TITLE: **Straylight model update: FIR scattering properties of CFIL1**

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CHANGE RECORD

ISSUE	DATE	SECTION	REASON FOR CHANGE
1.0	10/01/03	All	First issue of the document

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APPLICABLE AND REFERENCE DOCUMENTS

RD1 HP-2-ASED-TN0023 issue 2 (09/10/2002)
RD2 SPIRE-RAL-NOT-001483v2 (10/01/2003)

1. Introduction

In RD1, results from straylight analysis performed by ASED for SPIRE and PACS were given. Update to the model were briefly discussed by RAL, ASED and ESA in RD2. One of the remaining point to clarify was the modelling of the SPIRE CFIL1 filter (thermal filter at the instrument entrance focal plane) scattering properties.

This note summarises an attempt to derive a realistic scattering model for such a filter from a series of experiments made on a filter with similar structure and properties. Section 2 below recalls the main results from the measures and section 3 concludes on the fitting of the collected and processed data with standard models, compliant with an implementation under ASAP.

2. FIR scattering experiment results

The experimental approach and set-up used to characterise a dummy filter, thought to be representative of CFIL1 is briefly discussed in Appendix A.

The in-band measurements led to the plotted data below and a specular reflectance of ~20% at ~45deg incidence. Absorption for the filter was difficult to evaluate and is estimated to be below the beam stability and experimental measurement errors limit (a few % ?, TBC). The incident polarisation was maintained rotated ~45deg so that the collected scattered signal would be characteristics of both s and p polarisation effect at the same time (not s or p only), better suited for use in case of unpolarised straylight estimations.

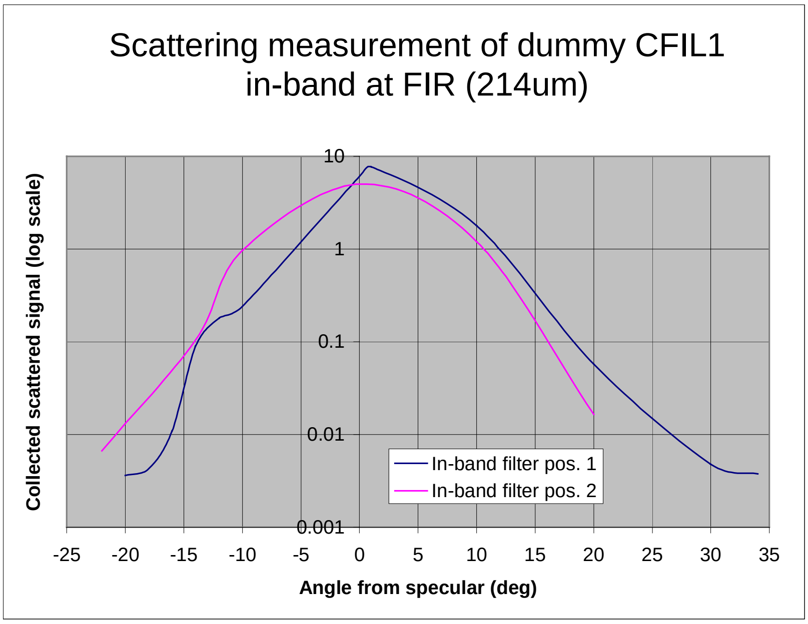

Figure 1: Graph summarising the collected data (corrected signal, unprocessed) for the 2 series of in-band measurements (same wavelength, 2 different sample surfaces)

For a narrow range of scattering angles, the diffuse level remains high, which can be partially explained by the sample under study and the detector aperture size and geometry[1] (convolution of the signal with acceptance aperture of detector, limiting the BRDF to lower max level). The complex internal structure of the filter was thought to be a potential source of diffraction resulting in modulation of the wide-angle scattered signal but this potential effect, if present for CFIL1, was not resolved here. Considering the relative level of signal fluctuations (form all background sources), the results seem to indicate a comparable behaviour of both filter surfaces.

Out-of-band, the case becomes more complex as the short wavelength used interacts differently with the components in the experimental set-up. More specifically, diffraction occurs on the polarising beamsplitter. This effect being strongly polarisation dependent for wire grid, which can explained some differences in the data collected before/after rotation of the beamsplitter. The lack of stability from the laser forced us to re-tune both lasers induced a major impact on signal stability. From this, less credit is given to experimental data as far as the out-of-band scattering characterisation of CFIL1 is concerned. For any incidence it was noticed that the level of transmission was below the measurement threshold (i.e. efficient blocking of shorter wavelength).

3. Update of straylight model

To be relevant for the SPIRE straylight model, the above collected and processed data (to take into account the fact that data were not collected at constant angle of incidence) were fitted with standard Harvey models (with shoulder parameter). This would allow their implementation in the ASAP straylight model, maintained by ASED.

For the in-band case (i.e. λ>200µm), it is therefore suggested to use the following model:

```
MODEL
  HARVEY 2 -50 0.3500
  HARVEY 0.6 -2 0.0400
  SUM .1 .2
RETURN
```

This is the combination of 2 Harvey models which represents the “main lobe” (leakage from specular) of the expected BRDF as well as the expected diffuse wide-angle part of it. This is expected to be approximately representative of the CFIL1 properties (at least it may be considered as more realistic than a lambertian surface). Below are shown plots of the BRDF as implemented under ASAP for normal incidence and 45deg incidence with approximate average TIS of ~5%. This BRDF estimate, valid for both surfaces of CFIL1, is derived from measurement made at only one wavelength (~214µm). The spectral variations of the model parameters are therefore not known. One can expect the BRDF to become

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[1] Although the aperture was found to be of an equivalent angular diameter of ~5deg as seen from the sample, which seems consistent with standard practice for these type of measurements.

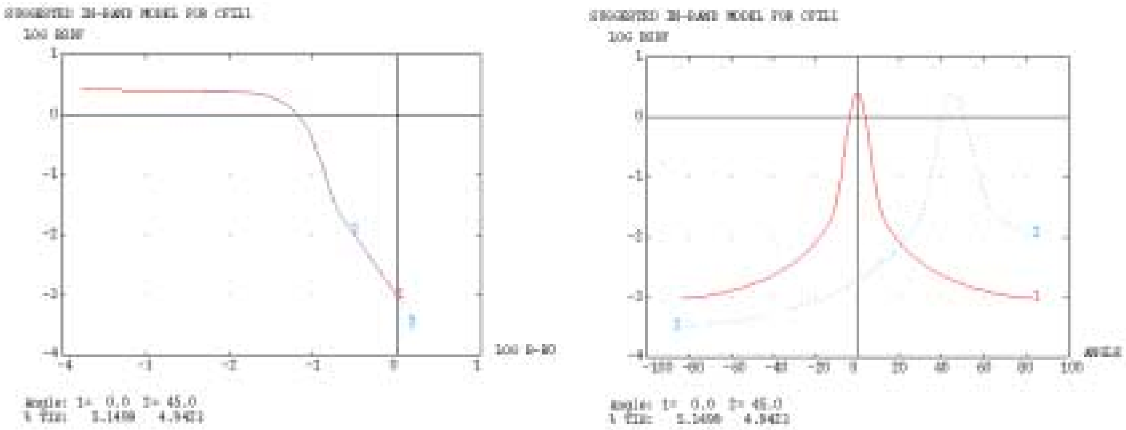

Figure 2: Log scale representation of the estimated in-band BRDF for CFIL.

For out-of-band (i.e. λ<200µm), uncertainty is even greater due to instability in the measurements. In case a surface function needs to be used (in broadband thermal straylight calculations for example), it is suggested to use the following basic model under ASAP:

```
MODEL
 HARVEY 1.3 -1.7000 0.0550
RETURN
```

which can be illustrated by the following log-log plot:

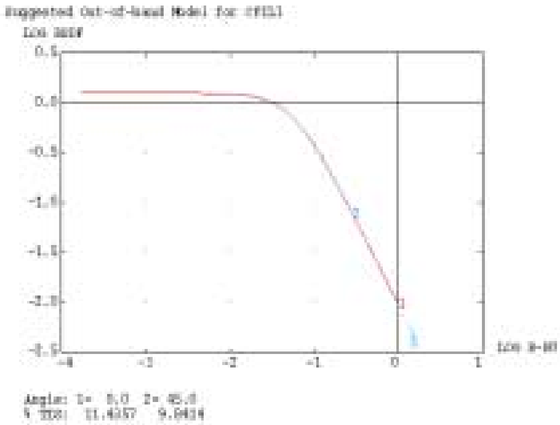

Figure 3: Log-log plot of the out-of-band BRDF for normal inc. and 45deg. incidence.

The average TIS is ~10% but the specular reflectance or absorption are not known precisely. It is just possible to say from the measured data that the transmission at ~117µm is very low (<1%, TBC).

Appendix A: Experimental set-up and measurement conditions

An experiment was carried out by Bruce Swinyard and Marc Ferlet in the SPIRE calibration lab at RAL. A dedicated set-up located on the laser bench was used to attempt a characterisation of the surface scattering properties of the SPIRE CFIL1 filter. The figure below is a schematic plan view representation of the experimental set-up. The sample is a dummy edge filter with cut-off at 52cm^{-1} (from spec. written on the filter) from Cardiff University.

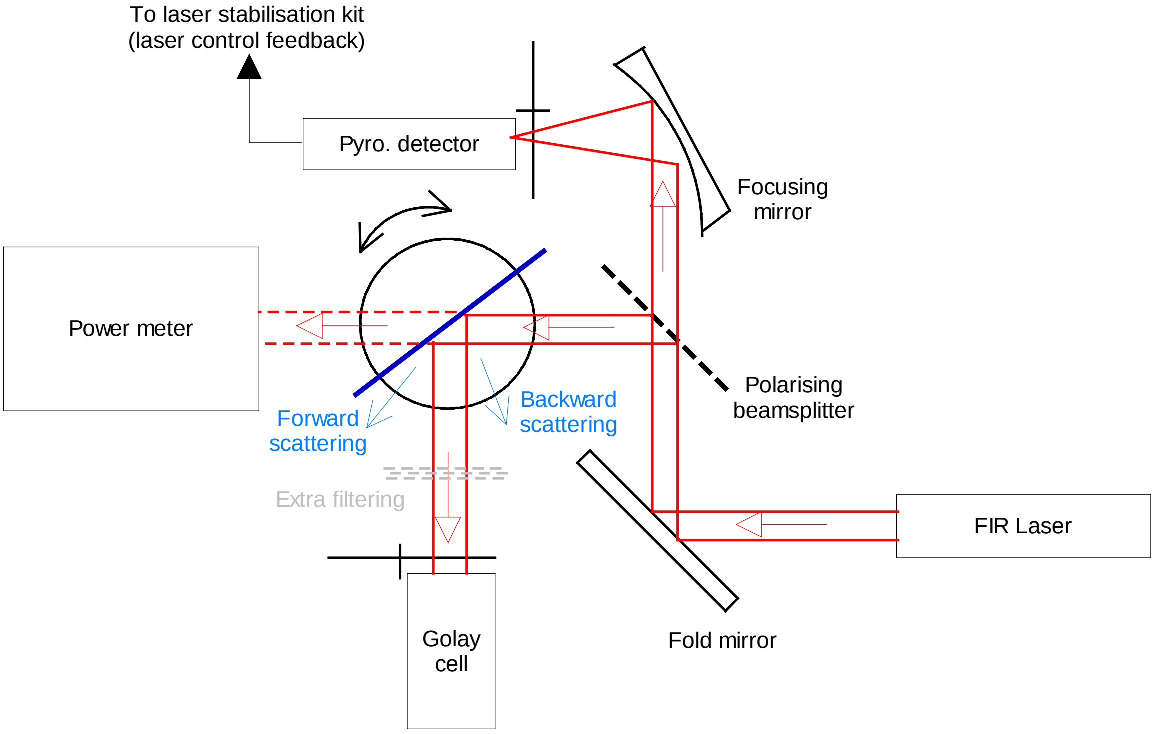

Figure 4: Experimental set-up used in the FIR scattering characterisation of CFIL1

The source is a FIR laser optically pumped by a high-power CO_2 laser. For the above experiments, DFM gas was used inside the FIR laser cavity with pump line tuned to 9R20 and 9R34 leading to laser effect at 117µm and 214µm respectively (for out-of-band and in-band measurements). In both cases, the output collimated (Gaussian beam, linearly polarised, with a waist ~5-7mm) beam contains a total power >1 mW. A polarising beamsplitter (wire grid) is tuned to transmit most of this power onto a pyroelectric detector (with chopper at 173Hz). This is to maximise the generated electronic signal, controlled and fed back into the CO_2 laser for stabilisation of the whole source system. In best case, FIR laser output was stabilised to ±5%, monitored for the experiment by the power meter. The experiment is carried out close to the output of the FIR cavity (minimum optical path) in order to reduce fluctuation and absorption from the room temperature atmospheric air along the beam paths.

The experimental configuration is different from the classic scatterometer set-up in the way that the detector of the scattered signal (here a high sensitivity Golay cell, partially shielded with Eccosorb and equipped with a chopper at its aperture) is not rotated around the sample. Here for stability and space constraint reason, the detector remains in fixed position but the sample is mounted on a rotating platform. Rotation of the sample allows angular scan of the specularly reflected and scattered (in partial forward and backward zones) signals from the illuminated surface of the sample to be measured. Extra filtering scheme (finite number of sheet of paper, pre-calibrated before the real scattering experiment for each wavelength of interest), along the scattered signal path was used to increase the dynamic range.

A total of 4 sets of measurements were taken: 2 in-band (i.e. above the filter cut-off, at 214um) and 2 out-of-band (at 117um). Each of the in-band measurements were performed with the different surface of filter illuminated i.e. the filter was rotated after the first measurement to assess the potential differences between the 2 surfaces. The difference between the 2 out-of-band measurements is the attempt to rotate the polarisation by ~90deg (by rotating the polarising beamsplitter) in the incident beam on the sample. In all cases, one tried to maintain the specular reflection at 45deg. Angular scans were limited by the beam vignetting due to interaction with sample ring mount on one side and lower threshold limit of detectivity on the other side.