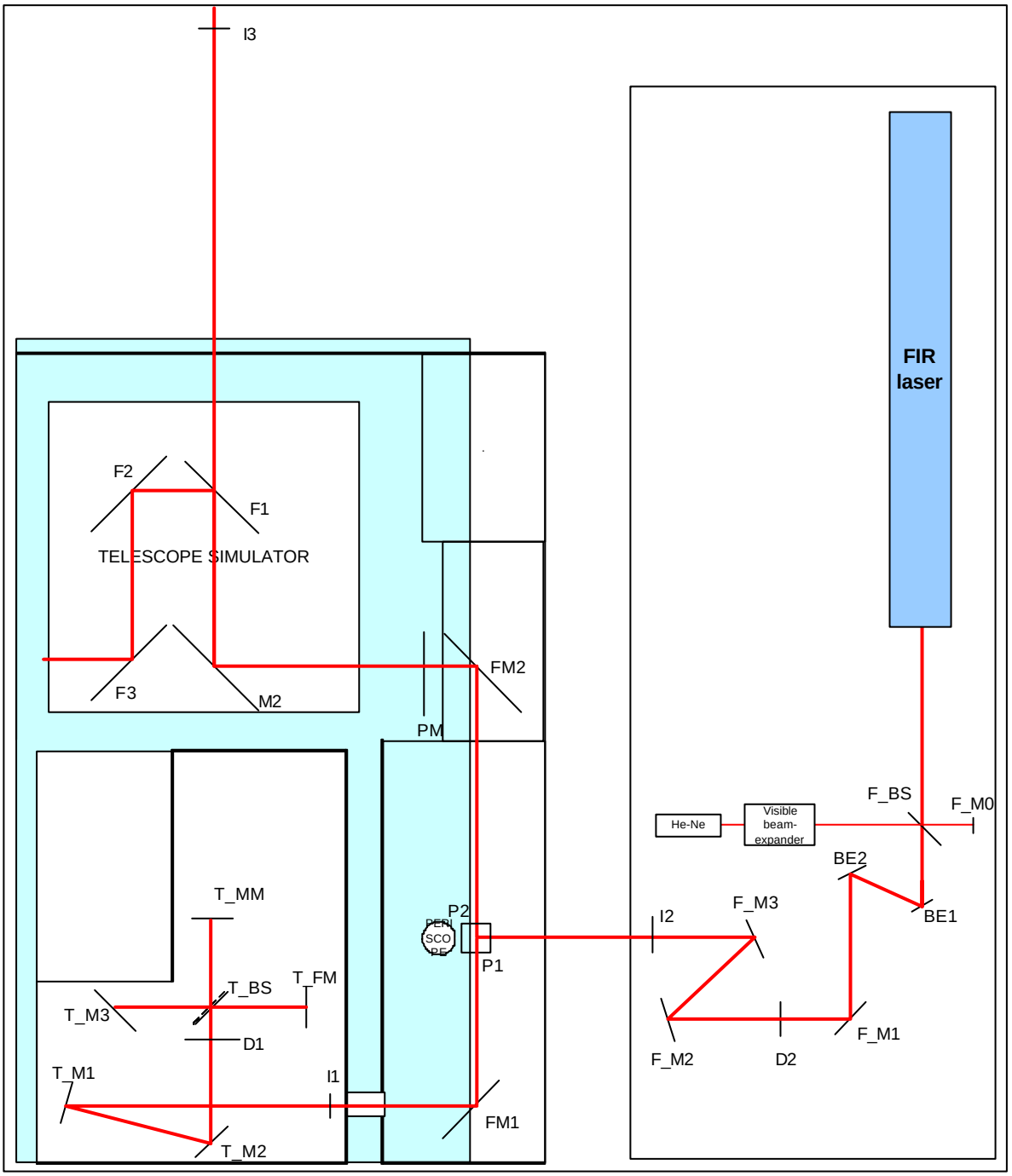


figure 1 Optical layout

3. PROCEDURES

3.1 Check parallelism of the optical table with the alignment bar

This is done with a level. Since the dry-air enclosure has been added on the bench, the feet may need to be re-pumped. Once this is done, a laser propagating through the centre of the mask (H=235mm, to check as well!) and the mark at the centre of M2 should fall on I3 at the end of the alignment bar.

3.2 Check fold mirrors orientation

a) Propagate laser from I3 to the centre of M2. This defines the optical axis of the telescope simulator.
b) Orientate the fold mirror FM2 in order to reflect the laser at 90 degrees (or at least parallel to the optical table) This can be done with a ruler: measure the distance of the beam from the edge of the table at two different points + check height of the beam (235 mm)
c) Repeat for the fold mirror FM1.

3.3 Move roughly TFTS in position

a) Orientate TFTS roughly parallel to the optical table
b) Put the white light source at I3 and look at its image at I1. Move the TFTS to have the two foci at the same point.
c) Tilt TFTS to have the image of the pupil mask centred on the pupil diaphragm D1.
d) Repeat b) and c) if needed. (just roughly, it will be done more accurately, see section 3.4

3.4 Check internal optics of the TFTS

a) Height of the optics is the height of the axis of the beam-splitter (T_BS) mount (reference)
b) Use the height tool to have an horizontal laser beam at the reference height
c) Place visible beam-splitter.
d) Place the laser between the parabola T_M3 and T_BS and orientate it in azimuth to have it going through I1. Mirrors of the Michelson should be well auto-collimated on this beam and both reflected beam should overlap properly, for any position of the mirror T_MM on the translation stage. If not, follow the next steps:
e) Place the BS and the dummy mirror (instead T_FM) that have a hole in their centre. Align the laser on those two points. Put the visible BS (with no hole) back.
f) Auto-collimate T_FM and T_MM.
g) Adjust T_M2 for the laser to go through the centre of T_M1.
h) Check the spot just before T_M1. Align T_MM in order that the spot does not move when the mirror travels along the translation stage.
i) Overlap the spots reflected by T_MM and T_FM.
j) Now, we want the laser beam to pass through the iris I1 (focus) and the centre of the pupil mask PM:
    (1) Move T_M1 to have the beam at the centre of PM
    (2) Move T_M2 to bring back the beam at the centre of I1
k) Repeat (1) and (2) until good alignment of the focus and the pupil.
l) If needed, re-adjust position of T_M1 for the beam to be at its centre and repeat steps j), k) and l).

Note: during the alignment just before CQM testing (21/01/2004), T_M1 has indeed been moved and is not exactly at the same height than the other mirror in the TFTS. This compensates the fact that the bench of the TFTS is not parallel to the plane of reflection of the mirror FM1.

3.5 Co-align precisely TFTS and tel-sim

This is to be done if the mirror FM1 has moved and you don't want to touch the internal optics of the TFTS. Otherwise, it can be done with the TFTS (see section 3.4)

a) Set up the bright white light source at the end of the alignment bar
b) Check where it is focused on I3
c) If needed, translate the beam with respect to the TFTS: move FM1 toward the TFTS or in the other direction (adjustment lateral) and adjust height of the TFTS (actually, this last adjustment shouldn't have to be done)
d) Check the image of the pupil mask at the pupil diaphragm (close the diaphragm to have its aperture as large as the image of the central obscuration of the pupil mask). Tilt the beam in order to have it co-centred: tilt FM1 in azimuth (rotation around the rod) and in elevation (rotation of the "45degrees" mount around an horizontal axis)
e) Repeat c) and d)
f) Re-open D1
g) Check full propagation of the beam: a white light point-like source at the focus of T_M3 has its image on I3, or I3 has its image at the focus of T_M3, in the HBB cavity.

3.6 Co-align FIR laser and tel-sim

a) Place the periscope. There are four movement possible:
    (1) Translating P1 along the rod
    (2) Rotating P1 around the rod
    (3) Translating P2 along the rod
    (4) Rotating P2 around the rod
b) (1) and (3) translate the beam, (2) and (4) tilt it. Using these adjustment, one has to make the beam passing through two points: the iris at the output of the FIR laser bench (focus, I2) and the centre of PM (pupil)
c) For this, set up the white light source at I3.
d) Close the diaphragm D2 in order to see a small circle on the pupil mask (= image of D2)
e) Using the different possible adjustment, aim to get the image of the white source on the iris and the image of the diaphragm centred on the pupil mask (this last point is less important than the first one. A misalignment of the pupils would mainly result in a small loss of light. A misalignment of the focus would result in a beam with strong aberration.). (1) and (4) are to be used if there is a misalignment along the vertical axis, (2) and (3) if there is a misalignment along the horizontal axis
f) Once this is done, re-open D2, as large as the image of the pupil mask
g) Make sure that I2 is not out of focus. If it is, and if you are certain that the periscope is at the right place, then it means that the plate supporting F_M2/F_M3/I2 has moved. See section 3.7

3.7 Aligning the optics on the FIR laser bench

This shouldn't have to be done in the scope of this check. Anyway, here are the main steps to align these optical elements if needed. The idea is to use a visible He-Ne laser and co-align it with what is the (supposed) FIR laser axis.

a) Adjust He-Ne laser: horizontal propagation at about 184mm above the surface of the table
b) Auto-collimate the He-Ne laser (without beam expander) on F_M0.
c) Place beam-splitter F_BS. Adjust it (tilt and translation) in order that the reflected beam falls in *the middle* of the FIR laser window and is reflected back on itself (i.e. do an auto-collimation in the cryostat window). There are actually several beams reflected. Use the brightest one.
Tip: the visible beam expander in its mount does not reflect the beam perfectly horizontally. To do so, the thickness of two sheets of paper slid under the base of the beam-splitter mount is very helpful
d) Place the visible He-Ne beam expander and check the alignment done in step c) for the new expanded beam. Repeat step c) if needed.
e) Adjust the FIR beam expander in order that the visible beam falls in the middle of BE1 and in the middle of the iris between BE1 and BE2. Check that the illumination pattern on BE2 is then satisfactory.
f) Set up the white light source at I3 and the periscope.
g) Place the plate supporting F_M2/F_M3/I2 in order that the image if I3 given by the telescope simulator is on I2 (assuming that all the mirror before, especially the periscope, are already correctly set up).
h) Check the overlapping of the pupils, i.e. check that the image of PM coincide with D2. If not tilt the plate supporting F_M2/F_M3/I2 around I2. Make sure that the focus remains on I2. If the plate appears to be badly orientated (with respect to the edges of the table) and/or if there is a bad overlapping of the pupils along a vertical axis, then it means that the periscope needs adjustment. In this case, orientate the plate parallel to the table and roughly facing P1 (within a centimetre), follow the next steps and repeat section 3.6 (to adjust the periscope) after section 3.7 is done.
i) Place mirror F_M1 and adjust it to have the beam focusing in the middle of I2. Make sure that the pupil is not clipped by a bad positioning of F_M1.

3.8 Telescope simulator check

a) Place the small He-Ne laser just before I2 and align it on I2 and centre of M2 (it should pass through the centre of PM as well). If the periscope is not in place, place the laser between FM1 and FM2 and align it on the centres of PM and M2
b) Place mirror F1 back using the markers on the plate (clamp, tape). F1 mount has to be well aligned along the clamp and the tape.
c) The laser beam should pass by the centre of each mirror (it is actually about 1cm below the centre of F2 and F3). If this need adjustment, follow the next steps.
d) Check position of the mirror. The distances centre to centre must be:
   (1) M2-F1= 300mm
   (2) F1-F2 = 250mm
   (3) F2-F3 = 350mm
e) Unplug linear actuators at the back of the motion controller, even if the motion controller is in STBY mode (and make sure you will re-plug it in the correct order!) to be able to move manually the actuator.

f) Adjust the orientation of F2. In azimuth, make the beam passing by the centre of F3, in elevation make the beam being 210 mm above the telescope simulator plate.
g) Adjust the orientation of F3. In azimuth, make the beam passing by the centre of the cryostat window, in elevation make the beam being 210 mm above the telescope simulator plate

3.9 Normal operations during testing

a) From FIR laser to TFTS/HBB

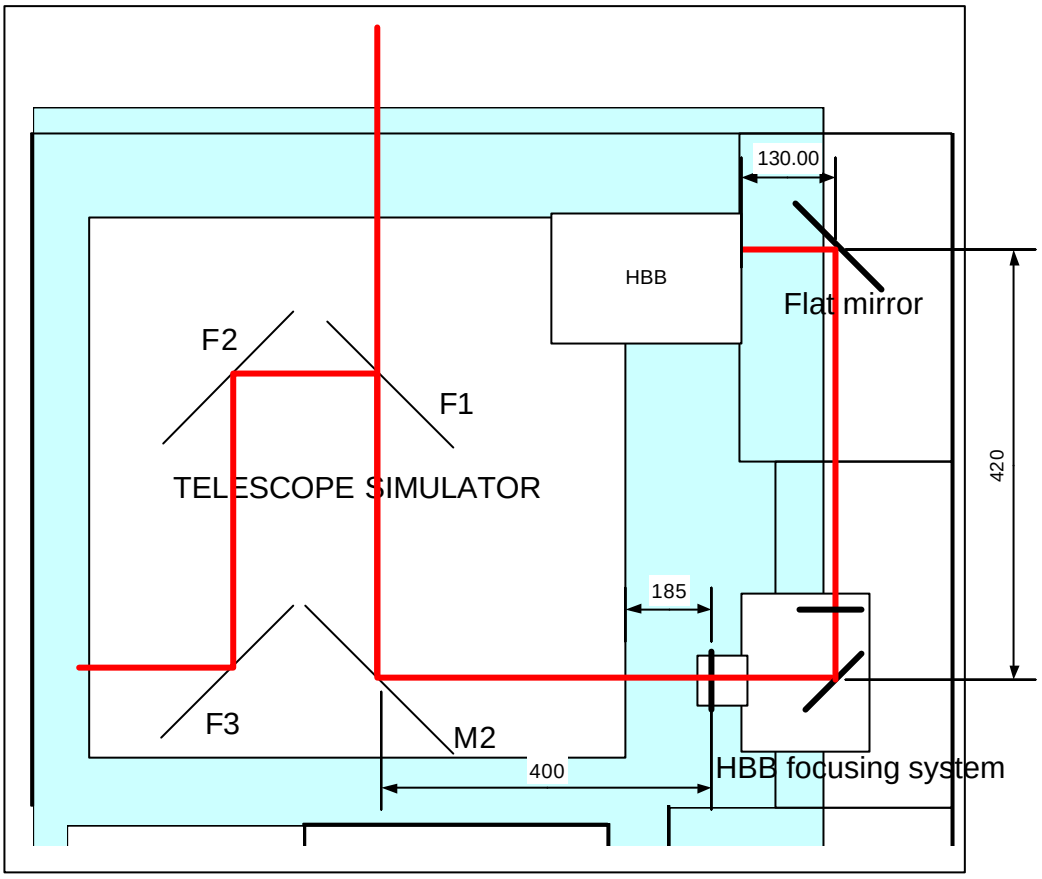
(1) Remove periscope

b) From TFTS/HBB to FIR laser

(1) Remove mirror F1
(2) Set up white light source at I3
(3) Place periscope. The mirrors shouldn't move with respect to the rod.
(4) Leave the bolts a bit loose and orientate periscope in order to have the image of I3 on I2. Tighten the bolts.
(5) Check that the image of the pupil is well centred on D2
(6) If it doesn't work, it means that the mirrors of the periscope have moved. See section 3.6
(7) Re-place F1, using marker (clamp and tape). F1 mount has to be well aligned along the clamp and the tape.

c) From anything to pupil scan

(1) Remove FM2
(2) Remove F1
(3) Remove pupil mask PM
(4) Propagate laser from I3 to centre of M2
(5) Place HBB focusing system. Align it on He-Ne laser (using both iris closed)
(6) Re-open first iris (before focusing mirror) with a diameter of 6mm.
(7) Place a flat mirror and HBB on lap jack aligned on the laser. The front panel of the HBB box has to be at 550mm from the iris (cf figure below)
(8) Place HBB on lap jack in front of first iris
(9) If HBB warm, switch the lights off, check on a white paper that its image falls on the second iris
(10) Put F1 back, using marker (clamp and tape). F1 mount has to be well aligned along the clamp and the tape
(11) Eventually, change size of the second iris to adjust amount of light



Set-up for the pupil scan

d) From pupil scan to anything

(1) Remove HBB focusing system
(2) Remove F1
(3) Put PM back, (eventually use laser aligned in I3 and M2)
(4) Set up white light source at I3
(5) Put FM1 back. Orientate it in order to have the image of I3 on I1 (if periscope not in place) or I2 (if periscope in place)
(6) Put F1 back, using marker (clamp and tape). F1 mount has to be well aligned along the clamp and the tape