Minutes of the SPIRE FTS/Optics Meeting 2/3 February 1999.

SPIRE-RAL-MOM-000164

Held at QMW

2 February - Photometer Optical Design and Instrument Layout

Present: B. Swinyard, P. Ade, M. Griffin, L. Rodriguez, J-P. Baluteau. J. Martignac, K. Dohlen, W. Gear, G. Wright, D. Henry.

Apologies from Tony Richards and Dominique Pouliquen.

i) Kjetil Dohlen presented his new optical design for the photometer (BOLPHT80). This has spread the beams apart compared to the first version of the design and allows room for the inclusion of baffles and filters at strategic points along the beam. The degree of anamorphism has been reduced. This design will accommodate a 4x8 arcmin field of view.

It was concluded that this design be adopted as the baseline design for the photometer with the mirrors sized to take a 4x8 arcmin field of view. The diffraction limited analysis and straylight analysis will be carried out using this design.

ii) The systems implications associated with the new design were highlighted by Bruce Swinyard and discussed. The conclusions were:

The whole instrument is now higher with respect to the FIRST optical bench.
M3 will now be mounted at 4 K – this means no optics apart from the input filter will be mounted at 15 K.
The wall next to M3 will therefore also be at 4 K lessening the possibility of diffracted straylight entering the detectors from the 15-K stage.
This design, as with previous designs, is "open" and will need careful consideration of the baffling to control possible straylight paths.
The baseline for the 2-K stage is to have everything beyond the final pupil image at 2-K – i.e. M9; the dichroics; the fold mirrors and the detectors – with a filter placed at or close to the physical cold stop. The maximum size for the filter is 75 mm and it has to be circular.
Another possibility is to have M7 and M8 at 2-K as well – this will only be done if it proves impossible to control the straylight.
The total envelope available for the instruments inside the cryostat for the instruments is described in a fax from ESA (PT-05908 October 1998 appended). This will be rendered as part of the translation from the optical model onto the CAD system and distributed to all interested parties.

The need for a shutter was discussed and the draft specification presented. Gillian Wright made the point that the chopper could be used as a shutter with an extreme position being used to point directly at M5. This option is to be studied as an alternative to the provision of a dedicated shutter.

iii) Some draft concepts for the layout of the structural support of the instrument were presented. The support from 4 to 2 K can be achieved using relatively straight forward materials such as stainless steel blades. Therefore for the initial study the 2 and 4-K stages are treated essentially as a single item. All the concepts use CFRP struts for the support from 15-K to 4-K. The issue of mounting the cooler from 4-K will be investigated.

The next steps in the study are the translation of the optical model into IGES format and the continuation of looking at various structural arrangements with a view to testing them against the launch environment.

iv) As Tony Richards wasn't present there was no presentation or discussion of the work being undertaken on the ESA straylight contract.

v) Kjetil has analysed the performance of the photometer for the extreme cases of the present highly tilted focal plane and for a perfectly flat focal plane. The difference in performance is minimal. The conclusion is that the SPIRE instrument does not need to move closer to the centre of the field of view. We also do not wish to surrender real estate on the optical bench as this may be required for structural support.

This will be our position at the focal plane sharing meeting to be held at ESTEC on the 15 Feb. This will be attended by Bruce Swinyard.

vi) Covered under (v)

vii) Bruce Swinyard presented (and managed to garble!) work by Martin Caldwell on the required size of the cold stop for the filled arrays and the Gaussian beam cases based on his note (SPIRE-RAL-NOT-000118). In the case of the filled arrays, diffraction and beam clipping at the field stop cause the system to "see" past the telescope secondary onto the sky and the tripod at the longest wavelengths. If the tripod legs are highly emissive this will lead to increased photon background on the detectors. His conclusion is that the pupil should not be undersized unless required by pupil aberrations but the design of the tripod must be carefully considered.

Martin has been asked to carry out the analysis for the new photometer including clipping at all the intermediate mirrors.

viii) The workplan for the next six months was discussed. The following was agreed:

The photometer design will be progressed on the basis on the model presented here and with a 4x8 arcmin FOV.
The optical design cannot be fully detailed until the detector type and the optical design of the telescope are finalised.

Issues that will be addressed by this group over the next six months – see also the action list:

1. Translation into CAD from optical model
2. Spot size and distortion
3. Error budget and alignment requirements – it was agreed that the requirements here will be that the "errors" in the optics shall cause no more than a 10% reduction in the Strehl ratio over the whole field of view compared to the optical model. And that there shall be no more than a 5% loss in throughput due to pupil misalignment compared to a perfectly aligned system i.e. this does NOT include losses due to filter transmission and mirror reflectivity.
4. The diffraction limited performance and straylight control will be analysed.
5. The baffles will be defined and the temperature at which each component is mounted confirmed.
6. The filtering scheme will be defined.

Progress on the opto-mechanical system design will be reviewed at meetings on or around the 8 March 1999 at MSSL and in mid/late April in Marseilles. This last to be concatenated with the SPIRE Science meeting date to be announced.

At the March meeting it was agreed that the following aspects will have been addressed and will be reviewed:

Size and position of all optical components for the photometer and, if possible, the spectrometer (see below).
Placement of the detectors.
Placement and mounting concept for the cooler.
Placement and mounting concept for the chopper.
Placement and envelope for the shutter – if required.
Structural support concept that meets the thermal; frequency and vibration design case requirements.
Concept for the covers.
A refined mass estimate.

3 February - Photometer Optical Design and Instrument Layout

Present: B. Swinyard, P. Ade, M. Griffin, L. Rodriguez, J-P. Baluteau. J. Martignac, K. Dohlen, G. Wright, D. Henry, P. Hamilton.

i) Peter Ade presented a report on the breadboard Mach-Zehnder FTS built using the new design broadband intensity beam splitters. The main features of the beam splitters are:

- 4RT~95% and their performance closely matches the model prediction.
- No polarisation sensitivity over the band of interest.
- Low emissivity – no greater than 5%.
- Air gap beam meshes is 66 μm – the performance of the beam splitters is insensitive to changes in the gap of up to +-5 μm.
- They also appear to split 50/50 in the optical – the breadboard was aligned using a HeNe laser!

The features of the Mach-Zehnder breadboard are:

- Feed optics representative of the FIRST optics – f/8.6 converted to f/5 through a Gaussian beam telescope.
- Drive accuracy nominally 0.1 μm using a Heidenhain Moire fringe position measurement system – the ability to reconstruct the ZPD is actually about 0.25 μm.
- Some low frequency noise is present in the breadboard – this could be due either to the drive or because of the absorption in the long air path. This noise means that it has not been possible to determine the effect of jitter in the drive position on the noise in the spectrum.
- There is very good cancellation with the same temperature source placed in both input ports.
- All tests show that the two output ports are very well balanced – i.e. one is the complement of the other as expected.

ii) Kjetil briefly presented an optical design that will fit into the instrument envelope. This design has not yet been linked to the input optics for the photometer and the pick off mirror.

The optical design uses powered mirrors within the FTS itself. The effect of this on the FTS performance should be minimal, however it should be tested using the breadboard. Another issue in the optical design is that the corner cubes are placed very close together – this may cause a problem with the accommodation of the mechanism. All the FTS optics and mechanism will be mounted at 4 K with the final cold stops defining the entrance to the 2-K box.

The issue of field of view was raised briefly – the FOV required to fit in a sensible number of 2fλ feedhorns is 2.6x2.6 arcmin (see note ……), it was agreed that the design should proceed on this basis and will be amended when the detector type was finalised.

iii) See below……

iv) Louis Rodriguez presented some work done on the possibility of using the Cassini CIRS mechanism for SPIRE. This mechanism would work with some adaptation. However, the mirrors would be placed at each end of the moving section making the instrument too big to fit in as currently conceived.

Jean Martignac gave a presentation on the affects of position and velocity jitter on the performance of an FTS with a detector with a roll off at 20 Hz. There is no dependence of the S/N achievable on the resolving power for either the position or the velocity jitter, or the two combined. It is expected that the noise induced in the spectrum should vary with wave-number – this was difficult to see from this study as an 80 K black body was used. The study will be continued with a flat input spectrum and using a compensating second input port.

Jean-Paul Baluteau presented work on the S/N achievable in an interferogram for the 0.5fλ and 2fλ detectors and how this relates to the jitter requirements on the drive. If the system is uncompensated the jitter accuracy required is very high (no more than 0.005 μm for R of 10 in the worst case). Alternatively the telescope signal would need to be well compensated.

Louis showed some work by Guy Michel (report attached) on the possibility of using a Heidenhain Moire fringe position encoder. This would need to use an NIR LED or laser working at 4 K. Louis is investigating the availability of either of these devices from LETI or commercially.

There was some(!) discussion on how the readout scheme might be implemented. The options might be summarised as follows:

- Fully or partially compensate – this leads to higher photon noise but reduces the specification on the position and velocity jitter.
- Time sample – this is dependent on the accuracy of the velocity of the drive system.
- Position sample – this is dependent on the accuracy of the position measurement.
- Accurate position and/or time sampling is only required over the few fringes close to the ZPD.
- Time or position sample and use the other measurement as a history channel to allow corrections.

Bruce Swinyard will write a note attempting to summarise the options.

v) Bruce Swinyard presented a brief study on the detectability of Arp220 if the ISO LWS spectrum is red-shifted. After some discussion it was agreed that the scientific requirements should be set for a resolving power of 20. The science requirements document will be updated appropriately.

vi) There was no discussion on the processing requirements – this will be taken offline.

vii) The workplan for the next six months was discussed. The following was agreed:

The spectrometer design will be progressed on the basis of the Mach-Zehnder design (see below) presented here and with a 2.6x2.6 arcmin FOV.
The optical design cannot be fully detailed until the detector type and the optical design of the telescope are finalised.

Issues that will be addressed by this group over the next six months – see also the action list:

1. Completion of the optical design linking the spectrometer and photometer.
2. Translation into CAD from optical model
3. Spot size and distortion
4. Error budget and alignment requirements – no discussion of the error budgets at this meeting. For the present they should be the same as for the photometer. The budget in relation to the spectroscopic performance needs to be decided.
5. The diffraction limited performance and straylight control will be analysed – this has a lower priority than the analysis of the photometer performance.
6. The baffles will be defined and the temperature at which each component is mounted confirmed.
7. The filtering scheme will be defined.
8. The requirements on the mechanism will be finalised and the type of mechanism identified.
9. The requirements on the mirror position sensor will be finalised and the type of sensor identified.
10. The nominal method of operating the FTS will be defined and the data rate and on-board software implications specified.
11. The number of spectral bands will be defined.
12. The number and type of feedhorns will be specified.
13. The requirements on the calibration source will be defined and the specification of the source drawn up.

By the March System team meeting and opto-mechanical progress review it was agreed that the following aspects will have been addressed:

First cut optical model and translation into CAD system

Data rate and on-board software requirements
The type of position sensor

By mid/late April there must be a first order solution for the mechanism to allow the optical model to be finalised.

Selection of FTS type:

Table giving the figure of merit calculation for the different types of FTS being considered for SPIRE. Reconstructed from notes made during the meeting and additions by Bruce Swinyard.

Parameter	Weight	Michelson		Martin-Puplett		Mach-Zehnder	
Theoretical Efficiency	10	50%	10	25%	0	50%	10
Path fold	1	2	1	2	1	4	0
Position measurement	3	Moire Fringe	0	LVDT(?)	3	Moire Fringe	0
Volume	3	No problem	3	No problem	3	Long path	0
Compensation	5	No	0	Yes	5	Yes	5
Calibration	8	No	0	Yes	8	Yes	8
Max. Resolution	5	500	0	500	0	1000	5
Polarisation Sensitive	3	No	3	Yes	0	No	3
Output port	1	Dichroic	0	Polariser	1	Amplitude BS	1
SCORE	39		17		21		32

Notes: The weights given reflect the relative importance given to that parameter in meeting the scientific goals of this instrument. To obtain a score the weight is multiplied by 1 in the row if the FTS type has the "ideal" performance and 0 if it doesn't. The scores are then totalled at the bottom of the columns. Our ideal FTS gives a score of 39.

Actions outstanding from previous meetings:

Action	Who	Due	Description	Status	Closed by:
-AI-FTS-0056-06	GM	Next meeting	Study use of NIR Moire fringe device	Closed	Report given at 2/3 Feb meeting
-AI-FTS-0056-05	JPB	Next meeting	Study use of tandem LVDT	Closed	Report given at 2/3 Feb meeting
-AI-FTS-0056-03	KD	Next meeting	Recast signal to noise analysis using realistic NEP for resolution 3-20	Closed	Report given at 2/3 Feb meeting

-AI-FTS-0041-04	BS	2 Jun 1998	Send baseline FTS spec to GM so that he can simulate it.	Deleted	A new baseline FTS has been established – this no longer relevant
-AI-FTS-0041-05	WG	2 Jun 1998	Define a new baseline design for the horn option and analyse the variation of sensitivity with wavelength across the band	Closed	Various e-mails and splinter meeting at the January 1998 array meeting
-AI-FTS-0041-03	KD	11 Jun 1998	To study Peter Ade's version of this option (as on final viewgraph). Bruce to provide him with ncessary information and parameters.	Deleted	New baseline renders this action irrelevant
-AI-FTS-0041-02	MJG	29 Jul 1998	SPIRE Consortium to do (M Griffin to co-ordinate). Peter Hamilton's note provided for this meeting (attached) is a good starting point	Deleted	What is this action?
-AI-FTS-0041-01	PC /BS /SJU	29 Jul 1998	(+Peter Hamilton)To do some modelling using LWS data to estimate how much better we can do (compare 0.04vs. 0.4cm -1)	Closed	BMS report at 2/3 Feb meeting and subsequent actions
-AI-FTS-0041-06	MJG	29 Jul 1998	Study the behavior of sensitivity as a function of wavelength for the filled array options	Open	
-AI-FTS-0056-01	BS	4 Dec 1998	Send Kjetil realistic NEP figures	Closed	E-mailed FTS Mathcad model results
-AI-FTS-0056-02	BS	11 Dec 1998	Send Kjetil information on Gaussian beam optics	Closed	Papers sent to Kjetil in December 1998
-AI-FTS-0056-04	BS	22 Dec 1998	Set date for next meeting in consultation with PARA	Closed	2/3 Feb meeting
-AI-FTS-0056-07	PA	24 Dec 1998	Provide Kjetil with sample filter profile	Open	

Actions from this meeting:

Action	Who	Due	Description	Status
AI-FTS-000164-01	RAL	12/2/99	Translate photometer optical model into CAD compatible format	Open
AI-FTS-000164-02	KD	12/2/99	Evaluate spot diagrams and distortion for 4x8 field for flat and curved telescope focal plane.	Open
AI-FTS-000164-03	KD	8/3/99	Draw up error budget and alignment tolerances for photometer	Open
AI-FTS-000164-04	MC	31/3/99	Analyse diffraction limited performance of new photometer.	Open
AI-FTS-000164-05	AR	8/3/99	Input new photometer design into APART and outline first order baffles	Open
AI-FTS-000164-06	BS	12/2/99	Confirm temperatures of optical elements in photometer	Open
AI-FTS-000164-07	BS	8/3/99	Define filtering scheme for photometer	Open
AI-FTS-000164-08	BS	12/2/99	Formally issue shutter specification.	Open
AI-FTS-000164-09	PA	1/4/99	Test effect of powered mirrors in breadboard FTS	Open
AI-FTS-000164-10	BS	19/2/99	Issue note outlining different options for sampling FTS mirror positions	Open
AI-FTS-000164-11	LR/ GM	8/3/99	Report on use of 4-K LED’s and/or lasers for Moire fringe encoder	Open
AI-FTS-000164-12	BS/ MG	19/2/99	Evaluate ability to reconstruct redshift of Arp220 like galaxy as function of R.	Open
AI-FTS-000164-13	KD	19/2/99	Complete optical model of baseline FTS and provide to RAL.	Open
AI-FTS-000164-14	RAL	23/2/99	Translate into CAD	Open

			compatible file	
AI-FTS-000164-15	KD	12/4/99	Draw up error budget and alignment tolerances for spectrometer optics	Open
AI-FTS-000164-16	MC	30/4/99	Analyse diffraction limited performance for spectrometer	Open
AI-FTS-000164-17	AR	12/4/99	Input new spectrometer design into APART and outline first order baffles	Open
AI-FTS-000164-18	BS	26/2/99	Confirm temperature of all components in the spectrometer	Open
AI-FTS-000164-19	DP	12/4/99	Identify candidate FTS mirror mechanism consistent with optical design.	Open
AI-FTS-000164-20	LR/ GM	4/3/99	Finalise requirements on the FTS drive mechanism and position sensor.	Open
AI-FTS-000164-21	JM/ LR	4/3/99	Report on further study into FTS operation.	Open
AI-FTS-000164-22	PA	30/3/99	Measure properties of JPL feedhorns.	Open
AI-FTS-000164-23	MG/ BS	30/3/99	Finalise number of bands and layout of FTS focal plane using feedhorns	Open
AI-FTS-000164-24	JPB	30/3/99	Define requirements on FTS calibration source	Open
AI-FTS-000164-25	MG/ BS	12/4/99	Write specification for FTS calibration source	Open
AI-FTS-000164-26	LR	4/3/99	Define draft data rate requirements for the new baseline FTS	Open
AI-FTS-000164-27	LR/ PAH	4/3/99	Define draft on-board software requirements for the new baseline FTS.	Open