## 1 Introduction

This note outlines the test philosophy and requirements for the SPIRE instrument CQM. It expands upon this to give the requirements on the instrument CQM sub-systems and the tests that we would wish to carry out at payload module level at ESTEC.

## 2 Instrument Level Test Philosophy

The CQM instrument will be built to be as near to flight representative as is possible given the resource and schedule constraints of the project. The basic requirement to build a CQM instrument is governed by the need to ensure that the proto-flight instrument can be integrated successfully; will fulfil the scientific and technical requirements and is capable of surviving the environmental conditions of launch and space operation. The tests can be broken down into five major categories:

Integration

- Optical alignment
- Mechanical and electrical interface checks
- Commanding and data transfer interface checks

Functional checkout

- Sub-system warm and cold functional checks
- Thermal balance tests - including cooler recycling
- On board software tests (control loops; synchronisation; data handling etc.)

Performance checkout

- Optical performance (alignment; focus; straylight etc.)
- Sub-system performance
- System operation (microphonics; thermal dissipation in each operating mode; EMI etc)
- Scientific performance (sensitivity; spectral response; etc)

Environmental tests

- FPU and JFET box bakeout
- Cold vibration of FPU and JFET box
- Warm vibration of electronics boxes
- Thermal vacuum test of electronics boxes
- Operation of electronics boxes versus thermal range
- Operation of cold FPU versus thermal range
- C.o.G and mass conformance of FPU; JFET box and warm electronics units.
- EMC (conducted susceptibility only?)

Operational checkout

- PLM level functional test sequence checkout
- PLM level performance test sequence checkout
- Observing mode checkout
- AOT preliminary end to end test
- Production of calibration tables
- Production of RTA limit tables

Although the details of most of these tests are not known and not needed at present to place requirements on the sub-systems, we do need to expand on some of them to ensure that the capabilities of individual subsystems are matched to the requirements of the CQM tests.

# 3 Detailed Test Requirements

## 3.1 Optical Alignment during integration

The details of the optical alignment procedures are given in the *SPIRE Optical Alignment Plan (ref?).* The plan calls for both mechanical metrology and optical (visible) verification. The implication of this is that all the mirrors are of suitable quality to allow for optical verification using standard techniques.

## 3.2 Thermal balance tests

The CQM FPU will be the first time that all the thermal hardware: $^3$He fridge; thermal straps; detectors; thermal control circuits; structure etc, will be integrated as a single system. The operation and performance of this system is of paramount importance to the SPIRE instrument. This hardware needs to be fully flight representative in terms of thermal conductance; impedance and dissipation in order that the fridge "sees" the environment that it will ultimately operate under. To test the thermal balance of the instrument as a whole the test cryostat also needs to replicate the thermal interface to the FIRST cryostat and all cold sub-systems, including the JFET box, must be thermally representative in terms of dissipation; conductance; contact impedance etc.

## 3.3 Performance Checks

Detector performance and characterisation

- Load curves under nominal operating conditions
- Speed of response under nominal operating conditions
- Noise performance under nominal operating conditions
- Performance versus thermal loading and instrument operating temperature
- Performance versus microphonic input
- Electrical cross talk
- Linearity

Performance and characterisation of photometer optics

- Alignment using sub-mm/FIR radiation
- Focus sensitivity using sub-mm/FIR radiation
- FOV of instrument
- Variation of instrument sensitivity versus position in FOV
- Beamsize versus position in FOV
- Straylight both non-optical path and far off axis into instrument aperture
- Spectral response
- Absolute optical efficiency
- Optical crosstalk
- Distortions and aberrations

Performance and characterisation of spectrometer optics

- Alignment using sub-mm/FIR radiation
- Focus sensitivity using sub-mm/FIR radiation
- FOV of instrument
- Beamsize versus position in FOV
- Straylight both non-optical path and far off axis into instrument aperture
- Absolute optical efficiency at ZPD
- Optical crosstalk

Distortions and aberrations

Spectrometer performance
- Spectral resolution
- Influence of position and velocity jitter on signal to noise in spectrum
- Fringe contrast versus spectral resolution
- Fringe contrast versus position in FOV
- Fringe contrast versus wavelength
- Nulling of telescope signal
- Electrical filtering characteristics
- Out of band signal rejection of system
- Beamsize versus mirror position
- Variation of ZPD position versus position in FOV.
- Exported microphonics

BSM performance
- Position calibration using sub-mm/FIR
- Stability and repeatability for all operational modes
- Exported microphonics

Calibrator performance and characterisation
- Photometer calibrator observed signal versus position of detector
- Photometer calibrator speed of response
- Spectrometer hot calibrator observed signal versus position of detector
- Spectrometer hot calibrator speed of response
- Spectrometer cool calibrator observed signal versus position of detector
- Spectrometer cool calibrator stability

Shutter performance
- Radiation rejection
- Characterisation of thermal source

EMC/EMI
- Test of conducted susceptibility of cold FPU(?)

# 4 CQM Functionality

## 4.1 General

All cold subsystems will need to be mechanically and thermally representative and capable of undergoing the environmental tests to be done on the CQM instrument. Any cold redundant hardware that will have a different operational characteristic to the prime hardware must be fitted. For instance a redundant FTS mechanism position encoder of a different type or in a different position to the prime encoder must be present. Any redundant hardware that will not have a different operational characteristic to the prime (e.g. thermistors) does not need to be operational but must have an equivalent mass dummy as replacement.

For almost all the cold subsystems this requirement will mean that they will be essentially fully flight compatible. The major exception to this will be the detectors where the cost and difficulty of providing five complete arrays will not be compatible with the resources available and the FIRST schedule. The requirements on the detectors are given in the next section and the requirements on all subsystems summarised in table 1 at the end of the document.

### 4.2 Implications for the detector provision

Although the detectors modules need not be fully scientifically representative, they will have to have to be externally structurally representative; have the correct mass and have the correct interfaces and thermal behaviour. The JFETs will have to be externally structurally representative and thermally representative. All the internal harnesses and connectors will need to be fully representative and all signal lines should have signals. The latter implies that resistors must be provided to replace any detectors and/or JFETs. All the thermometers and thermal control hardware will need to be flight-like in order to replicate the correct operating environment to test the correct implementation of the thermal control software.

The detector arrays will have to be sufficiently well populated to allow the optical performance of the instrument, both the spectrometer and photometer, to be fully characterised. The straylight and diffraction effects are likely to be worst at the longest wavelengths in both sub-instruments. Therefore the long wavelength arrays will have full coverage of the focal plane whilst the shorter wavelength arrays will only be required to have pixels at the centres of the arrays and at strategic points around the periphery. The required numbers and positions of detectors are given below and shown in figures 1 and 2

**Spectrometer:**

LW: Fully populated with 19 detectors. Only the central seven pixels need to be of full scientific quality.
This will allow any change in the spectrometer performance in terms of vignetting or straylight effects to be fully characterised.

SW: Minimum of centre and 4 corners

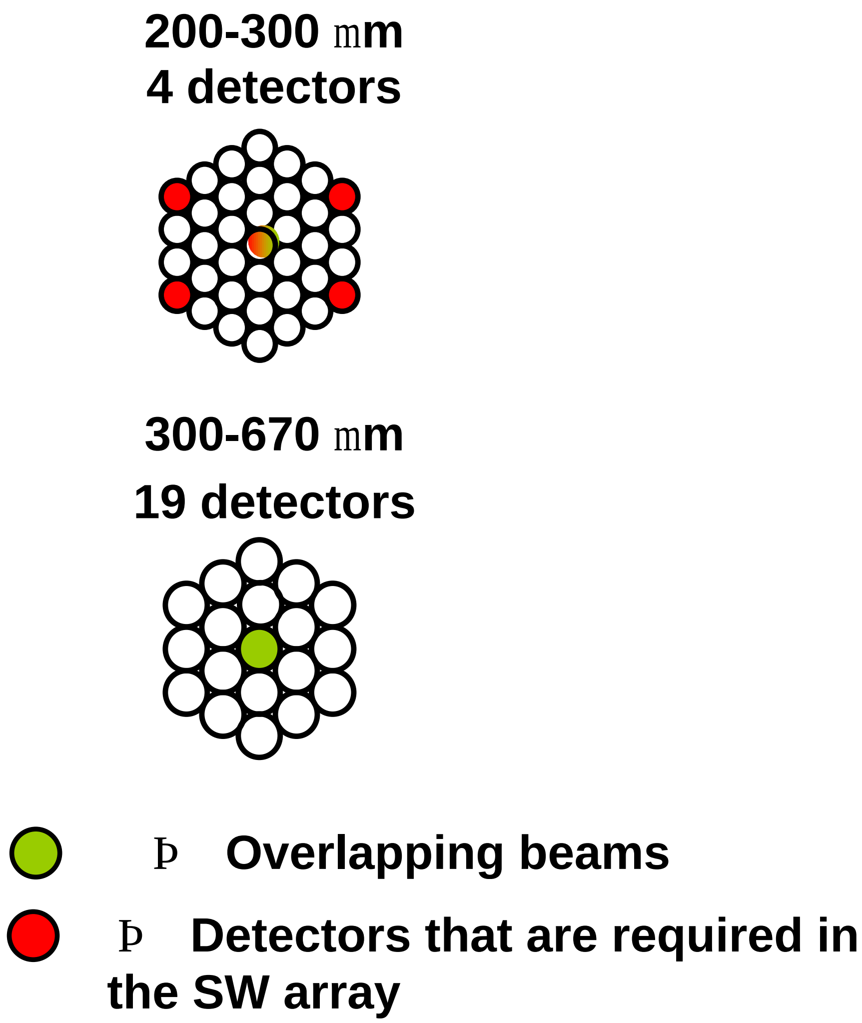


**Figure 1: Detectors to be provided for the spectrometer CQM**

**Photometer:**

500 µm: Fully populated but don't need to be all scientifically optimised. Again this will allow the optical performance to be fully characterised over the full focal plane.

350 µm: 8 detectors: two central co-aligned pixels and 6 around periphary

250 µm: 8 detectors: ditto

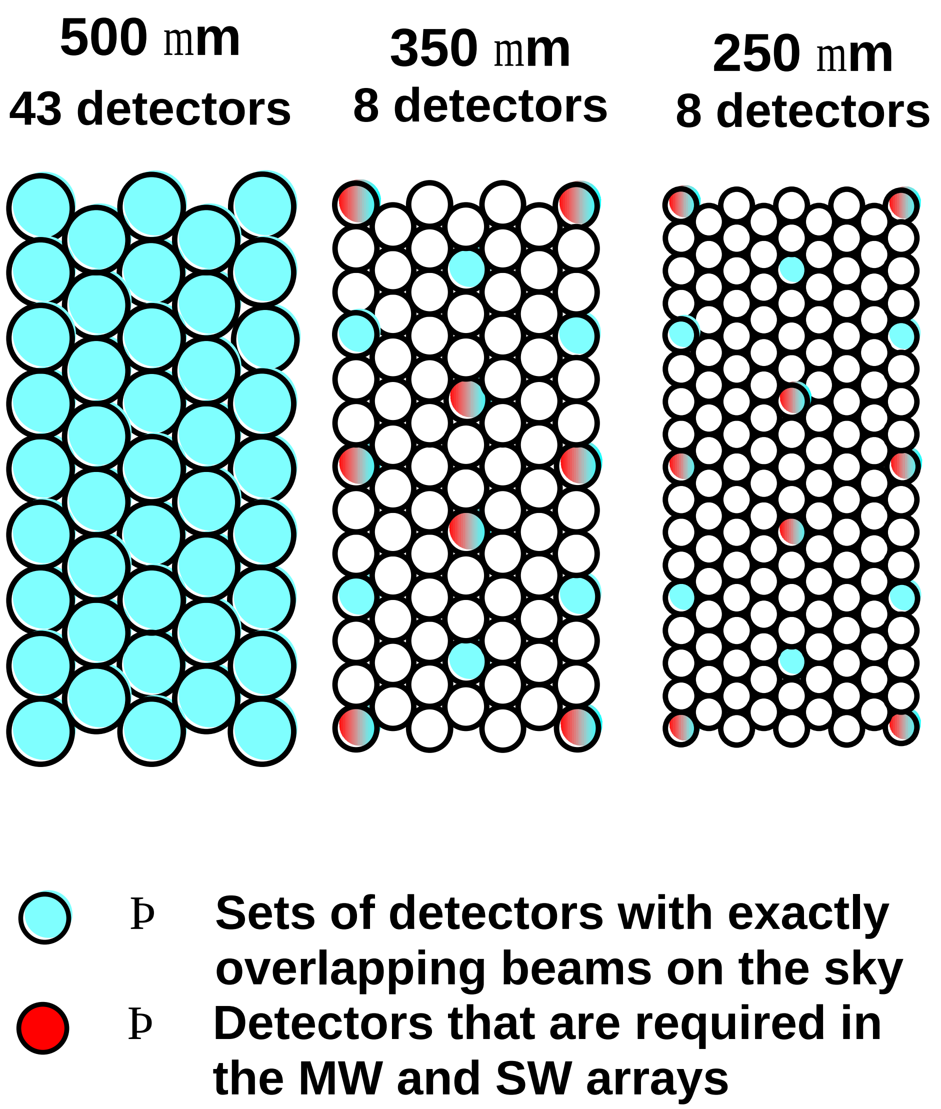


**Figure 2: Detectors required for the CQM photometer arrays**

### 4.3 Electronics

All instrument level tests except the warm vibration of the warm electronics units and the EMC tests can be carried out with the development model DPU and the "QM1" DRCU. These will have the following specification.

Development model DPU: No redundancy;
Industrial level parts for expensive or long lead items, possibly including spacecraft interfaces.
External structure will have correct mechanical configuration possibly only for "fit and form check" i.e. not capable of environmental testing.

QM1 DRCU: no redundancy necessary – we will check switching to redundant systems on the QM2;
non flight components;
not capable of qualification;
external structure will have correct mechanical configuration as for DPU.

If meaningful EMC tests are to be carried out then the full QM model DPU and the QM2 model DRCU will be required. These will have fully populated boards built to flight standards with flight quality components.

## 5 PLM level testing

### 5.1 Expected Environment

The cryostat will give flight representative temperatures at thermal interfaces.
The cryostat will have a large gas flow with the CVV at ambient temperature – the heat lift will therefore be greater than expected in space. A configuration may be possible to allow a gas flow nearer to that expected in-flight.
The cryostat shields will be warmer – possibly much warmer than flight.
The radiation environment will not be representative without some GSE in place. Notably the cryostat lid will be at a minimum of ~300 K
A configuration with the final radiation shield blanked off is being considered – this will give a lower background than expected in space.
A representative telecommanding and data handling environment will be provided by the prime contractor/ESA and the instrument will provide a quick look facility.
The nominal orientation of the cryostat means that FTS mechanism is in the wrong orientation and <u>cannot</u> be operated unless the cryostat is tilted through 90 degrees
The cooler will not recycle unless the cryostat is tilted to at least 17 degrees.

### 5.2 System level tests

FPU integration procedures
Optical alignment procedures
Integration with CCE
Test of checkout procedures to be done for PFM
Test of parallel operation with PACS

### 5.3 Instrument tests in PLM

Functional checks using standard test procedure to debug procedures for PFM testing
Thermal balance tests under more representative conditions. This will include cooler recycle and some mechanism operations. However, we can only test the FTS if the cryostat is tilted through 90 degrees (i.e. on its side).
Test switching sequences between all modes. Check length of tome required to change modes – including waiting for thermal environment to stabilise.
Test thermal dissipation in each "operating mode".
Straylight checks with GSE fitted or with final shield blanked off. This is an extreme test as the other shields will be at higher temperatures than expected in flight.
EMC test of conducted susceptibility only.

## 6 Summary of Instrument Requirements

| Subsystem/component | CQM Requirements |
|---|---|
| Structure/baffles | Flight representative |
| Mirrors | Flight representative |
| Filters | Flight representative |
| Beam steering mirror | Flight representative |
| $^3$He Fridge/thermal straps | Flight representative |
| Thermal control system | Flight representative<br>No redundancy necessary |
| Photometer LW array | Fully populated with flight representative detectors |
| Photometer MW array | Sparsely populated with flight representative detectors<br>Resistors used for other detectors positions<br>Temperature monitors flight representative |
| Photometer SW array | Ditto |
| FTS mirror mechanism | Flight representative |
| Spectrometer SW array | Sparsely populated with flight representative detectors<br>Resistors used for other detectors positions<br>Temperature monitors flight representative |
| Photometer LW array | Fully populated with flight representative detectors |
| Photometer Calibrator | No redundancy necessary |
| Spectrometer hot calibrator | No redundancy necessary |
| Spectrometer cool calibrator | No redundancy necessary |
| Shutter | Capable of surviving environmental testing |
| JFET Module | Thermally and mechanically flight representative<br>Only needs JFETs for “live” detector channels can use resistors for thermal dissipation in other channels |
| DRCU | Functionally flight representative – possibly industrial level parts; no redundancy<br>Will not be environmentally tested at PLM level<br>Box must be form and fit compliant – all connectors present even if not internally connected |
| DPU | Ditto |
| FPU internal harnesses/RF filters/connectors | Flight representative |
| Warm interconnect harness | Flight representative |