OGSE Characterisation During CQM/FM-ILT

PICC-ME-TR-005

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Abstract

OGSE elements and the corresponding HKs; Basic functionality and performance of the flip-mirrors, the OGSE chopper, the OGSE black-bodies, the integrating sphere and the cryostat windows; OGSE characterisation of the external sources (TBD); OGSE characterisation: photometer and spectrometer FOV scans, focus, central pointing (TBD).
Contents

1 Introduction .................................................. 3
   1.1 Main goals ................................................. 3
   1.2 Reference documents ...................................... 3

2 Overview OGSE elements and HK .......................... 4

3 Basic functionality and performance ...................... 6
   3.1 Flip-mirrors (FM) ........................................... 6
   3.2 OGSE chopper .............................................. 7
      3.2.1 Description ............................................. 7
      3.2.2 Dedicated FM-ILT Test ............................... 8
      3.2.3 Test Results ........................................... 9
   3.3 OGSE black-bodies (OGSE BBs) .......................... 12
      3.3.1 Description ............................................. 12
      3.3.2 CQM-ILT Test ........................................... 12
      3.3.3 Dedicated FM-ILT Test ............................... 14
      3.3.4 Test Results ........................................... 14
   3.4 Integrating sphere ........................................ 16
   3.5 Cryostat windows ........................................... 16

4 OGSE characterisation: external sources .................. 17
   4.1 External blackbody (ExtBBs) ............................ 17
   4.2 Water vapour absorption cell (H\textsubscript{2}O cell) ..... 17
   4.3 Hot plate .................................................. 17
   4.4 X-Y-stage .................................................. 17
   4.5 TUFIR Laser ............................................... 17

5 OGSE characterisation: photometer part ................... 18
   5.1 FOV scans ............................................... 18
   5.2 Photometer focus & central pointing .................... 19

6 OGSE characterisation: spectrometer part ................. 20
   6.1 FOV scans ............................................... 20
   6.2 Spectrometer focus & central pointing .................. 21
1 Introduction

1.1 Main goals

The main goals of this report are:

- to give an overview of the operational elements of the OGSE and the corresponding house
  keeping (HK) entries
- to summarise the key performance of various elements of the OGSE inside and outside the
  cryostat
- to give an overview of the commanding and CUS relevant issues, necessary wait times, warn-
  ings,
- to describe the various field-of-view (FOV) scans
- to compile the relevant measurements and results for future reference
- to distribute OGSE relevant information within the PACS ICC
- 
  ...

The FM-ILT tests belong to the test blocks “OGSE Characterisation I (basic functionality &
performance)”, ”OGSE Characterisation II (photometer)” and ”OGSE Characterisation III (spec-
trometer)".

1.2 Reference documents

- OGSE External Point Source Mask Specification, PACS-ME-DS-003
- PACS Cryo Test Equipment and OGSE Specification, PACS-ME-DS-002
- PACS Test Equipment Interface, PICC-ME-GS-001
- ...

3
2 Overview OGSE elements and HK

- **Test optics design**
  - Principal design unchanged to CQM ILT phase
  - 2 cryogenic blackbodies (BB):
    - Temp. range: 5K – 80K
    - Absolute temp. accuracy:
      - @20K: +/- 20mK
      - @50K: +/- 35mK
    - Thermal stability:
      - @30K: +/- 1.25mK
      - @50K: +/- 5mK
    - Power dissipation:
      - @30K: 12.5mW
      - @50K: 35mW
  - 1 integrating sphere w. light cone
  - 1 external focus access
  - 2 flip mirrors for optical path selection (internal or ext. sources)
  - 1 chopper wheel to chop between BB1 and BB2:
    - \( f_{\text{chop max}} @5K = 0.457\text{Hz} \)
  - 7 Cernox temperature sensors

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Figure 1: A schematic view of the PACS test optics and Herschel telescope simulator. (taken from PACS-ME-DS-002).
Table 1: The following elements are important for the OGSE operation (only elements inside the cryostat). Note: all HK-entries are part of the TM-packet PACS_ILT_EGSE (sampling interval ∼4-20 sec) or PACS_ILT_EGSE_TO (sampling interval ∼1 sec) or PACS_ILT_EGSE_TO_FAST (variable sampling interval: event driven; only relevant for OGSE chopper and FM1/2). Note, that the packet names might change in the future. For temperature sensors see dedicated report "Thermal Behaviour Tests During FM-ILT: SPEC & PHOT", PICC-ME-TR-002.

<table>
<thead>
<tr>
<th>HK-entry</th>
<th>Location</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>BB1_SetPoint</td>
<td>Temperature setpoint of BB controller 1</td>
<td>$10^{-2}$ K</td>
</tr>
<tr>
<td>BB1_Reading</td>
<td>Temperature reading of BB controller 1</td>
<td>$10^{-2}$ K</td>
</tr>
<tr>
<td>BB2_SetPoint</td>
<td>Temperature setpoint of BB controller 2</td>
<td>$10^{-2}$ K</td>
</tr>
<tr>
<td>BB2_Reading</td>
<td>Temperature reading of BB controller 2</td>
<td>$10^{-2}$ K</td>
</tr>
<tr>
<td>Optics_CW_Sensor</td>
<td>Chopper wheel sensor</td>
<td>0: no sensor signal, unknown position</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: sensor signal from position 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2: sensor signal from position 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: invalid</td>
</tr>
<tr>
<td>Optics_CW_Speed</td>
<td>Speed state of chopper wheel</td>
<td>0: accelerating or decelerating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: at nominal speed</td>
</tr>
<tr>
<td>Optics_CW_Mode</td>
<td>Chopper wheel mode</td>
<td>0: idle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: moving to 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2: moving to 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: rotating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4: coasting (uncontrolled)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5: fixed</td>
</tr>
<tr>
<td>Optics_CW_Freq</td>
<td>rotation frequency of the chopper wheel</td>
<td>range $[0 \ldots 457 \text{mHz}]$</td>
</tr>
<tr>
<td>Optics_FM1_Sensr</td>
<td>Flip mirror 1 sensors</td>
<td>0: no sensor signal, unknown position</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: sensor signal from position 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2: sensor signal from position 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: invalid</td>
</tr>
<tr>
<td>Optics_FM1_Ready</td>
<td>Flip mirror 1 at final position</td>
<td>0: moving</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: final position reached</td>
</tr>
<tr>
<td>Optics_FM1_Mode</td>
<td>Flip mirror 1 mode</td>
<td>0: idle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: moving to 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2: moving to 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: coasting</td>
</tr>
<tr>
<td>Optics_FM2_Sensr</td>
<td>Flip mirror 2 sensors</td>
<td>0: no sensor signal, unknown position</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: sensor signal from position 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2: sensor signal from position 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: invalid</td>
</tr>
<tr>
<td>Optics_FM2_Ready</td>
<td>Flip mirror 2 at final position</td>
<td>0: moving</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: final position reached</td>
</tr>
<tr>
<td>Optics_FM2_Mode</td>
<td>Flip mirror 2 mode</td>
<td>0: idle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: moving to 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2: moving to 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: coasting (uncontrolled)</td>
</tr>
</tbody>
</table>
3 Basic functionality and performance

OGSE Characterisation I (basic functionality & performance)
extensive pre-tests already during previous cool-downs of cryostat with
test optics; here final check-out

Functional check-out cold
duration = 1.5 h
- Functional check-out flip mirrors
- Functional tests OGSE BBs and temperature settings
- Functional tests OGSE chopper wheel at different frequencies
- Exercising (and documenting) the cryostat window shutter
- Commanding of x-y stage:
  manual commands
  available pointing modes with typical settings
  (number of raster points, raster step sizes, nodding, ...)

Performance check-out cold
duration = 6.0 h
- Duration of FM1/2 movements
- Determination of the OGSE BB stabilisation times
- Calibration of the OGSE chopper frequency
- OGSE chopper acceleration/deceleration phases
  between staring and chopping at high frequencies
- Synchronisation tests x-y-stage

3.1 Flip-mirrors (FM)
The functioning of the OGSE FMs (see Fig. [Fig. 1] connected to MD1 and MD2) has been tested extensively during CQM-ILT. In order to minimise the risk of mal-functions, the movements of these FMs should be reduced to a minimum. The position of the FMs can be seen in the HK entries "Optics_FM1_Sensr" and "Optics_FM2_Sensr" (value 1: position 1 and value 2: position 2), the HKs "Optics_FM1_Ready" and "Optics_FM2_Ready" should both be at "1" (final position reached).

The FMs are commanded via the CUS-script "OGSEOpticsSetUp" (selection of "FM1" or "FM2", selection of "POS1" or "POS2", "chopWheelFreq" will be ignored in this case).

<table>
<thead>
<tr>
<th>FM1</th>
<th>FM2</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 or 2</td>
<td>PACS sees through cryostat window 2 (x-y stage, extBB, water vapour cell, ...</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>PACS sees via FM1 (M3) onto M4/7/9 onto the OGSE BBs</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>PACS sees via FM1 (M3) and FM2 (M5) into the integrating sphere (cryostat window 1: TUFIR Laser</td>
</tr>
</tbody>
</table>

Note: The default positions (before cool-down of the cryostat) should be FM1 at position 2 and FM2 at position 1 (to look at the OGSE BBs).

The HeI operations of the flip-mirrors during CQM-ILT showed that the duration of such a position change is roughly 30 sec from "idle"-mode (in first position) via "MovingTo_1/2" and "Coasting" to "idle"-mode (in second position).
3.2 OGSE chopper

3.2.1 Description

Figure 2: A picture of the OGSE chopper inside the cryostat during ILT. OGSE BB1 is seen in reflection, BB2 in transmission. In addition to the fixed chopper position, rotations with different frequencies are possible.

Figure 3: Drawings of the OGSE chopper together with the positions of the magnets, hall sensors and the location of the beam. An event from hall sensor 1 means that BB1 is reflected into PACS.
The wheel is a vane shaped mirror (M6) which either reflects BB1 radiation via mirrors M7 and M8 or transmits BB2 radiation via mirrors M9 and M10 (see Figs. 1, 2, and 3). The OGSE chopper wheel is separated in four 90° sections. Each vane has a magnet located at the outer part of the wheel and 11° away from the edge at opposite directions. There are two hall sensors mounted on the structure of the OGSE chopper wheel. They are separated by 75°. One full rotation of the chopper wheel produces therefore 4 events (each magnet at each hall sensor), which are unequally distributed in time.

In case of an hall sensor 1 event the OGSE BB1 is seen, but the exact moment when the BB1 is reflected into the beam is not known. The estimated edge of the beam and the position of hall sensor 1 are separated by 37.5°. This means that the BB1 is seen already before an event from hall sensor 1 is sent. The exact timing between seeing one BB and the corresponding events has to be derived from a dedicated measurement during FM-ILT.

Due to the OGSE chopper shape, one full turn of the chopper wheel per second corresponds to a 2 Hz signal modulation. Typical chopping frequency range is 0-2 Hz, corresponding to a maximum OGSE chopper speed of about 1 rotation per second. The functioning of the OGSE chopper has been tested extensively during CQM-ILT (Fig. 6). The mode of the chopper (rotating, fixed, moving to pos1/2, idle) can be seen in "Optics_CW_Mode". In case the chopper is fixed, the position (1 or 2) can be found in "Optics_CW_Sensor". In case of rotation, "Optics_CW_Speed" shows when the full speed is reached.

The FMs are commanded via the CUS-script "OGSEOpticsSetUp" (selection of "CW", selection of "POS1" or "POS2" or "ROT" or "REL", specification of "chopWheelFreq" is only relevant for the option "ROT")

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW</td>
<td>uncontrolled, unknown position</td>
</tr>
<tr>
<td>REL</td>
<td></td>
</tr>
<tr>
<td>POS1</td>
<td>chopper placed in position 1 (via M6/M7/M8 to OGSE BB1)</td>
</tr>
<tr>
<td>POS2</td>
<td>chopper placed in position 2 (via M9/M10 to OGSE BB2)</td>
</tr>
<tr>
<td>ROT</td>
<td>chopper rotating (each BB is seen twice in one rotation)</td>
</tr>
</tbody>
</table>

Note: The default positions (before cool-down of the cryostat) should be at position 1 (to look to the OGSE BB1).

### 3.2.2 Dedicated FM-ILT Test

![OGSE Chopper frequency](image1)

![OGSE Chopper POS1 in DEFAULT HK](image2)

Figure 4: Left: commanded frequency for the OGSE chopper. Right: frequency of successive position 1 passages

Test on 31/Jul/2006:
filename: /dbBck/PacketFiles/Thomas_chopperwheel.tm

Operation of the OGSE chopper in the cold cryostat via SCOS2000. The following commanding units have been given in "TE_Test_Optic_Ctl":
OPTOUNT: ChopperWheel
OPTOCMD: Rotate
OPTOFREQ: 0000\text{--}\rightarrow 0100
0100\text{--}\rightarrow 0250
0250\text{--}\rightarrow 0457
0457\text{--}\rightarrow 0750
0750\text{--}\rightarrow 1500
1500\text{--}\rightarrow 2000
2000\text{--}\rightarrow 2500
2500\text{--}\rightarrow 3000
3000\text{--}\rightarrow 3500
3500\text{--}\rightarrow 4000
4000\text{--}\rightarrow 4500
4500\text{--}\rightarrow 5000
5000\text{--}\rightarrow 5500
5500\text{--}\rightarrow 6000
6000\text{--}\rightarrow 6500
6500\text{--}\rightarrow 7000
7000\text{--}\rightarrow 7500
7500\text{--}\rightarrow 8000

OPTOCMD: Goto\_Position\_1
OPTOFREQ: 0000

OPTOCMD: Rotate
OPTOFREQ: 1000

OPTOCMD: Goto\_Position\_2
OPTOFREQ: 0000

OPTOCMD: Release
OPTOFREQ: 0000

**Note:** The operation of the OGSE chopper dissipates heat, we noticed a \( \sim 1 \text{K} \) temperature increase of the OGSE BBs (from 5.4 to roughly 6.4 K) during 30 min operation. Even the controlling of “POS1/2” positions require some power, which means that if the OGSE chopper is not needed, the wheel should be “released”!

### 3.2.3 Test Results

![OGSE Chopper frequency calibration](image)

**Figure 5:** The relation between commanded OGSE chopper wheel frequencies and the final signal modulation frequency.
The Hel operations of the OGSE chopper during CQM-ILT showed that the duration from fixed position (POS1/POS2) to rotating with full speed requires roughly 5 sec. From rotating at full speed back to a fixed position takes up to 45 sec. To be on the safe side with enough margin for various conditions, one should introduce a wait-time of 10 sec after each acceleration and 60 sec for deceleration. The commanding values to obtain a certain signal modulation frequency is about a factor 3.5 higher (current best value is 3.494, see Fig. 5), i.e., a commanded frequency of 3500 mHz corresponds roughly to a signal modulation of 1 Hz. The maximal commanded value was 8000 mHz, corresponding to a signal modulation of 2.29 Hz. At this frequency the chopper was still working fine and higher frequencies are very likely possible.

Here are the values from the pre-ILT cold test:
Signal modulation frequencies between 0 and about 2.5 Hz are possible. Examples:

<table>
<thead>
<tr>
<th>commanded values before/after</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>from zero → 100 mHz</td>
<td>4 sec</td>
</tr>
<tr>
<td>from 8000 mHz → fixed position 1</td>
<td>44 sec</td>
</tr>
<tr>
<td>from fixed position 1 → 1000 mHz</td>
<td>5 sec</td>
</tr>
<tr>
<td>from 1000 mHz → fixed position 2</td>
<td>36 sec</td>
</tr>
</tbody>
</table>

Signal modulation frequencies between 0 and about 2.5 Hz are possible. Examples:

<table>
<thead>
<tr>
<th>commanded values</th>
<th>Signal modulation frequency</th>
<th>Signal plateau length</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 mHz</td>
<td>0.03 Hz</td>
<td>~17.5 sec</td>
</tr>
<tr>
<td>438 mHz</td>
<td>0.125 Hz</td>
<td>~ 4.0 sec</td>
</tr>
<tr>
<td>875 mHz</td>
<td>0.25 Hz</td>
<td>~ 2.0 sec</td>
</tr>
<tr>
<td>1000 mHz</td>
<td>0.29 Hz</td>
<td>~ 1.75 sec</td>
</tr>
<tr>
<td>1750 mHz</td>
<td>0.50 Hz</td>
<td>~ 1.0 sec</td>
</tr>
<tr>
<td>2000 mHz</td>
<td>0.57 Hz</td>
<td>~ 0.88 sec</td>
</tr>
<tr>
<td>3500 mHz</td>
<td>1.00 Hz</td>
<td>~ 0.5 sec</td>
</tr>
<tr>
<td>5000 mHz</td>
<td>1.43 Hz</td>
<td>~ 0.35 sec</td>
</tr>
<tr>
<td>7000 mHz</td>
<td>2.00 Hz</td>
<td>~ 0.25 sec</td>
</tr>
<tr>
<td>8000 mHz</td>
<td>2.29 Hz</td>
<td>~ 0.22 sec</td>
</tr>
</tbody>
</table>

Fig. 6 shows an example of bolometer signals recorded during CQM-ILT with the OGSE chopper at a fixed frequency. The signal levels were provided by two different OGSE BB temperature settings. The transitions between the two levels are instantaneous and are not perfectly clean. One of the transitions seems to reflect a lower signal level into the bolometer optics (reason unknown).
3.3 OGSE black-bodies (OGSE BBs)

3.3.1 Description

Absolute flux calibration, relative spectral response function and detector flat-fielding are applications to be performed close to realistic observation scenarios. For those cases two cryogenic blackbodies are used while one provides the calibrated signal and the other the calibrated background. A cryogenic mechanism (chopper wheel) is chopping between the two sources. Two blackbody devices were designed, built and calibrated at MPE. Their 18 mm opening of the cavity is adapted to the pupil sizes P4 and P5 inside the test optics (see Fig. 1). The nominal operational temperature range is within 4.2 K to 80 K. In combination with the LS370 controller the temperatures between 10 K and 60 K can be stabilized within 35 min with a heating power of 100 mW (see Fig. 2). The design of the thermal heat sink and the combination of a calibrated Cernox CX-1070 with controller LS370 provide an absolute temperature accuracy of ±20 mK at 20K and ±35 mK at 50 K. Thermal stability goal is < ± 1.25 mK at 30 K and < ± 5 mK at 50 K. Power dissipation is expected to be around 12.5 mW at 30 K and 35 mW at 50 K for each device.

The cryogenic OGSE BBs are commanded via “OGSEBBSetUp(BBunit, setPoint, setTime)”, with BBunit = ["BB1", "BB2"], the setPoint in [K] and the setTime in [sec]. Note, that the setTime can be specified to a few seconds to allow the continuation of the commanding and to integrate for example on the other OGSE BB.

3.3.2 CQM-ILT Test

![Figure 7: OGSE BB controller settings during the FM-ILT operations phase.](image)

Figure 8: Stabilisation of the OGSE BB1 after switching from uncontrolled 6.188 K to controlled 23.300 K. Left: 50 min overall temperature trend after setting the new temperature; Right: Zoom in to the mK-level.

![Figure 8: Stabilisation of the OGSE BB1 after switching from uncontrolled 6.188 K to controlled 23.300 K.](image)
Figure 9: Stabilisation of the OGSE BB1 after switching from uncontrolled temperature to controlled 30.000 K. Left: 50 min overall temperature trend after setting the new temperature; Right: Zoom in to the mK-level.

Figure 10: Stabilisation of the OGSE BB1 after switching from 30.0 to 30.50 K. Left: 50 min overall temperature trend after setting the new temperature; Right: Zoom in to the mK-level.

Table 2: Stabilisation times of the OGSE BBs for various temperature steps.

<table>
<thead>
<tr>
<th>Step</th>
<th>±10 mK</th>
<th>±5 mK</th>
<th>±1 mK</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.2 → 8.0</td>
<td>&lt;5 min</td>
<td>&lt;5 min</td>
<td>5 min</td>
</tr>
<tr>
<td>6.2 → 23.3</td>
<td>22 min</td>
<td>25 min</td>
<td>40 min</td>
</tr>
<tr>
<td>6.2 → 30.0</td>
<td>40 min</td>
<td>46 min</td>
<td>50 min</td>
</tr>
<tr>
<td>30.0 → 30.5</td>
<td>28 min</td>
<td>37 min</td>
<td>40 min</td>
</tr>
</tbody>
</table>
3.3.3 Dedicated FM-ILT Test

/Data/FM_ILT_data/20061102/0BSE_BB_test1.tm 101M

Figure 11: Stabilisation of the OGSE BB1. Left: overview of the complete test sequence. Right: Stabilisation steps from 10.10 K to 30.00 K and from 30.00 K to 30.01 K.

Figure 12: Stabilisation of the OGSE BB2. Left: overview of the complete test sequence. Right: Stabilisation steps from 4.83 K to 20.00 K and from 20.00 K to 20.10 K.

3.3.4 Test Results

Stabilisation times are proportional to the temperature step and to a high potential of the final temperature. In the nominal operation range between 20 and 40 K it should be sufficient to wait 40-50 min, depending on the stability requirements.

It would be possible to adjust the controller parameters for the BBs for a specific temperature range, but only for the prize of longer stabilization times and degraded performance at other temperature ranges. It is currently not foreseen to change the controller parameters.

The original requirement goals of $<\pm 1.25 \text{ mK}$ at 30 K and $<\pm 5 \text{ mK}$ at 50 K are reached, but at high temperatures the stabilisations times can be up to 3 hours.
Table 3: Stabilisation times [min] of the OGSE BBs for various temperature steps.

<table>
<thead>
<tr>
<th>Step</th>
<th>OGSE BB1</th>
<th>±100 mK</th>
<th>±10 mK</th>
<th>±5 mK</th>
<th>±1 mK</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.82 K → 10.00 K</td>
<td>2 min</td>
<td>3 min</td>
<td>4 min</td>
<td>6 min</td>
<td></td>
</tr>
<tr>
<td>10.00 K → 10.10 K</td>
<td>1 min</td>
<td>2 min</td>
<td>3 min</td>
<td>5 min</td>
<td></td>
</tr>
<tr>
<td>10.10 K → 30.00 K</td>
<td>25 min</td>
<td>40 min</td>
<td>48 min</td>
<td>65 min</td>
<td></td>
</tr>
<tr>
<td>30.00 K → 30.01 K</td>
<td>1 min</td>
<td>3 min</td>
<td>10 min</td>
<td>25 min</td>
<td></td>
</tr>
<tr>
<td>30.01 K → 50.00 K</td>
<td>80 min</td>
<td>140 min</td>
<td>160 min</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>50.00 K → 20.00 K</td>
<td>110 min</td>
<td>120 min</td>
<td>130 min</td>
<td>135 min</td>
<td></td>
</tr>
<tr>
<td>20.00 K → 19.90 K</td>
<td>2 min</td>
<td>8 min</td>
<td>10 min</td>
<td>15 min</td>
<td></td>
</tr>
<tr>
<td>19.90 K → &lt;5.00 K</td>
<td>100 min</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step</th>
<th>OGSE BB2</th>
<th>±100 mK</th>
<th>±10 mK</th>
<th>±5 mK</th>
<th>±1 mK</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.83 K → 20.00 K</td>
<td>8 min</td>
<td>13 min</td>
<td>15 min</td>
<td>20 min</td>
<td></td>
</tr>
<tr>
<td>20.00 K → 20.10 K</td>
<td>2 min</td>
<td>6 min</td>
<td>8 min</td>
<td>15 min</td>
<td></td>
</tr>
<tr>
<td>20.10 K → 40.00 K</td>
<td>40 min</td>
<td>60 min</td>
<td>&gt;60 min</td>
<td>&gt;60 min</td>
<td></td>
</tr>
<tr>
<td>40.00 K → 40.01 K</td>
<td>1 min</td>
<td>3 min</td>
<td>15 min</td>
<td>35 min</td>
<td></td>
</tr>
<tr>
<td>40.01 K → 60.00 K</td>
<td>100 min</td>
<td>165 min</td>
<td>200 min</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>60.00 K → 30.00 K</td>
<td>90 min</td>
<td>100 min</td>
<td>115 min</td>
<td>130 min</td>
<td></td>
</tr>
<tr>
<td>30.00 K → 29.90 K</td>
<td>2 min</td>
<td>15 min</td>
<td>20 min</td>
<td>35 min</td>
<td></td>
</tr>
<tr>
<td>29.90 K → &lt;5.00 K</td>
<td>100 min</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>
3.4 Integrating sphere

The integrating sphere (see blue part of Fig. 1) is seen when FM1 is in position 2 and FM2 in position 2 (see Sect. 3.1). This sphere contains a background heater, which can be controlled at various temperature (manual operation, no HK entries available). The sphere will be used via cryostat window 1 to feed the TUFIR laser into PACS. During CQM-ILT the heating was not exercised. No data are available yet.

The temperature of the integrating sphere can be controlled between a few Kelvin and about 150 K, with a target temperature of about 80 K to simulate the telescope background. Originally, the integrating sphere heater was supposed to be in-line with the PACS CSs, but after the last emissivity adjustment of the PACS CSs, the integrating sphere might have a different spectral behaviour (different from the PACS CSs).

3.5 Cryostat windows

Shutter 1 (cryostat window 1, next to integrating sphere) and shutter 2 (cryostat window 2) have to be operated manually. Shutter positions are not reflected in HK-entries. The following positions are available:

<table>
<thead>
<tr>
<th>Shutter/filter</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>window 1, no shutter</td>
<td>always open</td>
</tr>
<tr>
<td>window 2, shutter closed</td>
<td>77 K shield</td>
</tr>
<tr>
<td></td>
<td>FLE + Quartz filter</td>
</tr>
<tr>
<td></td>
<td>Quartz only</td>
</tr>
</tbody>
</table>
4 OGSE characterisation: external sources

4.1 External blackbody (ExtBBs)
Point-spread function and alignment aspects will be investigated by external point source simulators. Single point-source masks, arrays or patterns are used in combination with an extended BB with a temperature range of 300 K up to 1000 K. The operation of the ExtBB will be done manually (no overnight activities). Mounting, switch-on and stabilisation will require significant wait-times.

The design has been improved for FM-ILT with respect to well-defined pin holes (point sources) in a black painted surface. In addition, an improved contrast (30-50%) is expected when using the ExtBB in a N\textsubscript{2} gas environment.

Apertures: new ones will be available for FM-ILT; documentation not yet available.

The ExtBB will be operated manually, no HK-entries will be available.

4.2 Water vapour absorption cell (H\textsubscript{2}O cell)
The water vapour cell is typically operated with internal pressure of 10-25 mbar and an absorption path length of 300 mm to provide proper absorption lines in the complete wavelength range of PACS.

The water vapour cell has now a new design with imaging optics, covering the complete PACS FOV and with the following characteristics:

- ceramics heater with T=800 K
- thermal stability: $\sim \pm 1$ K
- settling time: $\sim 1$ min
- temperature and pressure data are available through dedicated HK-entries (GasCell_Pressure, ???)
- 10% deep lines relative to the measured continuum for saturated H\textsubscript{2}O
- improved line contrast of factor 2-3

The water vapour cell will be operated manually, but HK-entries are available.

4.3 Hot plate
Details are described in PACS-ME-DS-003 "OGSE External Point Source Mask Specification". The plate can be heated up to 600 K. There are various hole masks available. With the implementation of a N\textsubscript{2} environment a contrast improve of 30-50% will be feasible.

The hot plate will be operated manually, no HK-entries will be available.

4.4 X-Y-stage
Operated via "OGSEXYSstage" in CUS. A worked-out example is given in the CUS-script "PHOT_FOV_Distortion_3_1_3_V1.txt". Absolute x-y-stage positions can be commanded in that way, as well as complete rasters with or without nodding.

Open points:
- commandable range, limits, translation?
- how to command a scan, limits, translation?
- what are the expected zero points? for bolometer and spectrometer?

HK Packets are only send at the beginning and the end of a movement.

4.5 TUFIR Laser
TBW.
5 OGSE characterisation: photometer part

The photometer part of the OGSE characterisation has 2 main parts:
1) Characterisation of the PACS FOV under various conditions via OBCP 14, DMC Seq. 15 "Chopper up-down scan photometry"
2) Determination of the photometer focus & central pointing (PCD ID 3.1.1) via ExtBB mounted on the x-y-stage (cryostat window 2).

Both parts require bolometer signals, i.e., the setting of biases, gain and sequencer mode (in combination with the default SPU processing). The cooler has to be recycled before.

5.1 FOV scans

The FOV scans will be performed with OBCP 14, DMC Sequence 15 (see PACS-ME-LI-005). The following parameters are required:

`<< sequence number = 15, sequence time: to be calculated, number of up-down scans (P1), chopper plateau length in readouts (P2), number of chopper steps up (P3), number of chopper steps down (P4), step size up (P5), step size down (P6)>, detector = 4, compression blue = 0, compression red = 0, chopper start position, chopper default position = 0 >>`

The duration is calculated with the following formula:

Sequence duration in readouts: \(3 + P1 \times P3 \times P2 + P4 \times P2 + P2\)
Sequence duration in [msec]: \((\text{duration in readouts}) \times 25\)
OBCP duration [sec]: \((\text{duration in msec})/1000 + \text{few seconds communication and command execution overheads}\)

Example: One up-down chopper scan with step size of smaller of below two blue pixels (300 units ≤ 2*160-220 units) at all chopper deflection angles between chopper positions ±25 000 and 1 sec chopper plateau length:

`<< 15, 335075, 1, 40, 167, 167, 300, -300, 4, 0, 0, -25000, 0 >>`

Sequence duration in readouts: \(3 + P1 \times P3 \times P2 + P4 \times P2 + P2 = 13 403\) readouts
Sequence duration in [msec]: \((\text{duration in readouts}) \times 25 = 335 075\) msec
OBCP duration [sec]: \((\text{duration in msec})/1000 + \text{few seconds communication and command execution overheads} = 342 \text{ sec} = 5 \text{ min 42 sec}\)

**Note**, that this duration is only for one filter setting! It is also important to mention that the various PACS and OGSE settings need significant times for temperature stabilisation.

1. **Purpose**: scan under dark conditions I: dark OGSE BB
   **PACS/OGSE Setup**: PACS CSs off, OGSE BBs off, OGSE chopper off, cryostat shutter closed, everything stabilised at cold equilibrium temperatures; default PhotometrySetup, but without switching on the CSs
   **Bolometer settings**: high gain; biases for low flux? data mode: bolo & HK, sequence mode: V_{bolo} only?
   **Scan parameters**: default

2. **Purpose**: scan under dark conditions II: dark window 2
   **PACS/OGSE Setup**: PACS CSs off, OGSE BBs off, OGSE chopper off, cryostat shutter closed, everything stabilised at cold equilibrium temperatures; default PhotometrySetup, but without switching on the CSs; FM1 at position 1, shutter of window 2 closed
   **Bolometer settings**: high gain; biases for low flux? data mode: bolo & HK, sequence mode: V_{bolo} only?
   **Scan parameters**: default

3. **Purpose**: scan under dark conditions III: cold integrating sphere, dark window 1
   **PACS/OGSE Setup**: PACS CSs off, OGSE BBs off, OGSE chopper off, cryostat shutter closed, everything stabilised at cold equilibrium temperatures; default PhotometrySetup, but without switching on the CSs; FM1 at position 2, FM2 at position 2; shutter of window 2 closed
   **Bolometer settings**: high gain; biases for low flux? data mode: bolo & HK, sequence mode:
4. **Purpose**: scan under dark conditions IV: bright window 2  
**PACS/OGSE Setup**: PACS CSs off, OGSE BBs off, OGSE chopper off, cryostat shutter open, everything stabilised at cold equilibrium temperatures; default PhotometrySetup, but without switching on the CSs; FM1 at position 1, shutter of window 2 open  
**Bolometer settings**: high gain; biases for low flux? data mode: bolo & HK, sequence mode: \(V_{\text{bolo}}\) only?  
**Scan parameters**: default

5. **Purpose**: scan under dark conditions V: warm integrating sphere, dark window 1  
**PACS/OGSE Setup**: PACS CSs off, OGSE BBs off, OGSE chopper off, cryostat shutter closed, everything stabilised at cold equilibrium temperatures; default PhotometrySetup, but without switching on the CSs; FM1 at position 2, FM2 at position 2; shutter of window 2 closed; integrating sphere heated to default temperature  
**Bolometer settings**: high gain; biases for low flux? data mode: bolo & HK, sequence mode: \(V_{\text{bolo}}\) only?  
**Scan parameters**: default

6. **Purpose**: scan with OGSE BB1 at low temperature  
**PACS/OGSE Setup**: PACS CSs off, OGSE BB1 at 20 K, OGSE chopper at OGSE BB1, cryostat shutter closed, everything stabilised; default PhotometrySetup, but without switching on the CSs  
**Bolometer settings**: high gain; biases for low flux? data mode: bolo & HK, sequence mode: \(V_{\text{bolo}}\) only?  
**Scan parameters**: default

7. **Purpose**: scan with OGSE BB2 at high temperature  
**PACS/OGSE Setup**: PACS CSs off, OGSE BB2 at 50 K, OGSE chopper at OGSE BB2, cryostat shutter closed, everything stabilised; default PhotometrySetup, but without switching on the CSs  
**Bolometer settings**: high gain; biases for low flux? data mode: bolo & HK, sequence mode: \(V_{\text{bolo}}\) only?  
**Scan parameters**: default

8. **Purpose**: scan with PACS CSs at nominal temperatures, dark OGSE BB1  
**PACS/OGSE Setup**: PACS CSs on, OGSE BB1 at 6 K, OGSE chopper at OGSE BB1, cryostat shutter closed, everything stabilised; default PhotometrySetup;  
**Bolometer settings**: high gain; biases for low flux? data mode: bolo & HK, sequence mode: \(V_{\text{bolo}}\) only?  
**Scan parameters**: default

9. **Purpose**: scan with PACS CSs at nominal temperatures, nominal OGSE BB1  
**PACS/OGSE Setup**: PACS CSs on, OGSE BB1 at 30 K, OGSE chopper at OGSE BB1, cryostat shutter closed, everything stabilised; default PhotometrySetup;  
**Bolometer settings**: high gain; operational biases? data mode: bolo & HK, sequence mode: \(V_{\text{bolo}}\) only?  
**Scan parameters**: default

10. **Purpose**:  
**PACS/OGSE Setup**:  
**Bolometer settings**:  
**Scan parameters**:

11. **Purpose**:  
**PACS/OGSE Setup**:  
**Bolometer settings**:  
**Scan parameters**:

### 5.2 Photometer focus & central pointing

See PCD ID 3.1.1 for description (DL).
OGSE characterisation: spectrometer part

The spectrometer part of the OGSE characterisation has 2 main parts:
1) Characterisation of the PACS FOV under various conditions via OBCP 18, DMC Seq. 16 "Chopper up-down scan spectroscopy"
2) Determination of the spectrometer focus & central pointing (PCD ID 3.1.1) via ExtBB mounted on the x-y-stage (cryostat window 2).

Both parts require spectrometer detector signals, i.e., biases and CRE settings (in combination with the default SPU processing).

6.1 FOV scans

The FOV scans will be performed with OBCP 18, DMC Sequence 16 (see PACS-ME-LI-005). The following parameters are required:

```
<< sequence number = 16, sequence time: to be calculated,
< number of up-down scans (P1), chopper plateau length in readouts (P2),
  number of chopper steps up (P3), number of chopper steps down (P4),
  step size up (P5), step size down (P6)>,
  detector = 1, grating position, chopper start position, grating time,
  compression blue = 16, compression red = 16, grating default position,
  grating default time, chopper default position = 0 >>
```

The duration is calculated with the following formula:

Sequence duration in ramps: 3 + P1*P3*P2 + P4*P2 + P2
Sequence duration in [msec]: (duration in ramps) * 250 (assuming 64 readouts per ramp)
OBCP duration [sec]: (sequence duration in msec)/1000 + few seconds communication and command execution overheads

Example: One up-down chopper scan with step size of smaller than one spatial pixel (450...630 units) at all chopper deflection angles between chopper positions ±25000 and 1 sec chopper plateau length:

```
<< 16, 251750,
  <1, 4, 125, 125, 400, -400>
  1, 535000, -25000, 20000, 0, 0, 500000, 20000, 0 >>
```

Sequence duration in readouts: 3 + P1*P3*P2 + P4*P2 + P2 = 1007 ramps
Sequence duration in [msec]: (duration in ramps) * 250 = 251750 msec
OBCP duration [sec]: (sequence duration in msec)/1000 + few seconds communication and command execution overheads = 299 sec = 4 min 59 sec

Note, that this duration is only for one filter setting! It is also important to mention that the various PACS and OGSE settings need significant times for temperature stabilisation.

1. **Purpose:** nominal PACS/OGSE configuration scan at keywavelength 1
   - **PACS/OGSE Setup:** nominal PACS SetupSpectroscopy; OGSE BB1 at nominal temperature; OGSE chopper at BB1 position;
   - **Spectrometer settings:** default, filter?
   - **Scan parameters:** default, grating position?

2. **Purpose:** nominal PACS/OGSE configuration scan at keywavelength 2
   - **PACS/OGSE Setup:** nominal PACS SetupSpectroscopy; OGSE BB1 at nominal temperature; OGSE chopper at BB1 position;
   - **Spectrometer settings:** default, filter?
   - **Scan parameters:** default, grating position?

3. **Purpose:** nominal PACS/OGSE configuration scan at keywavelength 3
   - **PACS/OGSE Setup:** nominal PACS SetupSpectroscopy; OGSE BB1 at nominal temperature; OGSE chopper at BB1 position;
   - **Spectrometer settings:** default, filter?
   - **Scan parameters:** default, grating position?
4. **Purpose**: nominal PACS/OGSE configuration scan at keywavelength 4  
   **PACS/OGSE Setup**: nominal PACS SetupSpectroscopy; OGSE BB1 at nominal temperature; OGSE chopper at BB1 position;  
   **Spectrometer settings**: default, filter ?  
   **Scan parameters**: default, grating position: ?

5. **Purpose**: nominal PACS/OGSE configuration scan at keywavelength 5  
   **PACS/OGSE Setup**: nominal PACS SetupSpectroscopy; OGSE BB1 at nominal temperature; OGSE chopper at BB1 position;  
   **Spectrometer settings**: default, filter ?  
   **Scan parameters**: default, grating position: ?

6. **Purpose**: nominal PACS/cryo-window scan at one keywavelength  
   **PACS/OGSE Setup**: nominal PACS SetupSpectroscopy; FMs to window 2; shutter open;  
   **Spectrometer settings**: default, filter ?  
   **Scan parameters**: default, grating position: ?

### 6.2 Spectrometer focus & central pointing

See PCD ID 3.1.1 for description.