BOL/RAL/M/0018.1

FIRST BOL Optics Meeting June 25-27 1997

PART I

Attendance 25/6/97

Name	Institute	
MATT GRIFFIN	QMW	
COLIN CUNNINGHAM	ROE	
ROGER EMERY	RAL.	(a.m)
GILLIAN WRIGHT	ROE	
Peter Ade	QMW	
Bruno MAFFEI	QMW	
Ian Hepburn	MSSL	
François PAJOT	IAS	
Frazer Morrison	ROE.	
Ed Atad	ROE	
Tony Richards	RAL	
BRUCE SWINYARD	RAL.	
MARTIN CALDWELL	RAL.	
Kjetil DOHLEN	OMA	
Ken King	RAL	
Peter Gray	RAL	(p.m)

FIRST BOL Optics Meeting June 25-27 1997

Agenda for Wed. 25 June

1.	FIRST schedule and status of merger study	MJG
ACTIONS →		
2.	BOL performance modelling	MJG
3.	Photometer optical design	BMS
4.	Photometer stray light analysis	BMS
5.	Spectrometer optical design	BMS
6.	Cross-disperser possibilities	KD
7.	FTS OPTION	

Important issues for item 3:

1. FIRST schedule and status of merger study — MJG

ACTIONS →

2. BOL performance modelling — MJG

3. Photometer optical design — BMS

   Important issues:
   - ASAP analysis
   - Mirror sizes
   - Beam clipping,
   - Effect of Gaussian beams

4. Photometer stray light analysis — BMS

   Important issues:
   - Identification of important surfaces inside and outside the instrument
   - Effect of diffraction
   - Overall background on detectors

5. Spectrometer optical design — BMS

   Important issues:
   - Reports on ROE and LAS design work
   - Achievable resolution, aberrations
   - Diffraction analysis of these designs

6. Cross-disperser possibilities — KD

   Important issues:
   - Accommodation of cross disperser
   - Stray light,
   - Achievable number of detectors and array size
   - Overall factor of improvement

7. FTS OPTION

Aims for end of first day

Agreed optical designs for further study and definition of thermal design, layout, mass etc.

Agenda for Thursday 26 June

Splinter meetings

AM:	1.	Iteration of optical designs	BMS
	2.	Data rate and operating modes	KJK
PM:	3.	Mechanical/thermal engineering	CRC
	5.	Focal plane and final optics	MJG

Agenda for Friday 27 June

1.	Review of status and conclusions following splinter meetings	MJG
2.	Plan for future work and actions	BMS
3.	BOL consortium organisation	KJK

1. FIRST schedule re
status of merger study

FIRST status and schedule

1. Merger study

- Option of PLANCK HFI in FIRST dewar has been abandoned
- FIRST reverts to the original configuration:
  3-m telescope f/9.6
- 3.5-m or 4-m hoped for but not base-line
- Action to specify what science BOL could do simultaneously with PLANCK (spinning mode)
- ESA Executive decree: FIRST and PLANCK must be implemented within a budget of 632 MAU

  This is equivalent to the 10% less than the original budget for FIRST alone

2. BOL Instrument Interface Document (IID)

- First draft produced by ESTEC has been updated
- Additional information needed soon (mainly thermal/mechanical data)

3. FIRST Schedule (no change)

- AO issue still end September 1997
- Response due Feb. 1998
- Launch date still 2005/6

2. BOL Performance Model

BOL Performance Model

Assumptions:

- Telescope temperature = 80 K
  diameter = 3.5 m
  emissivity = 4%
- Optics efficiency = 30% (photometry)
  = 20% (spectroscopy)
- Spectral resolution = 3 (phot.)
  = 400 (spect.)
- Bolometer NEP = 1.0×10^{-17} W $Hz^{-1/2}$
- Bolometer quantum efficiency = 0.8
- Telescope coupling efficiency = 0.7
- Chopping efficiency factor = 0.45
- Observing efficiency = 70%
- Single-mode throughput $A\Omega = \lambda^2$
- Required spatial step size for imaging = 9 arcsec. (full spatial sampling at 250 μm)
- Spectral sampling interval = ¼ resolution element
- Number of detectors sampling the spectrum = 20
- Number of spectral elements which must be scanned to measure an unresolved line = 5

- Photon noise (taking into account partial correlation of the photon stream on the detector):

$$NEP_{PH}^2 = \int_{\nu_0}^{\infty}\left[\frac{2P_b(\nu)h\nu}{\eta} + \frac{\lambda^2}{A\Omega}P_b(\nu)^2\right]d\nu$$

P_b = total power incident on bolometer
η = bolometer quantum efficiency;
$A\Omega$ = throughput

- Telescope pointing accuracy is good enough to allow blind pointing for single pixel observations of point sources (currently NOT TRUE)

Results

Spectroscopy

- Total background power = 14×10^{-15} W of which > 90% is from the telescope

- Very low background ⇒ stray light must be eliminated

- $NEP_{PH} = 5 \times 10^{-18}$ W Hz$^{-1/2}$ ⇒ Detector noise limited

Full spectrum (1 σ; 1 hr)	2.0×10^{-18} W m^{-2} 80 mJy
Known line (1 σ; 1 hr)	1.2×10^{-18} W m^{-2} 46 mJy

- Sensitivity for full scans scales with no. of detectors

Photometry

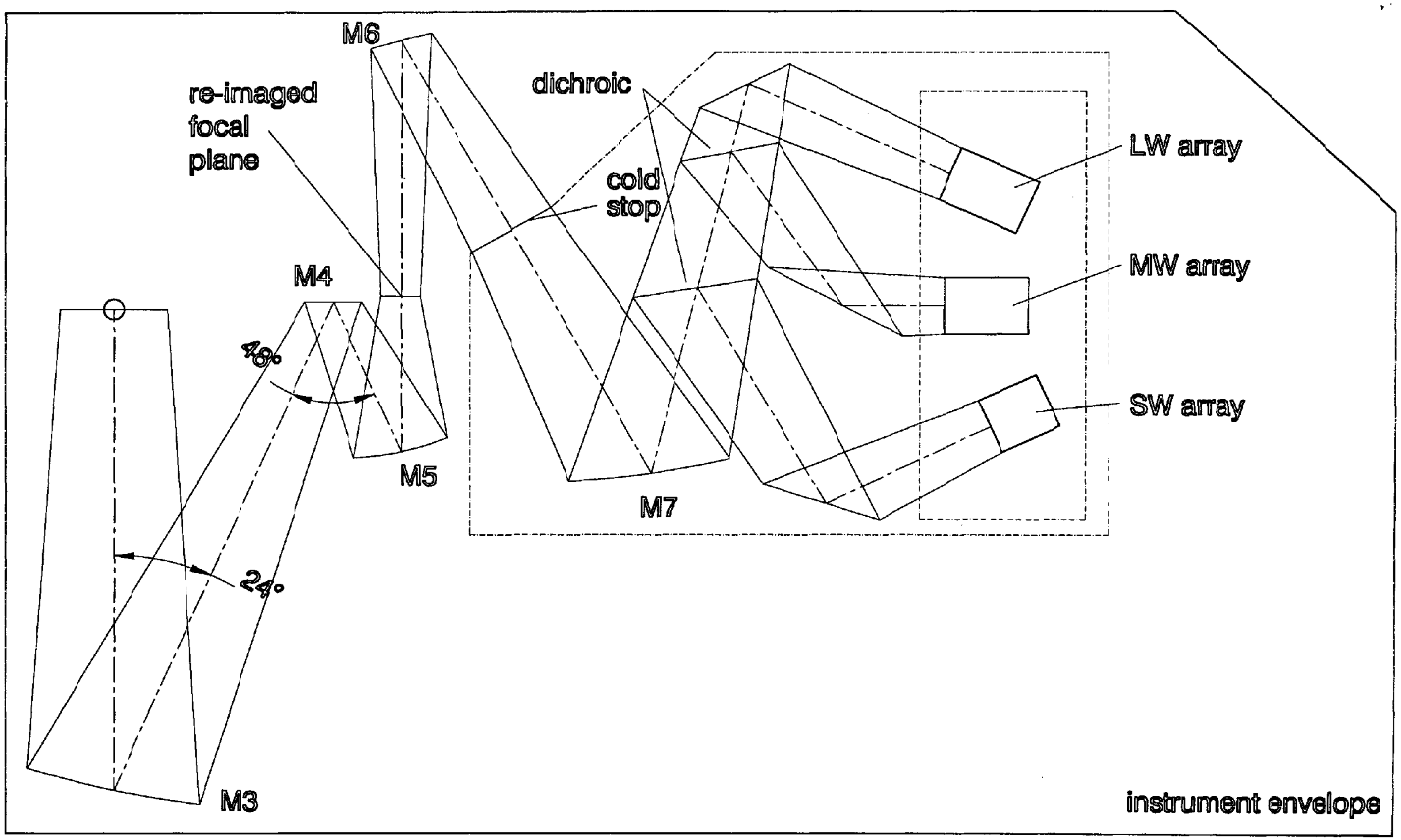
- Background power, NEP dominated by telescope

λ_o	(μm)	250	350	500
P_b	pW	22	10	4
NEP_{PH}	W Hz$^{-1/2}$ x 10^{-17}	26	13	6
NEFD	mJy Hz$^{-1/2}$	58	51	43
Limiting flux density for point source	mJy (1 σ; 1 hr)	0.68	0.60	0.51
Limiting flux density for 5' x 5' map	mJy (1 σ; 1 hr)	3.3	2.9	2.4

- Sensitivity for mapping scales with the number of detectors

- Model currently being updated (no significant effect on results)

3. Photometer Optical Design



BOL photometer 24.06.97
f/5 final beam size
dichroic angle - 22.5 degrees

Preliminary Optical Design of BOL

Eli Atad , ROE , 25 June 1997

Photometer / Imager

- Working wavelengths: 200-600 microns
- Fnumber: F/5
- Field of View: 6.7 arcmin
- Chopper in the instrument and placed at the image of FIRST secondary mirror which is the stop of the telescope.
- Has to fit with the spectrometer in the 700*300*300 mm space enveloppe.
- A physical cold stop at 4K to reduce background radiation.
- The photometer will share the same foreoptics as the spectrometer (one chopper only, weight)
- 3 arrays of detectors optimized for 3 separate wavelengths: 250, 350,480 microns .
- No Filter wheel .

Photometer/Imager Optical Data:

Component	Radius of Curv (mm)	Thickness (mm)	y- Tilt (degrees)	CA Diameter (mm)
telescope FP f/9.5915 (7.64"/mm)	Plano	240		53.0
M3	480.00 k=-0.928	266.42	12.0	85.0
M4 (chopper)	Plano	81.88	24.0	28.0
M5	150.12 159.38	77.42	12.0	46/ 100
cold reimaged focal plane f/3	Plano	127.45		20/50
M6	295.03	110.0	15.0	60/120
cold stop	Plano	140.0		55
M7	443.95 553.25	110.0	22.0	75/
M8 (dichroic)	Plano	200.0	22.0	65/
detector/f/5				40
(14.66"/mm)				

IMAGE QUALITY

Encircled Energy Diameters (mm) and Strehl ratios:

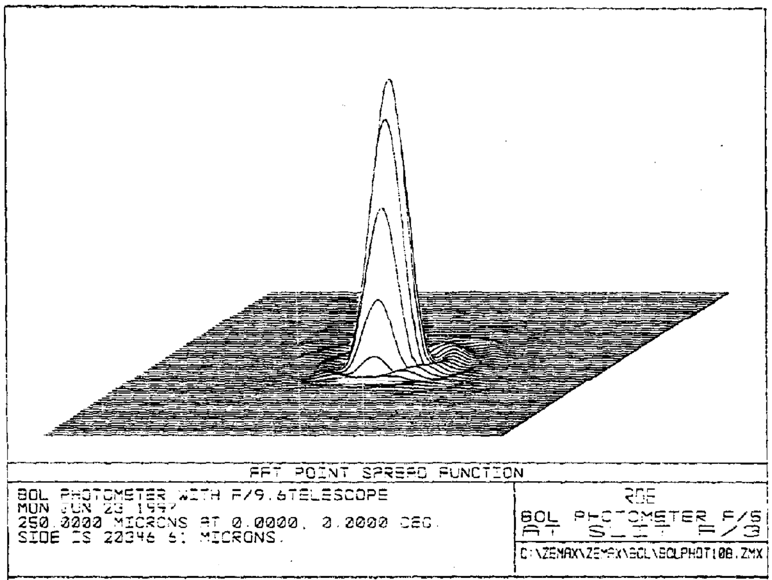
Wavelength (µm)	250	350	480
Airy disk (80%) (mm)	2.5	3.5	4.8
Geometrical spots (mm)			
80% on-axis	1.30	1.30	1.30
off-axis	1.70	1.70	1.70
Strehl ratios			
on-axis	0.99	0.99	1.0
off-axis	0.95	0.97	0.99

THROUGPUT : 0.89 (without filters)

(assuming 0.98 reflectivity per mirror)

PSF BOLPHOT

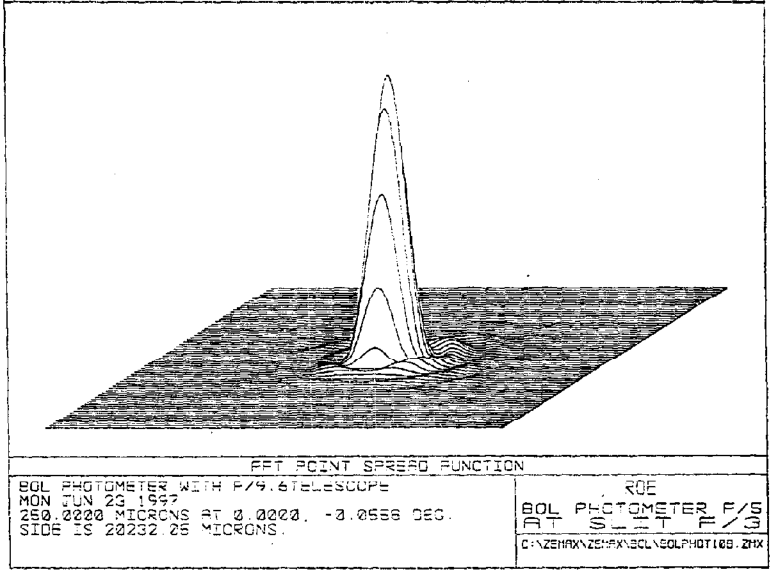
On-axis and Off-axis



FFT POINT SPREAD FUNCTION

BOL PHOTOMETER WITH F/9.6TELESCOPE
MON JUN 23 1997
250.0000 MICRONS AT 0.0000, 0.2000 DEG.
SIDE IS 20346.61 MICRONS.

ROE
BOL PHOTOMETER F/5
AT SLIT F/3
C:\ZEMAX\ZEMAX\BOL\BOLPHOT10B.ZMX

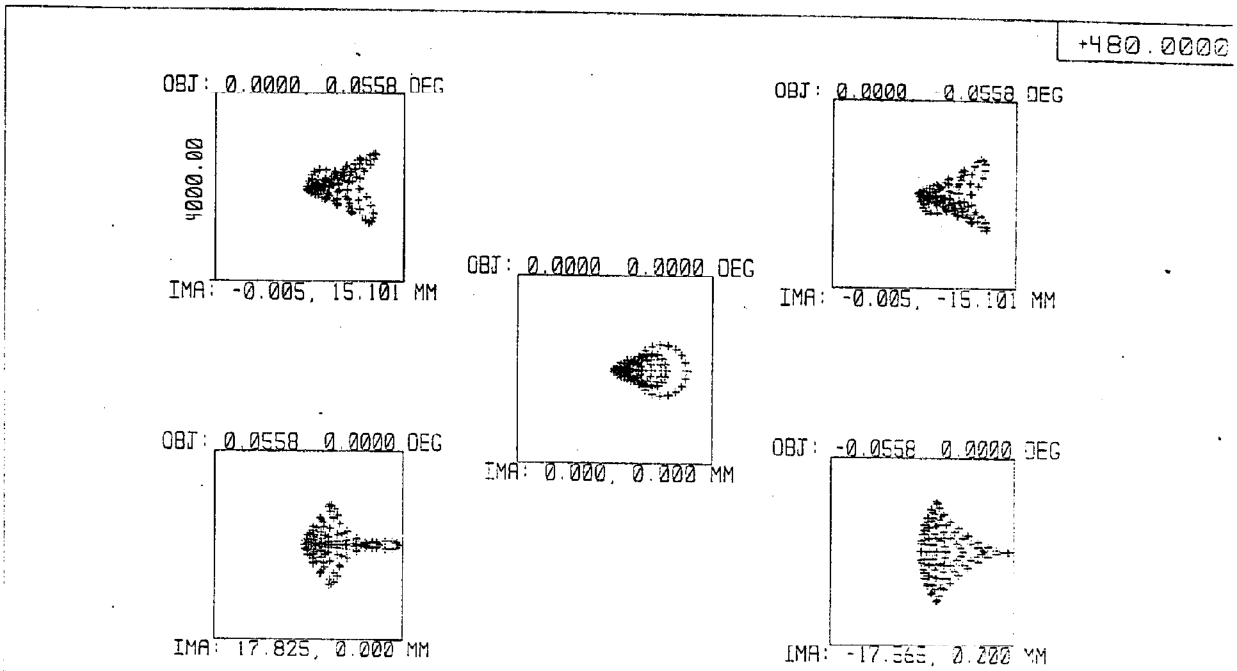


FFT POINT SPREAD FUNCTION

BOL PHOTOMETER WITH F/9.6TELESCOPE
MON JUN 23 1997
250.0000 MICRONS AT 0.0000, -0.0556 DEG.
SIDE IS 20232.25 MICRONS.

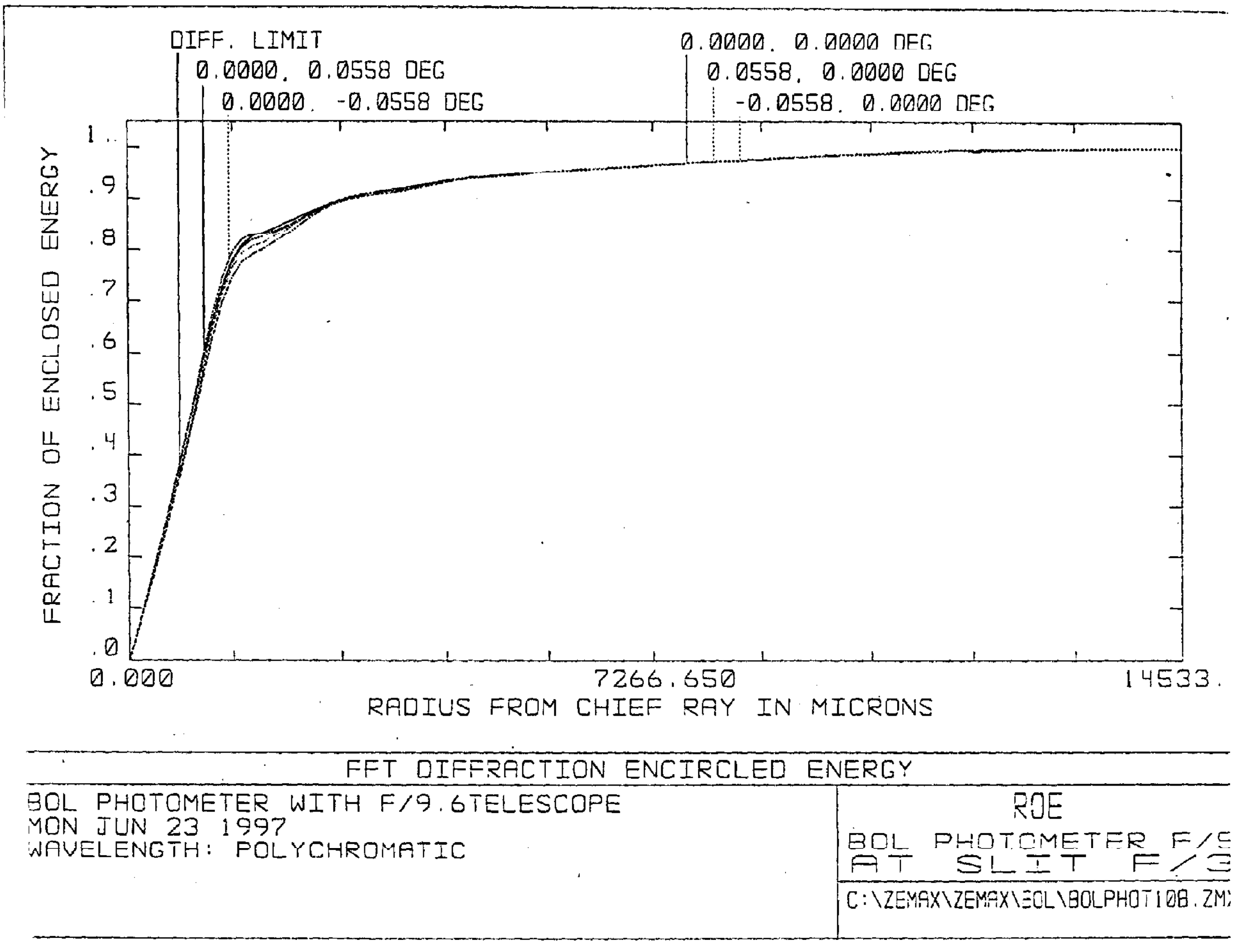
ROE
BOL PHOTOMETER F/5
AT SLIT F/3
C:\ZEMAX\ZEMAX\BOL\BOLPHOT10B.ZMX

SPOT DIAGRAMS:



```
SURFACE: IMA
                                  SPOT DIAGRAM
BOL PHOTOMETER WITH F/9.6TELESCOPE                                      RCE
MON JUN 23 1997  UNITS ARE MICRONS.                       BOL PHOTOMETER F/5
FIELD        :        1        2        3        4        5     AT SLIT F/3
RMS RADIUS   :    739.222  739.222  659.513  792.634  852.453
GEO RADIUS   :   1.5E+003 1.5E+003 1.5E+003 1.9E+003 1.9E+003  C:\ZEMAX\ZEMAX\BOL\BOLPHOT10B.ZMX
BOX WIDTH    :     4000               REFERENCE  : CHIEF RAY
```

ENCIRCLED ENERGY:



FFT DIFFRACTION ENCIRCLED ENERGY

BOL PHOTOMETER WITH F/9.6TELESCOPE
MON JUN 23 1997
WAVELENGTH: POLYCHROMATIC

ROE
BOL PHOTOMETER F/
AT SLIT F/
C:\ZEMAX\ZEMAX\BOL\BOLPHOT108.ZM

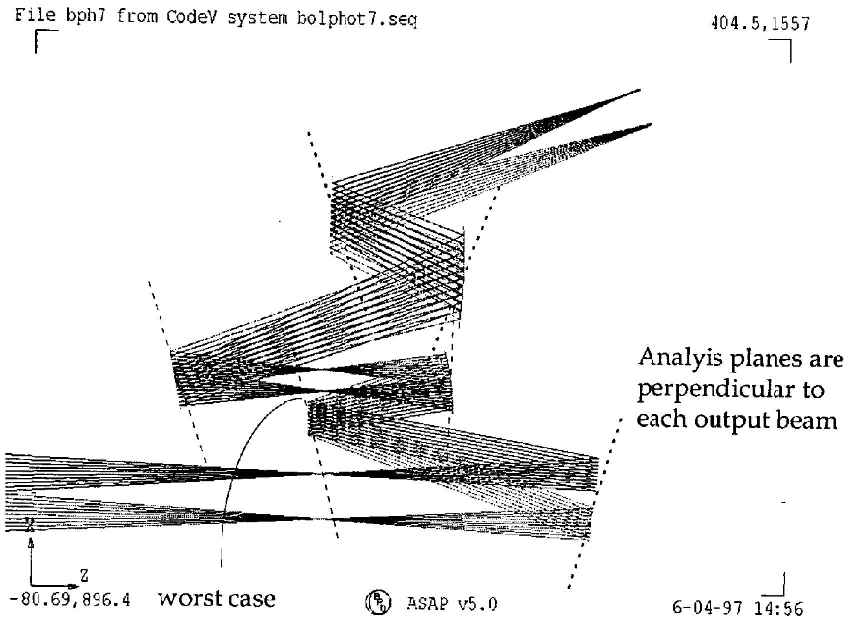
- **Cross dispersion Echelle** (tech. note 5.1), Ray-trace of geometry (CodeV™)
- **Beam patterns in PHOT-BOL design** (ASAP©, tech note 6.1)

Martin Caldwell, RAL.

Beam patterns in PHOT-BOL design. RAL/BOL/N0006.1

Summary.

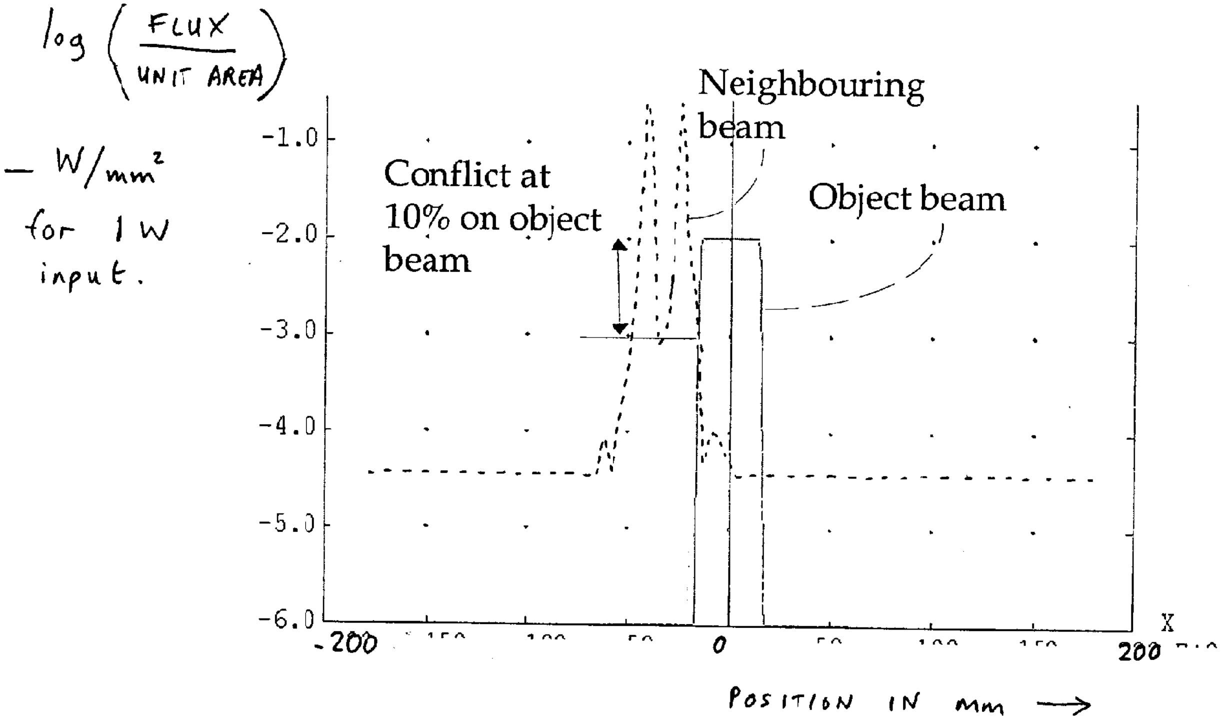
1. To show potential 'clipping' of beams, as an aid to design.
2. To compute FOV with clipping included (not done yet).



Analyis planes are perpendicular to each output beam

worst case conflict, (10% intensity level)

Example case: worst-case beam conflict, at M4



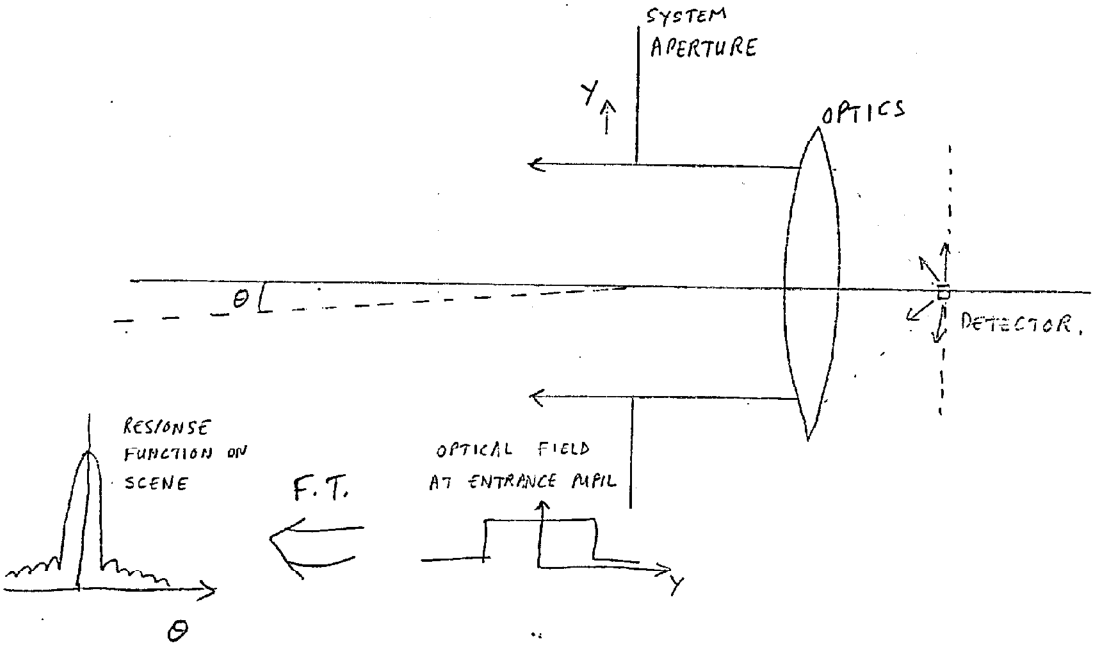


Fig. 1 'Optical' system, incoherent detector

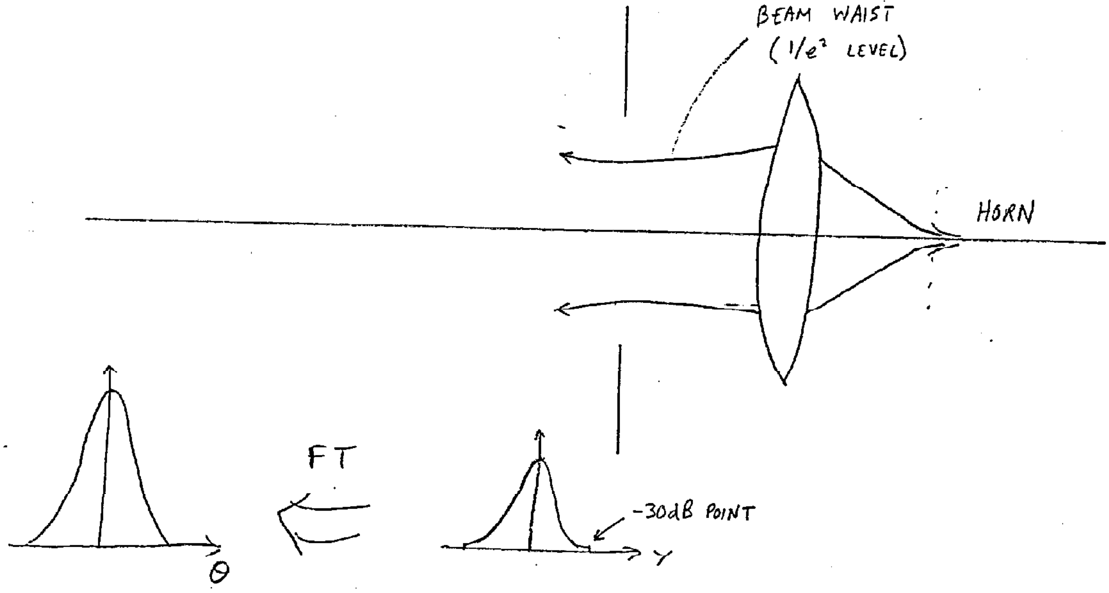


Fig. 2 mm-wave system, coherent detector

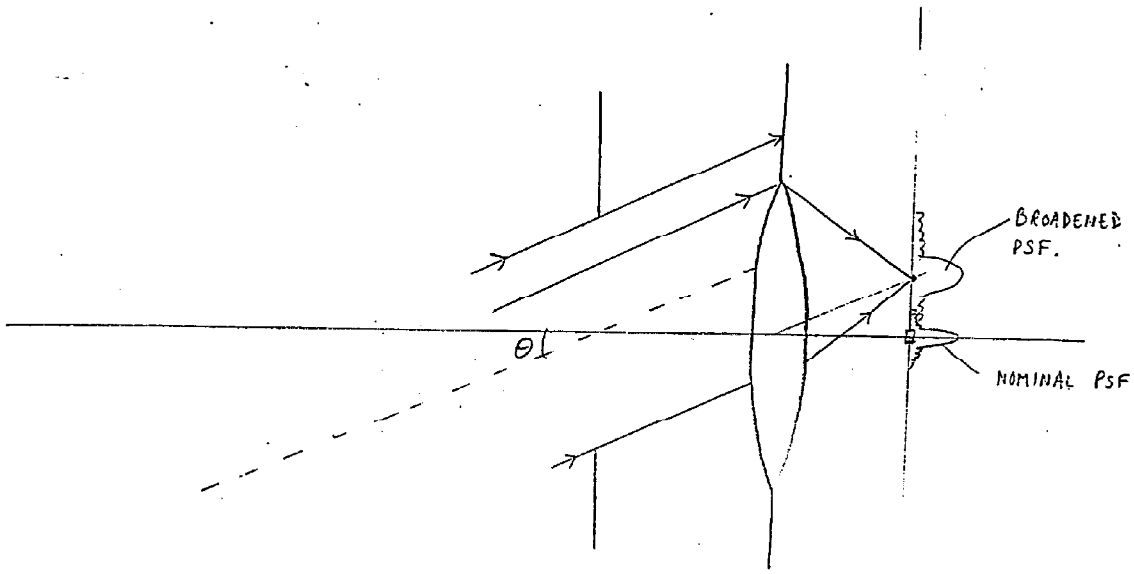


Figure 3. Ray-trace at an off-axis angle where clipping occurs.

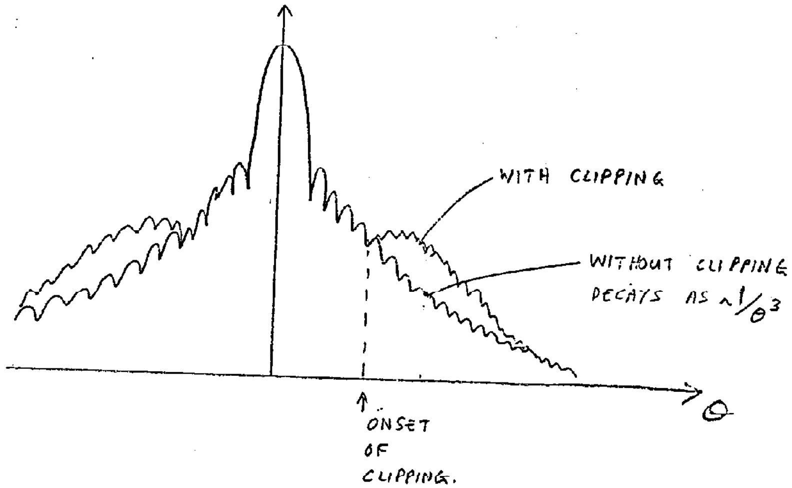
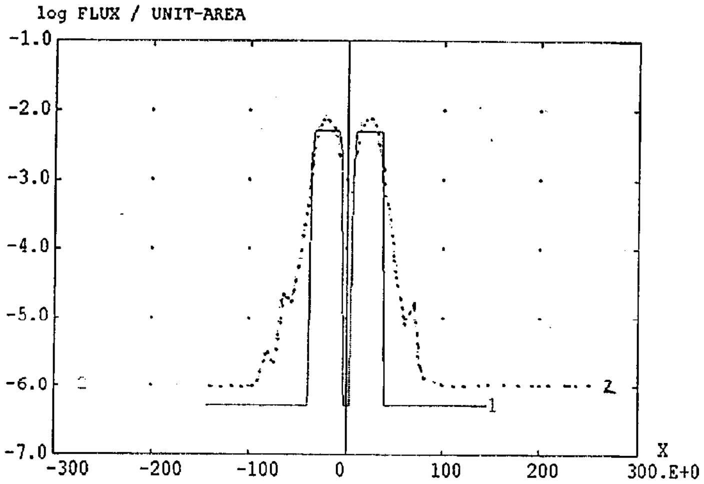


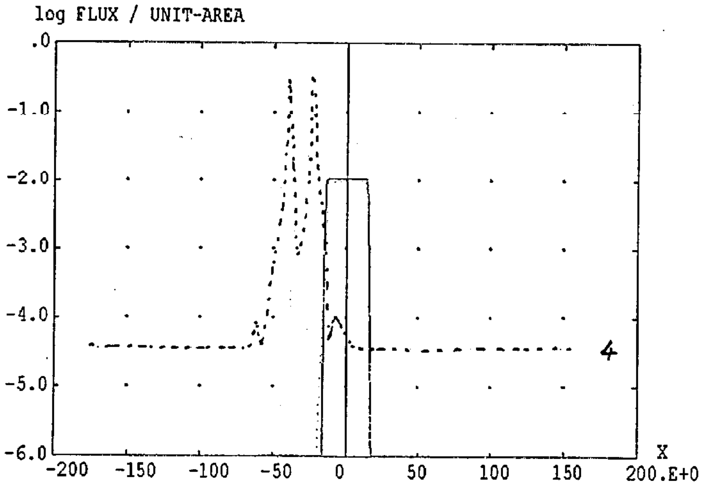
Fig. 4. PSF response function with & without clipping (vignetting).

GRAPH



ASAP v5.0 6-04-97 10:01

GRAPH



ASAP v5.0 6-04-97 10:01

4. Photometer Stray Light Analysis

5. Spectrometer Optical Design

2.3 Optical design

Figure 2 shows a perspective view of the proposed spectrometer and Table 2 summarizes the optical design. The fore-optics transforming the telescope F/9.5 beam into the F/2.2-beam required by the spectro is not yet designed, but it will probably consist of two powered mirrors following the M4 pupil-chopping mirror, plus a small folding flat just after the slit. Since the chopper will probably be shared with the photometer, the fore-optics design depends upon the photometer design.

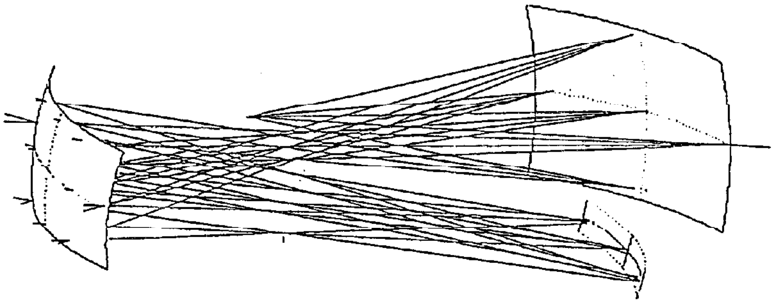


Figure 2. Perspective view of the proposed system. The slit is coplanar with the intermediate spectral image and the final image is folded below this plane. The pupil image accessible for a cold stop is just below the intermediate spectral image. Scale of the drawing is approximately 1:5, distance between grating (on the right) and camera mirror (on the left) is 500 mm.

Table 2. Summary of the optical design. All dimensions are in mm unless otherwise stated.

Surface	Radius	Notes	Size	Separation
Slit			Width: 1.9	325
Grating	-357.36	Mean gr. const.: 0.39 g/mm	220 x 160	-300
Intermediate spectrum				-200
Camera mirror	285.00	Deformation: R^4: 9.87e-10 y^2: 1.17e-5 R^4y: -2.33e-11 y^3: 6.18e-7 R^4x: 9.97e-12 x^3: 5.90e-7	230 x 110	200
Cold stop			Oval: 75 x 61	300
Detectors	-307.00	Horn spacing: 6.5 Horn ap. dia.: 4.2 Mask width: 3.4	Length: 117 (18 detectors)	

Bernie Back (Hyperfine) comments upon the feasibility of making concave gratings and terrible aspheres for FIRST BOL

- Machining is no problem
    - diamond milling machine with steps of 25 A
    - grating ruling machine with 1/100 arcsec groove straightness

- ... but “a bit like turning peanut butter and rubber”
    - Final result is not what was programmed
    - Art of precision turning is to turn so that it becomes what it should

- Key to success: A valid measurement scheme
    - Single components: Mechanical co-ordinate measuring machine, ¼ μm
    - Assembled system: 10 μm interferometry

- Gratings: Ruling or machining?
    - Usually prefer ruling, but no variable blaze
    - Machining probably OK: any blaze variation
    - ISO LWS grating was machined (Schmidt plate)
    - No machined spherical grating yet.
    - Know how to do it, but need some trial runs
    - 25-50% more expensive

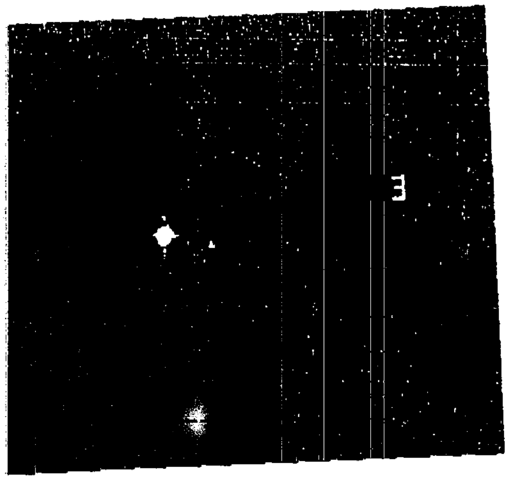
4-5 ?

SOFIA grating (?): ~~4-8~~" Al light wt. 2 l/mm 74° blaze:

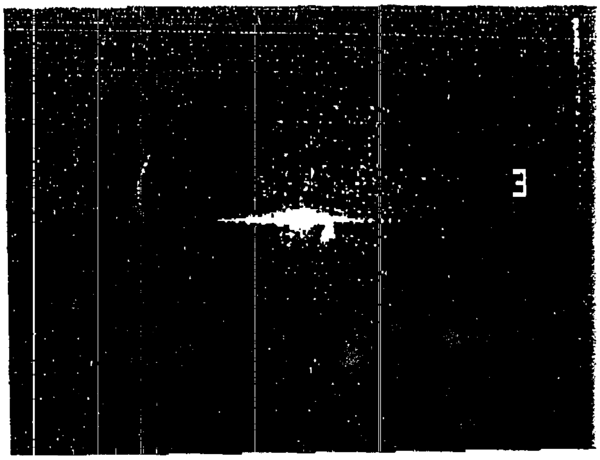
high-contrast fringes in visible light

Concave grating, 5 l/mm, 97% reflectivity in first order at 10.7 μm

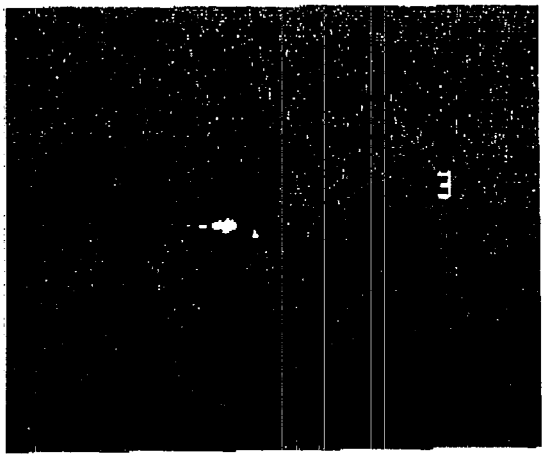
FROM B BACH HYPERMNE



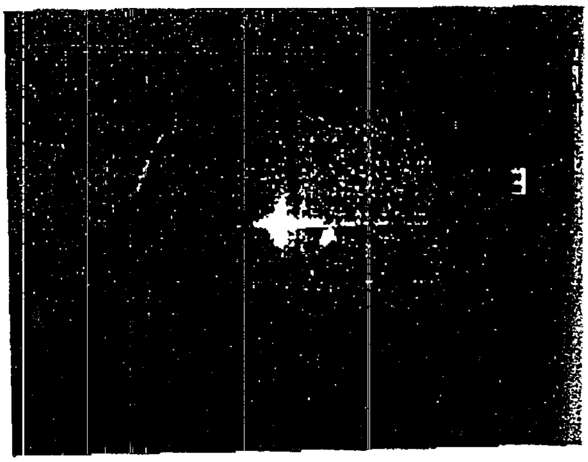
16° blaze angle
650nm



74° blaze angle
650nm



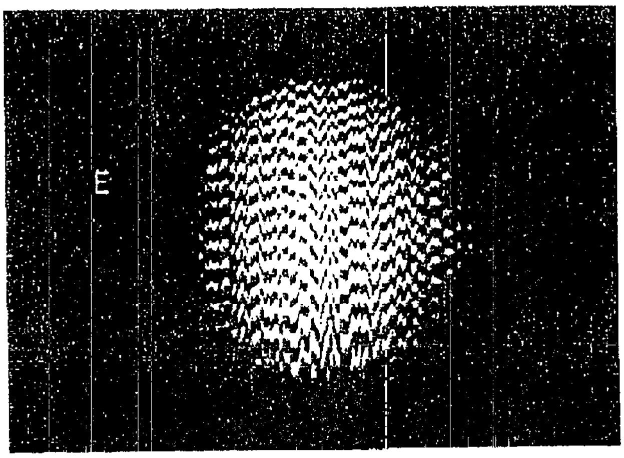
74° blaze angle



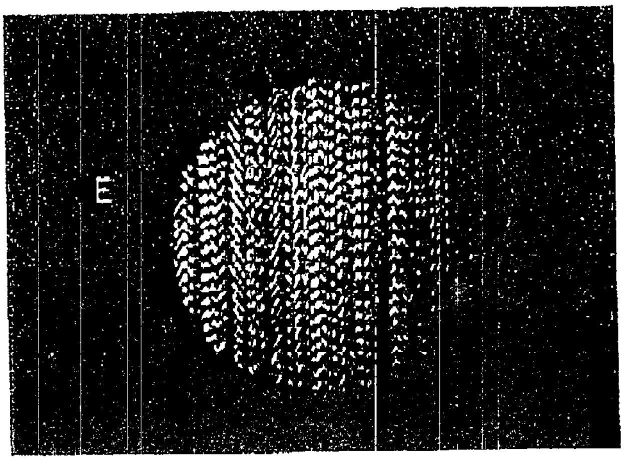
16° blaze angle
650nm space

Image of optics on interferometer setup.
— central spot •
ghost reflection → •
is encircled in circle.

ROM J. BACH . HYPERFINE

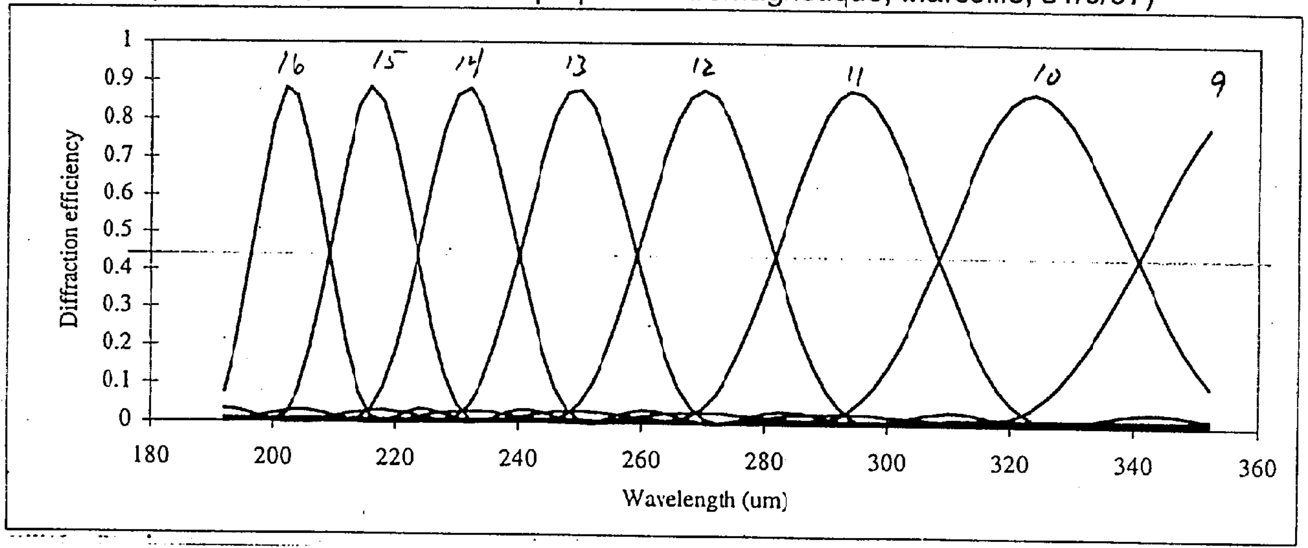


Line spacing
650um
16° blaze L
565 order
@ .6328



Line spacing
650um
74° blaze an
2000 th order
@ .6328

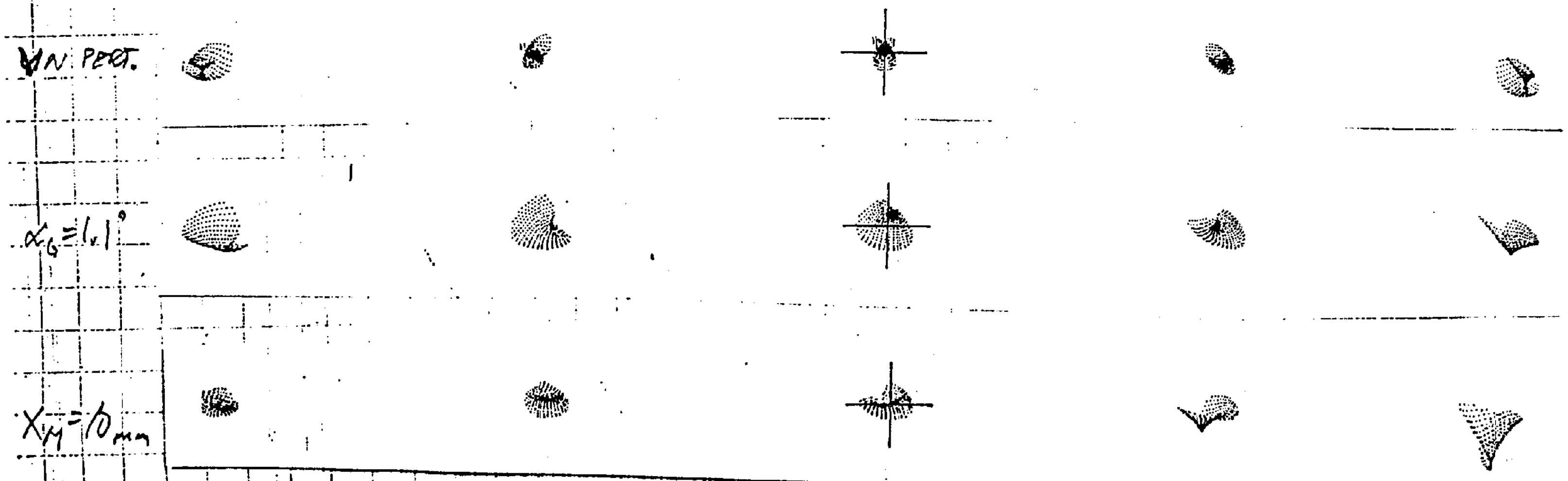
Average (s,p) efficiency for orders 9 to 16, d=2.531mm, blaze=40.08deg, alpha=45deg
(M. Neviere, Laboratoire d'Optique Electromagnetique, Marseille, 31/5/97)

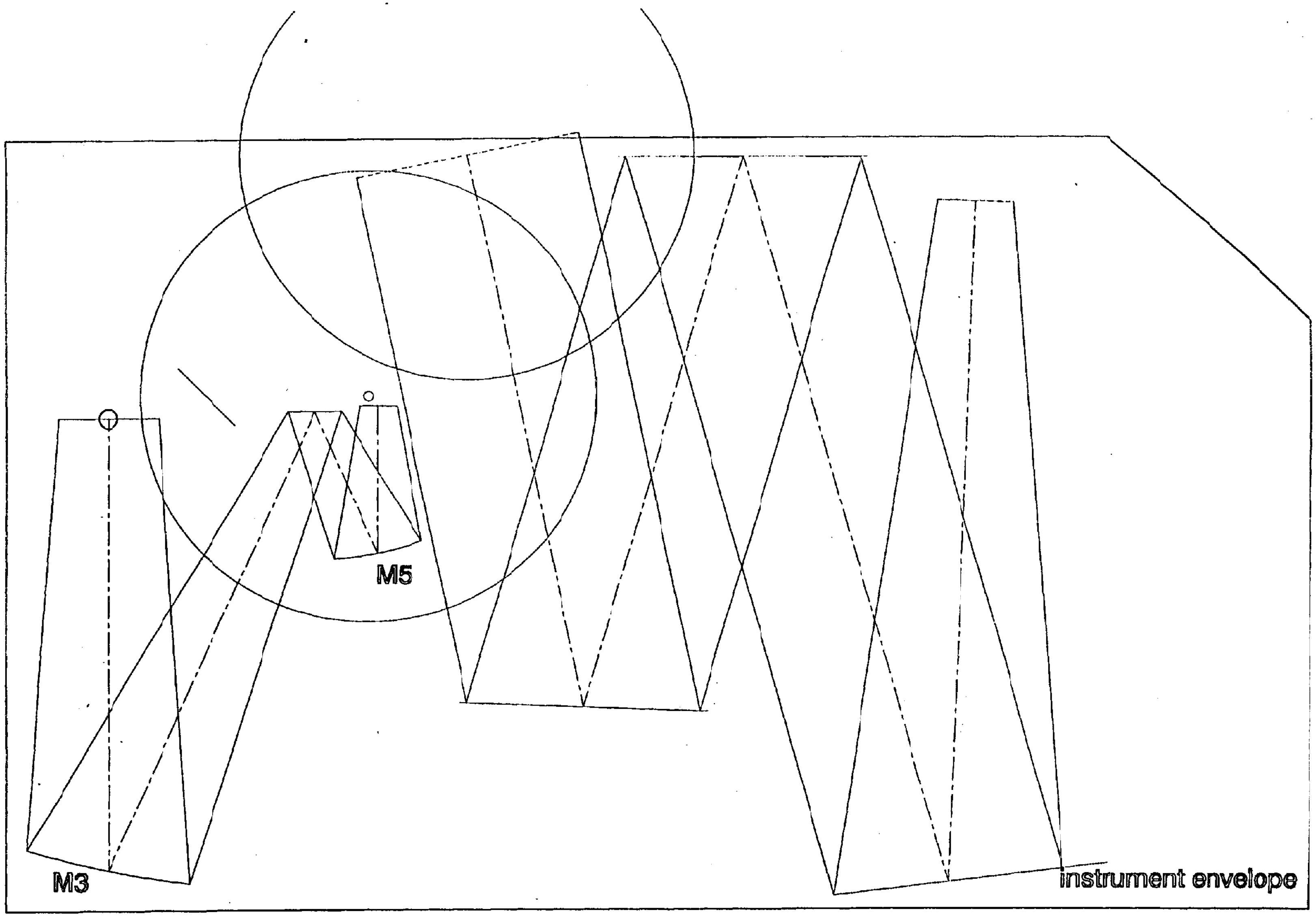


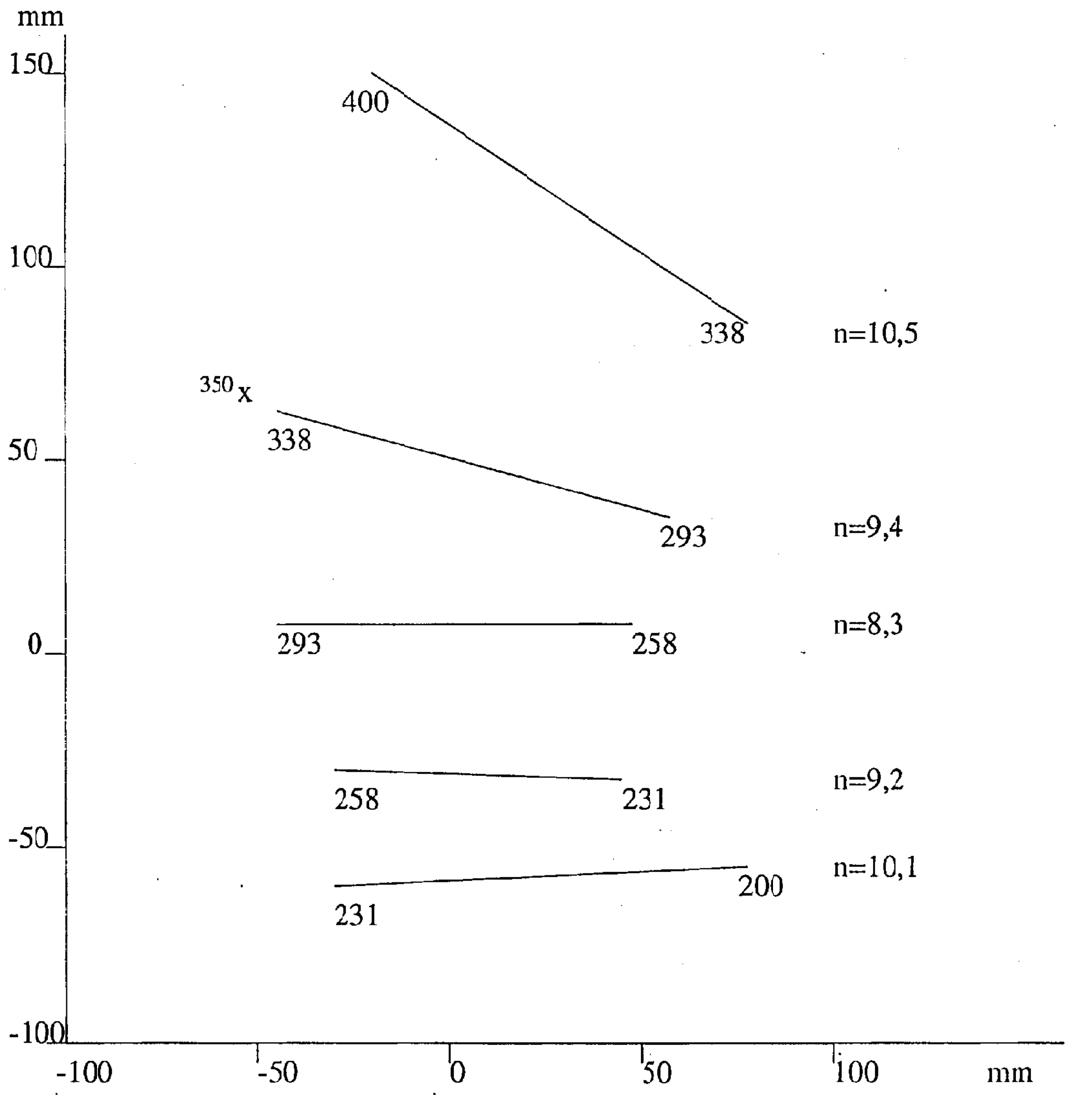
Summary

Ray ab. < 3mm (OPD < 0.5λ @ 325μm)

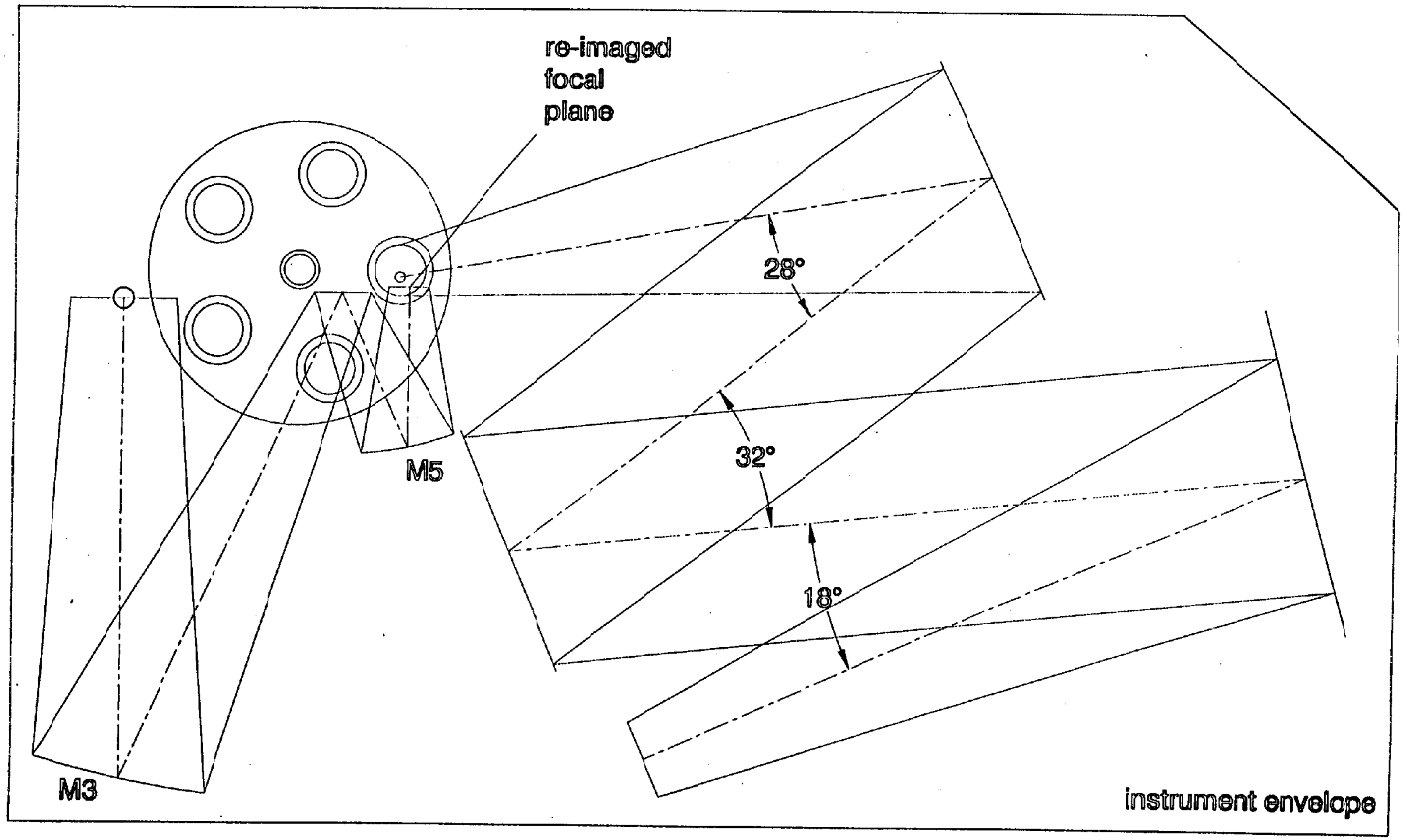
	TILT		DECENTER	
	α (deg)	β (deg)	X (mm)	Y (mm)
Grating	1.1 (1.1)	0.8 (0.7)	1.2 (2.0)	5.8 (4.5)
Mirror	4.0 (3.1)	5.1 (7.0)	9.9 (7.5)	5.2 (8.2)




M5
M3
instrument envelope



Positions of orders and wavelengths in focal plane


re-imaged
focal
plane
28°
32°
18°
M5
M3
instrument envelope

BOL Optics Workshop RAL 25-28 June 1997

Affect of Diffraction at a Slit

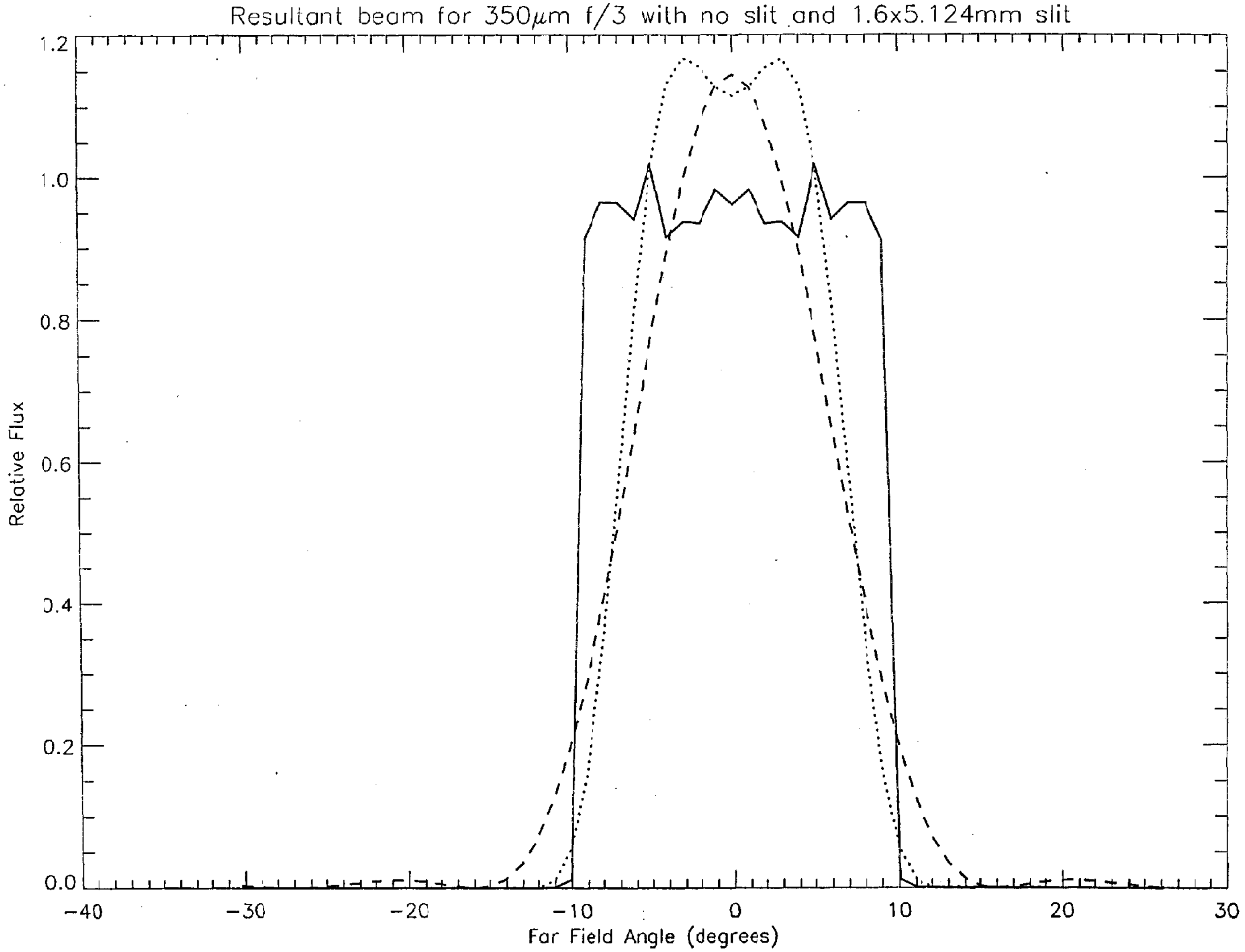
B. Swinyard

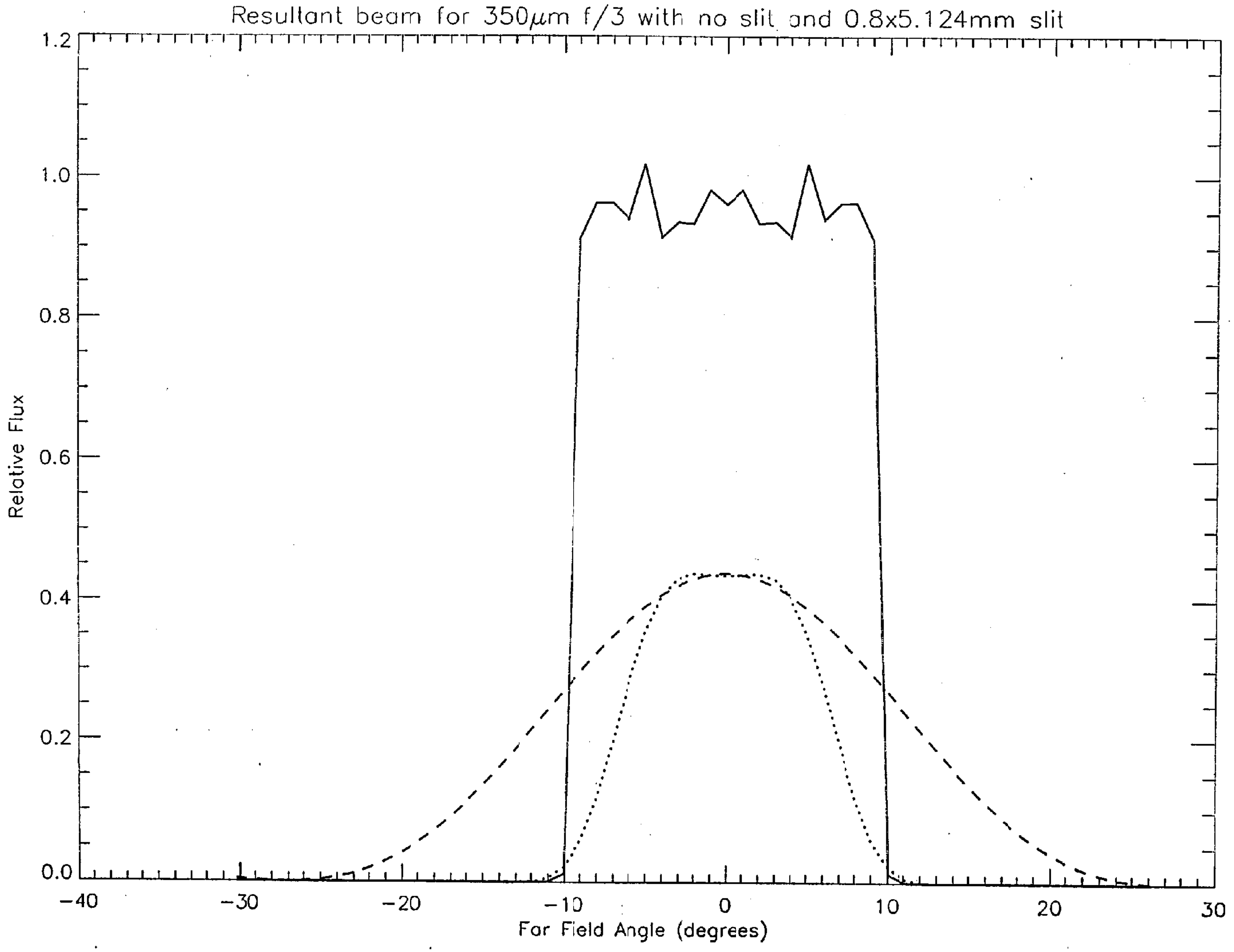
1. The story so far....

- **At the last meeting I presented a study showing that diffraction at an entrance slit is going to be important in determining the throughput of the spectrometer and the achievable resolving power.**

- **However that study was only done in relative terms as a way of studying the grating response function.**

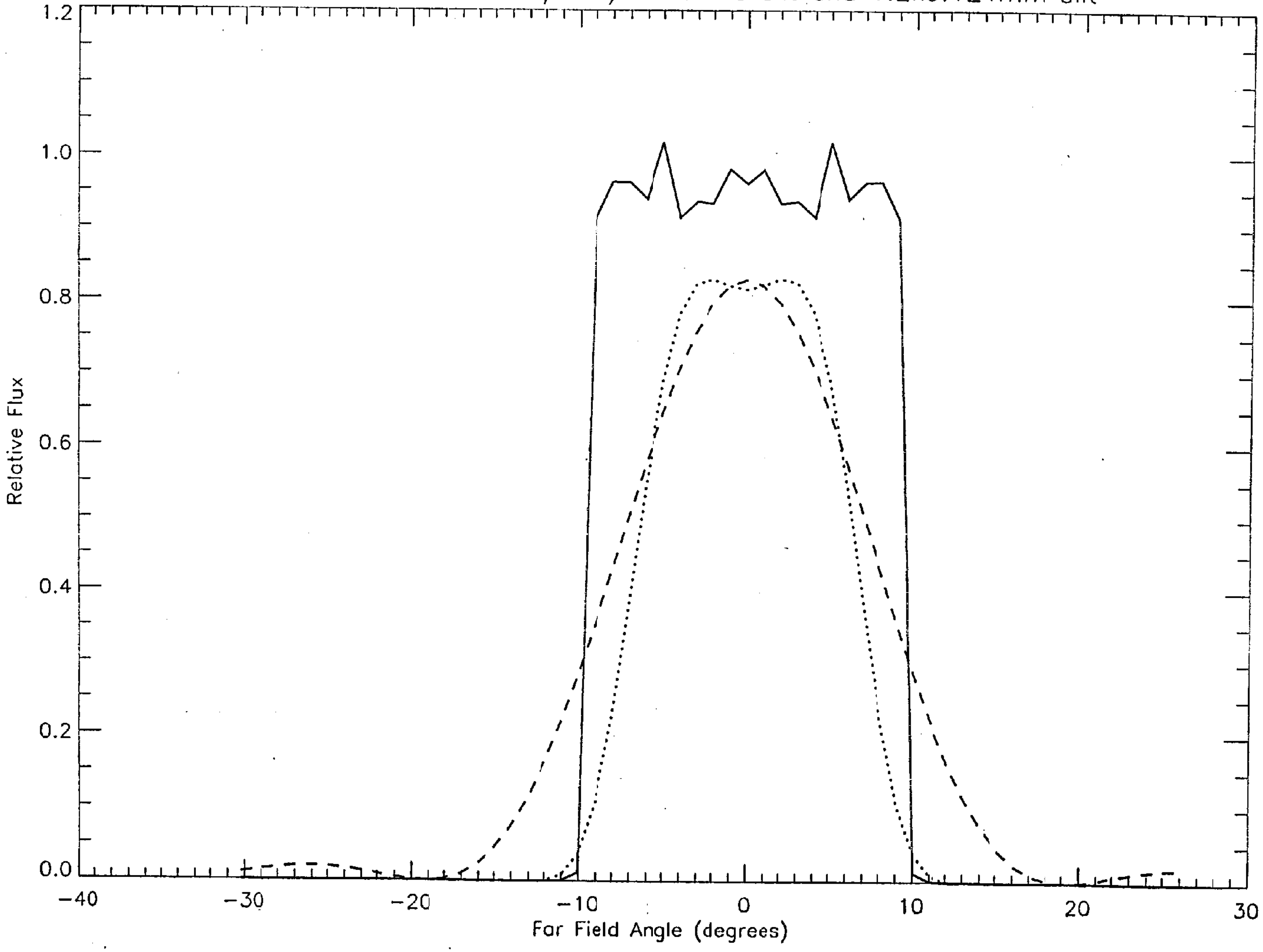
- **I have now "calibrated" the model by using the digital analogy of Parseval's theorem.......**

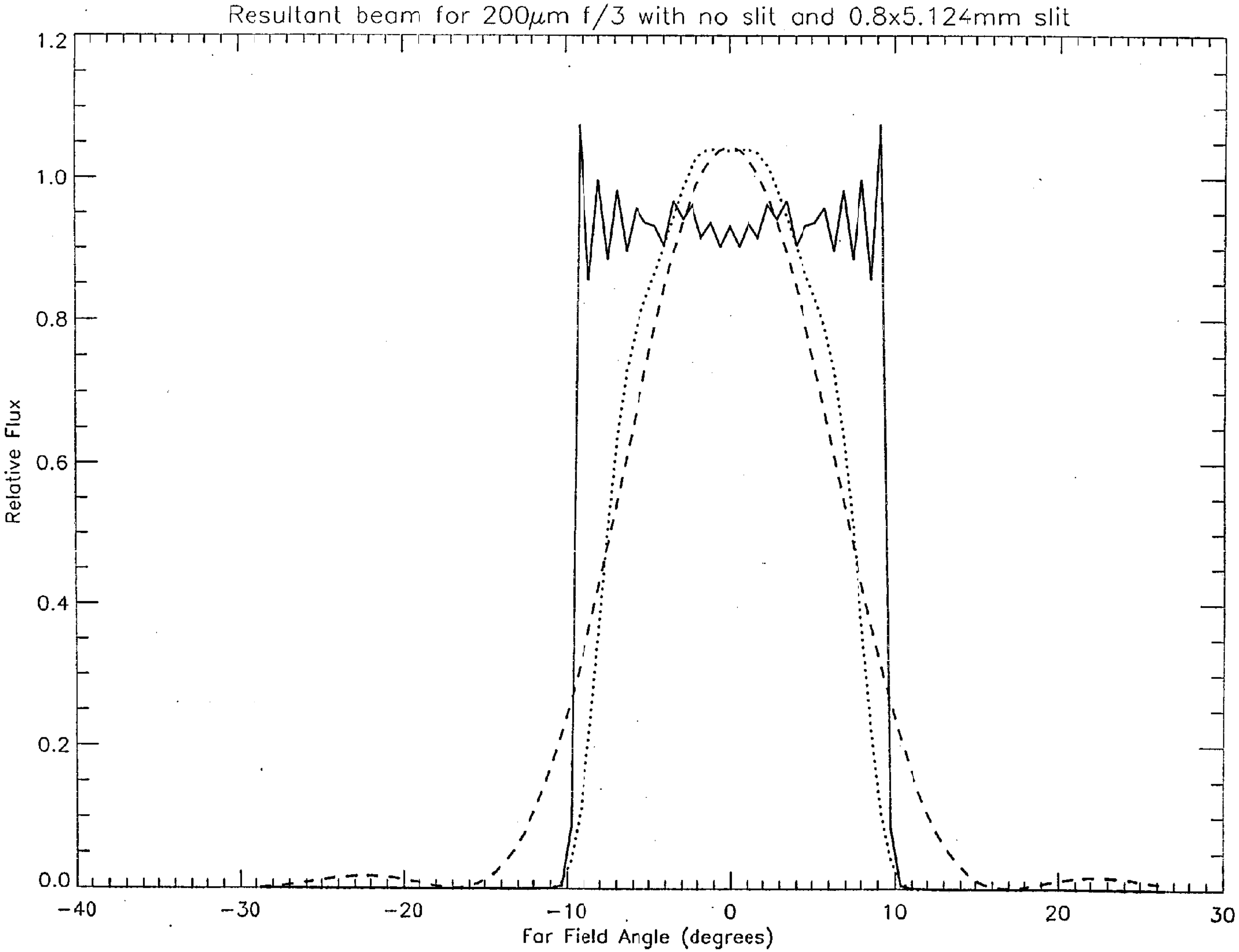

Resultant beam for 350μm f/3 with no slit and 1.6x5.124mm slit
Relative Flux
0.0
0.2
0.4
0.6
0.8
1.0
1.2
−40
−30
−20
−10
0
10
20
30
Far Field Angle (degrees)



Resultant beam for 350μm f/3 with no slit and 0.8x5.124mm slit

Resultant beam for 350μm f/3 with no slit and 1.2x5.124mm slit




Resultant beam for 200μm f/3 with no slit and 0.8x5.124mm slit

BOL Optics Workshop RAL 25-28 June 1997

Affect of Diffraction at a Slit

B. Swinyard

2. Throughput versus slit size.

Wavelength	Condition	0.8 mm Slit	1.2 mm Slit	1.6 mm Slit
200	No Coll.	0.802	0.878	0.897
200	f/3 Coll.	0.623	0.761	0.786
350	No Coll.	0.564	0.737	0.830
350	f/3 Coll.	0.310	0.533	0.685

BOL Optics Workshop RAL 25-28 June 1997

Affect of Diffraction at a Slit

B. Swinyard

3. Conclusions

- A slit is not a great idea!
- Better have a slit-less spectrometer with a defining aperture set at the longest wavelength.
- This will reduce the imaging and spectroscopic ability of the instrument for extended sources.
- It makes Paolo's long slit spectrometer unfeasible

6. Cross-disperser Possibilities

BOL Optics Workshop RAL 25-28 June 1997

Cross Dispersing Echelle Grating Spectrometer

B. Swinyard

1. Overview

- **The present design(s) for the grating spectrometer use a linear array of detectors with order sorting filters to cover the waveband.**
- **This has some disadvantages:**
    1. **Detectors have a finite size, therefore to get the detectors in requires a long focal length on the re-imaging optics and - necessarily - a long focal plane.**
    2. **If we want more detectors > longer focal plane.**
    3. **The grating must be scanned a reasonably long way.**
    4. **Order sorting filters are required *on every detector* to block the higher and lower orders from the grating.**
- **At the FIRSU conference we saw the need for greater sensitivity in the BOL spectroscopic channel. We can't do much about the detector NEP's (except make them worse!), so -**

Put More Detectors IN!

BOL

BOL Optics Workshop RAL 25-28 June 1997

Cross Dispersing Echelle Grating Spectrometer

B. Swinyard

2. Getting More Detectors In

- **If we assume that a detector cannot be <5 mm diameter (more of this later) then in order to fit 20 detectors we will need ~100 mm minimum distance in the focal plane.**
- **The focal length required of the collimator if these are to be spaced at 0.5° intervals (about the minimum to be useful in covering the orders) will be of the order of 500-600 mm.**
- **To get more detectors in will require either that the detectors are smaller, or that the focal plane grows longer.**
- **This is not necessarily a very efficient way of doing things as there are only certain "slots" in the diffraction angle space that are useful for wavelength coverage.**
- **Also as the focal plane grows one is of necessity working further from the blaze angle thus reducing the efficiency.**

> Spread the diffraction orders in the orthogonal direction -
> Use a cross dispersion grating

Cross Dispersing Echelle Grating Spectrometer

B. Swinyard

3. A "Standard" Echelle

- **In order to make a fair comparison between a cross dispersion system and a "standard" grating spectrometer I have invented a simple spectrometer with a plane grating and a Schmidt camera collection optics.**

- **The parameters of the system are as follows:**

Groove Spacing	**1767.67 μm**
Incident Angle	**-45°**
Diffraction angle range	**28 to 37°**
Focal length/ratio of collector	**300mm; f/3**
Number of detectors	**10**
Spacing of detectors	**1° (≅ 5mm)**
Grating Scan Range	**-3 to +3.5° for full λ coverage**

- **Note that here the number of detectors is restricted to 10 because of the relatively short focal length. It is assumed that the corrector plate will be added to the grating a la LWS.**

- **The length of the focal plane is also relatively short compared to other designs (~50 mm)**

Cross Dispersing Echelle Grating Spectrometer

B. Swinyard

4. Standard Echelle Wavelength Coverage

- The wavelength coverage of the ten detectors is as follows:

Detector Order	Detector Angle w.r.t. to 33°	Wavelength at grating angle +3.5°	Wavelength at grating angle +1°	Wavelength at grating angle -3°
10	1	201.5	213.8	231.8
10	-4	214.7	226.7	245.0
9	2	220.8	234.6	255.8
9	-3	235.7	249.1	269.6
8	3	245.0	260.6	284.6
8	-2	261.9	277.0	300.2
7	4	276.0	294.0	321.5
7	-1	295.5	313.0	339.6
6	5	317.4	338.4	370.7
6	0	340.3	360.8	392.1

Cross Dispersing Echelle Grating Spectrometer

B. Swinyard

5. Number of Grating Steps

- **The number of grating steps required is:**

$$N_{steps} = FIX\left(\frac{4x500x(231.8-213.8)}{201}+0.5\right) = 180 \qquad (1)$$

in order to give *contiguous* coverage from 214 μm to 392 μm.

- **To cover the *full* wavelength range from 201 μm to 392 μm requires:**

$$N_{steps} = FIX\left(\frac{4x500x(231.8-201.5)}{201}+0.5\right) = 302 \qquad (2)$$

Cross Dispersing Echelle Grating Spectrometer

B. Swinyard

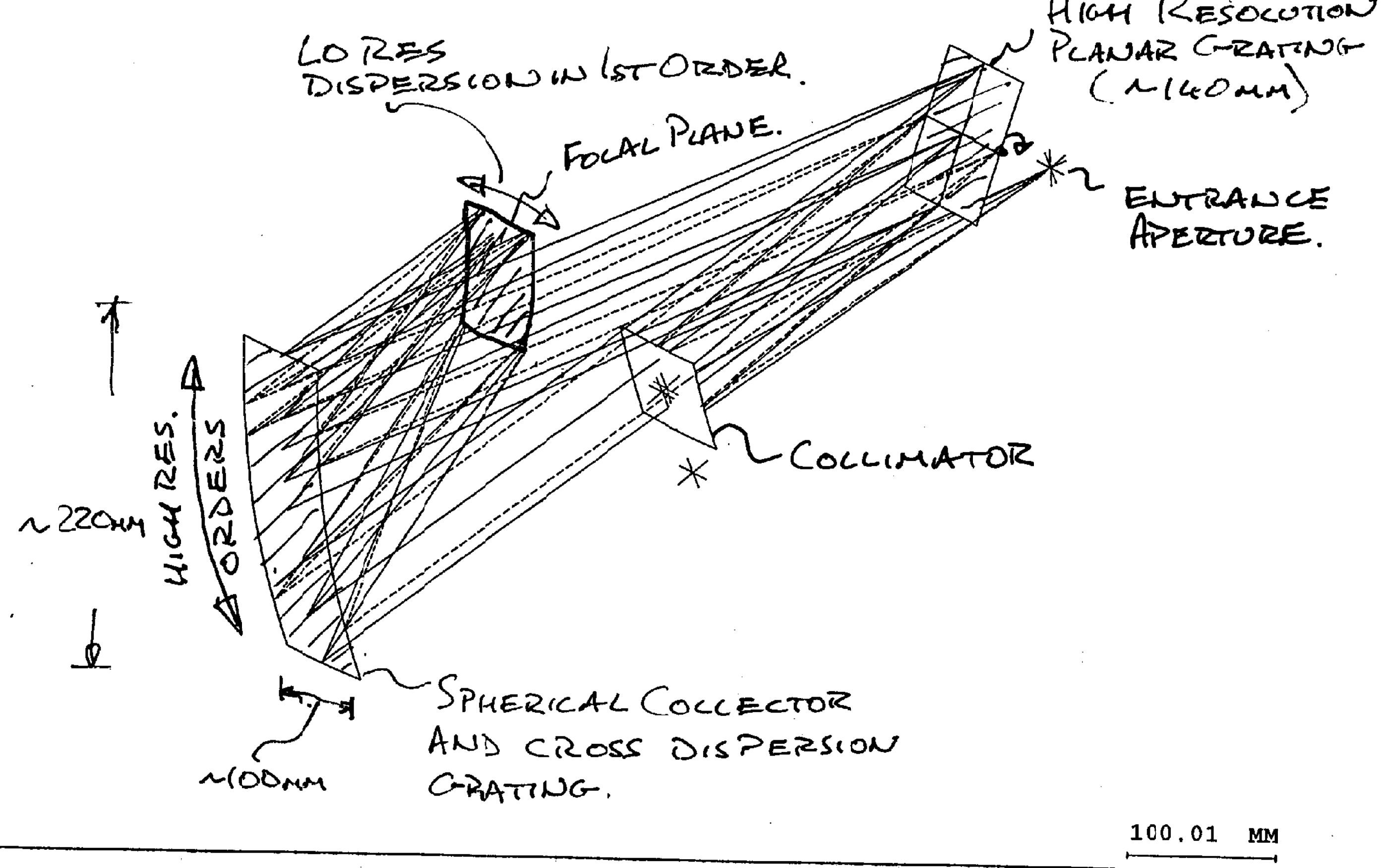
6. Cross Dispersion Echelle Spectrometer

- **If the spherical collection mirror in the standard design has grooves ruled on it orthogonal to those on the "high resolution" grating, the light in the different orders can be dispersed in two dimensions.**

- **The parameters for the cross dispersion grating could be as follows:**

Groove Spacing	**1000 μm**
Incident Angle	**5°**
Diffraction angle range	**16 to 29° - only first order used**
Radius of curvature/aperture	**600mm; ~100mm**
Number of detectors	**~62**
Spacing of detectors	**1° (≅ 5mm)**
High Resolution Grating Scan Range	**-0.3° to +0.3° for full λ coverage**

10:33:27 MEC



cros2

mec 24-JUN-97

BOL Optics Workshop RAL 25-28 June 1997

Cross Dispersing Echelle Grating Spectrometer

B. Swinyard

7. Wavelength Coverage

Diffraction Angle (deg)	10th Order	9th Order	8th Order	7th Order	6th Order
25	199.708	221.898	249.635	285.298	332.847
26	202.493	224.992	253.116	289.276	337.488
27	205.254	228.060	256.568	293.220	342.090
28	207.991	231.101	259.989	297.130	346.651
29	210.702	234.114	263.378	301.003	351.170
30	213.388	237.097	266.734	304.839	355.646
31	216.046	240.051	270.057	308.637	360.076
32	218.676	242.974	273.346	312.395	364.461
33	221.279	245.865	276.598	316.112	368.798
34	*223.851*	248.724	279.814	319.788	373.086
35	*226.394*	251.549	282.993	323.420	377.323
36	*228.906*	*254.340*	*286.132*	327.008	381.510
37	*231.386*	*257.096*	*289.232*	330.551	385.643
38	*233.834*	*259.815*	*292.292*	334.048	389.723
39	*236.248*	*262.498*	*295.310*	*337.497*	393.747
40	*238.629*	*265.143*	*298.286*	*340.898*	397.715
Detectors	9	11	12	14	16

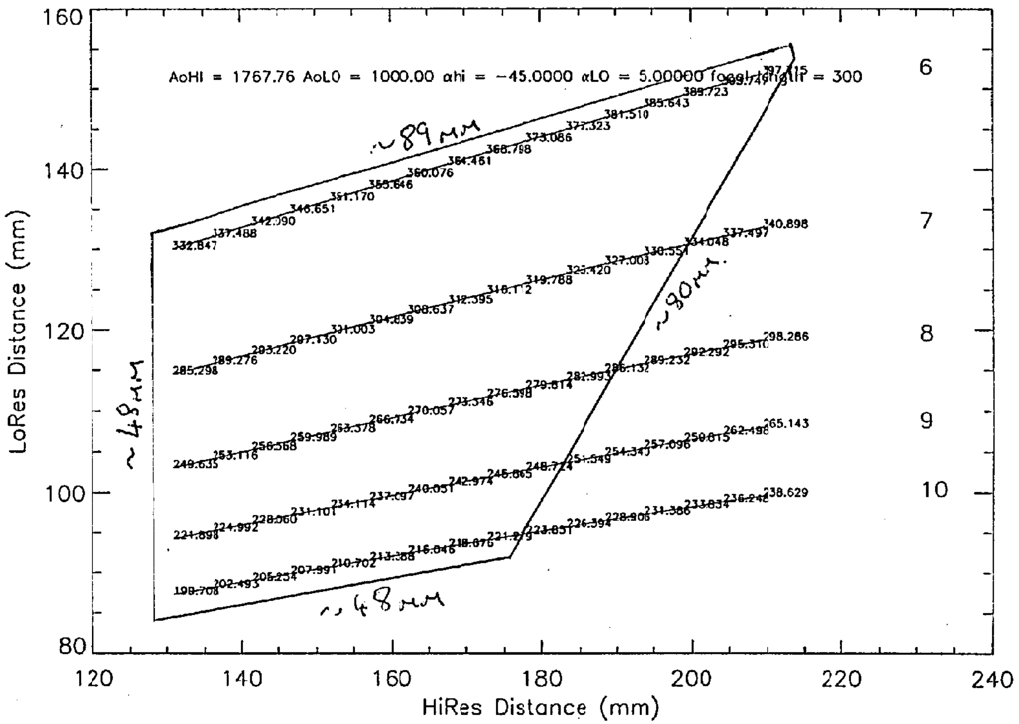
Total number Detectors 62

BOL Optics Workshop RAL 25-28 June 1997

Cross Dispersing Echelle Grating Spectrometer

B. Swinyard

8. Size of Focal Plane



Cross Dispersing Echelle Grating Spectrometer

B. Swinyard

9. Improvement in observing efficiency

- **To cover the *full* wavelength range from 199 μm to 397 μm requires:**

$$N_{steps} = FIX\left(\frac{4x500x(202.493-199.708)}{199.708}+0.5\right) = 28 \qquad (3)$$

- **Compare this to (1) 180 and (2) 302 steps.**
- **IF we assume that the cross dispersion system has 50% of the throughput of the standard system, then the improvement in collection efficiency for an end to end spectrum is:**

$$\frac{302}{28 \times 4} = 2.7$$

or

$$\frac{180}{28 \times 4} = 1.6$$

to cover the minimum contiguous wavelength range.

10. More realistic assumptions.....

- **If we assume the average transmission of the blocking filters is actually 70% and that the cross dispersion grating efficiency gets close to 60% then the increase in efficiency is:**

$$\frac{302}{28 \text{ x } (70/60)^2} = 7.9$$

or

$$\frac{180}{28 \text{ x } (70/60)^2} = 4.7$$

to cover the minimum contiguous wavelength range.

BOL

BOL Optics Workshop RAL 25-28 June 1997

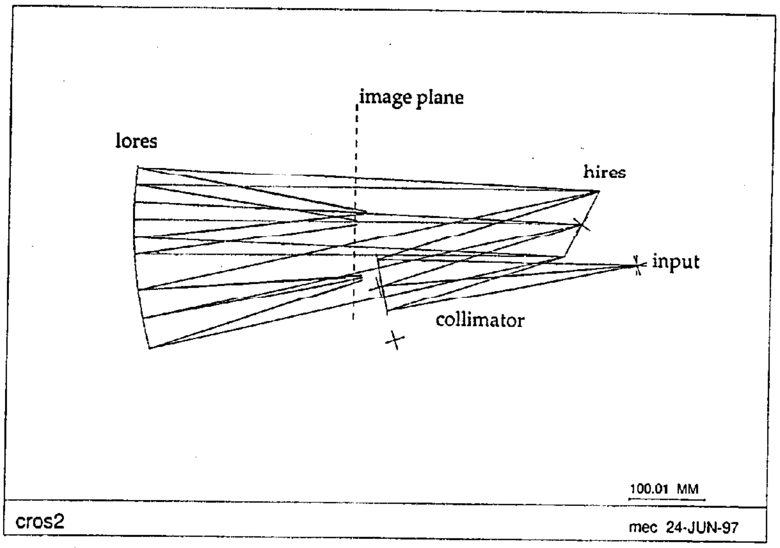
Cross Dispersing Echelle Grating Spectrometer

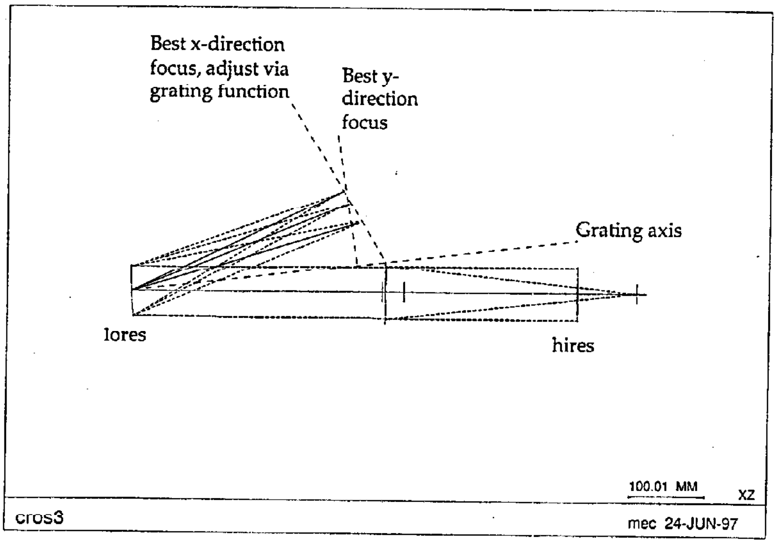
B. Swinyard

11. Conclusions and Problems

- **Conclusions:**
  1. **The cross dispersion echelle offers a factor of between 3 and 8 in observing efficiency for coverage of the band between 200 μm and 400 μm.**
  2. **A Schmidt camera arrangement would appear to be feasible with a reasonable size focal plane and around 60 detectors.**
- **Problems:**
  1. **Straylight control/suppression of unwanted orders must be carefully studied.**
  2. **Can such a grating be built?**
  3. **What IS the throughput of two orthogonal gratings at these wavelengths?**
  4. **Will it fit in the box?**
  5. **Can we have this many detectors (61+37+19+62=179)?**
- **Further improvements are possible if the detector size can be reduced - especially the dead area around the pixel and if the focal ratio requirement of the final optics can be relaxed.**

Cross dispersion Echelle (BOL/RAL/N0005.1)





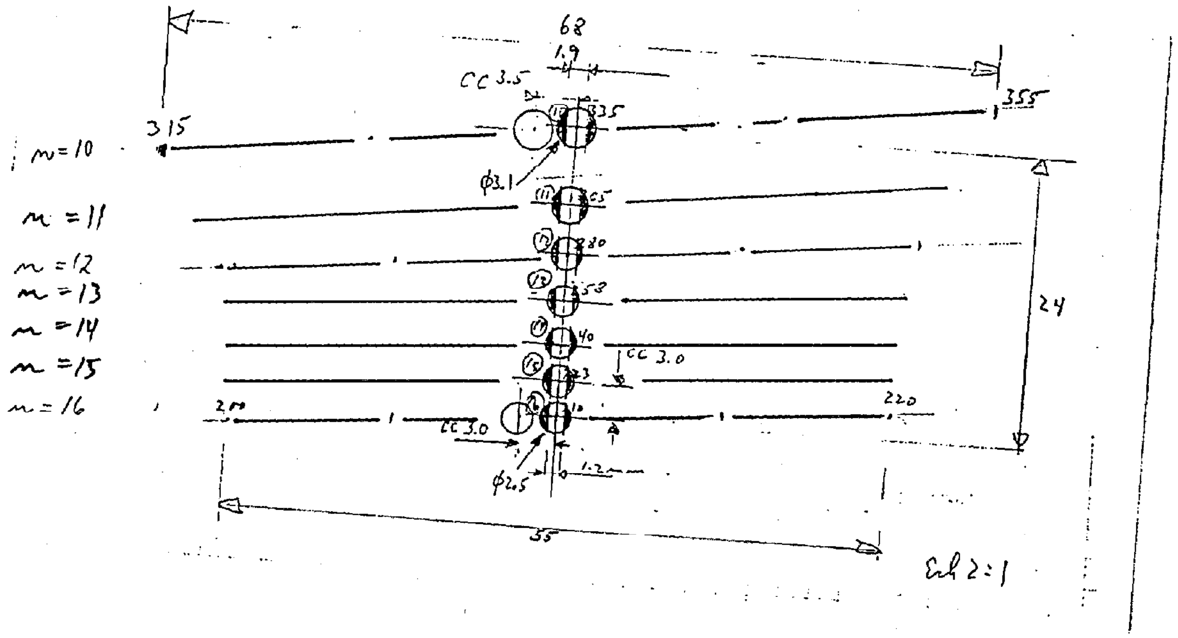
CLRC

MIRS grating (mid infra-red spectrometer, Onaka)

1. Rowland circle configuration.
2. Image plane fixed at cross-dispersion focus position
3. Grating function (pitch modulation) used to deform the along-dispersion focus from Rowland circle towards image plane of 2. (correcting astigmatism).
4. Residual aberration depends on wavelength range of design.

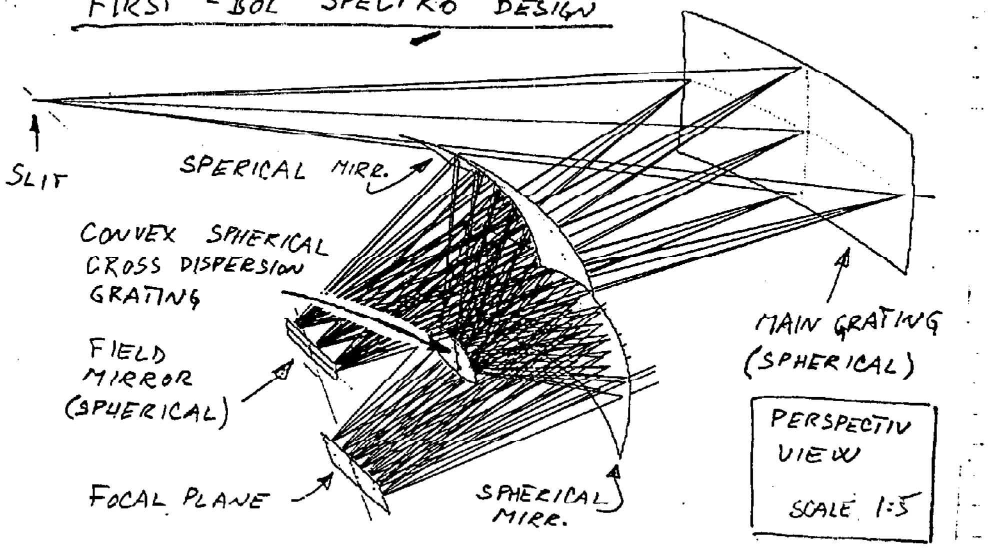
In our case, with Wadsworth mount, to date we have minimised the effect of astigmatism only by optimising the detector plane position. This gives spot diameter ≈ 2mm, improvement obtainable with grating function is TBD.

X-dispersed focal plane

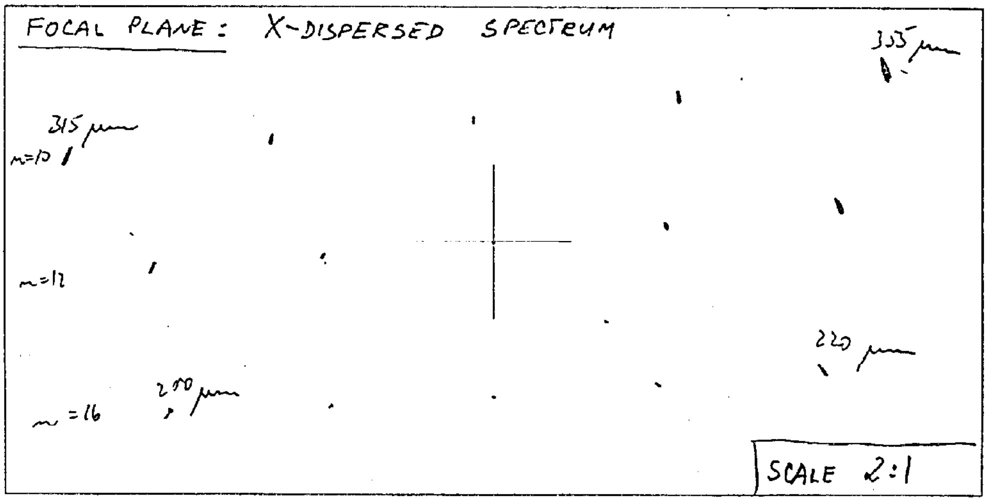


m		ΔY	$\bar{\lambda}$	w_{spat} Dair @ F/3.8		w_{spec} Dair @ F/2.3	Alt I: Max det density CC	l_{spec}	Ndet	cc/w_{spec}	Alt II: Equal CC CC = 3.15 Ndet	cc/w_{spec}	R $= \frac{D_B}{2.4\lambda}$	$\frac{\sin\alpha + \sin\beta}{\cos\beta}$
10		0	335	3.1		1.9	3.5	68	19	1.8	19	1.8		
11	6.5	6.5	305	2.8		1.7	3.2	62	19	1.9	18	2.1	309	
12	4	10.5	280	2.6		1.6	3.0	57.5	19	1.9	16	2.2	339	
13	4	14.5	258	2.4	2.5	1.4	2.9	56	19	2.1	16	2.5	369	
14	3.5	18	240	2.2	2.5	1.3	2.9	55	19	2.2	16	2.7	401	
15	3	21	223	2.07	2.5	1.3	2.9	55	19	2.2	16	2.7	431	
16	3	24	210	1.9	2.5	1.2	2.9	55	19	2.4	16	2.9	464	
									133		117	Avg: 2.4	492	

FIRST-BOL SPECTRO DESIGN



FOCAL PLANE: X-DISPERSED SPECTRUM



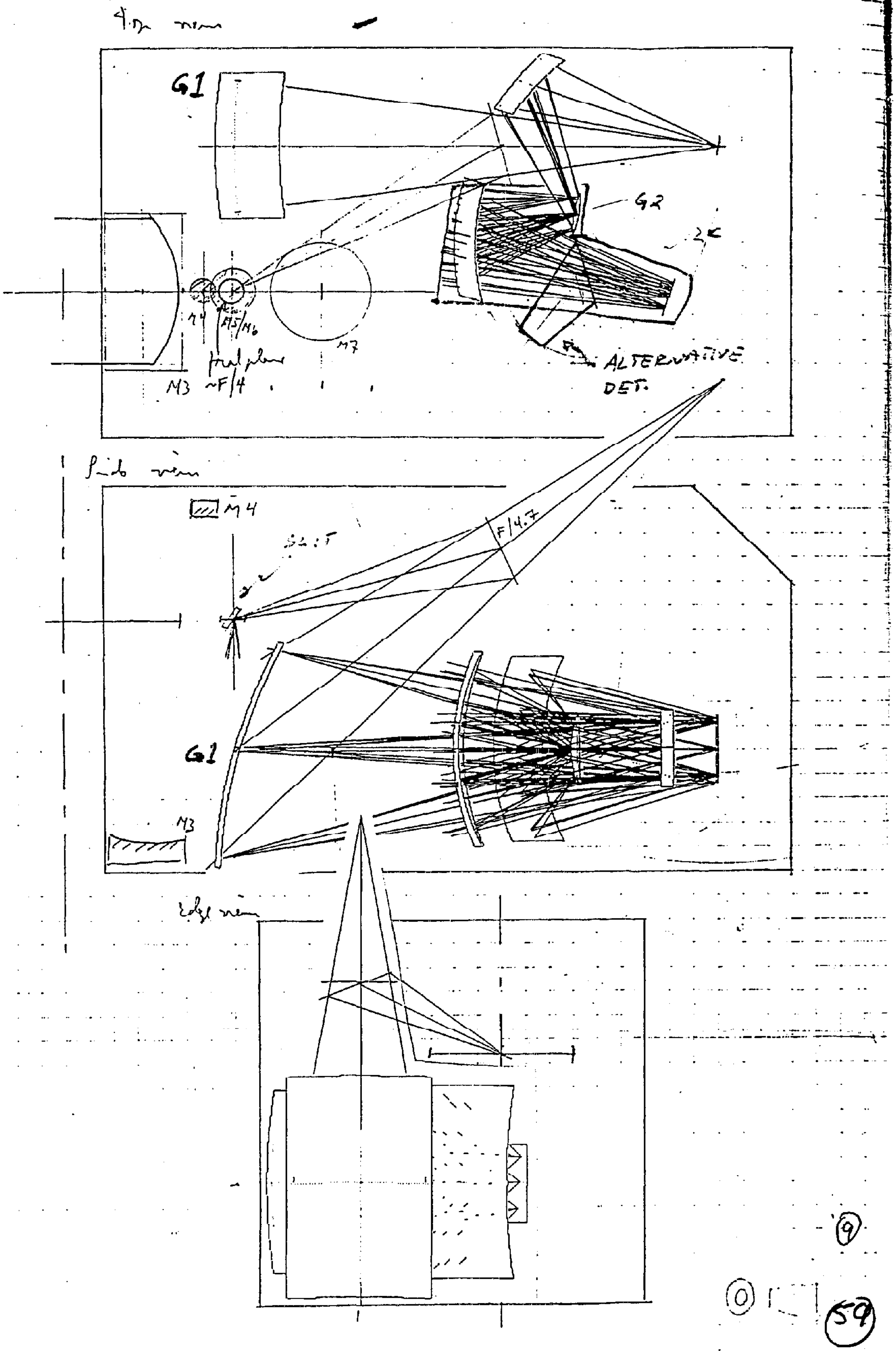
```
!       135 110697 Compact
!       136          Slightly longer
ID Spec-bol compact, n=10 (bolsp136)

!Order 10
WAVL 315 335 355 325 345
!Order 12
!wavl 266 280 294 273 287
!Order 16
!wavl 200 210 220 205 215
OBJECT FINITE 634.40 1 1
REFERENCE HEIGHT 68
APS 1
UNITS MM
novig
1 nodraw
! Slit angle
2 bt 53 0 99
2 nodraw
3 nodraw
4 HOE
HIN 1 1
CWAV 2135.3401
HTH 0
p1 -351.51 0  -423.34 1
p2   23.01 0  -523.70 1
ORDER -10
5 RD -517.55
5 rao 240 150 mair
```

```
! Mean diffraction angle
6 bt -16 0 99
6 mair nodraw
7 th -500   MAIR nodraw
! Field mirror
8 at 9 0 1
8 rd 2850 rao 70 20 air
9 at 18 0 99
! Offner system
10 decent 0 -97 0 99
10 th 240 air nodraw
! Primary
11 rd -240 th -120 rao 190 70 0 96 mair
! Grating
12 grating y 1.6 1
13 rd -120 th 120 eao 34 22 0 -15 air
! Tertiary
14 decent 0 -12 0 1
14 rd -240 rao 200 116 0 -62 mair
!15 decent 0 -100 0 99
15 th -240 mair nodraw
! Focus
16 rao 80 40 0 -67
END
```

K.D. 11/6/97

ALX II


Top view
G1
G2
2K
M4
M5/M6
M7
focal plane
M3 ~F/4
ALTERNATIVE DET.
Side view
M4
SLIT
F/4.7
G1
M3
Edge view

⑨

0

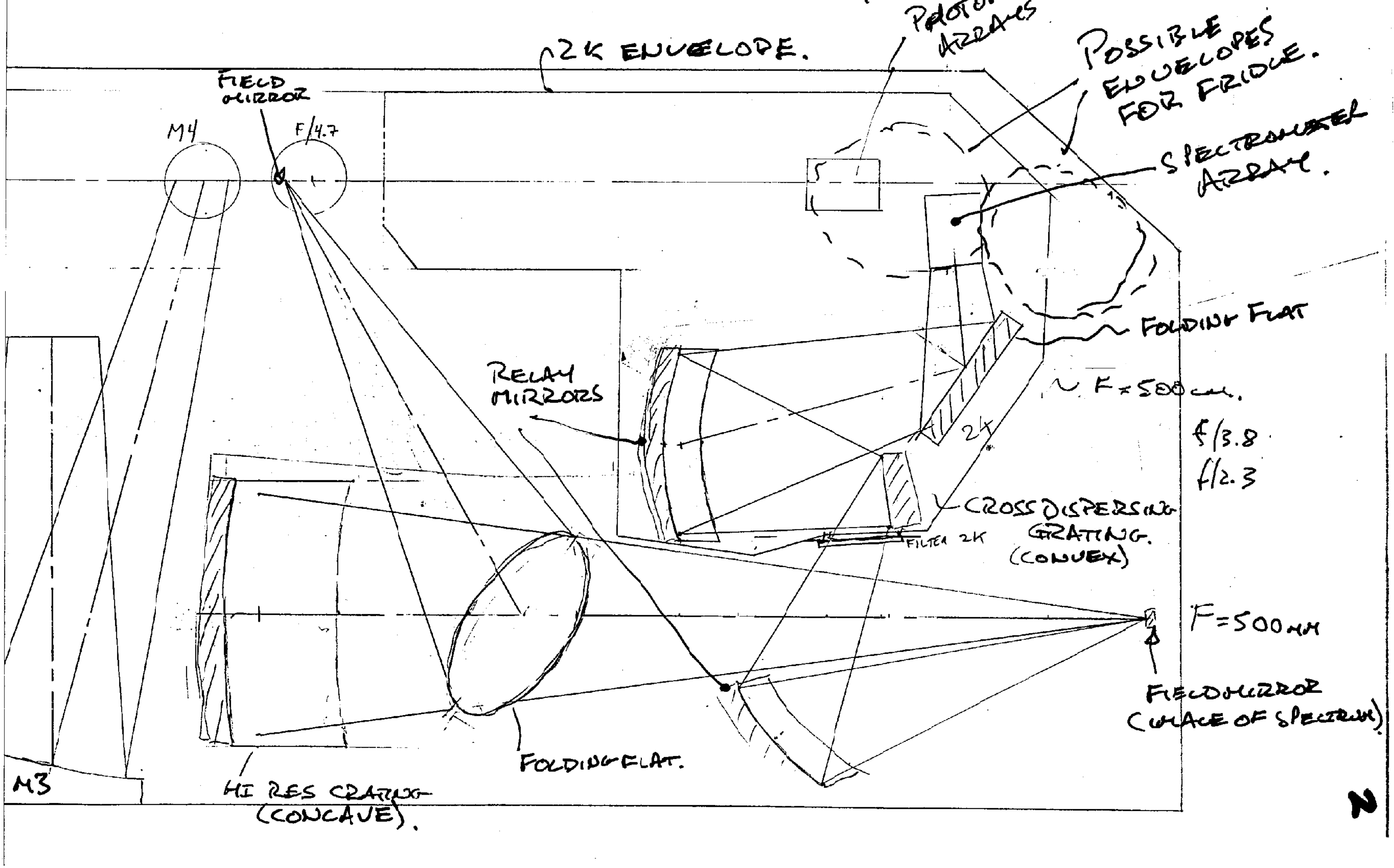
BOL | RAL | M | 0018.1 /

PART II

Agenda Friday June 27

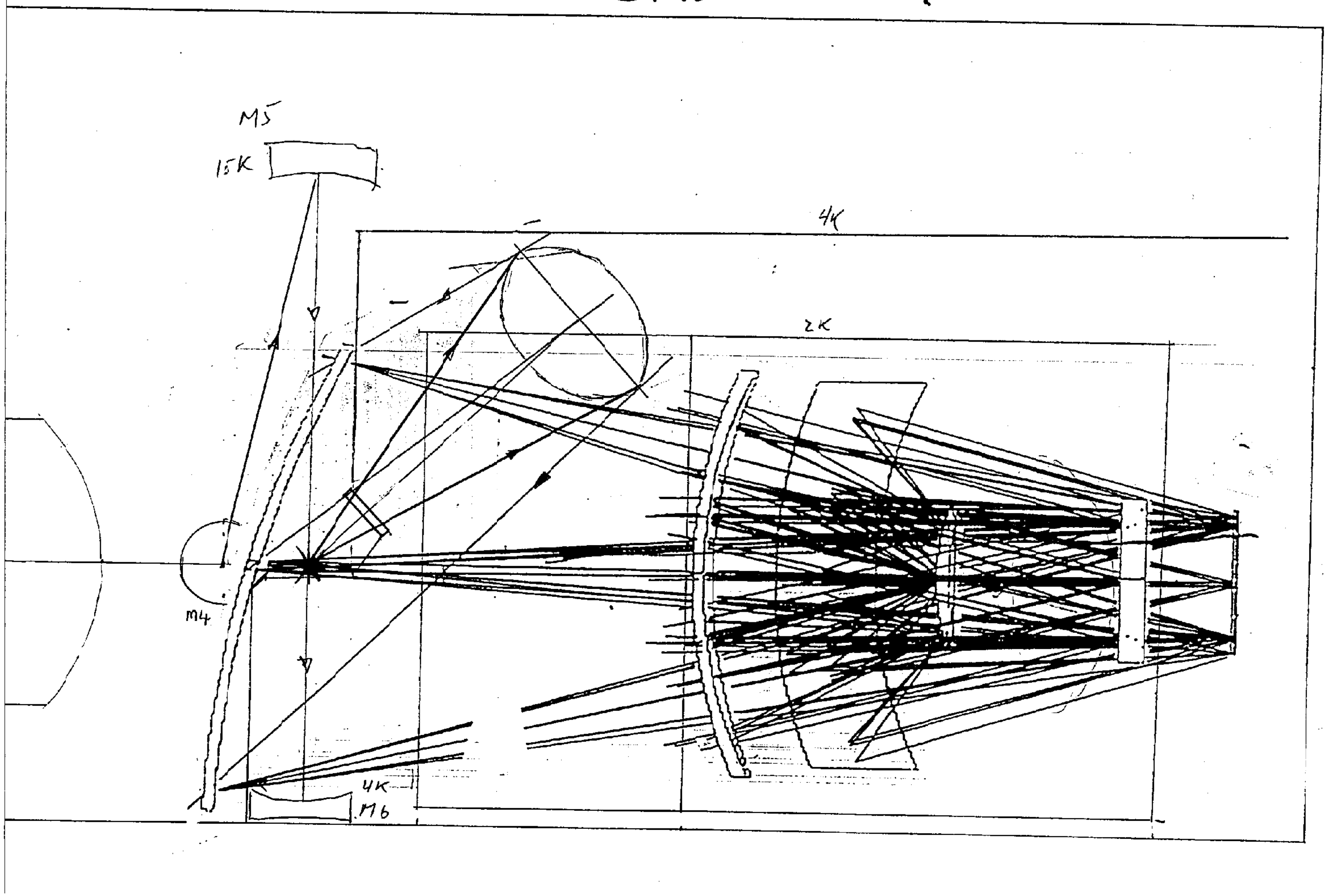
1. Reports from yesterday's splinter meetings:	
Summary of base-line optical designs	BMS
Base-line focal plane optics	MJG
Thermal/mechanical engineering	CRC
Data rate and operating modes	CRC
2. Assumptions for first-cut stray light analysis	MJG
3. Plans for FTS study	MJG
4. Review of actions from this meeting	MJG
5. BOL project office	KJK
6. Plans for future meetings	MJG

NEW SPECTROMETER LAYOUT



NEW SPECTROMETER LAYOUT

OTHER VIEW.



Base-line Focal plane optics

Three options:

1. **Single mode feeds:**
   - **Throughput = λ^2**
   - **Approx Gaussian beam pattern**
   - **Pixel size = $2F\lambda$**
   - **Similar to SCUBA**
   - **All apertures in front of horn are oversized (to typ. 30 dB level)**
   - **Throughput not convincingly demonstrated in real systems as yet**

2. **Winston cones:**
   - **Size still around $2F\lambda$ so profile is not top hat**
   - **Throughput > λ^2 but not by a lot**
   - **Beam pattern quasi-Gaussian (somewhat flat-topped)**
   - **Cold stop could be undersized to truncate beam and reduce background**

3. **Bare arrays:**
   - **Pixel size $0.5F\lambda$ or less (full sampling of the field)**
   - **F needs to be around 10 to make pixel diameter around 5λ or more**
   - **Cold stop essential to reduce background since pixel fov is up to 2π Sr.**
   - **Not base-line option as (i) not yet proven in the lab**
     (ii) possibly unacceptable from stray light point of view

Base-line:

- **Assume Winston cones of diameter $2F\lambda$**
- **Assume (as first approx.) that beam pattern is Gaussian, of 1/e width equivalent to f/5**

  or

  to first order, beam pattern = diffraction pattern of the circular aperture.
- **For stray light and beam analysis, it would be useful to study two extremes:**
  - **Gaussian of 1/e width = horn focal ratio**
  - **Top hat of same width**

MASS ESTIMATES

	TEMP. K	MASS Kg	AREA cm²
ARRAY STAGE	0·1/0·2/0·3	1·8	960
FILTER STAGE	2	3·5	2860
HELIUM STAGE	4	10·5	9774
COLD PLATE	15	8·9	13325
		24·7	
JFET BOX 1	15	0·8	2000
JFET BOX 2	50	0·6	1000
JFET STAGE	120	1	600
		2·4	
SUPPORTS & WIRING		5·4	

NEEDS REVISION
FOR NEW
SPECTROMETER DESIGN

THERMAL LOADS

200 BOLS 217
400 WIRES

STAGE	TEMP	LOAD		
ARRAY	0·1	8 μW	10·7 μW	11·4
FILTER	2	40 μW	53 μW	57
HELIUM	4	2·7 mW	3 mW	3·1
COLD PLATE	15	50 mW	59 mW	61

ASSUMPTIONS

142 BOLOMETERS
284 WIRES
28 SHIELDS
NO HEAT SINKS ON 2 → 0·1K
KEVLAR 2 → 0·1K
CARBON FIBRE 4 – 2 K
" 15 – 4K

FET MODULE IN 50K BOX
OFF 15K PLATE

Data rate and operating modes:

Below is a note written by CRC and KJK prior to the meeting. The total data rate will need to increase in proportion with the increased number of detectors. CRC and GSW will also write a detailed note on the on-board samlping requirements.

1. The phometric and spectroscopic subsystems will be operated in parallel - so all the detectors will be sampled all the time. Number of detectors = 61 + 37 + 19 + 19 + 19 = 117 + 38 = 155

2. Assume we have to sample 15 other channels with these in order to measure parameters that change rapidly. e.g. grating posn, current etc.
   Number of channels to be sampled = 170

3. Chopper will operate at 5Hz or slower. Therefore we need to telemeter 10 samples per second at least to the ground.

4. In order to allow for possibility of on-board deglitching we need to sample the detectors at a higher rate. The time constant for the detectors at 300mK is ~ 30 ms. Therefore on-board sampling interval should be about8 msec (sample rate = 125 Hz).

   [The time to sample one channel is likely to be a few hundred us - limited by the time taken for the signal from the input multiplexor to stabilise and the ADC to settle. This means the maximum number of channels that can be sampled by one ADC is about 30. We will therefore need 6 or more ADCs operating in parallel to collect the data]

5. In order to sample at the same points on each chopper cycle, the sampling has to be synchronised with the chopper movement. The easiest way to do this is if the on-board software controls the chopper movement.

6. We assume DC coupling in the electronics chain and that we transmit an absolute value for the signal (encoded in 24 bits) for each half chop cycle. [The number of bits required depends on the science requirements for the instrument - in particular signal to noise required for sources with small spectral features on bright backgrounds]

7. On-board science data rate = 170 channels * 125 Hz * 24 bits = 510,000 bps

8. Telemetry data rate is the sum of the housekeeping + scienece data rates

   Housekeeping data rate assumes 256 channels of 16 bits at 2 sec intervals = 2048 bps

   Science data rate = 170 detectors * 10 Hz * 24 = 40,800 bps

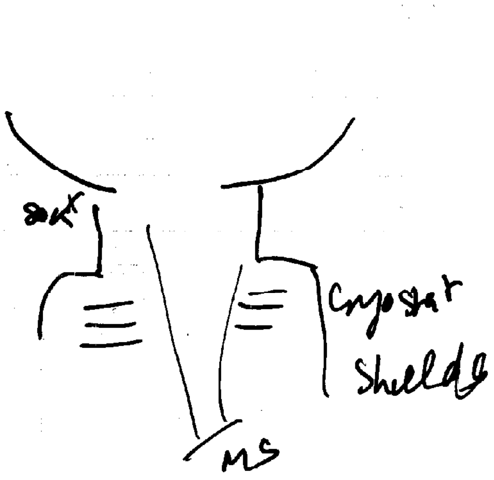
   Total telemetry data rate = 42,848 bps = 42Kbps

9. Parallel/Serendipity mode data rate

   We assume we do not need to send all channels - if slewing, about 30 channels will cover the complete beam width for the photometer. Therefore assume we can reduce the number of channels to 50 and that we only need to sample at 1Hz (this need to be checked with the satellite slew speed) data rate = 50 * 1 * 24 = 1,200 bps

STRAY LIGHT ANALYSIS

PHOTOMETER (AND SPECTROMETER?)



- DIFFRACTION ONLY
- ALL BOXES ARE BLACK
- WHAT'S IN FRONT OF INST.
- [illegible] BACKGROUND (IN BAND) ON DETECTOR

2 CASES

SAME FWHM (OR 1/e)

- 250 μm : 22 pW
  350 μm : 10
  500 μm : 4
  PHOT
  FOR 30% TRANS

~14 pW
Spect.

Action: BMS / MJG / TRIMC work on Specifications for study.

FIRST-BOL Optics meeting - June 25-27 Tony Richards, RAL

Straylight signals from the optics - sizing the problem

The most recent design for BOL involves 8 optical surfaces (including the two telescope mirrors), without counting any filters required). The table below shows estimates of the figures for the radiant power from each component (seperately integrated over all wavelengths and integrated over the BOL waveband of 200-650 microns) which is emitted directly into a solid angle covering the whole FOV covered by all the detectors. All quantities given or used in the table are defined and justified below.

Table 1. Integrated power from each component radiated towards the BOL FOV

Component	T°K	ε	P(ε,T,Ac,Ωc) watts	F(T, 200µ,650µ)	P(ε,T,λmin,λmax,Ac,Ωc) watts
Primary(M1)	80	0.01	1.07*10^-7	0.025432	0.0272*10^-7
Secondary(M2)	80	0.01	1.07*10^-7	0.025432	0.0272*10^-7
M3	15	0.01	1.32*10^-10	0.636075	0.8396*10^-10
M4	15	0.01	1.32*10^-10	0.636075	0.8396*10^-10
M5	15	0.01	1.32*10^-10	0.636075	0.8396*10^-10
M6	4	0.01	6.67*10^-13	0.183191	1.2219*10^-13
M7	2	0.01	4.17*10^-14	0.004343	0.0181*10^-14 see note
M8	2	0.01	4.17*10^-14	0.004343	0.0181*10^-14 see note

NOTE. Whereas is is proposed that the band-limiting of power from M1-M6 be imposed using a filter at the image of the aperture stop between M6 and M7 (which is the proposed location of the aperture in the '2°K box' which is intended to surround the optics subsequent to M6), the band-limiting of power from M7 and M8 will not be possible, because there must be at least one component at 2°K which the detector array sees unfiltered, unless the detector array is isolated at a lower temperature and an additional band-limiting filter at this lower temperature can be located in front of it.

Integrated power from each component radiated towards the instrument FOV

The expression used for the total wavelength integrated power P(ε,T,Ac,Ωc) in watts from a component with emissivity ε at temperature T is (with σ = Stefan's constant = 5.67*10^-8 watt/metre^2/deg^4)

$$P(\varepsilon,T,Ac,\Omega c)=\varepsilon\frac{\sigma * T^{4}}{\pi} * Ac * \Omega c$$

Ac is the area in square metres of the component 'seen' by a 'detector' which appears to occupy a fov covering Ωc steradians, viewed from the component. The product Ac*Ωc = A*Ω is the throughput which is constant at all points in an optical system (if we ignore diffraction), up to the last aperture stop before the final image plane, where the detector is located.

The power integrated over the Bol waveband, P(ε,T,λmin,λmax,Ac,Ωc) was found from the following expression,

$$P(\varepsilon,T,\lambda\,min,\lambda\,max,Ac,\Omega c)=\frac{\varepsilon * Ac * \Omega c * \sigma * T^{4}}{\pi} * F(T,\lambda\,min,\lambda\,max)$$

with F(T, λmin,λmax) being the fraction of the total black-body spectral power emitted within the specified waveband. F(T, λmin,λmax) is given by

$$F(T,\lambda\,min,\lambda\,max)=\frac{\int_{\lambda\,min}^{\lambda\,max}\frac{2\pi hc^{2}\lambda^{-5}}{exp(hc/\lambda kT)-1}d\lambda}{\sigma * T^{4}}$$

MATHCAD was used to evaluate the integral as a summation at 1/4 micron intervals multiplied by 1/4 micron. The table gives F(T, λmin,λmax) for each component and the P(ε,T,λmin,λmax,Ac,Ωc) value that results.

Optics AΩ - value (throughput)

For the FIRST telescope and the BOL instrument optics, we have taken an AΩ - value commensurate with an effective **3.2 metre** diameter primary mirror imaging a **5.2 arc minute** diameter FOV (radial FOV size = 2.6 arc minute = 0.04333 degree). This gives

$$A.\Omega = \left(\frac{\pi * 3.2^2}{4}\right) * \left(\frac{\pi * \left(\frac{5.6 * \pi}{60 * 180}\right)^2}{4}\right) = 1.445 * 10^{-5} metre^2 - steradian$$

This figure can be appropriately scaled to any diameter telescope DTEL (in metres) and FOV diameter DFOV (in arc minutes) by multiplying by $(DTEL/3.2)^2 * (DFOV/5.6)^2$

Component Emissivities

The broadband emissivities of all mirrors have been equated to **ε=0.01**, effectively assuming very high 99 % reflectivity coatings for all optical surfaces. Results can be easily scaled to emissivities higher than this likely minimum figure.

Component Temperatures

The temperatures assumed for the telescope components (M1 and M2) were T=80°K. The temperatures assumed for the other 6 surfaces (M3 to M8) were T=15°K for M3-M5, T=4°K for M6 and T=2°K for M7 and M8. These are guesstimates proposed by those present at the meeting.

The BOL waveband

The complete waveband which BOL is deemed to be designed to cover was taken to be λmin = 200μ, λmax= 650μ.

The BOL wavebands

The complete waveband which BOL is deemed to be designed to coverwill be divided into three separate wavebands, nominally assumed to be as given in table 2below. Each waveband will have its own detector array. Wavelength seperation will be achieved using dichroic filters in the 2°K box.

Table 2. BOL wavebands

waveband	λmin, microns	λmax, microns
1	200	300
2	300	400
3	400	650

The Detector sizes in each waveband

The BOL FOV will be covered by a different number of detectors, depending on the waveband. Table 3 shows some estimates of the number of detectors which can usefully be employed in each waveband (taken from anote by M.Griffin and B.Maffei, 21/3/97).

Table 3. Number of pixels/detectors in each BOL waveband

waveband	λmin, microns	λmax, microns	number of pixels
1	200	300	49
2	300	400	31
3	400	650	17

Power from each component radiated towards each detector in each of 3 wavebands in the instrument FOV

Given that the BOL waveband is divided into three, the next table shows the reult of extending the computations shown in table 1 to take into account this division and the fact that the FOV will be divided between a number of detectors/pixels. Table 4 shows the results of

1. Introducing the fractional power covering each waveband and
2. dividing that power by the number of detectors

in order to obtain a contribution expected to the background at each detector in each band from each component.

Note that when calculating the background contribution from an optical component no allowance has been made for the reflectivities of following components, or for the transmission factors of any filters because any sky signal will be affected by the same factors.

Table 4. Integrated power from each component radiated towards each detector in each waveband

Component	T°K	ε	P(ε,T,Ac,Ωc) watts unfiltered power whole FOV	F(T, 200,300) band 1	F(T, 300,400) band 2	F(T, 400,650) band 3	Filtered Power,watts per pixel, band 1	Filtered Power,watts per pixel, band 2	Filtered Power,watts per pixel, band 3
M1	80	0.01	1.07*10^-7	0.017517	0.004859	0.002952	3.8251*10^-11	1.6771*10^-11	1.858 *10^-11
M2	80	0.01	1.07*10^-7	0.017517	0.004859	0.002952	3.8251*10^-11	1.6771*10^-11	1.858 *10^-11
M3	15	0.01	1.32*10^-10	0.291783	0.173938	0.171244	0.786 *10^-12	0.7406*10^-12	1.3297*10^-12
M4	15	0.01	1.32*10^-10	0.291783	0.173938	0.171244	0.786 *10^-12	0.7406*10^-12	1.3297*10^-12
M5	15	0.01	1.32*10^-10	0.291783	0.173938	0.171244	0.786 *10^-12	0.7406*10^-12	1.3297*10^-12
M6	4	0.01	6.67*10^-13	0.002125	0.017268	0.163532	2.8926*10^-17	3.7154*10^-16	6.4162*10^-15
M7	2	0.01	4.17*10^-14	9.367*10^-8	1.641*10^-5	0.004306	7.9715*10^-23	2.2074*10^-20	1.0562*10^-17
M8	2	0.01	4.17*10^-14	9.367*10^-8	1.641*10^-5	0.004306	7.9715*10^-23	2.2074*10^-20	1.0562*10^-17

Fourier Transform Spectrometer option for the BOL

Advantages:

1. Much easier detector NEP requirement.

The much broader instantaneous passband of the FTS compared with the grating results in a higher photon noise limited NEP (of order 5 x 10^{-17} W $Hz^{-1/2}$). The detector sensitivity specification is therefore easier to meet. An operating temperature of 300 mK should be sufficient, for which a dilution fridge is not needed.

2. Adjustable spectral resolution

The spectral resolution of the FTS is easily adjusted by merely changing the scan range of the moving mirror. In the case of the BOL, it could be set at an value between ~ 10 and ~1000, depending on the scientific application.

3. Imaging spectroscopy

For the modest resolution requirement of the BOL, the FTS is compatible with imaging spectroscopy using a compact array at the focal plane.

4. Immunity to stray light

Only radiation which is modulated by the instrument is detected.

5. Spectral purity

Out-of-band leaks are encoded and measured spectrally, and so do not contaminate the signal.

6. No chopper required

An FTS, operated in continuous scan mode, requires no chopping, giving an increase in observing efficiency and greater reliability.

7. Straightforward wavelength calibration
8. Accurately measurable instrument response function
9. Easy to extend wavelength coverage to shorter and/or longer wavelengths.

Disadvantages:

1. The FTS is optimised for broad spectral measurements rather than observations of known lines. However, this is not a drawback for the main science driver for the BOL instrument: full spectral scans of high-z galaxies following their detection in the photometric survey.

Key question:

How does the sensitivity compare with that of the grating instrument?

Engineering aspects of the FTS:

1. Moving mechanism

   For a resolving power of 1000 at 350 μm (approx. 30 cm^{-1}), a spectral resolution of 0.03 cm^{-1} is needed, corresponding to a path difference of 33 cm. With a proven method of folding, the mechanism travel can be made eight times smaller, about 4 cm. While this mechanism might be more difficult and heavier on power than the proposed grating drive mechanism, at first sight it does not seem impractical.

2. Scan rate, audio frequency range and data rate

3. Volume, mass, power for a feasible and competitive instrument.

Conclusion:

A preliminary study of the FTS option should be carried out to determine the following:

1. How do the sensitivity and overall scientific capabilities of a credible FTS instrument for the BOL compare with the expected performance of the grating option?

2. What are particular the requirements for calibration, observing modes etc.?

2. Are there any serious engineering difficulties associated with the FTS option (e.g., the drive mechanism)?

3. What are the thermal/mechanical/data sampling/telemetry parameters for a base-line FTS instrument?

It is proposed that a small group (Peter Ade, Kjetil Dohlen, Matt Griffin, Bruce Swinyard, Gillian Wright) carry out a quick study and produce an initial assessment (deadline end July) of the feasibility/desirability of the FTS option.

Matt Griffin
27 June 1997

BOL meeting, RAL, June 25-27 1997 Actions:

1	Write short note on glitch identification and removal	CRC	July 31
2	Write note on data sampling and dynamic range and implications for on-board A-D conversion (inc. glitch removal, ac/dc coupling	CRC	July 31
3	Get information from ESA on telescope surface roughness	MJG	July18
4	Provide information on power dissipation of LWS grating drive in “grating chopping” mode	KJK	July 18
5	Raise with ESA possible need to peak up before point source observations	MJG	July 18
6	Provide reflectivity data on QMW black material	PARA	July 18
7	Produce diagram for IID summarising characteristics of the BOL thermal model	CRC/BM	July 18
8	Provide information on dilution fridge dimensions	MJG	July 4
9	Revise mass estimates and thermal model using new baseline optical designs and address prolem of the FET module	CRC/BM/ IDH	July 18
10	Model efficiency of two-grating system with Russian grating analysis code	BMS	July 31
11	Write brief summaries of the new optical designs and E-mail/fax to BMS for inclusion in short document	KD/EA	July 4
12	Finalise and write more detailed notes on the optical designs including alignment tolerances	KD/EA/ BMS	July 31
13	Write full description of the base-line instrument	MJG/BMS	July 25
14	Organise small group to examine FTS option	MJG	July 4
15	Specify parameters and assumptions for stray light analysis	BMS/MJG	July 18
16	Carry out initial stray light analyisis to evaluate background power on the detectors	MC/TR	July 31
17	Revise beam analysis	MC	July 31
18	Write summary of 3He and ADR technology relevant to the BOL (in collaboratio with Lionel Duband if possible)	IDH	July 31
19	Write minutes of this meeting	BMS/MJG	July 4

FIRST Bolometer Project Office

Duties

1. Documentation;
    - Set-up and maintenance of an archive of the project documentation.
    - Distribution of documents within the consortium.
    - Issue and Configuration Control of approved documents.
    - Maintenance of project lists (e.g. Master Action List, Issued Document Log etc.)
    - Maintenance of a project address database. ← [illegible] of Report Templates
2. Information and Publicity
    - Maintenance and coordination of project WWW site(s) at RAL.
3. General support
    - Provision of secretarial assistance (e.g. minute taking).
    - Organisation of meetings.
    - Making travel arrangements.
    - Responding to queries (e.g. by telephone, fax or e-mail)
    - facilities maintenance (fax, stationary etc.)

Videoconferencing

FIRST Bolometer Project Office

Document Archive

The intention is that, as far as possible, all project documentation will be held in an electronic form in a central archive to which all project members have (read only) access.

- The access will be via the World Wide Web using a standard browser (Netscape, I.E.).
- The user will be able to search the Archive index, for documentation by Author, Date , Document Number, Title etc.
- The user will be able to view the documentation on-line.
- The user will be able to download a copy of the document (e.g. for printing).

In order for this to be feasible it is expected that all documentation (including mail) will be submitted electronically in a small number of formats;

- Microsoft Word (version 6) — MS office
- RTF + HTML
- ASCII Text
- Postscript
- Graphics formats TBD

All documentation in the archive will be held in its original form and in Adobe Acrobat (.PDF) form. PDF viewers are available for most platforms and allow searching, printing, commenting etc.

FIRST Bolometer Project Office
Document Numbering

All documents will be given a reference number in the form;

PPP-BBB-T-NNNN.II

- PPP denotes the issuing project (e.g. FIRST for documents issued by ESA project, BOL for the Bolometer project documents etc.)
- BBB denotes the issuing body (e.g. RAL, QMW, ROE etc. for instrument documents)
- T denotes the document type;
  - . N for project notes,
  - . D for approved documents,
  - . M for minutes of meetings,
  - . R for reference documentation,
  - . S for drawings,
  - . P for photographs and
  - . C for correspondence
- NNNN is the serial number (starts from 0001 for each document type)
- II is the issue number (issues .00 to .09 denote draft issues, issue .10 to .99 denote issued versions etc. For correspondence II is replaced by the last two digits of the year.

FIRST Bolometer Project Office

Procedures

Submitting a document (electronically):

- Write or acquire document .
- Ask Project Office for Note Number (and supply a title) - An entry will be added in the index with the status 'to be written'
- Supply note in electronic form - as attachment to an e-mail including a distribution list, if necessary (submission by ftp TBC).
- Entry of document to Archive:
  - note copied to Archive directory
  - index updated to reflect new entry
  - e-mail sent to distribution list notifying them of note's arrival
  - note copied and sent, by paper to distribution list

Submitting a document (by paper):

- Supply note in paper form, with distribution list attached
- Document scanned into computer and converted to .PDF format
- Entry of document into Archive (as above)

FIRST Bolometer Project Office
Information

Contact: Judy Long
Tel: +44 (0)1235 446322
Fax: +44 (0)1235 446667
E-mail: j.a.long@rl.ac.uk

Schedule:
14th July: Address Database on line + Action List
1st August: Document index on line
1st September: Document Archive on line

People's holiday plans

KJK	July 21 - 25; Aug. 25-29; Aug. 11-15 ?
KD	August
TR	Last week July + 1st week Aug.
MC	No holiday before Sept.
EC	August
BMS	Last week July + 1st week Aug.
CRC	3 wks from July 12
GSW	Aug. 1 - 10; Aug. 25 - Sept. 10
EA	July
IDH	July 27 - Aug. 3; Aug. 25 - Sept. 14
MJG	July 26 - Aug. 10; not in UK in following week

Future meetings:

BOL instrument technical meeting	Marseille Oct. 2, 3
Full BOL consortium meeting	3rd or 4th week in Oct. Venue TBD
Early September	Meeting to discuss spectrometer configuration (FTS or grating)
Mid. Aug.	Meeting on FTS option ?