PLANS FOR THE SPIRE INSTRUMENT AIV AND CALIBRATION

D.L. Smith, G.M. Toplis, M.R. Harman, M. Caldwell and M. Ferlet

Rutherford Appleton Laboratory, CLRC, Chilton, Didcot, Oxfordshire, OX11 0QX, United Kingdom,
Email: d.l.smith@rl.ac.uk SPIRE-RAL-PUB-000730

ABSTRACT

Spectral and Photometric Imaging Receiver, SPIRE, for the Herschel telescope due to be launched in 2007 is designed for measurements of high redshift galaxies and investigations of star formation. The instrument comprises an imaging photometer and an imaging Fourier Transform Spectrometer.

In this paper we present a brief overview of the SPIRE AIV Programme and the test facilities that are being developed. In particular we describe the calibration cryostat that will simulate the thermal environment of the Herschel cryostat, a telescope simulator and a cryogenic vibration facility.

1. INTRODUCTION

The Herschel Telescope (formerly known as FIRST) will perform photometry and spectroscopy in the 60-670 µm range. It will have a radiatively cooled telescope and carry a science payload complement of three instruments housed inside a superfluid helium cryostat. It will be operated as an observatory for a minimum of three years following launch and transit into an orbit around the Lagrangian point L2 in the year 2007.

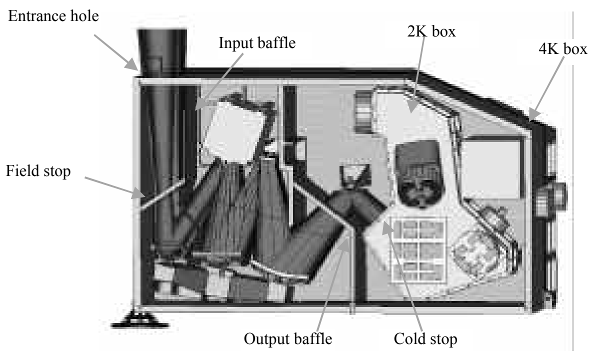

Fig 1. SPIRE Photometer

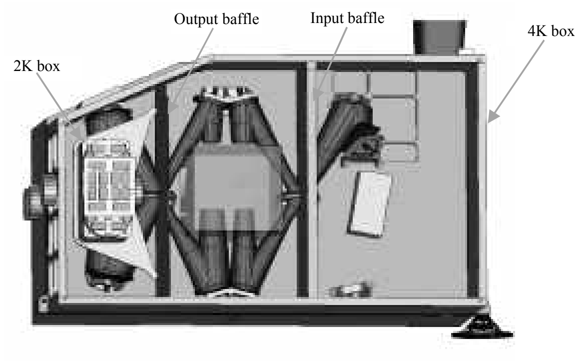

Fig 2. SPIRE Spectrometer

The Spectral and Photometric Imaging REceiver, SPIRE is designed primarily to exploit Herschel's unique capabilities in addressing two of the most prominent questions of modern astrophysics:

- The investigation of the statistics and physics of galaxy and structure formation at high redshift.
- The study of the earliest stages of star formation, when the protostar is still coupled to the interstellar medium.

SPIRE consists of a three band imaging photometer with channels at 250, 350 and 500µm respectively, fig.1, and an imaging Fourier Transform Spectrometer covering 200-300µm and 300-650µm, fig.2. The detectors used by both are feedhorn-coupled NTD germanium bolometers cooled to 0.3K by a ^{3}He Joule-Thomson refrigerator. The Focal Plane Unit, FPU, is 690 x 410 x 410mm in size and has three temperature stages at 4K, 2K (provided by the Herschel cryostat) and 0.3K (provided by the internal cooler). The optical bench at 4K is supported from the 10K cryostat optical bench by stainless steel mounts. The instrument design is described in further detail by Griffin *et al*[1].

2. SPIRE AIV PROGRAMME

2.1 Model Philosophy

There are essentially four main models of the SPIRE FPU and electronics units to be integrated and tested at RAL. A Structural Test Model, STM, for verifying that the mechanical and thermal design of the instrument meets the performance requirements. The Cryogenic Qualification Model, CQM, will use the same structure as the STM but will have functionally representative cold-subsystems and warm electronics units. The cold-electronics units will be close to the expected flight performance, but will not necessarily have the full flight capability nor built to flight standards. For example, only a limited number of detectors will be functional. The Proto-Flight-Model, PFM, will be the instrument model intended for flight. It will be the only fully functional model. The flight-spare, FS, unit will be built from the refurbished CQM structure. It is not clear at this stage whether the FS will be fully integrated and tested prior to delivery at ESA. There will also be an Avionics model, AVM, of the warm electronics units that will not be tested at RAL.

2.2 AIV Activities

The Assembly Integration and Verification, AIV, of the SPIRE instrument will be conducted at RAL. Upon delivery of the instrument structure, the positions of the mirror interfaces will be measured to <10µm using a 3D-inspection facility. The optical components will then be integrated and the alignment verified at room temperature.

The SPIRE instrument will then be mounted in a purpose build calibration cryostat (see section 3) and cooled to operating temperatures. A series of tests will be performed to exercise the full operational modes of the instrument and to characterise its performance. The measurements will include verification of the optical alignment, verification of the thermal performance, characterisation of the detector and electronics system, radiometric and spectral calibrations, straylight analysis and functional performance tests.

Because SPIRE will be launched cold, it is necessary to demonstrate the responses to vibration at cryogenic temperatures (<10K). Cold vibration of the whole SPIRE instrument will be performed with the STM and PFM at the Herschel common cold vibration facility. Cold vibration of instrument subsystems will be performed at the RAL cryogenic vibration facility (see section 4).

3. CRYOGENIC TEST FACILITY

The SPIRE calibration cryostat is required to simulate the thermal conditions provided by the Herschel cryostat, namely 7-11K, 4K and 1.7K. External calibration sources will be viewed via a telescope simulator situated outside the cryostat at room temperature. A cold blackbody source (4K-20K) mounted in the cryostat will provide an absolute calibration reference. The control and monitoring of the calibration sources, the telescope simulator and cryostat temperatures will be performed via a single test facility systems computer (TFCS), connected to the main SPIRE EGSE.

3.1 Cryostat

The calibration cryostat shown in fig. 3 will accommodate the SPIRE FPU, two JFET boxes and a 4-20K-blackbody calibration source. The cryostat will simulate the thermal environment provided by Herschel and cool the instrument to its operating temperatures of 7-11K, 4K and 1.7K.

The main vacuum chamber will be a stainless steel vessel approximately 1.2m in diameter that can be pumped to a pressure of $<10^{-6}$mbar (with instrument and support equipment) prior to filling the cryogen tanks.

There will be three separate tanks containing LN_2, He at 4K and He at 1.7K. The hold time of the tanks are designed to allow at least three days when the instrument is cold to allow work to continue uninterrupted over the weekends. The tanks will be pre-cooled with LN_2 to reduce the overall cool-down time. There are no plans to regenerate the He.

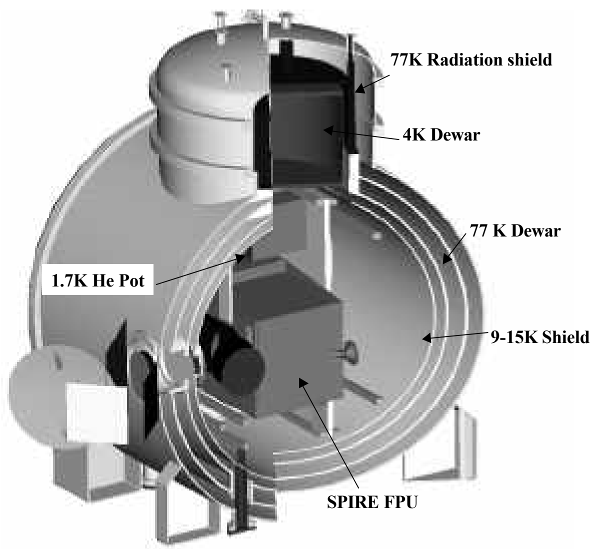

Fig. 3 SPIRE Calibration Cryostat

The instrument thermal interfaces will be connected to the 1.7K and 4K vessels via fluid links, giving more efficient cooling power than conventional copper straps. This differs slightly to the flight configuration where the thermal interfaces of the instrument are connected to a gas-cooled pipe.

To minimise the stray light and unwanted thermal loads, the instrument will be completely surrounded by a 7K-15K thermal shroud. The temperature of the shroud will be controlled using a combination of the boil-off from the 4K pot and in-line heaters.

The SPIRE instrument and associated equipment will be mounted to a support structure outside of the vacuum chamber. The complete assembly will be moved into the cryostat and locked into position. The design will ensure that the structure and instrument are thermally isolated from the tank walls. The support structure will also be cooled via a thermal strap to the 10K shield.

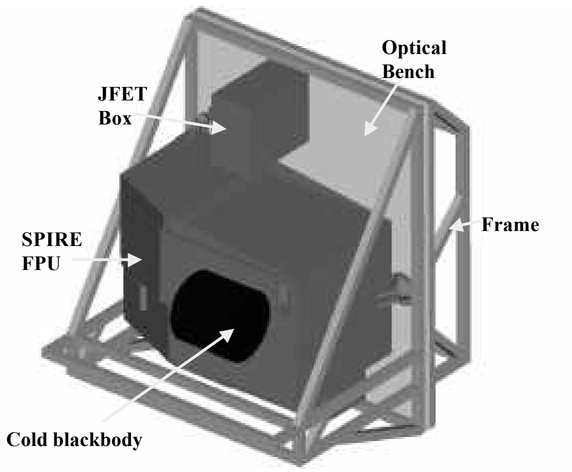

Fig 4. Support Frame and optical bench for cryostat

It is vital that the total heat flux incident on the SPIRE FPU during calibration be of the same magnitude as presented by the 80K Herschel telescope. During calibration the SPIRE instrument will view a 1000K point source with a 300K background, and with no optical filtering the heat flux would be too great and have significant effects on the performance of the cryostat. Thus to bring the measured signal to representative levels, and to reduce the heat loading on the cryostat thermal shields, optical filters will be mounted at each of the cryostat temperature boundaries, namely 300K, 77K and 4K. Filters at 77K and 10K will block the thermal IR signal from the 300K environment. Neutral density filters at the 4K interface will reduce the signal to levels approximating the expected in-flight fluxes.

To ensure that a commissioned cryostat is ready in time for the delivery of the SPIRE STM, much of the cryostat design has had to be completed before the SPIRE instrument design was finalised and the calibration requirements completely defined. This clearly presents a major risk to the project. These risks are minimised by ensuring that the body of the cryostat is not dependent on the final instrument design. Thus the mechanical, optical and electrical interfaces are not built into the cryostat, but will be produced when the instrument design has been finalised.

3.2 Telescope Simulator

The purpose of the telescope simulator is to reproduce the Herschel telescope f8.68 beam, such that a point source is imaged at the SPIRE input focal plane. The problem then is to scan a single point source over the entire SPIRE field-of-view aberration free whilst keeping the design simple. The solution shown in fig.5 is based on a similar telescope simulator built for the ISO LWS calibration[2].

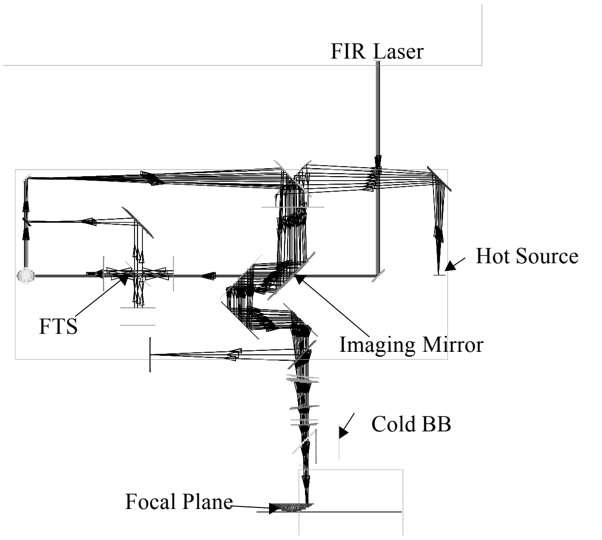

Fig. 5 Optical design for the Telescope Simulator

The SPIRE focal plan is at the focus of a single imaging mirror that produces a virtual image of a real pupil aperture. Because the Herschel telescopes pupil distance is 2.44m and there is restricted space in the test facility, the optical path of the is 'folded' by a series of planar mirrors, F1, F2 and F3. The source is scanned across the SPIRE input aperture in azimuth and elevation by two of the fold mirrors F2 and F3. To correct for the non-planar focal surface of SPIRE, two of the mirrors F1 and F2 are mounted on a translation stage in a 'trombone' arrangement. The motions of these mirrors are defined by a complex control law that is currently being tested.

3.3 Sources

A number of calibration sources are currently being developed or adapted for the SPIRE test facility. The primary sources will be:

- A 4K-20K-blackbody source will be used as an absolute radiance standard. This will be mounted within the 4K enclosure of the cryostat and viewed via a relay mirror.

- An Edinburgh Instruments PR5 gas FIR laser with lines from 30µm to 1000µm and power up to 100mW. This laser was previously used for the ISO LWS calibration. Some modifications will be required to improve the output stability and a Fabry-Perot interferometer will be used to improve the spectral quality.

- A Fourier Transform Spectrometer (FTS) to allow the spectral response of the photometer channels to be measured.

- A 1000ºC blackbody source.

3.4 Test Control System

The calibration system will not be under automatic control since the duration of the cryogenic test runs is expected to last only a few weeks and the development costs and risks would be too high. Nevertheless, remote control and monitoring will be provided, where appropriate, for temperature monitoring, liquid nitrogen and helium levels, and control and data acquisition of the calibration equipment.

A single Test Facility Control System (TFCS) PC will control and monitor the test equipment. Each subsystem will have its own control application. For example a cryostat monitoring application will log the cryostat temperatures, heater output and cryogen levels. Other applications will allow control of mechanisms such as the telescope simulator.

The TFCS will itself form part of the overall instrument EGSE as shown in fig. 6 to enable synchronisation of the facility data with the instrument data. Instructions to the instrument or TFCS will be sent from SCOS-2000 as command packet via a packet router. The command packets will be interpreted by the TFCS and the instructions sent to the facility control applications. Data from the applications will in turn be assembled into telemetry packets having the same structure as instrument telemetry packets. These will be sent back to the main EGSE via the packet router and SCOS-2000 for analysis.

4. CRYOGENIC VIBRATION FACILITY

The Cold Vibration Facility consists of a vacuum cryostat that is mounted to the nose of an LDS 954LS three-axis shaker, as seen in fig. 6. The facility was developed and used extensively during the ISO LWS test campaigns and will be refurbished for SPIRE subsystem tests.

The moving mass is kept to a minimum by mounting the cryostat to the stationary support frame of the shaker, and utilising a vacuum rolling seal between the shaker and the cryostat, thus maintaining vacuum during test item excitation.

The moving mass is limited to the armature of the shaker and the fibreglass drive tube, which connects the test item with its helium-cooled vibration fixture, to the shaker. A turbomolecular-pumping unit will evacuate the vacuum chamber and when at a suitable pressure the cryostat is cooled down with liquid nitrogen by filling an outer toroidal reservoir. When the cryostat is at approximately 90K liquid helium is introduced into an inner toroidal reservoir and the vibration fixture. Once a stable temperature, typically <20K, has been achieved the vibration test can then take place. A typical operation cycle for the vibration facility would be:

Day 1	Install Test Item and connect Instrumentation.
Day 2	Pump down cryostat.
Day 3	Cool down to <20K and perform test.
Day 4	Warm up and letup cryostat.
Day 5	Reconfigure test item.

fig. 7: Cryogenic vibration facility being prepared for ISO LWS testing.

5. REFERENCES

1. Griffin M., Swinyard B, and Vigroux L, *The SPIRE instrument for HERSCHEL,* Proc. of "The Promise of FIRST" symposium, Toledo, Spain, ESA SP-460 (in press), 2000

2. W Duncan et al, *Long Wavelength (sub-mm) Telescope Simulator*, Infra-red Phys. Vol.34, 1-15, 1993