Introduction

It has been proposed that the SPIRE spectrometer wavelength coverage be extended down to 150 μm with the long wavelength range being left as it is. This would allow the instrument to cover both the astrophysically interesting CII(157); NII(205); CI(370) and, possibly CI(609) over the same field of view, as well as providing narrow band spectro-photometery to complement the PACS long wavelength photometric channel.

This note considers the major systems impacts of such an extension of the SPIRE capabilities. The overriding criterion in even considering this extension is that the core waveband (200-400 μm) performance is not compromised. The second order criteria are that the current optical layout of the FTS be changed as little as possible in order to accommodate the extension; that there are no changes made to the layout of the common fore optics and that the field of view remains at 2.6 arcmin or thereabouts.

Concept.

The current prototype FTS intensity beam dividers give a flat response from ~10 to 65 cm^{-1}. The present conceptual design for the FTS can therefore be maintained. However we now have to cover a factor of four in wavelength (~150 to ~600). If this were to be attempted with only two arrays it would imply a) having detectors/filters covering wavebands of R=1.5 (150-300 and 300-600) and b) a large loss in sensitivity in the 200-300 band owing to the increased background from the telescope. We can, instead, consider adding a third array that would cover the short-wavelength extension. The arrays would therefore be:

Wavelength Coverage	Centre Wavelength	Equivalent Resolving Power
150-210	180	3
210-303	256	3
303- ≥ 500	401	≤ 2

If the final focal ratio remains at about f/5 then the 2.6 arcmin FOV will be ~12.4 mm in diameter. The sizes of the arrays are, for 0.5Fλ pixels: ~572; ~314; ~114 pixels and, for the 2Fλ feedhorns: 37; 19 and 7 pixels.

Figure 1 shows the optical layout of the spectrometer as currently conceived with three arrays included. It can be seen that three arrays can just about be fitted in within the envelope of keeping 50 mm from the last cryostat shield.

The optical quality of the present FTS design is just about good enough at λ>200 μm (i.e. Strehl ratio ~>0.9). Maintaining this performance at shorter wavelengths will be extremely difficult with the current optical design and instrument layout. Therefore, it is proposed that, if the extension to shorter wavelengths is approved, the optical quality of the system is set at 200 μm and the short wavelength performance is taken as is. That is, the Strehl ratio at 150 μm is going to be somewhat worse than 0.9 and the pixels will be sized accordingly.

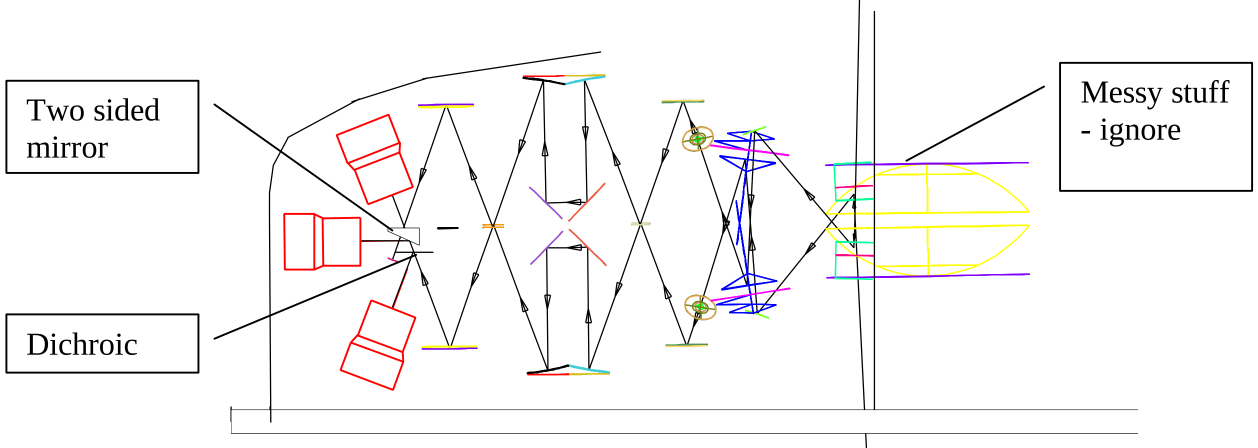

Figure 1: Sketch showing possible accommodation of three detector arrays in the FTS optical layout.

Systems Impact.

Parameter	**Implication of short wavelength extension**
Mass	Increases by one array (say 500 g) for all detector options. Increases some more for JFET option with extra amplifiers
Thermal load at 300 mK	For feedhorn and TES options the increase will be negligible For the CEA option some more – 1-2 µW?
Thermal load from 4-2 K	Small increase due to parasitics from structure and wiring
Wiring	Another ~80 wires
Resolution	No change – stays at 0.4 cm^{-1} required and 0.04 cm^{-1} goal
Linear travel	No change – 14 cm total OPD (-0.3 to +3.2 cm in actual mirror travel)
Step size	Nyquist step size is now 75.7 µm in OPD. If we have a folding of four times and over sample by 5 this translates to 3.75 µm in actual mirror position.
Mirror position accuracy	Goes from 100 nm to 75 nm – assumes over sampling of 5; four times folding and 1/50 of a step resolution requirement. We could relax this back to the original and accept the loss of performance at the short wavelength end.

Mirror velocity	Goes from 0.1 cm/s to 0.0757 cm/s This puts the lowest frequencies at an equivalent audio frequency of 4.5 Hz rather than 6 Hz
Number of samples/sec	No change – maximum is ~200 s^{-1} Because the mirrors have been slowed down – the readout rate remains the same
Data rate	200x16x1000 = 3124 kbit/s for filled arrays (~x2.3 higher) Implies we have to co-add 15 interferograms if 40 kbit/s telemetry Or 3 interferograms if 200 kbit/s telemetry 200x16x63=197 kbit/s for feedhorns (~x2 higher) Do not have to co-add interferograms but do now require decimation for 40 kbit/s. Can transmit everything for 200 kbit/s.
Time per scan for full resolution	46.2 seconds – increases from 35 seconds A net loss of 15% in sensitivity at all wavelengths for the highest resolution. This does not mean that there will be the same loss at lower resolution.

Table 1: Systems implications of extending the FTS to shorter wavelengths.

Performance

A brief examination of the performance of the FTS in the three wavebands gives the results shown in table 2. These figures should be treated with caution as the model needs some revision and the detector sensitivity needs to be checked for the short wavelength band. However, they do serve to show that the new short wavelength band will be less sensitive than the original bands but will still be respectable. For comparison PACS quote a 1-σ 1-hour sensitivity of ….. W m^{-2} at 157 μm and the ISO-LWS had a point source 1-σ 1-hour sensitivity of ~1-2x10^{-18} W m^{-2} at 157 μm at a resolution of a few hundred.

Point source continuum sensitivity (1 σ -1 hr; 0.4 cm^{-1} resolution)	Band A 150-210 53 mJy (TBC) Band B 210-303 μm 43 mJy (TBC) Band C 303-500 μm 37 mJy (TBC)
Point source unresolved line sensitivity (1 σ -1 hr)	Band A 150-210 μm 6.4 x 10^{-18} W m^{-2} (TBC) Band B 210-303 μm 5.2 x 10^{-18} W m^{-2} (TBC) Band C 303-500 μm 4.4 x 10^{-18} W m^{-2} (TBC)

Table 2: Nominal performance of the three band FTS

Conclusions

The systems impacts of extending the FTS to 150 μm are not so severe as to instantly preclude this option. The major implication is a large increase in the data rate from the FTS – this is especially true for the filled arrays where even the increase to 200 kbit/s will not be enough to remove the necessity of on-board co-addition of the interferograms or some other form of lossless compression. For the feedhorn option an additional array can be accommodated within the 200 kbit/s telemetry rate with no on-board processing required.

Further study will be required on the cost; risk and schedule implications of having to design and build a third array type.