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BOL	**FIRST Bolometer** **Affects of beam shear in a Fourier Transform Spectrometer** **B. Swinyard**	**Ref: BOL/RAL/N/0017** **Issue: 1** **Date: 10/10/97** **Page: 1 of 2**

INTRODUCTION

One possibility for the spectrometer channel on the FIRST bolometer instrument is to use an imaging FTS. One unknown in the use of an FTS for imaging is the affect of off-axis beams on the performance of the instrument. In this note a simple numerical model is described for calculating the affects of off-axis beams on the apodisation of the interferogram and the resultant spectroscopic performance of the FTS.

BEAM SHEAR IN AN FTS

An FTS can be thought of as being two mirrors inline as shown in figure 1 - the first mirror being magically both half silvered and having the same reflectivity as the second. The detector then sees two images of the source at twice the spacing of the mirrors themselves - these behave the same as two coherent sources.

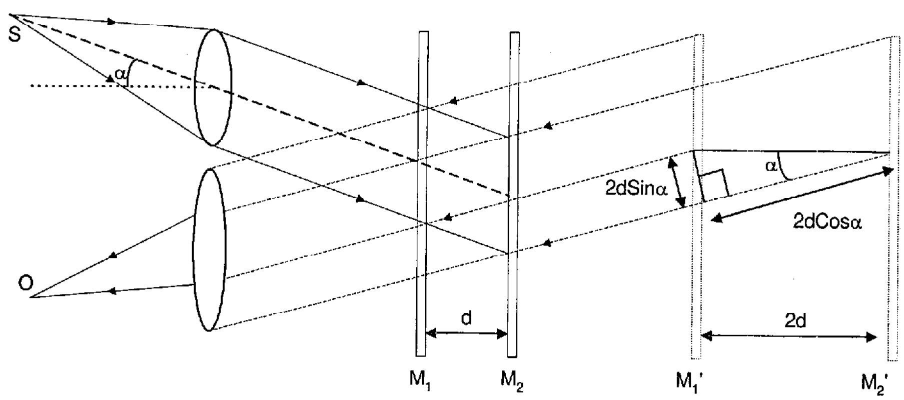


Figure 1: The principle of operation of an off axis FTS. The source at S is at an angle α w.r.t. the instrument axis, the mirrors M_1 and M_2 give images of the collimating lens at M_1' and M_2'. These appear to be a pair of coherent sources a distance of 2d apart to the detector at O: d being the distance between the mirrors. The optical path difference between the two beams is then 2dCosα and the distance between the centres of the two beams - the shear - is 2dSinα. Only the flux contained in the overlapping portion of the two beams will interfere and contribute to the interferogram.

As shown in figure 1, the distance between the centres of the two beams passing through the instrument is given by 2dSinα or ΔSinα – Δ being the optical path difference (OPD) for an on axis beam. Using this resukt, the overlapping portion of two beams can be calculated numerically as a function of off axis angle by creating two 2-D arrays of the appropriate shape, shifting one with respect to the other, multiplying them together and taking the ratio of the total sum of the result with respect to the total in the unshifted array. The amount of shift being fixed by the optical path difference and the off axis angle.

The shift, and therefore the loss in depth of modulation, will be at a maximum at the maximum OPD. This is set by the required resolving power for the instrument. For the FIRST bolometer instrument this is R=1000 at 250 μm, giving a maximum OPD of 12.5 cm. An IDL program has been written to calculate the fractional overlap for top-hat beams and Gaussian beams as a function of off axis angle and beam size. For the top-hat beams the beams size is given by the radius, for the Gaussian beams it is the FWHM. A comparison between the two types of beam shape for the same "beam size" is shown in figure 2.

RESULTS AND CONCLUSIONS

Figure 3 shows the fractional overlap vs. off axis angle for beams sizes from 2 to 25 mm for off axis angles up to 9 degrees for the top hat (figure 3a) and Gaussian (3b) cases. It can be seen that, for any reasonable beam size - i.e. an aperture of >20mm diameter - there will not be a serious affect on the modulation efficiency out to angles of 3 degrees or more. This is more than adequate for the size of field of view contemplated for the FIRST instrument (3 arcmins or less!).

To illustrate this point further, a model FTS has been constructed in IDL that allows for the shearing of the beams as the mirrors are moved. Figure 4 shows the FTS response together with the input spectrum representing an 80K black body with some lines imposed for an on axis source. No apodisation was performed on the interferogram, hence the Sinc function response. Figure 5 shows the same data but for a source placed off-axis by 1 degree and for a gaussian beam with FWHM of 15 mm (i.e. an aperture of ~30mm). The wavenumber scale has been adjusted to account for the off-axis beam and it is apparent that there is no loss of resolution.

It is therefore concluded that it will be possible to have an imaging array in an FTS on the FIRST Bolometer instrument of whatever practical size is required or possible, given the limited space available on M3.

FIGURE 2:

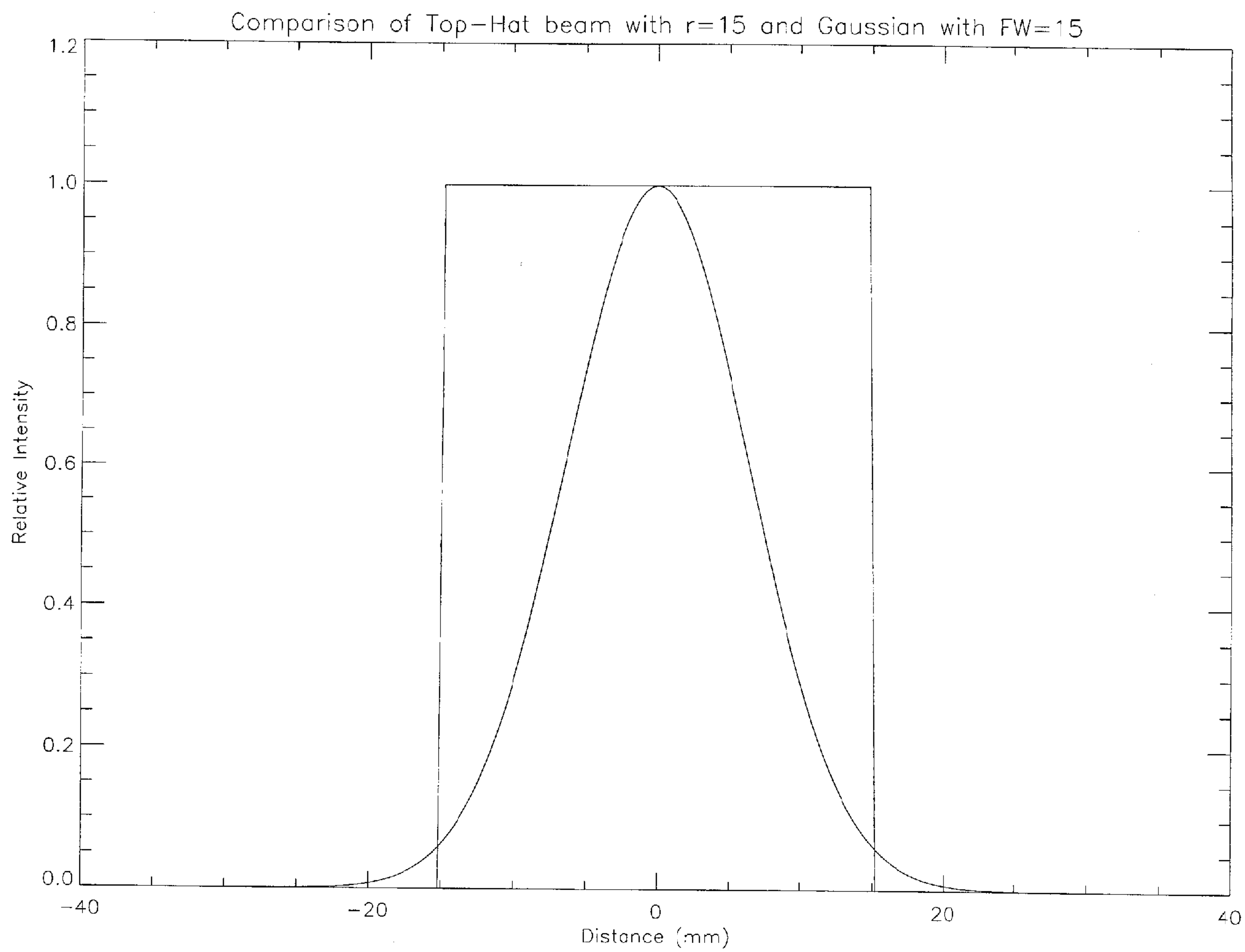

Comparison of Top−Hat beam with r=15 and Gaussian with FW=15
Relative Intensity
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−40
−20
0
20
40
Distance (mm)

FIGURE 3.

a)

b)

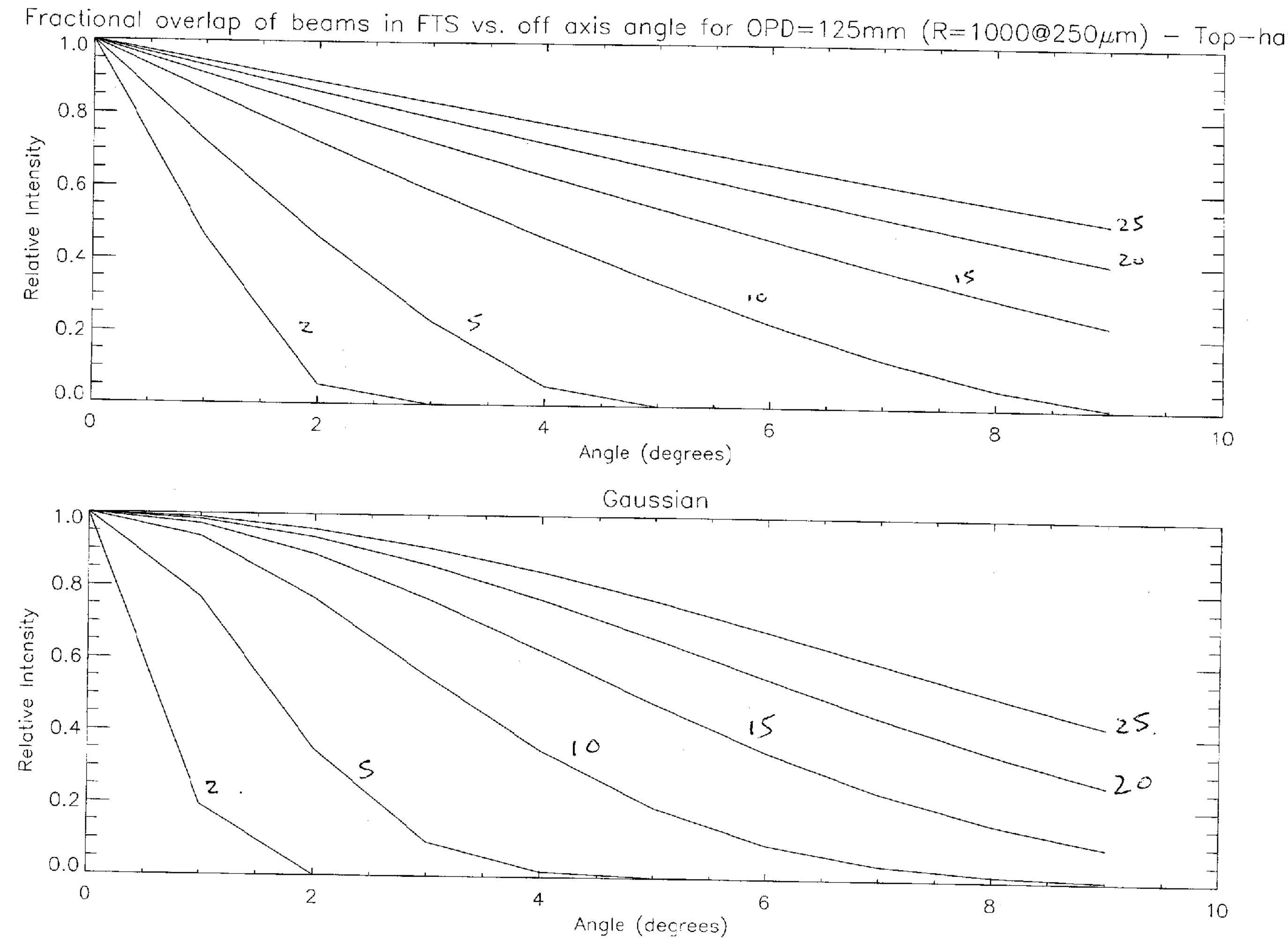
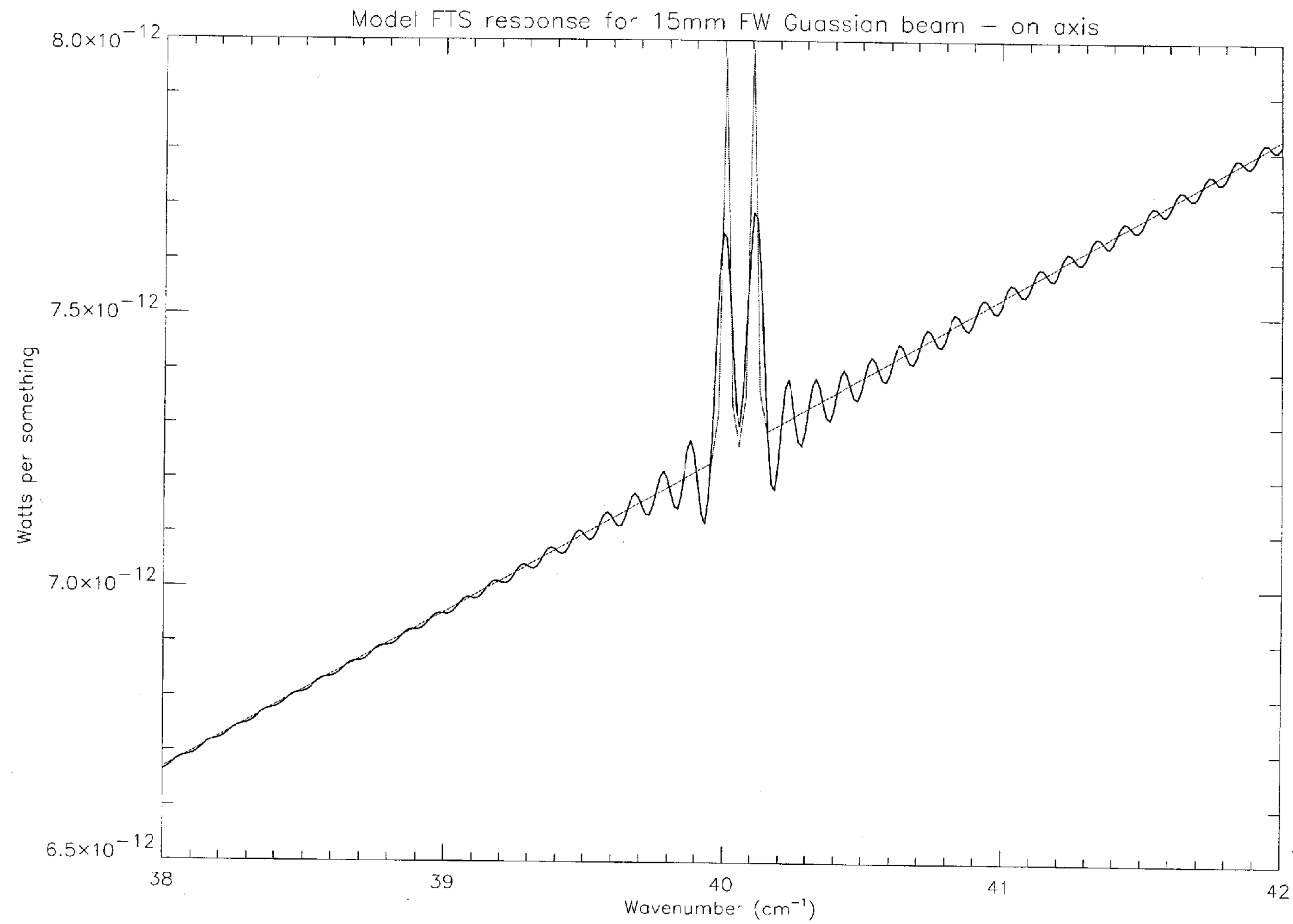
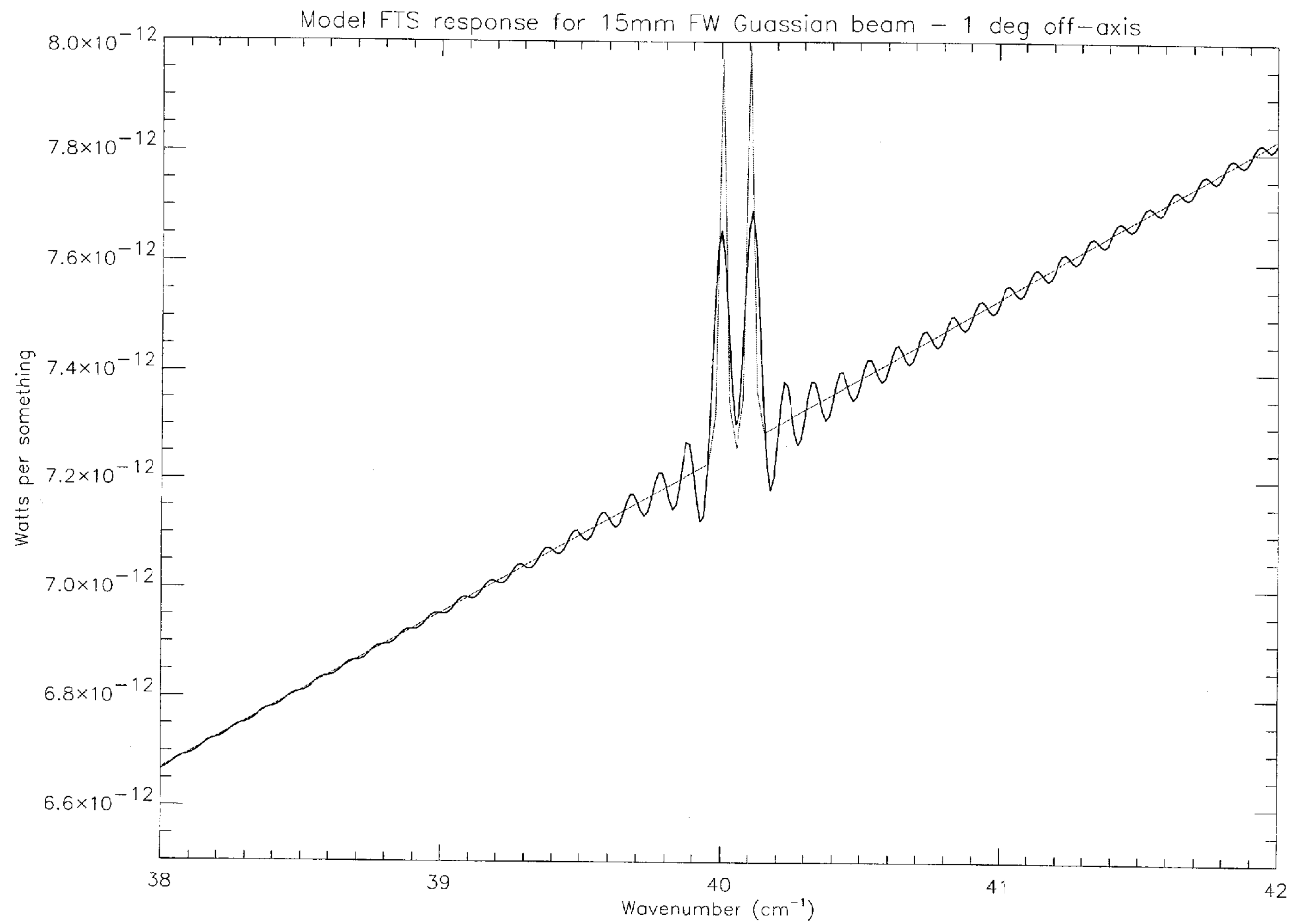

Fractional overlap of beams in FTS vs. off axis angle for OPD=125mm (R=1000@250μm) – Top–hat
Relative Intensity
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
Angle (degrees)
2
5
10
15
20
25
Gaussian
Relative Intensity
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
Angle (degrees)
2
5
10
15
20
25

FIGURE 4.



Model FTS response for 15mm FW Guassian beam – on axis
8.0×10^{-12}
7.5×10^{-12}
7.0×10^{-12}
6.5×10^{-12}
Watts per something
38
39
40
41
42
Wavenumber (cm^{-1})

FIGURE 5.



Model FTS response for 15mm FW Guassian beam – 1 deg off–axis
8.0×10^−12
7.8×10^−12
7.6×10^−12
7.4×10^−12
7.2×10^−12
7.0×10^−12
6.8×10^−12
6.6×10^−12
Watts per something
38
39
40
41
42
Wavenumber (cm^−1)