SPIRE	Technical Note	**Ref:** SPIRE-RAL-NOT-001258 **Issue:** Issue 1.0 **Date:** 03/05/2002 **Page:** 1 of 8

TITLE: Hardware development of the Telescope Simulator (as part of the OGSE for SPIRE AIV)

DISTRIBUTION

D Smith	(RAL)
B Swinyard	(RAL)
P Collins	(Univ. Cardiff)
M Caldwell	(RAL)
T Richards	(RAL)
M Ferlet	(RAL)

CHANGE RECORD

ISSUE	SECTION	REASON FOR CHANGE
1.0		First issue of the document

CONTENTS

APPLICABLE AND REFERENCE DOCUMENTS

RD1 SPIRE-Telescope simulator requirements specification, ???
RD2 SPIRE-Telescope simulator optical design, SPIRE-RAL-NOT 000622v3
RD3 SPIRE-Design of the telescope simulator imaging mirror, SPIRE-RAL-NOT 000621v4
RD4 SPIRE-Set-up and alignment procedure for the Telescope Simulator imaging mirror, SPIRE-RAL-NOT 000734v2
RD4 SPIRE-Test Facility Control System requirements, SPIRE-RAL-DOC-001172 draft 0.4
RD5 Herschel-Optical design analysis, HER.NT.0026.T.ASTR issue 02

1. Introduction

Following the requirements in RD1 related to optical hardware (OGSE) for SPIRE ground calibration, a design for the SPIRE AIV facility / Telescope Simulator system concept was presented in RD2.
This document summarises the results of the hardware development phase initiated beginning of January 2002 with the arrival of the dedicated optical benches to the end of the opto-mechanical prototyping of the main subsystems (ended in end of April 2002). During that period, an Excel document (***TelSim_HardwareList.xls***) including a list of the identified/specified/used equipment was maintained and constantly updated. The last version is attached to this note, as external appendix. The components related to the Telescope Simulator/Calibration cryostat are excluded from that list, as well as the items related to TBD experiments on the FIR bench only. This note can be used by anyone as a basis of the system actual status for any further hardware development

2. Description of the sub-systems

Figure 1 and 2 below give a general view of the Telescope Simulator and its sub-systems, with the actual hardware in place (fig.1) compared to the optical model from design (fig.2).

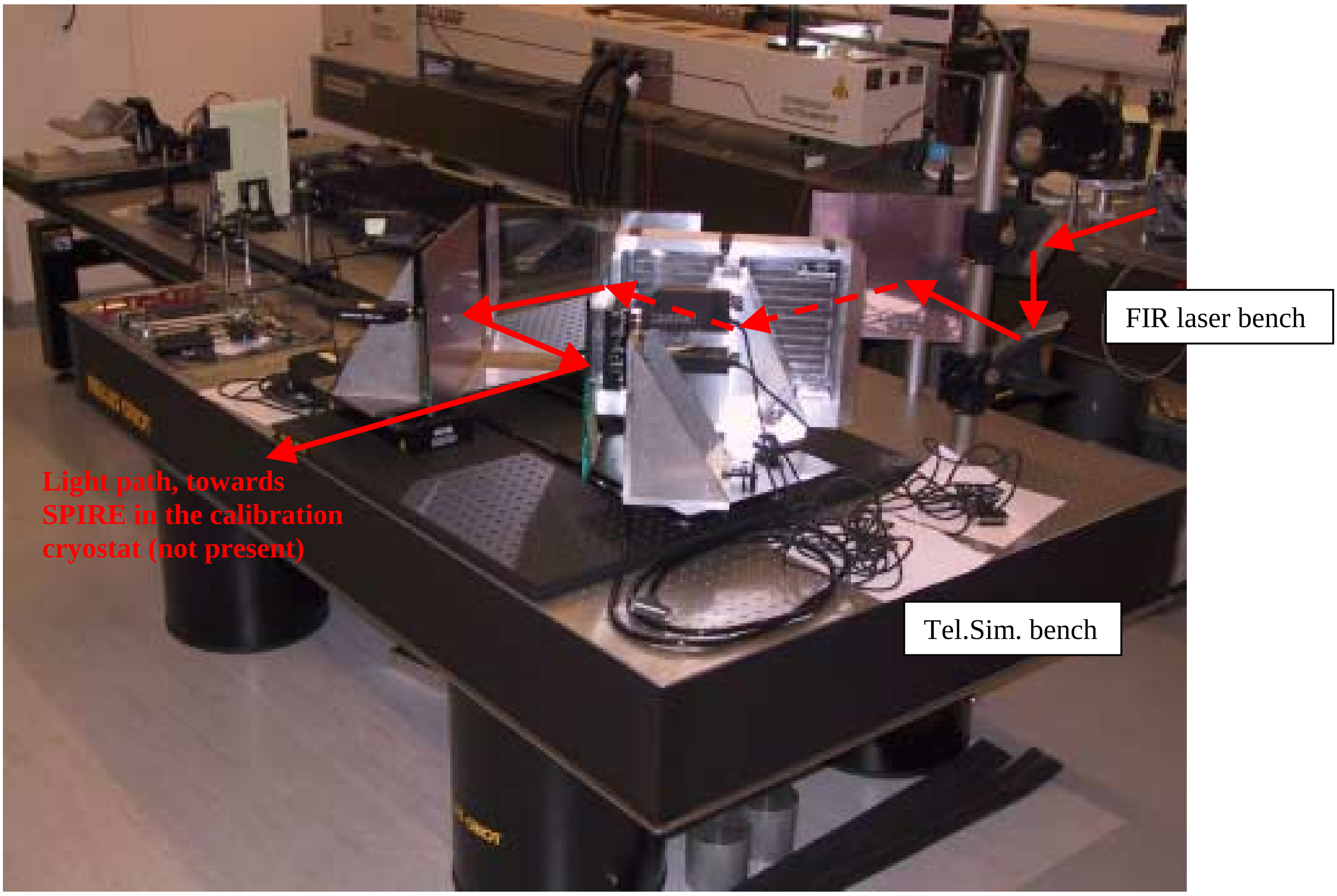


Figure 1: Telescope Simulator hardware in the SPIRE cryolab (03/05/2002)

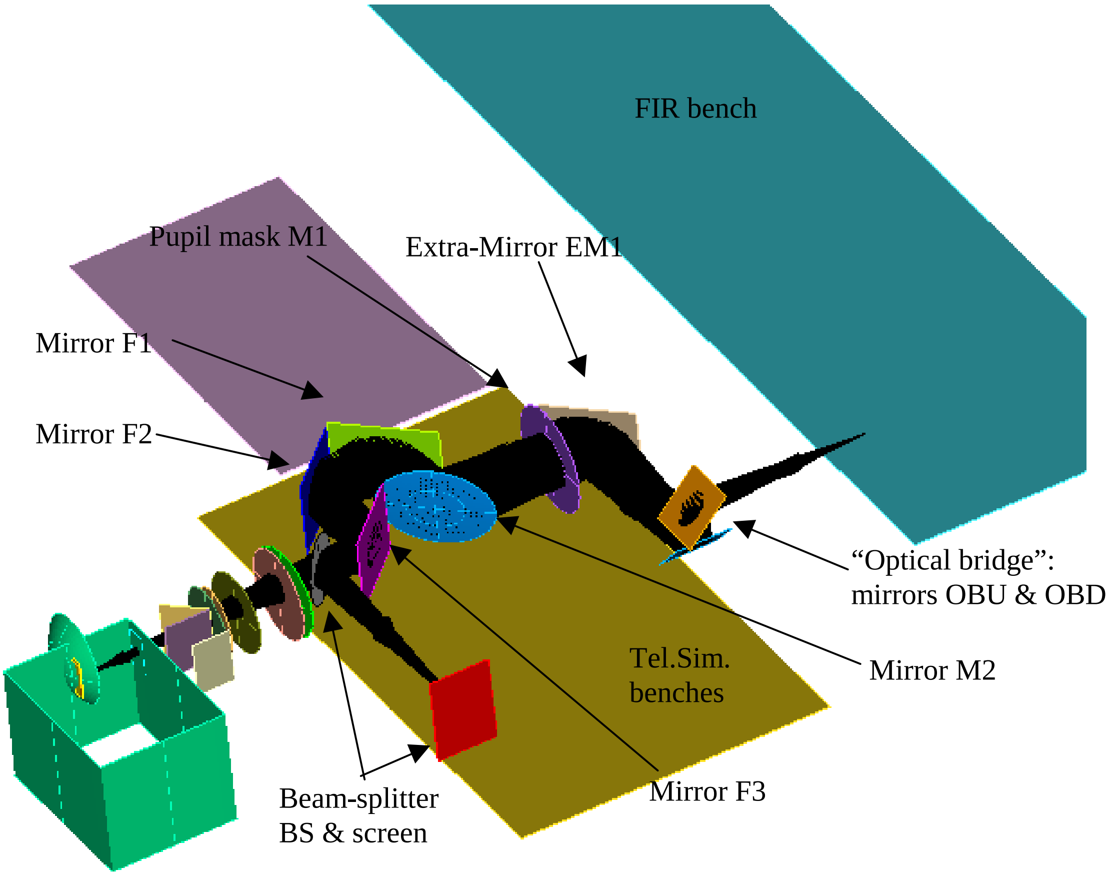


Figure 2: 3D view of the Telescope Simulator system optical path (ASAP model)

2.1 Optical benches and baseplate

The system is supported by an optical bench with passive vibration damping system (in bench and via air-filled legs). In order to accommodate the required sources (the hot-black body for example, RD1) and for alignment equipment purpose, an extra optical breadboard with rigid frame was added. The height of these benches is approximately[1] 615±5mm above the floor surface.

The central part of the telescope simulator is resting on an ultra-light optical breadboard (providing extra vibration damping) which can be manually translated in 2 horizontal directions on the top surface of the Tel.Sim. main bench. This should allow positioning of the system with respect to the future calibration cryostat.

2.2 Imaging components

The main imaging mirror M2 is described, including the design/specification/manufacturing and metrology test, in RD3, along with its dedicated mounting system (triangular-shaped, height-adjustable bracket). The mirror with its mount sits on a small plate supported by 4 pillars clamped on the baseplate. This allows coarse positioning the mirror centre with respect to the SPIRE instrument optical axis when inside the calibration cryostat.

The pupil mask M1 is discussed in section 3.

---

[1] The non-uniformity of the lab floor flatness induced uncertainty. The benches can be height adjusted over a small range, and for levelling purpose mainly.

2.3 Beam-steering system and verification path

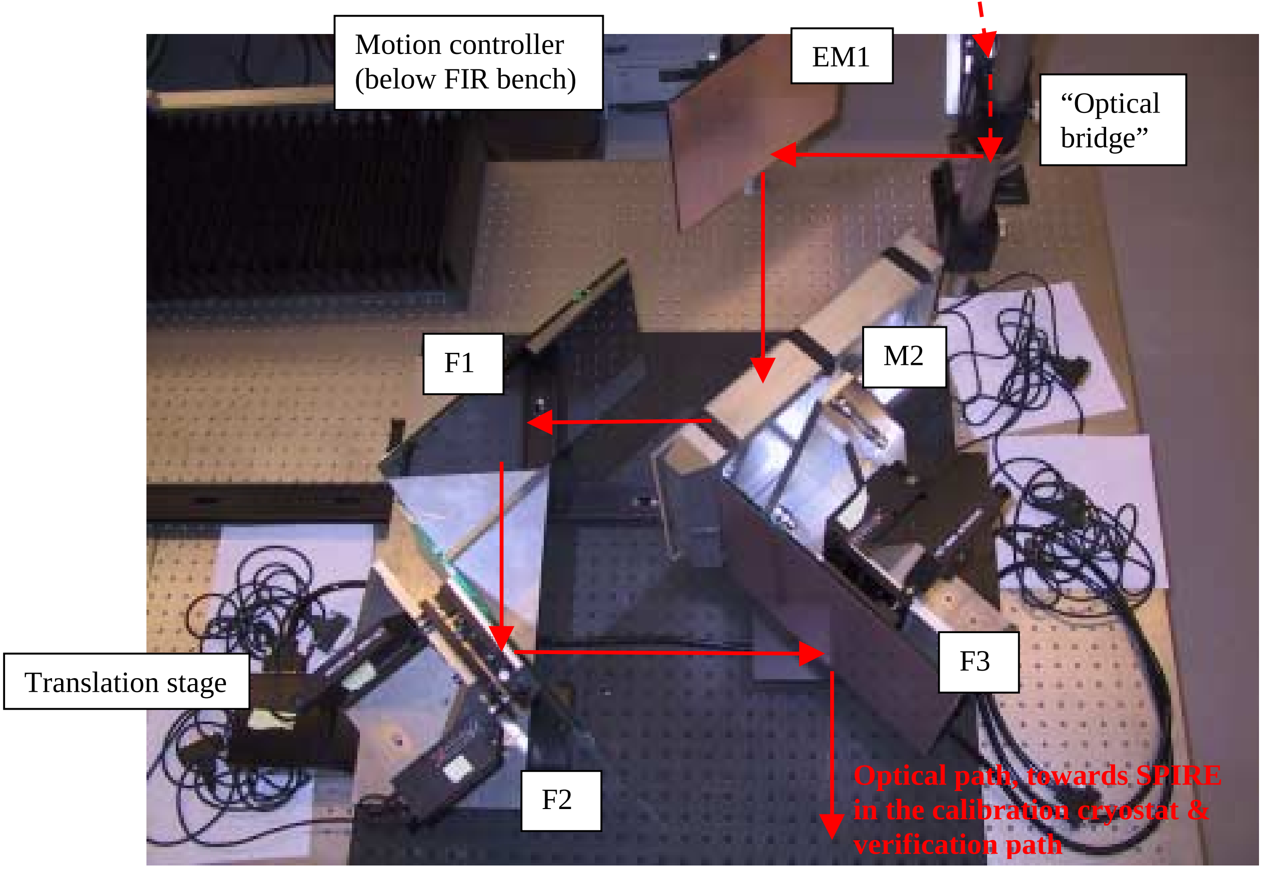


Figure 3: Top view of the Telescope Simulator central part on the baseplate

The conceptual design of the FoV scan and pupil scan is described in RD2. Experimental tests of the control laws have been performed on dedicated experimental set-up (see Tim Grundy’s Master thesis). The motion controller is located below the FIR bench and linked to a computer in the control room for remote control and processing. The motion controller was equipped with specific daughter boards and parameterised to receive connection from 4 axis +1 translation axis as described in RD4.

The folded optical path after M2 is obtained via reflection on 3 thin lightweight first-surface mirrors. Only F1 for the moment has its vinyl coating removed. This was done to allow interferometric measurements (with the WYKO interferometer in G56) of F1 reflective surface to be performed. Results are shown in appendix A. Thin aluminium interfaces plates were glued in the back of the 3 fold mirrors. For F2 and F3, a 2-axis tilt platform (+ dual actuators system for each mirror) with was mounted on the interface plates and held with recycled L-shaped aluminium brackets. The mirrors were all adapted in height in order to have their centre at about 840±10mmabove the lab floor, to comply with the cryostat design (optical port axis and instrument height). All the fold mirrors are oversized with respect to the beam (including wandering effect during scan and 20% factor for diffraction). The mirror size (relative to the thickness) and the spring system in the tilt platform make F3 and F4 relatively fragile. For F1, small manual height adjustment is possible. F3 shares the supporting small plate with mirror M2. F1 and F2 share the moving table on top of the translation stage[2]. On the other

---

[2] Due to atmospheric absorption (~4-5m optical path between laser output and cryostat window) at FIR/submm wavelengths over, one can think of enclosing the system and keeping it under vacuum. The translation stage would not work properly under vacuum, neutral N2 (or other, TBD) atmosphere at standard pressure should be preferred.

end of the moving plate (i.e. below F1), a short dove-tail rail with pillars on a rail carrier support the weight of F1 while allowing the common horizontal movement driven by the translation stage.
Additional features for definitive clamping of F1 and F2 on the moving plate could be added when optimal respective position of the mirror is found. No full-scale test of the scan mechanisms have been performed and remotely controlled yet.

2.4 Alignment and source interface hardware

The alignment for the central component of the system (the shaped mirror M2) is described in RD4.

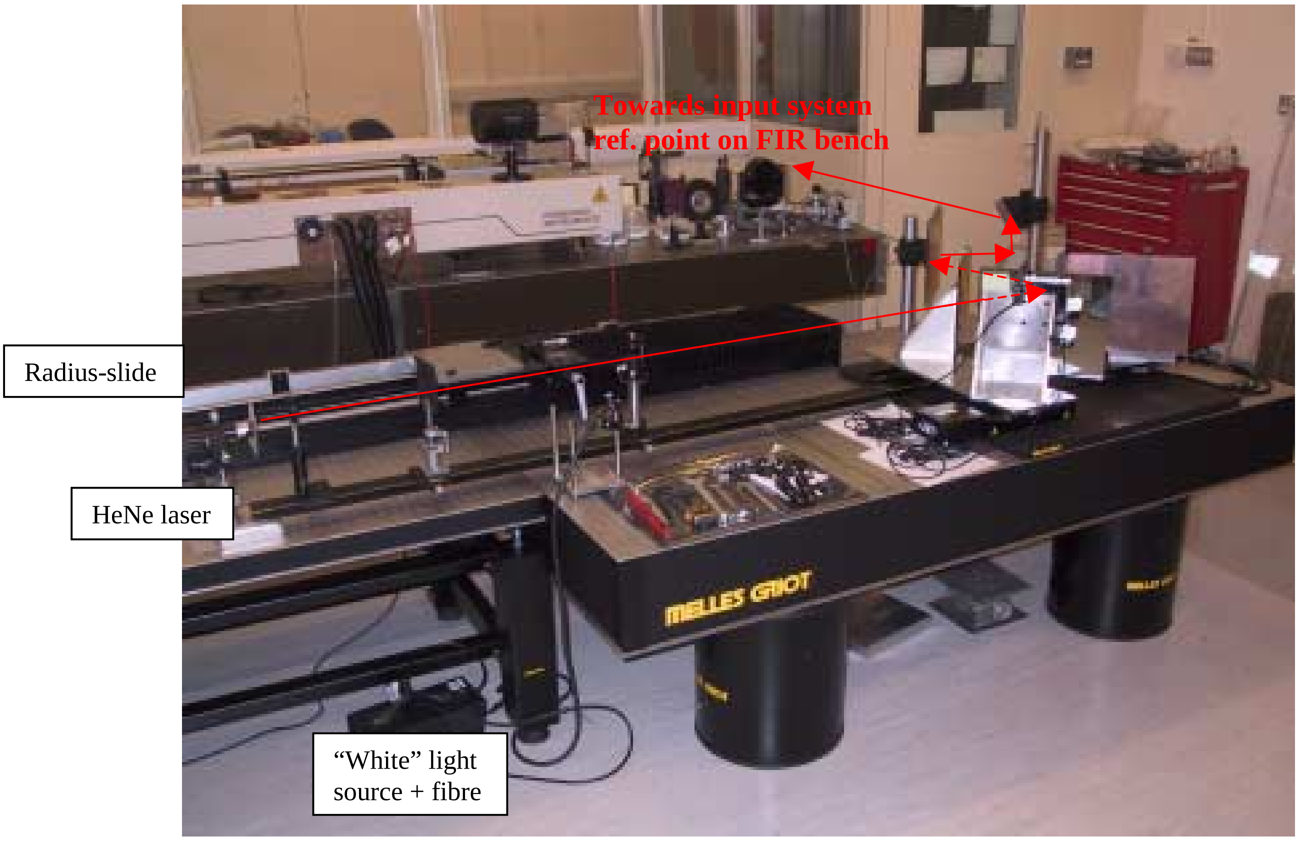


Figure 4: General view of the alignment equipment for the Telescope Simulator.

A bar/rail (2metres in length) fixed at one end on the baseplate (below M2, passing below the moving table) supports at the other end the permanent reference point for alignment (iris diaphragm on rail carrier). The rail supports also the temporary equipment such as extra iris for intermediate reference point and the pentaprism. Parallel to the bar, the radius-slide allows a MAT (not shown in figure 4 above) to translate along the optical axis of the mirror M2. F1 has to be removed for the HeNe laser to illuminate the fiducial mark on M2.
The extra mirror EM1 can act as the flat mirror for retro-reflection. EM1 is mounted on 45deg-angle bracket supported in height with a rod. This system allows coarse height adjustment (the mirror is expected to be well oversized compared to the test beam size) and rotation about the rod axis makes it act as a simple manual switch. One can then choose to feed the Telescope Simulator central part with different sources (one at a time) at this point.
After angular and position alignment of the permanent reference point and the mirror M2, the location of the source input point on the FIR bench is found with the help of EM1 and an “optical bridge” composed of 2 smaller flat mirrors, OBU and OBD, mounted on 45deg-angle bracket on a vertical rod.

This system allows basic redirection of the beam towards an image on the reference point, located via another iris diaphragm, on the FIR bench. A CCD video camera or a screen can be set on a rail carrier and the short rail used for the moving table (see section 2.3) to find longitudinally the best focus (becoming the input point for a source such as the FIR laser source).

3. Identified remaining issues

The estimated total weight of the actual Telescope Simulator system (including the baseplate and alignment bar + ref. point at focus) is around ~50kg. The sub-systems were kept simple, easy to mount and dismantle and are composed of low-cost standard items that can be easily re-used outside the Telescope Simulator application. A few identified issues that may need further investigation are listed below.

1) The pupil mask M1 has not yet been specified for the following reasons:

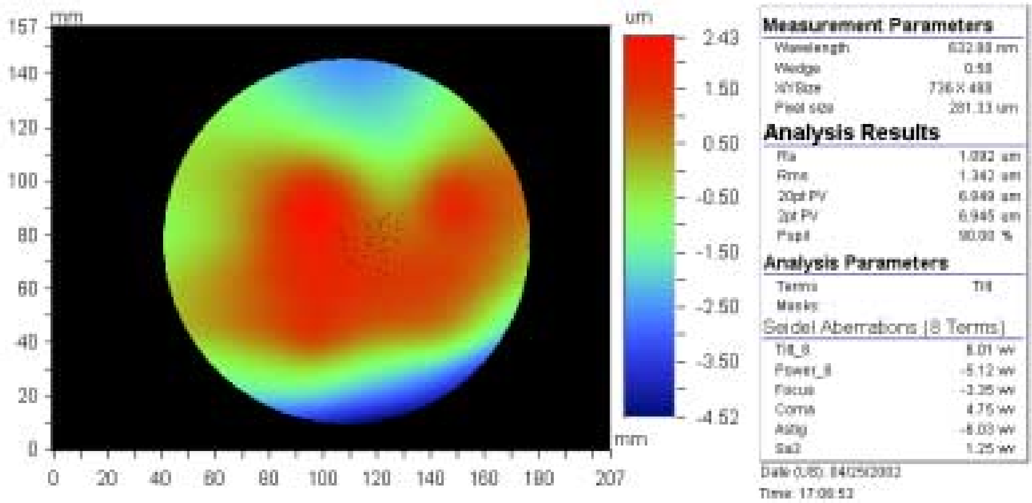
- it does not represent a priority as it is needed only with the test FIR beam,
- the Herschel telescope obscuration design has been recently modified: the change from a tripod configuration to hexapod for the support of the secondary has impact on the pupil obscuration pattern (the most recent one is shown in RD5).

2) The final beam-splitter to be used after the beam-steering system (splitting the test beam + visible track beam) need to be large enough for the narrow visible beam wandering during scan but not for the large full FoV test FIR beam.

3) The mirror system (“optical bridge”) interfacing the 2 optical benches at different heights has been inserted in the ASAP model of the Telescope Simulator. It was found that the mirrors would be sufficiently large only in a certain configuration: when they are as close as allowed by the bench spacing, from the system input point FIR laser beam (physical location with an iris diaphragm). If this condition is not satisfied because of extra requirements/constraints on the input location from the beam-expander system (and/or other experiments on the FIR bench, TBD). An alternative scheme with another extra mirror EM2 can be used on the Tel. Sim. bench if necessary to adapt to the constrained location of the laser input point and the mirror M2 distance to focus.

Appendix A. Interferometric test of F1 surface

Investigations on the flatness quality of the mirror F1 were carried out with the WYKO laser interferometer located in clean-room G56. To be representative of the fold mirror system, a tilt platform was fixed in the back of the mirror (via interface plates glued on F1 and 4 M6 screws). Together they were mounted on an aluminium L-shaped bracket dedicated to F1.
A total of 9 zones of the large F1 surface were probed with the interferometer largest aperture beam (150mm diameter). The result for the centre zone is displayed in figure 5 below.



Measurement Parameters

Wavelength	632.80 nm
Wedge	0.50
X/Y Size	736 X 480
Pixel size	281.13 um

Analysis Results

Ra	1.092 um
Rms	1.342 um
20pt PV	6.949 um
2pt PV	6.945 um
Pupil	90.00 %

Analysis Parameters

Terms	Tilt
Masks	

Seidel Aberrations (8 Terms)

Tilt_8	8.01 wv
Power_8	-5.12 wv
Focus	-3.35 wv
Coma	4.75 wv
Astig	-8.03 wv
Sa3	1.25 wv

Date (US): 04/25/2002
Time: 17:08:53

Figure 5: Contour plot of the reduced interferogram at the centre of F1. The analysis is performed on 90% of the max 150mm pupil aperture of the interferometer. The darkest red zones have been linked to the location of the M6 screws holding the tilt platform in the back of the mirror.

The results show rms values for the flatness between ~λ and ~3λ max (at 632.8nm) over the 135mm diameter analysis zones. The max being reached for the central zone and is due to the pressure from the holding points in the back of the thin mirror, increasing mainly the amount of astigmatism. The mirrors F2 and F3 come from the same manufacturer (same material) but are slightly smaller in size. Only F1 was tested but the results can be extrapolated as representative worst-case figures for the other fold mirrors.

Considering the FIR test beam size on the mirrors F1, F2 and F3, an estimation of the max WFE from reflection on the fold mirrors would be 5-6µm rms. Together with 4-5µm rms value from the imaging mirror M2 (at best focus, from form factor and surface roughness, see RD3), it would lead to total WFE~10µm rms which should still maintain the system diffraction-limited with a Strehl ratio >90% at the shortest SPIRE wavelength (200µm).