SPIRE-QMW-MHO-00015.10 ~~BOL/QMW/M/0015~~-1

Viewgraphs presented at FIRST Bolometer Working Group meeting, Grenoble, April 14 1997

1. Matt Griffin:	FIRST status and schedule
2. Bruce Swinyard:	The BOL grating option
3. Ian Hepburn:	ADR and ^{3}He cryogenics
4. Emmanuel Caux:	CESR readout electronics
5. Louis Rodriguez:	CEA/LETI Bolometer array development
6. Matt Griffin:	Bolometer arrays: 2Fλ feedhorns or bare pixels (≤ 0.5Fλ)
7. Colin Cunningham:	SCUBA status
8. Paolo Saraceno:	Imaging across the slit for galactic sources
9. Peter Hastings:	BOL thermal/mechanical engineering
10. Bruno Maffei:	BOL thermal modelling
11.Ken King:	BOL observing modes
12.Ken King:	The role of the Instrument Control Centre
13.Roger Emery:	BOL work-packages
14.Matt Griffin:	Summary of meeting
15.Matt Griffin:	Copies of viewgraphs from BOL talk at Grenoble FIRSU symposium

– FIRST BOLOMETER INSTRUMENT WORKING GROUP MEETING

– GRENOBLE 14 APRIL 97

Bruce Swinyard	RAL
Roger Emery	RAL.
Laurent Vigroux	SAP
F.Xavier Désert	IAS
Jean-Michel LAMARRE	IAS
Peter Hastings	ROE
Colin Cunningham	ROE/JAC
Mark Casali	ROE
Eli Atad	ROE
Sye Murray	QMW
Bruno MAFFEI	QMW
Ken King	RAL
Louis RODRIGUEZ	SAp/SACLAY.
Patrick Agnese	LETI .
Philippe LAVOCAT	SAp/SACLAY
Christophe Buzzi	LETI
SARAH CHURCH	CALTECH
Ian HEPBURN	MSSL
Gary Davis	U of Sask
Saraceno Paolo	IFSI-CNR
TIM SUMNER	ICSTM
Emmanuel CAUX	CESR

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Matt Griffin

FIRST status and schedule

FIRST BOL Working Group
Grenoble, April 14 1997

1. FIRST/PLANCK merger schedule

- Tiger team study to has not identified any "show-stoppers" (yet)
- ESA are intent on launch in 2005/6
- Accelerated phase-A study June 97 - early 98
- AO issue ~ Sept. 1997 (during phase A)
- EID Part A definition to begin ~ late 97 (during phase A)
- Proposal submission February 98
- Confirmation of new mission at June 98 SPC meeting
- (Formal) instrument selection by ESA ~ June 98.

2. Implications of merger for BOL

- Pressure to simplify instruments to reduce cost and risk - we are doing this already

  Still pressure to simplify cryogenics (higher operating temperature)
- Instrument consortium must be clearly defined soon (this summer)
- Reduction in telescope focal ratio to around f/7 - should be a relatively minor change
- Existing thermal and mass budgets not likely to be relaxed

3. SAG recommendations for BOL

- SAG supports the current re-design work on the BOL (and the PHOC) to simplify and optimise for key science goals
- PHOC will have imaging spectroscopy with $\geq 5 \times 5$ array up to ~ 220 μm
- PHOC also working on developing GaAs photoconductors (possible extension to 300 μm)
- SAG endorses the emphasis on imaging photometry and point-source spectroscopy for the BOL

  More detectors if possible - esp. to measure the spectrum more rapidly

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BOL Requirements

Science drivers

- Deep photometric survey for high-z galaxies
- Followed up by spectral survey of detected sources (of unknown or poorly known z)
- Optimise for moderate resolution spectroscopy
- Bright-source science of lower priority
- Simplify instrument but put in more detectors if possible

Spectroscopy

- λ = 200 - 350+ μm
- $\lambda/\Delta\lambda \sim 1000$
- Imaging ?

Photometry

- $\lambda \sim$ 200 - 600 μm
- $\lambda/\Delta\lambda \sim 3$
- Background-limited by telescope emission
- Imaging essential

Advantages of Grating Spectrometer

- Simpler instrument construction, operation, and calibration
- Reliability (F-P has mechanisms in series)
- Less development effort
- Lower cost
- Higher efficiency
- Better instrument response function
- More suited to spectral survey work
- Can cover a wide wavelength range
- Easier to separate photometry and spectroscopy and optimise both

Disadvantages of Grating

- Not optimum for 2-D imaging spectroscopy
- Cannot easily get $\lambda/\Delta > 1000$

Spectrometer

- $R = 1000$ $T_{tel} = 80$ K $\varepsilon_{tel} = 4\%$
  $t = 0.2$ $\lambda = 300\ \mu m$ $A\Omega = \lambda^2$

  ⇒ $NEP_{ph} \sim 4 \times 10^{-18}$ W $Hz^{-1/2}$
  $NEP_{det} \sim 1 \times 10^{-17}$ W $Hz^{-1/2}$
  ⇒ Detector noise limited

- No. of detectors ~ 20 - 25

- Imaging spectroscopy ?

  - High-z galaxies: isolated point sources
    ⇒ Better to emphasise spectral rather than spatial multiplexing

  - SF regions; nearby galaxies:
    - Few strong lines in 200-350 μm range NII (205 μm), CI (370 μm)
    - High-J rotational lines (e.g., OH, H_2O, CO) much weaker (and many lines within PHOC range)

  - Conclusion:

    Better to multiplex spectrally - measure complete point source spectrum in shortest possible time

- Is $R = 1000$ really necessary?
  - Faint sources:
    - Time taken for full spectrum $\propto R$
    - Line of known λ: $S/N \neq f(R)$
    - Lower $R \rightarrow$ Better S/N on continuum

    $\Rightarrow$ Lower resolution better
  - Bright sources: $S/N \propto R^{1/2}$
  - Conclusion:

    R = a few 100 better for high priority extragalactic spectroscopy
- Outline grating design:
  - Littrow or Rowland circle mount
  - Grating size ~ 200 mm for $R = 1000$
  - $\lambda = 200 \rightarrow > 350$ µm
  - Grating at 4 K (or ≤ 7 K)
  - Pupil stop at or near grating
  - Small grating scan range (< a few deg.)
  - Design driver for optics = stray light control
  - Photometer and spectrometer beams separated near instrument input

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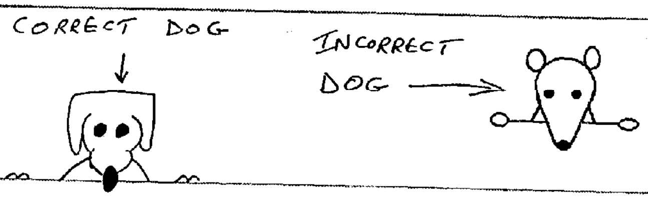
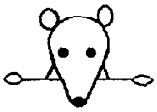
Bruce Swinyard

The BOL grating option



History

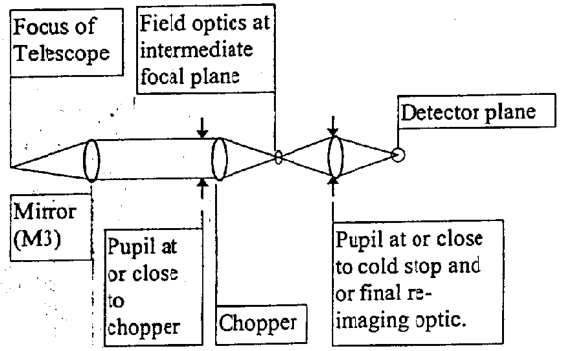
- Grating spectrometer became feasible with the reduction in the resolving power requirement.
- Interested parties met at RAL on 10/2/97 for a workshop on the spectrometer design.
- Several options were discussed and the basic optical design parameters established.
- Using these parameters the three groups (LAS, RAL, ROE) went through a second design iteration.
- A second meeting of the group on 3 April discusssed these designs which have highlighted some further difficulties.



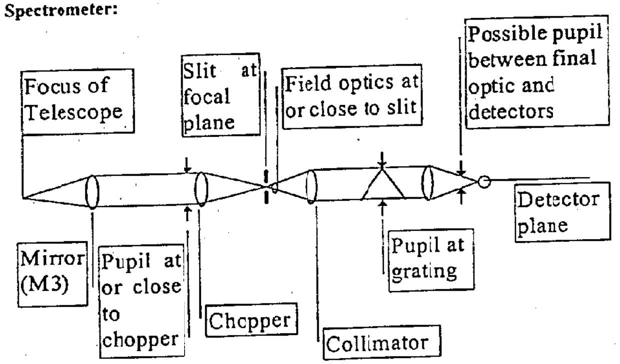
Design Criteria (spectrometer)

- Spectrometer detector spacing 4-4.5 mm with minimium detector size 2.5 mm.
- Final f-ratio no greater than 3.
- Wavelength range 210 - 350 μm minimum - extension to longer wavelengths desirable if “free”.
- Input beam from telescope f/9.6 at present.
- Pupil image on the grating - desirable to have cold stop between grating and focal plane.
- Imaging no-longer required.
- Sky chopping.
- Calibration source.
- Minimum grating angle scan and minimum spread of detectors in focal plane.
- Has to fit in the box!

Photometer:



Spectrometer:



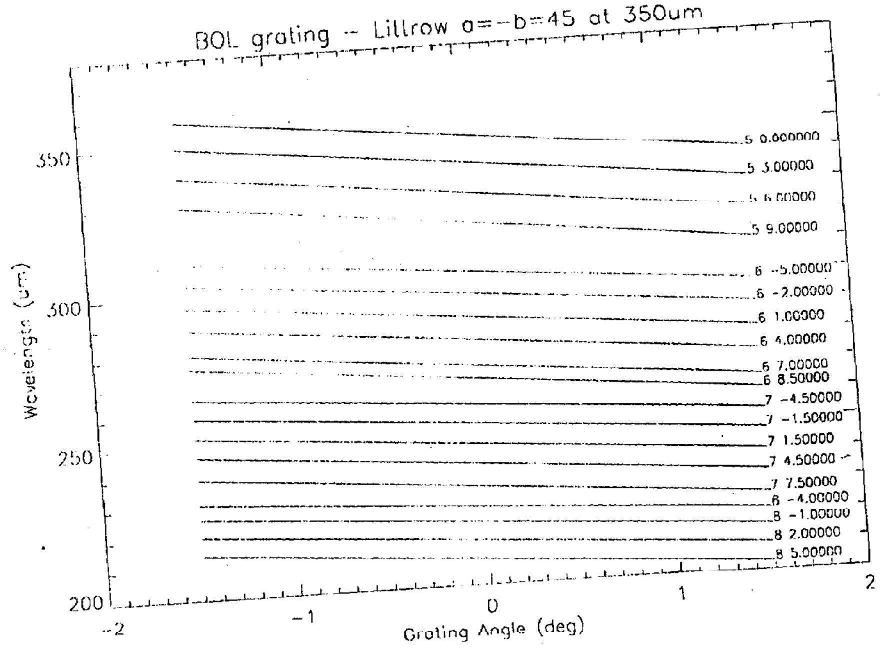
Actions/next meeting:
The three design groups (ROE, RAL and LAS) will circulate outline designs within two weeks and comment on these by e-mail. The next meeting proper will be in the week before the Grenoble meeting (7-11th April), probably in Edingburgh

BOL grating - Littrow with $\alpha=-\beta_o=45$.

Table of detector central wavelengths, angles and filter requirements (assuming triangular filter function)

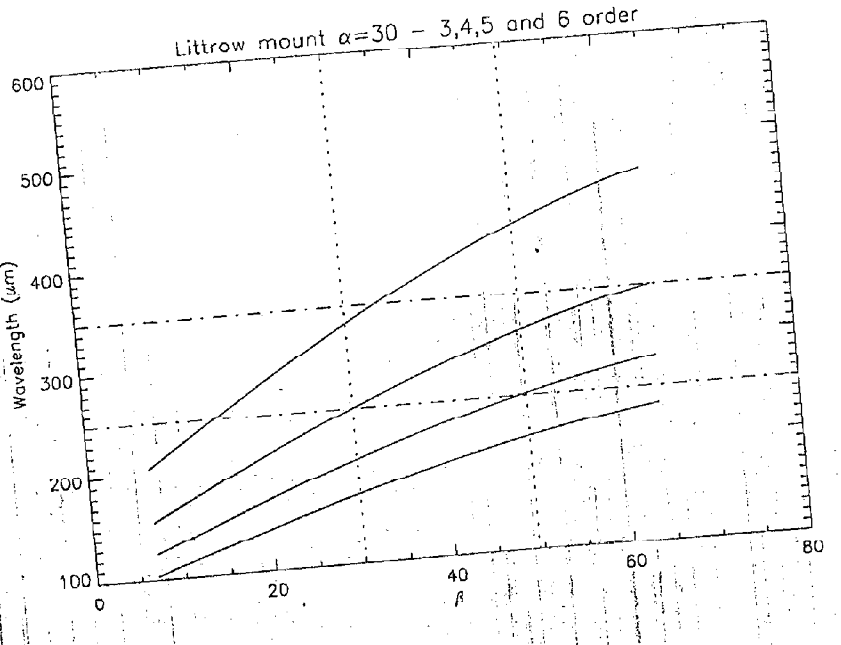
Central Wavelength	Wavelength at m-1	Wavelength at m+1	Central Order	Resolving power required for filter	Angle of Detector centre w.r.t. β_o
350.000	437.500	291.667	5	4.80000	0.000000
340.601	425.752	283.834	5	4.80000	3.00000
330.749	413.436	275.624	5	4.80000	6.00000
320.469	400.587	267.058	5	4.80000	9.00000
303.822	364.586	260.419	6	5.83333	-5.00000
296.667	356.001	254.286	6	5.83333	-2.00000
289.099	346.919	247.799	6	5.83333	1.00000
281.139	337.366	240.976	6	5.83333	4.00000
272.807	327.368	233.835	6	5.83333	7.00000
268.509	322.211	230.151	6	5.83333	8.50000
259.422	302.659	226.994	7	6.85714	-4.50000
253.229	295.434	221.576	7	6.85714	-1.50000
246.685	287.799	215.849	7	6.85714	1.50000
239.807	279.775	209.831	7	6.85714	4.50000
232.615	271.384	203.538	7	6.85714	7.50000
226.113	258.415	200.989	8	7.87500	-4.00000
220.642	252.163	196.126	8	7.87500	-1.00000
214.866	245.561	190.992	8	7.87500	2.00000
208.801	238.630	185.601	8	7.87500	5.00000

$a = 1237\mu m$.



Study Workshop 10 February 1997

FIRST - BOL Grating Study Working Group



Slit Width

Required slit width is given by:

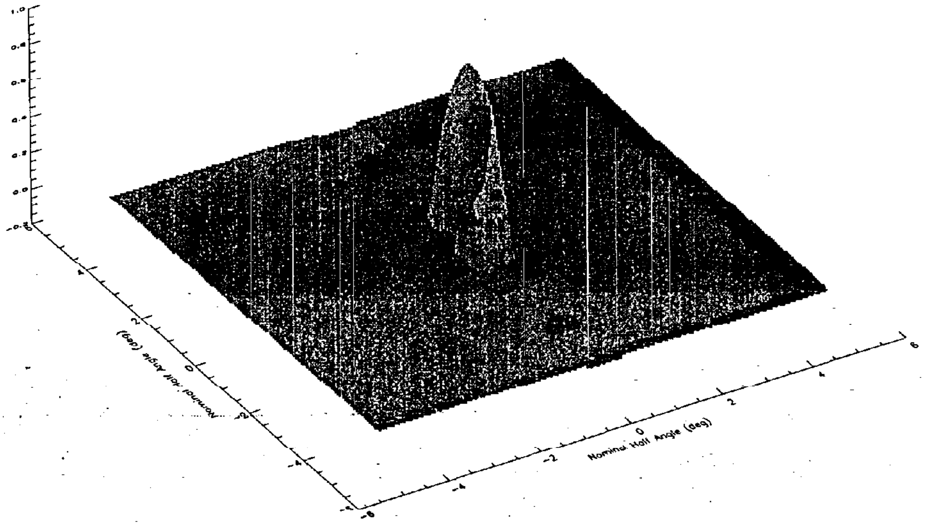
$$w = \frac{m\, f_{coll}}{a\mathrm{Cos}\beta} \times \frac{\lambda}{R}$$

For R=1000 and λ=250μm

f_{coll} = 416 mm (Rowland design), w = 0.85

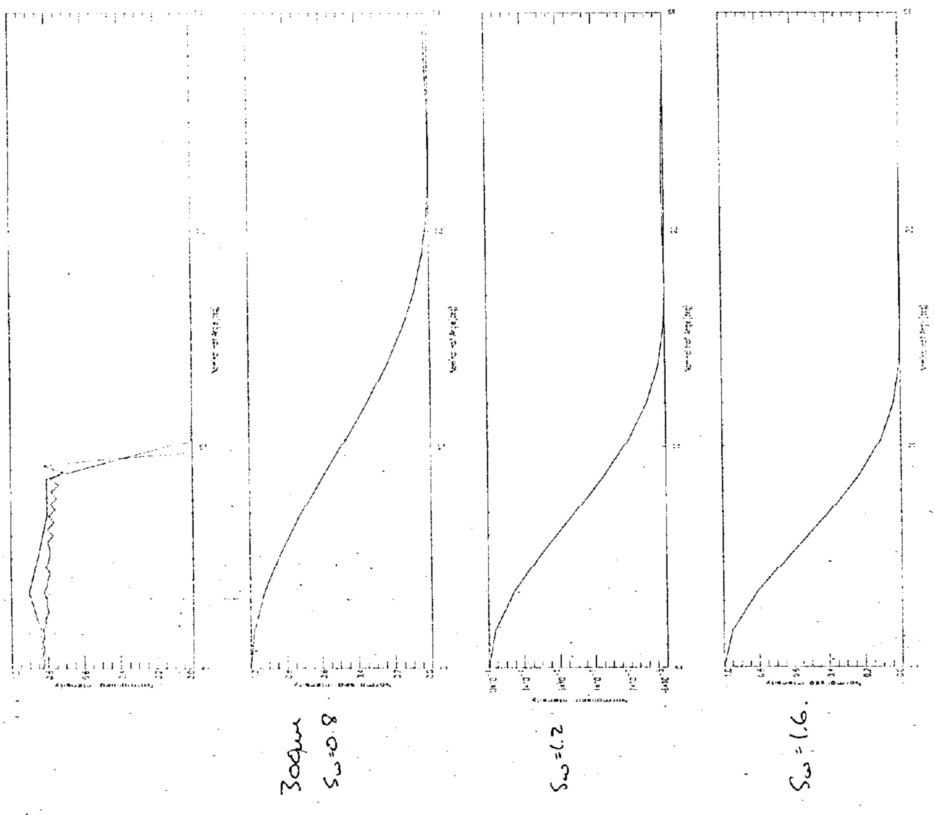
What is the effect of diffraction for this slit width?

f_{coll} = 900 mm, w = 2.1 mm



Outstanding Issues

- Image distortion in the PHOT channel.
- What is the actual resolution available for a grating spectrometer?
- Diffraction through the system - including slits.
- Increase in the spectral multiplexing to reduce the grating scan angle.
- Straylight is still an important design driver.
- Still an open choice between plane and concave gratings.
- Pixel size needs to increase with wavelength.



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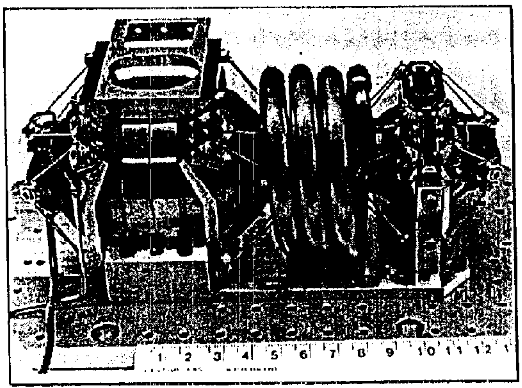
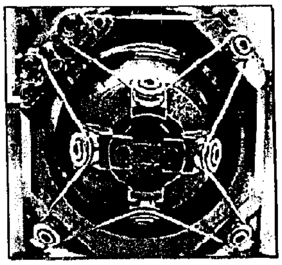
Ian Hepburn

ADR and ^{3}He cryogenics

IRTS 3He Orbital Cooler

KEVLAR SUPPORT SYSTEM





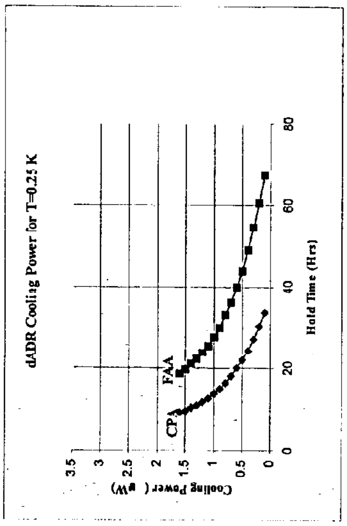
Materials :
- Kevlar 29 (45 Kg)
Cord : Braided Kevlar cords with 8 strands (cord: 2.92 10-3 cm2)

- Titanium brackets

Lionel Duband CEA - SBT

Proto Type double ADR (dADR)

- This system is reaching the final stages of proto type (proof of concept) design
- Operates from a 4.3 K stage
- No design diffence for 0.25 K operation compared with 0.1 K or 0.3 K operation
- 0.25 K Hold Time as a funcion of Cooling Power



Key Parameters

ADR composed of two stages 0.25 K stage
1.0-2.0 K stage (currently not activelly controlled but can be at reduced hold time).

Size Approximately 66mm diameter
Approximately 300mm long

Mass Magnet wire 2-3 Kg (TBC by magnet design)
Magnet former ~2-3 Kg (this may be reduced by considering a carbon fibre/ metal construction)
ADR parts 0.3 Kg

~20% greater cooling power could be acheived for ~30 grams more mass

Thermal

(4.3 K)

This is dominated by current leads (High Tc leads are yet to be assessed)

Maximum disipation (both magnets magnetized and assuming heat extraction from ADR at 2mW) (based on scaling down a larger magnet. Can be considered pessimistic)

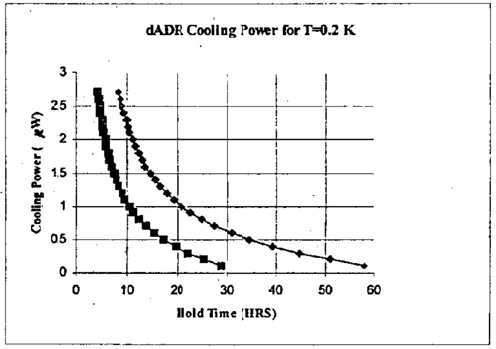
150um wire 1.5 Amp magnet design (off the self)	14 - 8 mW	(8-5 mW)
100um wire 0.76 Amp magnet design (development)	8 - 5 mW	(5 - 3.5 mw)

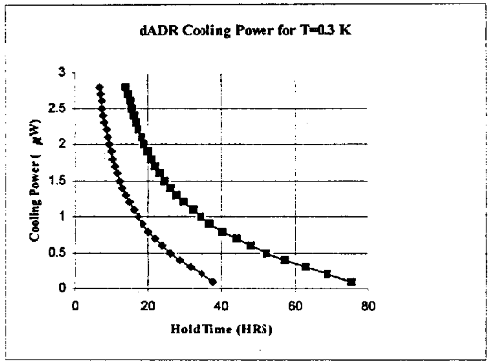
<u>These can be reduced by a different mode of operation which results in ~20% reduction in cooling power (shown in brackets)</u>

Off conductance ~1.2 mW

recycle time ~few hours

Other operating temperatures





More details of a **large** space adr can be found in a design study performed for ESA. Obtainable from I. Hepburn at MSSL NOTE it is now slightly out of date

This report includes

Magnet design
Mechanical design
Thermal design
Electrical design
Software
PA
AIV
Flight operations
Performance

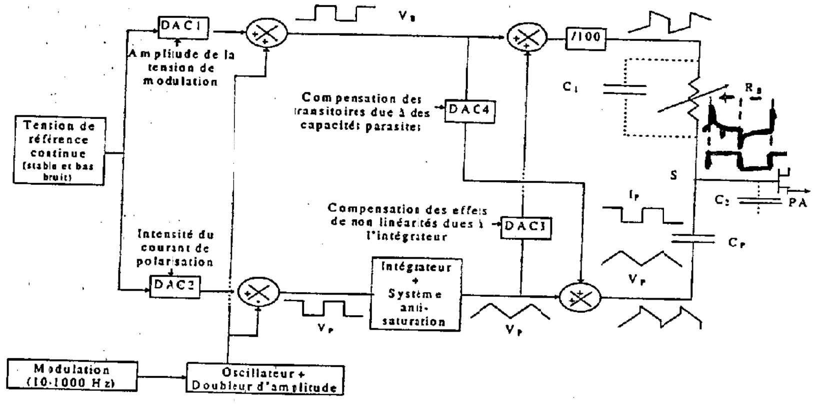
4

Emmanuel Caux

CESR readout electronics

REALISATION DU MODULATEUR

⇨ Schéma du modulateur



⇨ 5 caractéristiques :

① Modulation électrique

② Modulation de tension carrée

③ Montage en pont

④ Capacité de polarisation

⑤ Modulateur contrôlé numériquement

PERFORMANCES DU SYSTEME

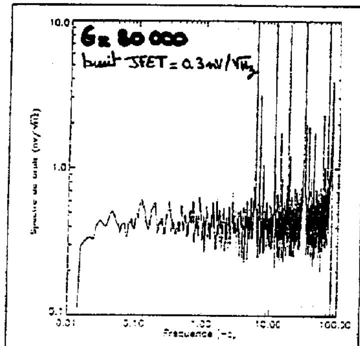


Figure 1 : *Spectre de bruit de la chaîne d'amplification après détection synchrone à 81.38 Hz*

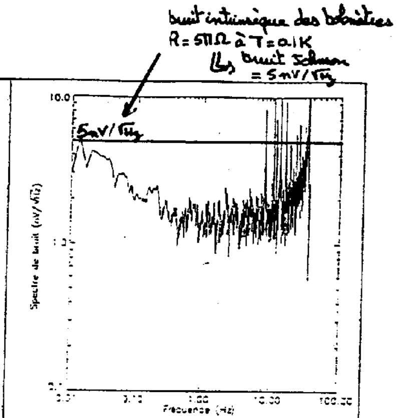
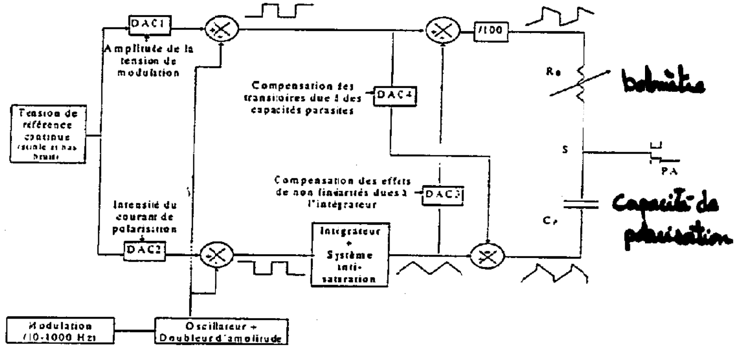


Figure 2 : *Spectre de bruit de l'amplitude de modulation (f_{mod} = 36.85 Hz)*



PERFORMANCES DU SYSTEME (Suite)

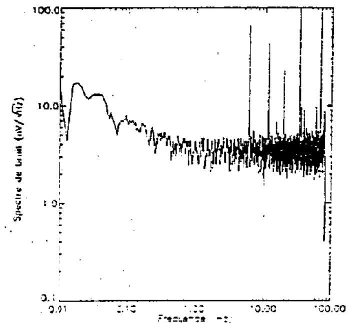


Figure 3 : *Spectre de bruit mesuré sur une résistance à 300K qui simule un bolomètre (f_{mod} = 81.38 Hz)*

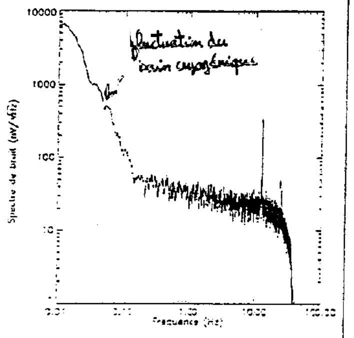
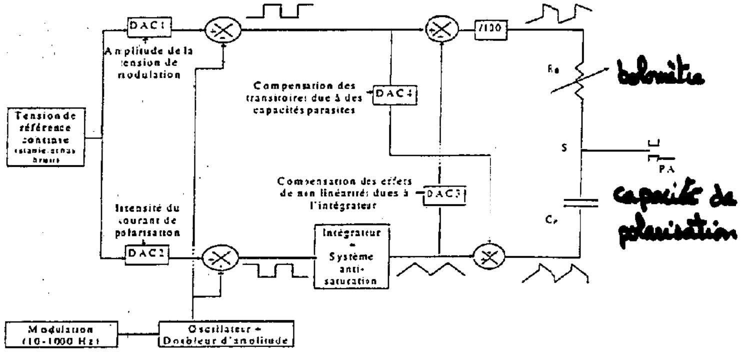


Figure 4 : *Spectre de bruit mesuré sur un bolomètre (R=40MΩ) de Diabolo (f_{mod} ≈ 38 Hz)*

↳ $15 nV/\sqrt{Hz}$

$R = 1k\Omega$ à $T = 300K \Rightarrow$ bruit Johnson : $4 nV/\sqrt{Hz}$

$R_{bolo} = 3M\Omega \Leftarrow$ à $T = 0.1K$ ↵

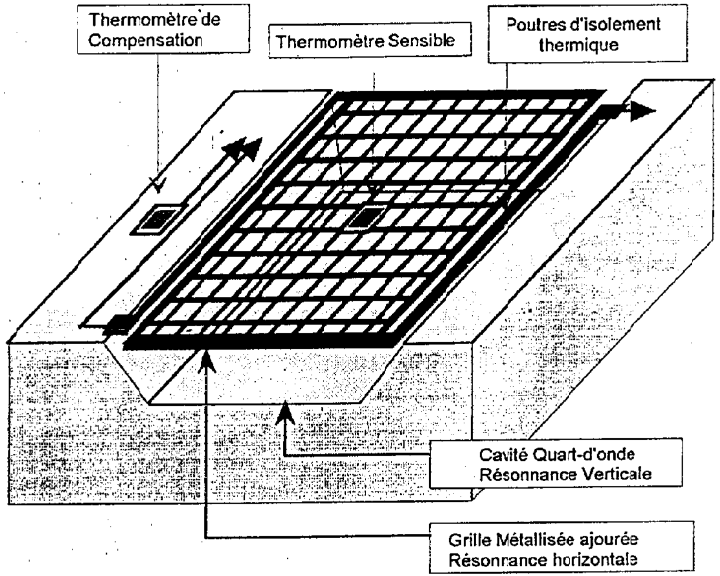


5

Louis Rodriguez

CEA/LETI Bolometer array development

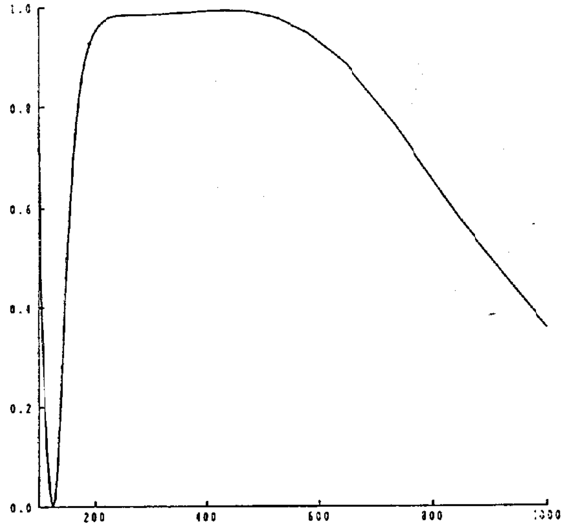
PIXEL ELEMENTAIRE



THERMOMETRIE	Principe: variation exponentielle de la résistance en fonction de la température (transition métal-isolant) Matériau: Si implanté Phosphore compensé Bore Particularité: Haute Impédance, lecture différentielle
GRILLE SILICIUM	Structure suspendue isolée thermiquement par des poutres silicium. Ajourée pour diminuer la masse, la capacité calorifique et la sensibilité aux particules cosmiques
ABSORPTION RESONNANTE	Résonnance verticale par cavité quart d'onde Résonnance horizontale par interaction boucle à boucle Métal absorbeur compatible avec les filières silicium

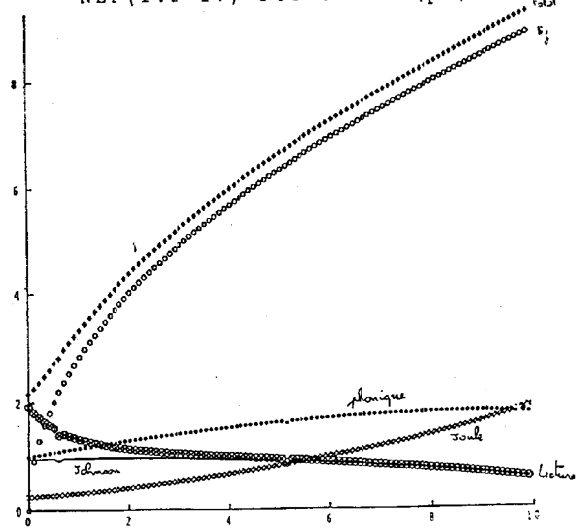
REPONSE SPECTRALE

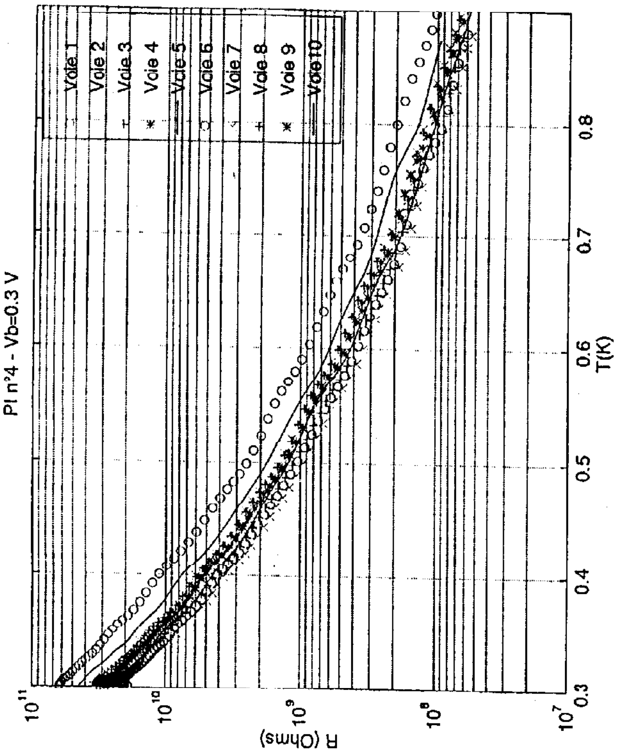
Absorb. fct lambda



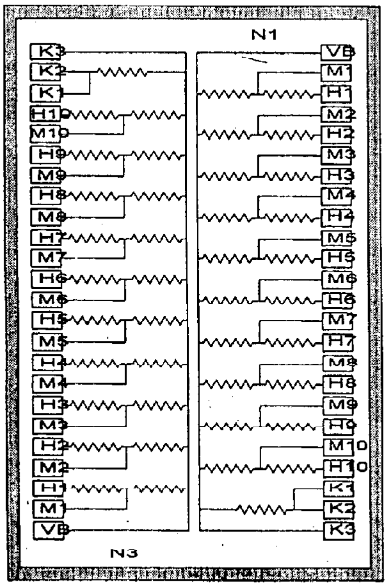
N.E.P.

NEP(1.D-17) FCT CHARGE(pW)





MONTAGE DE CARACTERISATION

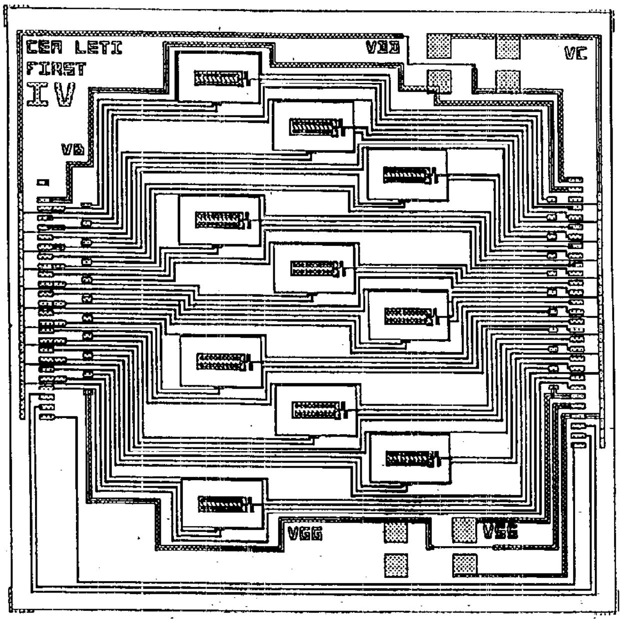


T=0.3-300 K

Barettes de Résistances implantées à géométrie variable pour mesures d' I(V) et de Bruit.

Motifs de contrôle de l'ohmicité des contacts.

Dispersion faible et grande échelle.

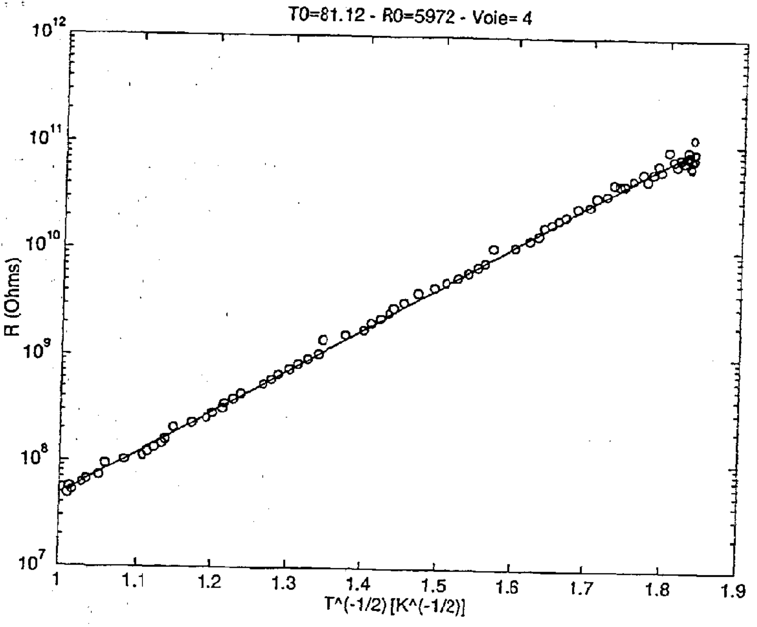


T=4 K

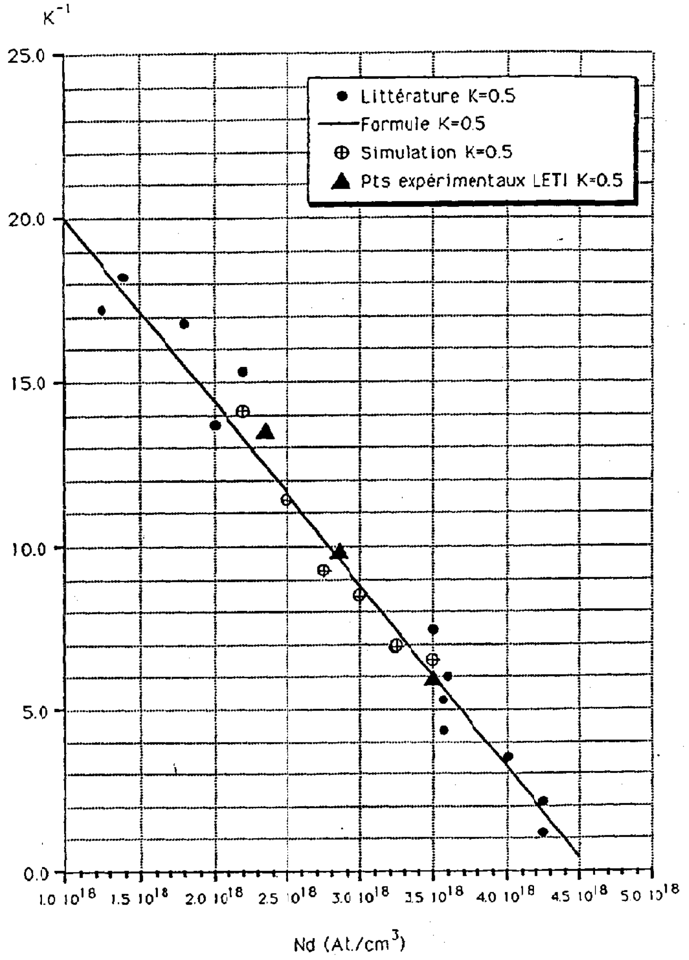
Circuit de lecture CMOS.

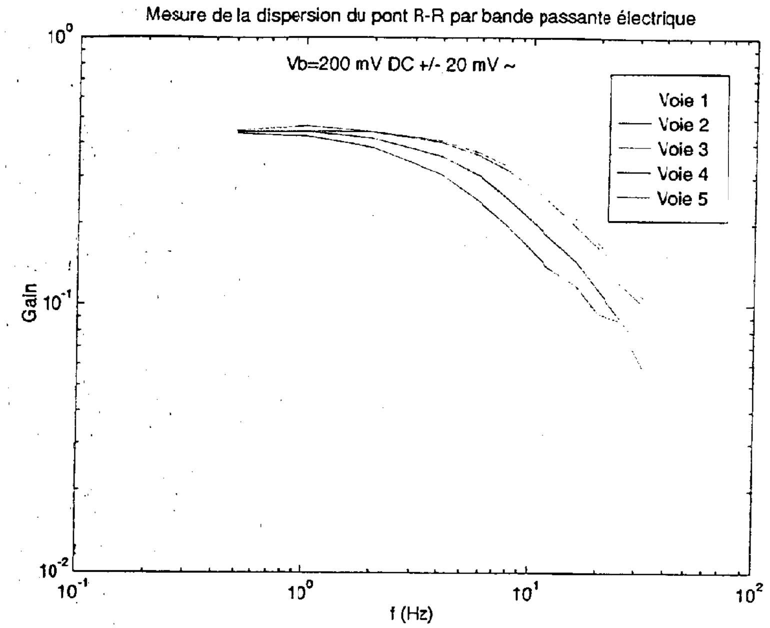
Mesures en courant ou en tension.

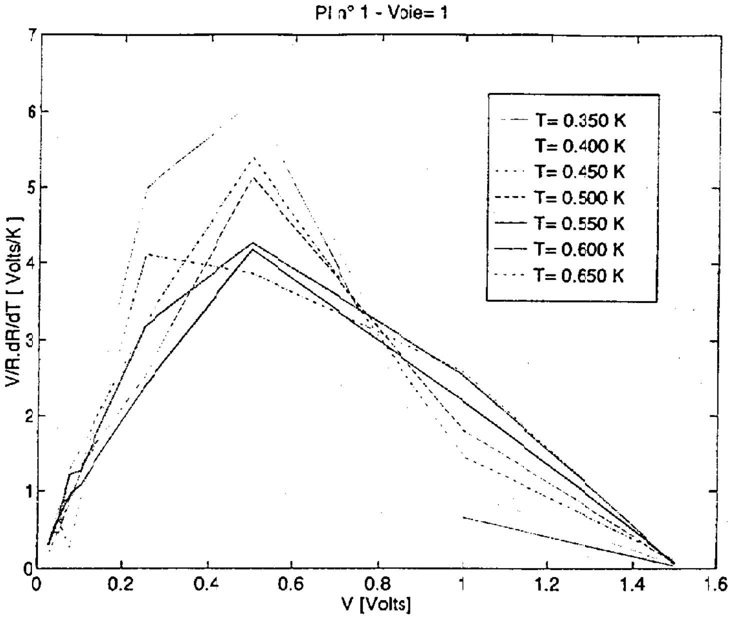
Réduction de la Capacité par Effet Miller.

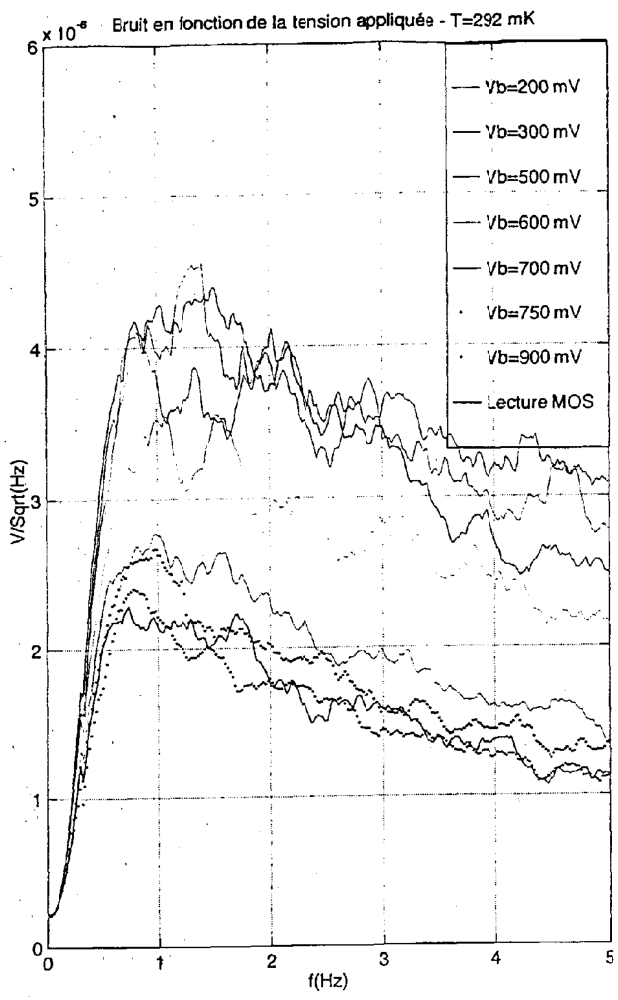


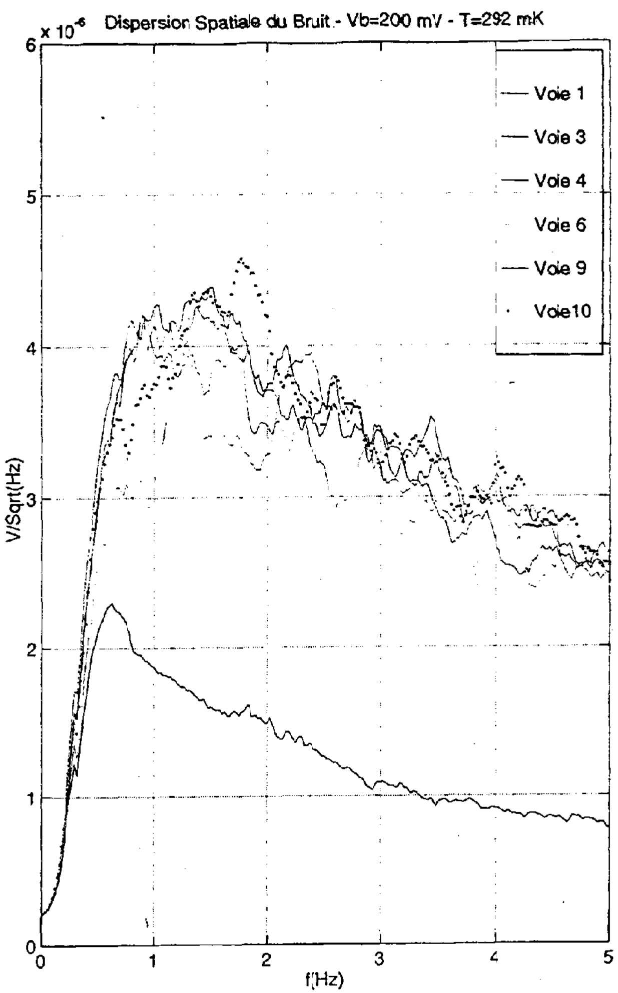
· Racine (T0) dans le modèle d'Efros




Mesure de la dispersion du pont R-R par bande passante électrique
Vb=200 mV DC +/- 20 mV ~
Voie 1
Voie 2
Voie 3
Voie 4
Voie 5
Gain
10^0
10^{-1}
10^{-2}
10^{-1}
10^0
10^1
10^2
f (Hz)


Pl n° 1 - Voie= 1
T= 0.350 K
T= 0.400 K
T= 0.450 K
T= 0.500 K
T= 0.550 K
T= 0.600 K
T= 0.650 K
V/R.dR/dT [Volts/K]
0
1
2
3
4
5
6
7
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
V [Volts]


Bruit en fonction de la tension appliquée - T=292 mK
x 10⁻⁶
V/Sqrt(Hz)
f(Hz)
0
1
2
3
4
5
6
Vb=200 mV
Vb=300 mV
Vb=500 mV
Vb=600 mV
Vb=700 mV
Vb=750 mV
Vb=900 mV
Lecture MOS


Dispersion Spatiale du Bruit - Vb=200 mV - T=292 mK
x 10⁻⁶
V/Sqrt(Hz)
f(Hz)
0
1
2
3
4
5
6
Voie 1
Voie 3
Voie 4
Voie 6
Voie 9
Voie10

Bilan

$$\boxed{e_b = 4\,\mu V/\sqrt{Hz}}$$

$$\downarrow$$

$$\boxed{S = \frac{dR}{RdT}\frac{V_b}{4} = 1.4\ \ V/K}$$

$$\downarrow$$

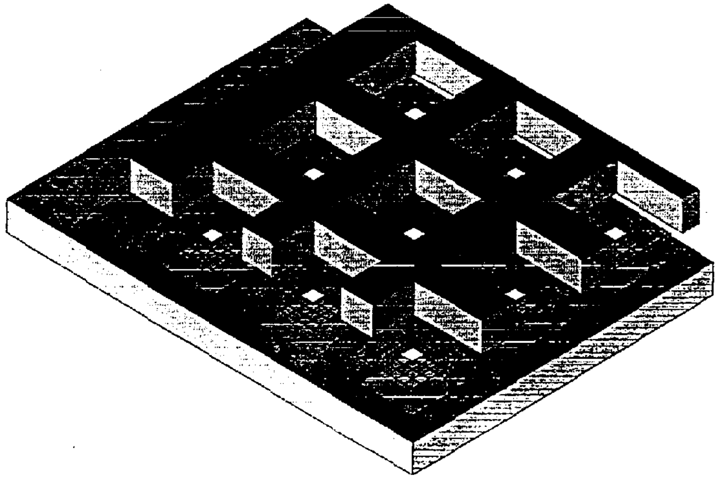
$$\boxed{\sqrt{<T^2>} = 3\,\mu K/\sqrt{Hz}}$$

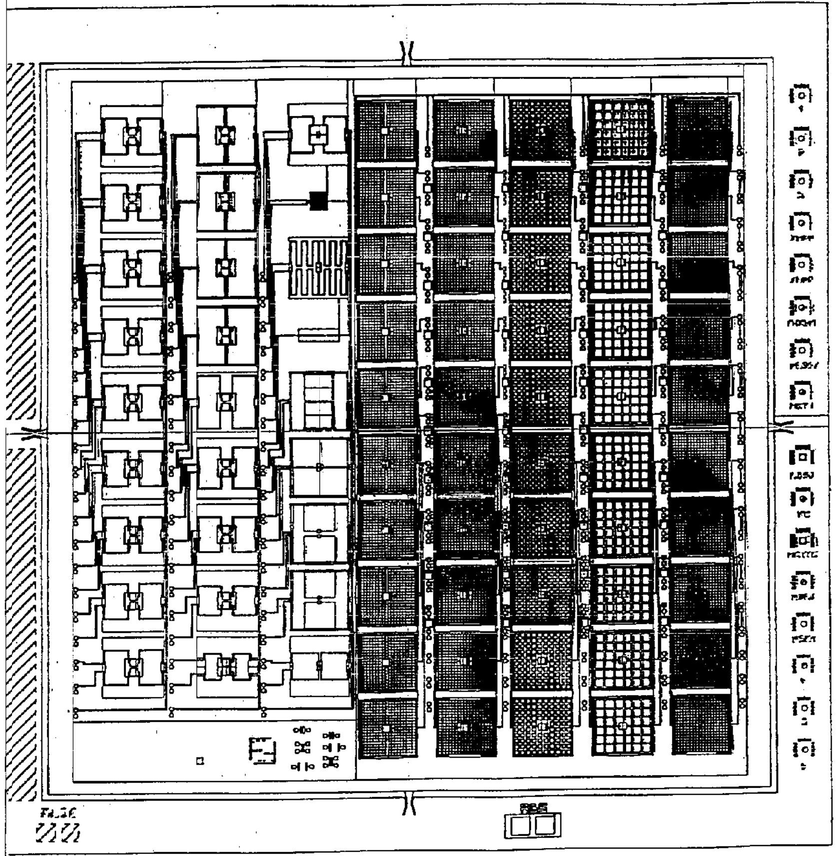
$$\downarrow$$

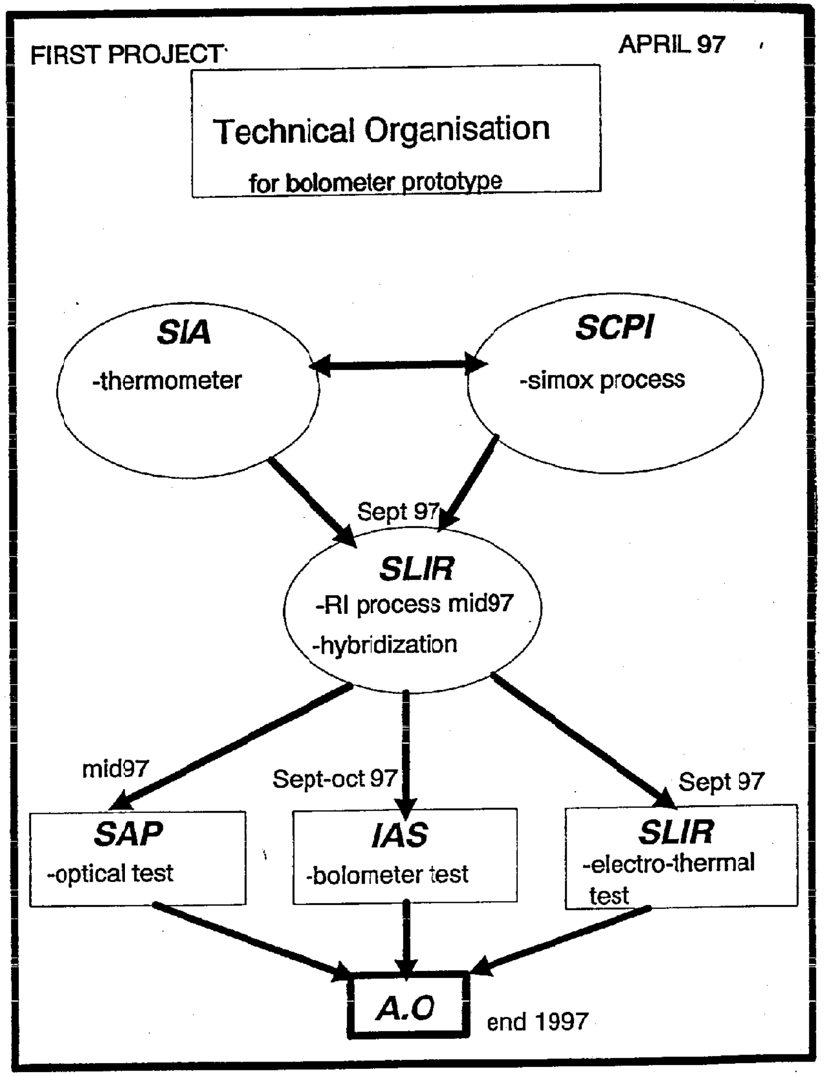
$$\boxed{R_{th} = 10^{11}\,K/W}$$?→ Maquette Thermique

$$\downarrow$$

$$\boxed{NEP = 3 \times 10^{-17}\ W/\sqrt{Hz}}$$







FIRST PROJECT

APRIL 97

Technical Organisation
for bolometer prototype

6

Matt Griffin

Bolometer arrays: 2Fλ feedhorns or bare pixels (≤ 0.5Fλ)

AT
TELESCOPE
FOCUS

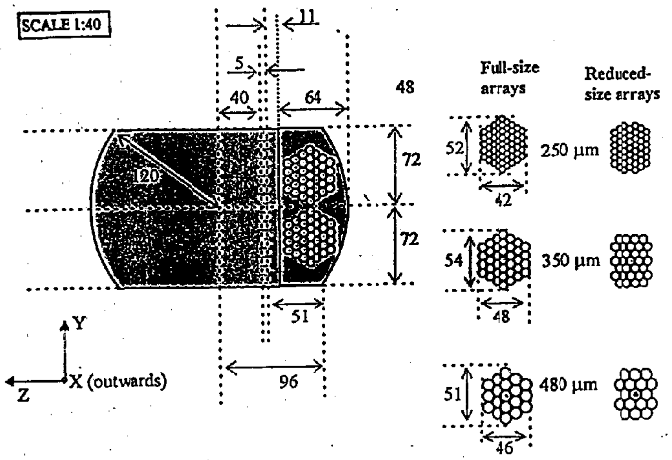


Figure 3 Available area (unvignetted field of view) and array sizes at the telescope focal plane (all dimensions in mm). The shaded area is the part of the focal plane which is effectively available to the BOL. The largest (350-µm) array is superimposed. Possible reduced size arrays are also shown to scale.

ON
M3

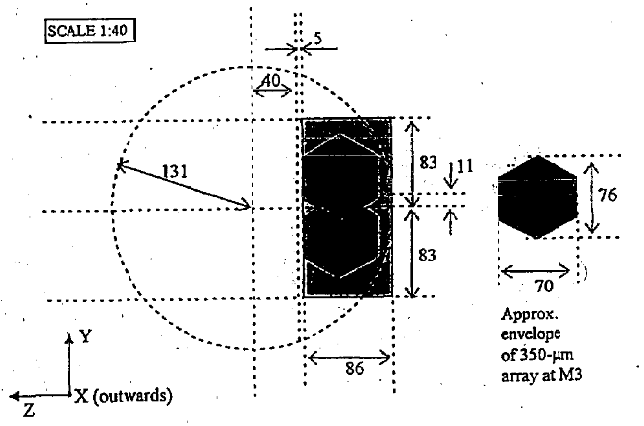
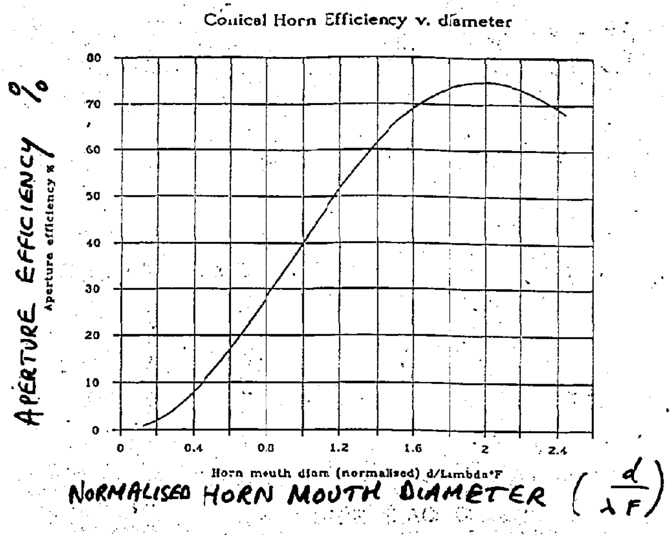
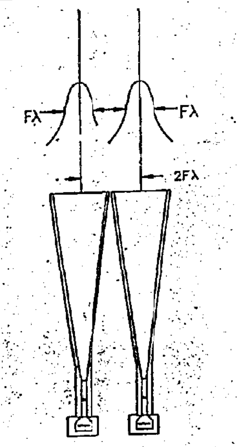
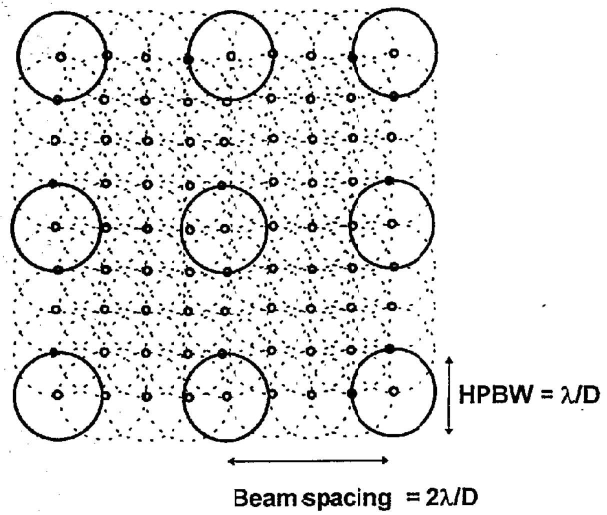


Figure 4 Available area and array sizes at the M3 mirror focal (all dimensions in mm). The shaded area shows the size of a practical M3 mirror. The size needed for the 350-µm array is shown superimposed on the mirror.







4 x 4 = 16 array pointings are needed for fully sampled map

CLOSE-PACKED ABSORBER ARRAYS (SPATIAL SAMPLING ≤ 0.5Fλ)

ADVANTAGES:

- MORE DETECTORS FOR SAME COOLING POWER, FIEL
- INSENSITIVITY TO POINTING JITTER
- LOWER OVERHEADS FROM TELESCOPE MOTION

REQUIREMENTS:

- DEMONSTRATION OF
  - OPTICAL NEP
  - SPEED OF RESPONSE
  - QUANTUM EFFICIENCY
  - COSMIC RAY IMMUNITY
- STRAY LIGHT REJECTION
- HIGH YIELD
- LOW CROSSTALK
- LOW POWER DISSIPATI
- MICROPHONIC IMMUNITY

⇒ NEED DEMONSTRATION IN A WORKING LAB PHOTOMETRIC SYSTEM

7

Colin Cunningham

SCUBA status

ROE/JAC

SCUBA : LATEST STATUS

WORKING WELL!

REMINDER OF SPEC:

SW ARRAY:
91 BOLOMETERS 350 & 450 µm

LW ARRAY:
37 BOLOMETERS
(100) 750 & 850 µm

PHOTOMETRIC PIXELS:
(+1) 1.35 & 2.0 mm

DILUTION REFRIGERATOR:
73 mK ± 1.5 mK

PERFORMANCE:

NEFD in mJy/$\sqrt{Hz}$

λ µm	BEST	'AVERAGE'	
2000	120	120	
1350	60	60	×2
1100	DEAD		
850	80	90	×2
750	120*	150	
450	450	700	×2
350	1500*	2000	

* NOT WELL DETERMINED

PIXEL YIELD:

ALL FUNCTIONAL EXCEPT 1100 µm
10% 1/f NOISE
1 PIXEL ON EACH ARRAY
UNUSABLE DUE TO HIGH NOISE

PROBLEMS & SOLUTIONS

NEFD x4 ↑
  NOW x2 ↑
    FILTERS DISTORTION

DILUTION FRIDGE

LW ARRAY UNSTABLE NOISE

1/F NOISE ON 10% OF PIXELS

MICROPHONICS
  CHOPPER 5th @ 35Hz

BOLOMETER TEMPERATURE
  +30mK

OBSERVING MODES COMMISSIONED:

- JIGGLE-MAP
- SINGLE PIXEL PHOTOMETRY
- SKY DIPS
- POINTING & FOCUS
- SKY NOISE REMOVAL
- SCAN-MAP FUNCTIONAL
  BUT NOT COMPLETE

8

Paolo Saraceno

Imaging across the slit for galactic sources

PAOLO SARACENO

IMAGING ACROSS THE SLIT FOR
GALACTIC SOURCES

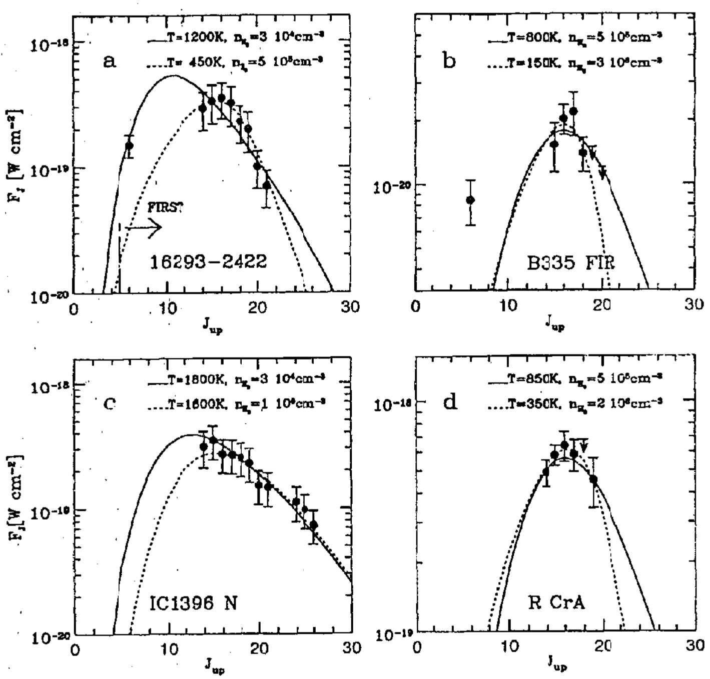
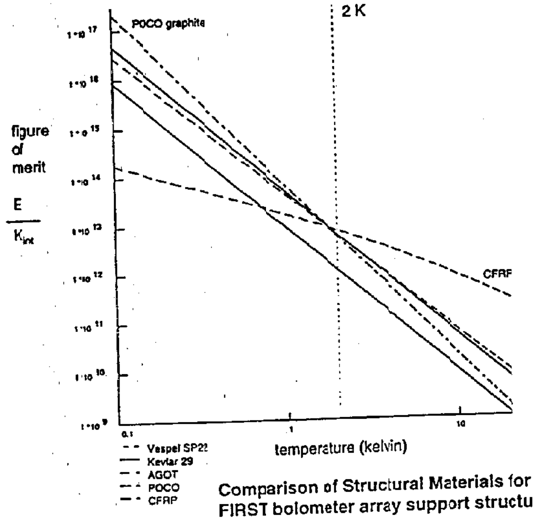


Fig. 1.— Figure 1: the CO line fluxes observed by ISO-LWS are plotted as a function of the rotational quantum number J_{up} for the four YSOs IRAS16293-2422 (a), 3335 FIR (b), IC1396 N (c) and R CrA (d). Also plotted are the ground-based observations of the CO 6-5, when available. For each source, the continnum and dotted lines give the range of possible model fits through the observations. In Fig. 1a, the range of transitions that will be observed by the FIRST instruments is indicated.

9

Peter Hastings

BOL thermal/mechanical engineering



Comparison of Structural Materials for the FIRST bolometer array support structure(s)

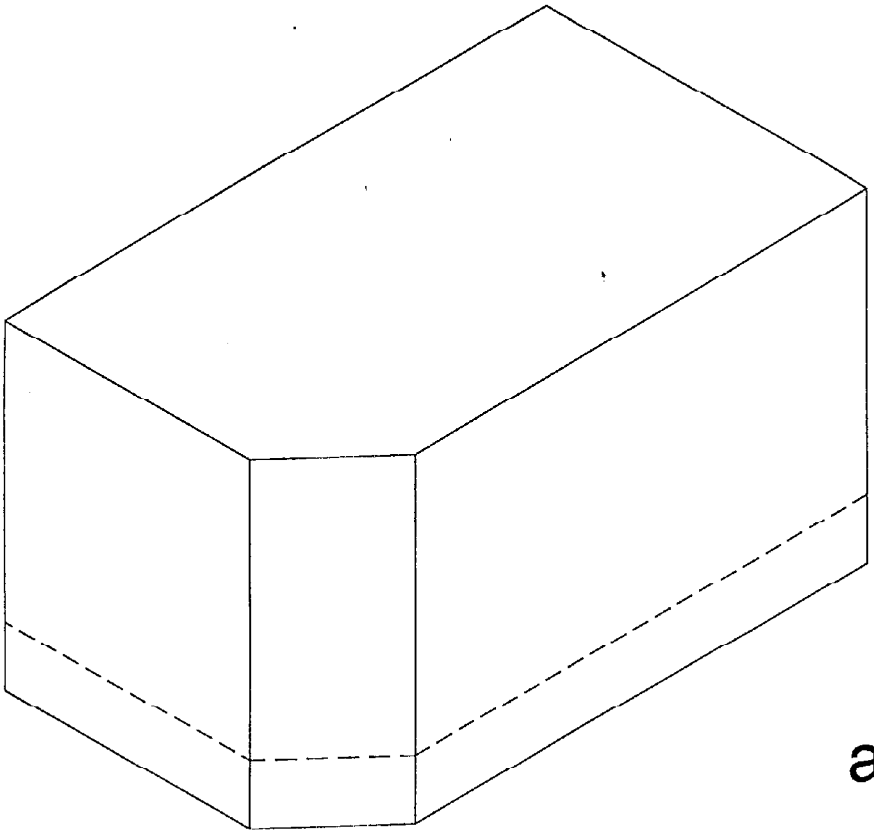
Comparison of candidate materials for the structures in the BOL instrument

mass at a given temperature which can be supported without exceeding the heat budget

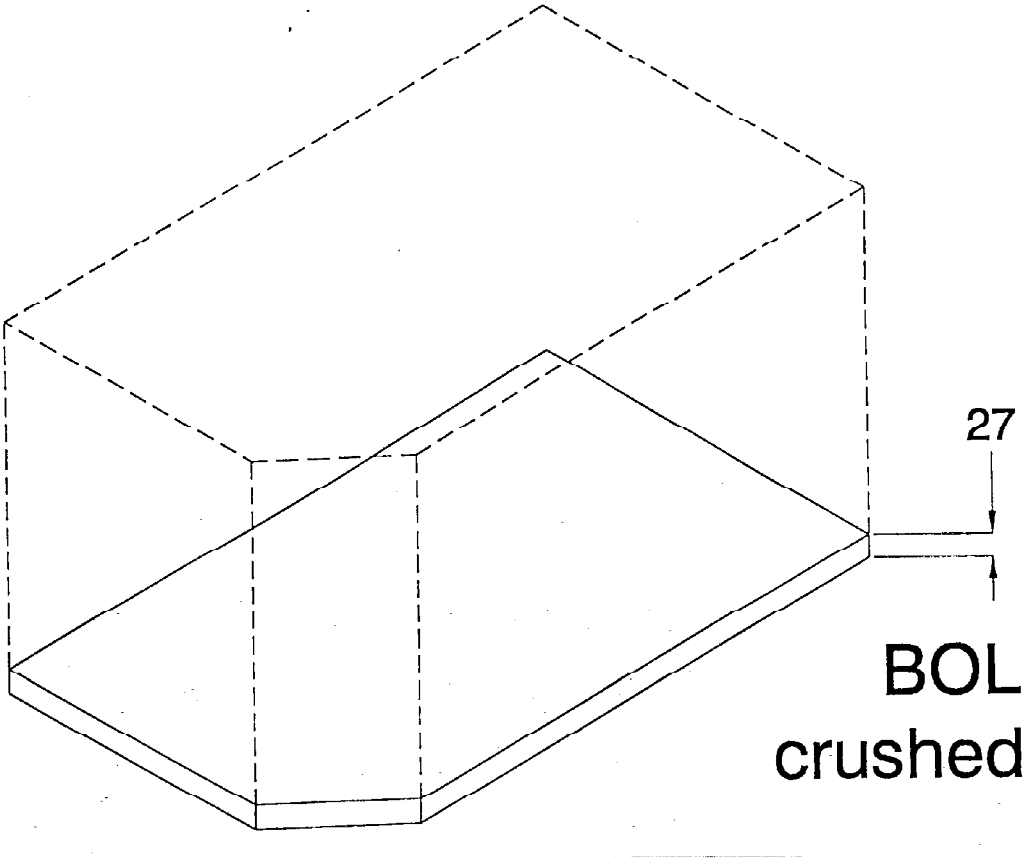
material	4 K	2 K	0.1 K
Kevlar 29 cord	12.8 kg	877 kg	175 gm
graphite (pre-stressed)	1.5 kg	330 kg	104 gm
high-modulus CFRP	208 kg	2039 kg	94 gm
graphite (plain)	1.5 kg	185 kg	58 gm

BOL Instrument
Mass Budget

• 20 K	outer casing, fore-optics (two sets), choppers (two)
• 4K	inner enclosure, photometer optics, spectrograph optics, grating mechanism, filter wheel (order sorting)
• 2K	photometer dichroics (?), filters, array enclosure, outer feedhorns
• 0.1K	feedhorns & arrays, dilution refrigerator
•	
•	
• 20K	8 kg
• 4K	10.5 kg
• 2K	1 kg
• 0.1K	0.5 kg
• wiring	1 kg
• TOTAL	21 kg



BOL
afloat



BOL
crushed

10

Bruno Maffei

BOL thermal modelling

THERMAL MODEL

Estimates of dissipation and conduction by wires and supports

Assumptions

- Stainless steel wires diameter: 100 µm
- Brass wires diameter (for grating drive coils): 100 µm
- Wire length between stages: 20 cm
- Stage temperatures: 0.1,2,4,15,50K
- Suppose that the dissipation in the wiring --> lowest temperature (worst case)
- Grating scan: +/- 3 degrees (Imax=5mA)
- 1 chopper at 15K, Imax=2mA

Wiring

Temperature	SST wire number	Brass wire number	Devices at lowest temp.
0.1 - 2K	318	0	142 bolometers 2 thermometers
2 - 4K	326	0	2 thermometers
4 - 15K	350	8	grating, 4 therm.
15 - 50K	376	8	chopper, 2 therm.

Assumed mass on stages (P. Hastings)

0.5 Kg on 0.1K stage
1 Kg on 2K stage
10.5 Kg on 4K stage
8Kg on 15K stage
Kevlar supports

Stage temperature	Cooling power	Conduction by wires	Dissipation by wires	Conduction by supports	Dissipation by devices	Radiation	Total
2K	2 mW	32 µW	0.04 µW	2.3 µW	0	0.1 mW	0.14 mW
4K	7.8 mW	0.7 mW	0.35 mW	0.84 mW	25 µW (grating 25% of time)	0.3 mW	2.22 mW
15K		8.4 mW	0.9 mW	14 mW	80 µW (chopper)		23.4 mW

11

Ken King
BOL observing modes

Bolometer Observing Modes

	Photometry					Spectrometry						
	Map (X*Y arcmin)	Scan (X*6 arcmin)	Image (6x6 arcmin)	Pointing		Map (X*Y arcmin)			Pointing			
Satellite Pointing	N*M Raster	N*1 Raster fixed direction	4*4 Raster	5 Point Star	Fixed Point	N*M Raster			5 Point Star		Fixed Point	
Chopping	Yes >6 arcmin User direction	Yes size? direction? (ideally perp. to scan)	Yes size?	Yes size?	Yes 2 pixels	Yes		No	Yes		Yes	
Grating	-----	------	------	------	------	Line Scans	Scan Range	Freq Chop Line Scans	Scan Range	Line Scans	Scan Range	Line Scans

12

Ken King

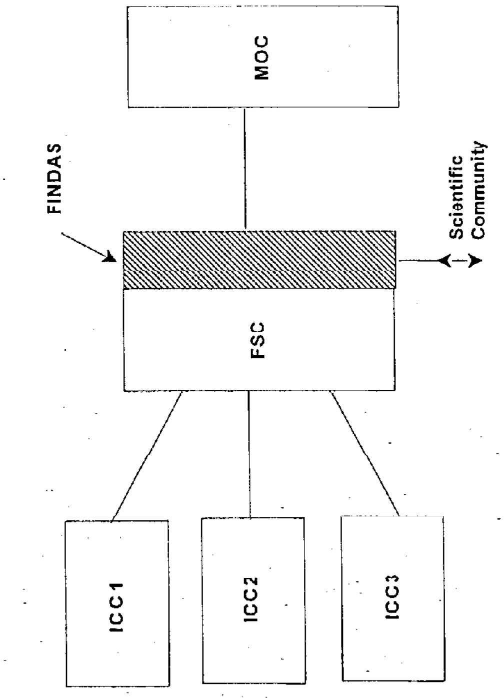
The role of the Instrument Control Centre (ICC)

Instrument Control Centre(s) - (1)

- IMPLEMENTATION AND OPERATIONS RESPONSIBILITIES SHOULD BE ASSIGNED TO THE MOST QUALIFIED GROUPS "COMPETENCE CENTRES"
    - INCREASES EFFICIENCY
    - REDUCES OVERHEAD
    - INCREASES MOTIVATION
    - SIMPLIFIES INTERFACES
- ISO IDTs VERY SUCCESSFUL, BUT 1) SET-UP VERY LATE
  2) COLLABORATION WITH SUPPORT TEAMS DIFFICULT

⇓

- ESTABLISH INSTRUMENT CONTROL CENTRES (ICCs) UNDER PI RESPONSIBILITY



- MOC PROVIDED BY ESOC
- ICCs PROVIDED BY THE PI-INSTITUTES
- FSC : TWO POSSIBILITIES
  1) FSC PROVIDED BY ESA
  2) FSC PROVIDED BY A EUROPEAN INSTITUTE

Fig. 4.2 - FIRST OPERATIONAL SCENARIO

Instrument Control Centre(s) - (2)

MAIN FEATURES:

- OPTIMUM USE OF INSTRUMENT TEAM EXPERTISE
- ONE ICC PER INSTRUMENT
- LOCATED AT PI - INSTITUTES
- ICC RESPONSIBLE FOR ITS OWN ACCOMMODATION, ORGANISATION AND MANAGEMENT
- NO DIRECT INTERACTION WITH OBSERVERS → FSC
- NO REAL-TIME OPERATIONAL RESPONSIBILITY

MAIN TASKS:

- DEFINE INSTRUMENT DATA BASE
- DEFINE INSTRUMENT MODES AND COMMAND SEQUENCES
- CALIBRATE INSTRUMENT (PRE- AND POST LAUNCH)
- PRODUCE INSTRUMENT USER's MANUAL

Instrument Control Centre(s) - (3)

- PRODUCE INSTRUMENT FLIGHT OPERATIONS PROCEDURES
- PRODUCE SCIENTIFIC PROCESSING SOFTWARE
- SUPPORT INSTRUMENT COMMISSIONING AND PV PHASES (CO-LOCATION AT THE MOC) IN REAL-TIME
- PRODUCE "TIME" ESTIMATORS (OBSERVERS SUPPORT)
- PRODUCE INSTRUMENT SOFTWARE SIMULATORS (OPERATIONAL TESTING)
- PROVIDE INSTRUMENT ON-BOARD SOFTWARE MAINTENANCE (PRE- AND POST LAUNCH)
- SUPPORT ROUTINE OPERATIONS (LOCATION ICC)
- SUPPORT INSTRUMENT-LEVEL TESTS, AIV AND SIMULATIONS
- PROVIDE PRE-LAUNCH INSTRUMENT CALIBRATION TABLES
- POPULATE AND USE 'FINDAS' AS EARLY AS POSSIBLE

13

Roger Emery

BOL work-packages

The FIRST BOL Workpackage Descriptions

Introduction

This note gives an outline of the workpackages for the development, test and operation of the FIRST Bolometer instrument. This includes workpackages covering both the design and build of the BOL instrument and the setup and operation of the BOL Instrument Control Centre. It is intended as a starting point for further development and discussion. A nominal workpackage number has been given - this is subject to change as the overall project nomenclature is evolved.

For the purposes of this note the following assumptions have been made:

- The instrument will have separate photometer and spectrometer channels; the spectrometer will be a grating and there will be no filter wheel for the photometer.
- Both channels will be fed from a single input optics containing a chopper and calibration source(s)
- Five models of the instrument wil be provided; a Mass Thermal Model (MTM), an optical Alignment Model (AM), a Qualification Model (QM), a Flight Model (FM) and a Flight Spare model (FS). An additional development model of the Warm Electronics will be required for development and test of the On Board Software.

BOL Instrument Workpackages

BOL-WP-01 - Management

T-01.01 Project Management

- **T-01.01.01** Definition of Project milestones and schedule
- **T-01.01.02** Organise Project meetings and monitor progress
- **T-01.01.03** Report progress to ESA.
- **T-01.01.04** Participation in Ground Segment Steering Committee meetings

T-01.02 Scientific Coordination

- **T-01.02.01** Definition of Instrument Science Requirements
- **T-01.02.02** Definition of Instrument Calibration Requirements
- **T-01.02.03** Coordination of Consortium Observing Programme
- **T-01.02.04** Participation in FIRST Science Working Group(s)

T-01.03 Quality Assurance

- **T-01.03.01** Provision of Quality Assurance Plan
- **T-01.03.02** Definition of AIV Requirements
- **T-01.03.03** Provision of Instrument Level Test Requirements
- **T-01.03.04** Provision of System Level Test Requirements
- **T-01.03.05** Provision of Ground Calibration Requirements

T-01.04 Project Office

- **T-01.04.01** Setup of the Bolometer Project Office
- **T-01.04.02** Operation of the Project Office throughout the Design, Build, Operations and Post-Operations phases

T-01.05 Systems Engineering

- **T-01.05.01** Mechanical/Thermal Systems Engineering - leading to Mechanical/Thermal design
- **T-01.05.02** Optical Systems Engineering - leading to optical design
- **T-01.05.03** Electrical Systems Engineering
- **T-01.05.04** Software Systems Engineering

T-01.06 Interfaces

- **T-01.06.01** Coordination of instrument subsystem interfaces definition
- **T-01.06.02** Definition of Bol/ESA interfaces - generation of EID part B
- **T-01.06.03** Definition of ICC interfaces with other centres

T-01.07 Documentation

- **T-01.07.01** Definition of documentation tree
- **T-01.07.02** Coordinate production of documentation
- **T-01.07.03** Provision of Instrument User's Manual

BOL-WP-02 - Structure

This covers production of the instrument structure, integration of the other instrument subsystems (excluding the detector assemblies) and the testing of this configuration. Integration of the detector assemblies into the instrument and the subsequent testing is covered elsewhere.

The Structure is assumed to consist of the 20K box and the internal 4K box plus and temperature sensors included in those. The 2K box is considered elsewhere.

T-02.01 Instrument Mechanical/Thermal Design

It is assumed that a development model of the structure will need to be built in order to determine the vibrational load placed on the instrument subsystems during qualification.

- **T-02.01.01** Define Instrument Mechanical Design
- **T-02.01.02** Define Instrument Thermal Design
- **T-02.01.03** Provision of Structure Development Model
- **T-02.01.04** Integration of 2K box Development Model
- **T-02.01.05** Vibration Test of integrated Development Model (DM) (cold)
- **T-02.01.06** Definition of Structure/Subsystem interfaces

T-02.02 Mass Thermal Model (MTM)

This may be combined with the Alignment Model.

- **T-02.02.01** MTM design
- **T-02.02.02** MTM manufacture
- **T-02.02.03** MTM testing
- **T-02.02.04** Provision of MTM delivery documentation

T-02.03 Qualification Model (QM) Structure
- **T-02.03.01** Manufacture of QM Structure
- **T-02.03.02** Integration of QM Structure and Optics including Grating and Chopper and cold boxes
- **T-02.03.03** Alignment of QM Optics (warm)
- **T-02.03.04** Vibration testing of QM Structure (cold)
- **T-02.03.05** Provision of QM Structure delivery documentation

T-02.04 Flight Model (FM) Structure
- **T-02.04.01** Manufacture of FM Structure
- **T-02.04.02** Integration of FM Structure and Optics including Grating and Chopper and cold boxes
- **T-02.04.03** Alignment of FM Optics (warm)
- **T-02.04.04** Vibration testing of FM Structure (cold)
- **T-02-04.05** Provision of FM Structure delivery documentation

T-02.05 Flight Spare (FS) Structure Manufacture
- **T-02.05.01** Manufacture of FS Structure
- **T-02.05.02** Integration of FS Structure and Optics including Grating and Chopper and cold boxes
- **T-02.05.03** Alignment of FS Optics (warm)
- **T-02.05.04** Vibration testing of FS Structure (cold)
- **T-02-05.05** Provision of FS Structure delivery documentation

T-02.06 Ground Support Equipment
- **T-02.06.01** Provision of Mechanical Ground Support Equipment
- **T-02.06.02** Provision of Electrical Ground Support Equipment

T-02-07 Management
- **T-02.07.01** Management
- **T-02.07.02** Definition of Structure Test Requirements
- **T-02.07.03** Specification of Warm Electronics Interfaces

BOL-WP-03 - Optics

T-03.01 Instrument Optical Design
- **T-03.01.01** Define Instrument Optical design
- **T-03.01.02** Provision of Optical design support

T-03.02 Alignment Model (AM)
- **T-03.02.01** AM design
- **T-03.02.02** AM manufacture
- **T-03.02.03** AM Testing
- **T-03.02.04** Provision of AM delivery documentation

T-03.03 Qualification Model (QM) Optics
- **T-03.03.01** Manufacture of QM Optics
- **T-03.03.02** Testing of QM Optics
- **T-03-03.03** Provision of QM Optics delivery documentation

T-03.04 Flight Model (FM) Optics
- **T-03.04.01** Manufacture of FM Optics
- **T-03.04.02** Testing of FM Optics
- **T-03-04.03** Provision of FM Optics delivery documentation

T-03.05 Flight Spare (FS) Optics
- **T-03.05.01** Manufacture of FS Optics
- **T-03.05.02** Testing of FS Optics
- **T-03-05.03** Provision of FS Optics delivery documentation

T-03.06 Ground Support Equipment
- **T-03.06.01** Provision of Mechanical Support Equipment
- **T-03.06.02** Provision of Optical Support Equipment

T-03.07 Management
- **T-03.07.01** Management
- **T-03.07.02** Definition of Optics Test Requirements

BOL-WP-04 - Detector Assemblies

T-04.01 Detector Assembly Design
- **T-04.01.01** Photometer Detector Arrays design
- **T-04.01.02** Spectrometer Detector Array design
- **T-04.01.03** Feedhorn design
- **T-04.01.04** Filter design

T-04.02 Qualification Model (QM) Detector Assembly
- **T-04.02.01** Provision and test of QM Photometer Detector Arrays
- **T-04.02.02** Provision and test of QM Spectrometer Detector Arrays
- **T-04.02.03** Provision and test of QM Feedhorns
- **T-04.02.04** Provision and test of QM Filters
- **T-04.02.05** Provision and test of QM Cold Electronics
- **T-04.02.06** Integration of QM Detector Assembly
- **T-04.02.07** Vibration test of QM Detector Assembly (cold)
- **T-04.02.08** EMC test of QM Detector Assembly
- **T-04.02.09** Calibration of QM Detector Assembly
- **T-04.02.10** Provision of QM Detectors delivery documentation

T-04.03 Flight Model (FM) Detector Assembly
- **T-04.03.01** Provision and test of FM Photometer Detector Arrays
- **T-04.03.02** Provision and test of FM Spectrometer Detector Arrays

T-04.03.03 Provision and test of FM Feedhorns
T-04.03.04 Provision and test of FM Filters
T-04.03.05 Provision and test of FM Cold Electronics
T-04.03.06 Integration of FM Detector Assembly
T-04.03.07 Vibration test of FM Detector Assembly (cold)
T-04.03.08 EMC test of FM Detector Assembly
T-04.03.09 Calibration of FM Detector Assembly
T-04.03.10 Provision of FM Detectors delivery documentation

T-04.04 Flight Spare (FS) Detector Assembly

T-04.04.01 Provision and test of FS Photometer Detector Arrays
T-04.04.02 Provision and test of FS Spectrometer Detector Arrays
T-04.04.03 Provision and test of FS Feedhorns
T-04.04.04 Provision and test of FS Filters
T-04.04.05 Provision and test of FS Cold Electronics
T-04.04.06 Integration of FS Detector Assembly
T-04.04.07 Vibration test of FS Detector Assembly (cold)
T-04.04.08 EMC test of FS Detector Assembly
T-04.04.09 Calibration of FS Detector Assembly
T-04.04.10 Provision of FS Detectors delivery documentation

T-04.05 Ground Support Equipment

T-04.05.01 Provision of Mechanical Ground Support Equipment
T-04.05.02 Provision of Optical Ground Support Equipment
T-04.05.03 Provision of Electrical Ground Support Equipment

T-04.06 Management

T-04.06.01 Management
T-04.06.02 Definition of Detectors Test Requirements
T-04.06.03 Specification of Warm Electronics Interfaces

BOL-WP-05 - Dilution Cooler Assembly

As the cooler has parts both inside and outside the 2K box, this subsystem is assumed to include provision of the integrated Cooler/2K box assembly.

T-05.01 Cooler Assembly Design

T-05.01.01 Design of cooler subsystem
T-05.01.02 Mechanical/Thermal design of 2K box
T-05.01.03 Provision of Cooler Assembly Development Model
T-05.01.04 Definition of 2K box/Detector Assembly interfaces

T-05.02 Qualification Model (QM) Cooler Assembly

T-05.02.01 Provision and test of QM Cooler
T-05.02.02 Provision of QM 2K box
T-05.02.03 Integration of QM Cooler Assembly
T-05.02.04 Vibration test of QM Cooler Assembly (cold)
T-05.02.05 EMC test of QM Cooler Assembly
T-05.02.06 Calibration of QM Cooler Assembly
T-05.02.07 Provision of QM Cooler Assembly delivery documentation

T-05.03 Flight Model (FM) Cooler Assembly

T-05.03.01 Provision and test of FM Cooler
T-05.03.02 Provision of FM 2K box
T-05.03.03 Integration of FM Cooler Assembly
T-05.03.04 Vibration test of FM Cooler Assembly (cold)
T-05.03.05 EMC test of FM Cooler Assembly
T-05.03.06 Calibration of FM Cooler Assembly
T-05.03.07 Provision of FM Cooler Assembly delivery documentation

T-05.04 Flight Spare (FS) Cooler Assembly

T-05.04.01 Provision and test of FS Cooler
T-05.04.02 Provision of FS 2K box
T-05.04.03 Integration of FS Cooler Assembly
T-05.04.04 Vibration test of FS Cooler Assembly (cold)
T-05.04.05 EMC test of FS Cooler Assembly
T-05.04.06 Calibration of FS Cooler Assembly
T-05.04.07 Provision of FS Cooler Assembly delivery documentation

T-05.05 Ground Support Equipment

T-05.05.01 Provision of Mechanical Ground Support Equipment
T-05.05.02 Provision of Electrical Ground Support Equipment

T-05.06 Management

T-05.06.01 Management
T-05.06.02 Definition of Cooler Assembly Test Requirements
T-05.06.03 Specification of Warm Electronics Interfaces

BOL-WP-06 - Grating Assembly

This assembly includes both the Grating and the mechanism used to scan the Grating

T-06.01 Grating Assembly Design

T-06.01.01 Grating design
T-06.01.02 Mechanism design

T-06.02 Qualification Model (QM) Grating Assembly

T-06.02.01 Provision and test of QM Grating
T-06.02.02 Provision of QM Mechanism
T-06.02.03 Integration of QM Grating and Mechanism
T-06.02.04 Vibration test of QM Grating Assembly (cold)
T-06.02.05 EMC test of QM Grating Assembly
T-06.02.06 Calibration of QM Grating Assembly

- **T-06.02.07** Provision of QM Grating Assembly delivery documentation

T-06.03 Flight Model (FM) Grating Assembly
- **T-06.03.01** Provision and test of FM Grating
- **T-06.03.02** Provision of FM Mechanism
- **T-06.03.03** Integration of FM Grating and Mechanism
- **T-06.03.04** Vibration test of FM Grating Assembly (cold)
- **T-06.03.05** EMC test of FM Grating Assembly
- **T-06.03.06** Calibration of FM Grating Assembly
- **T-06.03.07** Provision of FM Grating Assembly delivery documentation

T-06.04 Flight Spare (FS) Grating Assembly
- **T-06.04.01** Provision and test of FS Grating
- **T-06.04.02** Provision of FS Mechanism
- **T-06.04.03** Integration of FS Grating and Mechanism
- **T-06.04.04** Vibration test of FS Grating Assembly (cold)
- **T-06.04.05** EMC test of FS Grating Assembly
- **T-06.04.06** Calibration of FS Grating Assembly
- **T-06.04.07** Provision of FS Grating Assembly delivery documentation

T-06.05 Ground Support Equipment
- **T-06.05.01** Provision of Mechanical Ground Support Equipment
- **T-06.05.02** Provision of Optical Ground Support Equipment
- **T-06.05.03** Provision of Electrical Ground Support Equipment

T-06.06 Management
- **T-06.06.01** Management
- **T-06.06.02** Definition of Grating Assembly Test Requirements
- **T-06.06.03** Specification of Warm Electronics Interfaces

BOL-WP-07 - Chopper

T-07.01 Chopper Design
- **T-07.01.01** Optical design
- **T-07.01.02** Mechanical design

T-07.02 Qualification Model (QM) Chopper
- **T-07.02.01** Provision of QM Chopper
- **T-07.02.02** Vibration test of QM Chopper (cold)
- **T-07.02.03** EMC test of QM Chopper
- **T-07.02.04** Calibration of QM Chopper
- **T-07.02.05** Provision of QM Chopper delivery documentation

T-07.03 Flight Model (FM) Chopper
- **T-07.03.01** Provision of FM Chopper
- **T-07.03.02** Vibration test of FM Chopper (cold)
- **T-07.03.03** EMC test of FM Chopper
- **T-07.03.04** Calibration of FM Chopper
- **T-07.03.05** Provision of FM Chopper delivery documentation

T-07.04 Flight Spare (FS) Chopper
- **T-07.04.01** Provision of FS Chopper
- **T-07.04.02** Vibration test of FS Chopper (cold)
- **T-07.04.03** EMC test of FS Chopper
- **T-07.04.04** Calibration of FS Chopper
- **T-07.04.05** Provision of FS Chopper delivery documentation

T-07.05 Ground Support Equipment
- **T-07.05.01** Provision of Mechanical Ground Support Equipment
- **T-07.05.02** Provision of Optical Ground Support Equipment
- **T-07.05.03** Provision of Electrical Ground Support Equipment

T-07.06 Management
- **T-07.06.01** Management
- **T-07.06.02** Definition of Chopper Test Requirements
- **T-07.06.03** Specification of Warm Electronics Interfaces

BOL-WP-08 - Calibration Source(s)

T-08.01 Calibration Source(s) Design
- **T-08.01.01** Optical design
- **T-08.01.02** Mechanical design

T-08.02 Qualification Model (QM) Calibration Source(s)
- **T-08.02.01** Provision of QM Calibration Source(s)
- **T-08.02.02** Vibration test of QM Calibration Source(s) (cold)
- **T-08.02.03** EMC test of QM Calibration Source(s)
- **T-08.02.04** Calibration of QM Calibration Source(s)
- **T-08.02.05** Provision of QM Calibration Source(s) delivery documentation

T-08.03 Flight Model (FM) Calibration Source(s)
- **T-08.03.01** Provision of FM Calibration Source(s)
- **T-08.03.02** Vibration test of FM Calibration Source(s) (cold)
- **T-08.03.03** EMC test of FM Calibration Source(s)
- **T-08.03.04** Calibration of FM Calibration Source(s)
- **T-08.03.05** Provision of FM Calibration Source(s) delivery documentation

T-08.04 Flight Spare (FS) Calibration Source(s)
- **T-08.04.01** Provision of FS Calibration Source(s)
- **T-08.04.02** Vibration test of FS Calibration Source(s) (cold)
- **T-08.04.03** EMC test of FS Calibration Source(s)
- **T-08.04.04** Calibration of FS Calibration Source(s)
- **T-08.04.05** Provision of FS Calibration Source(s) delivery documentation

T-08.05 Ground Support Equipment
- **T-08.05.01** Provision of Mechanical Ground Support Equipment
- **T-08.05.02** Provision of Optical Ground Support Equipment
- **T-08.05.03** Provision of Electrical Ground Support Equipment

T-08.06 Management
- **T-08.06.01** Management
- **T-08.06.02** Definition of Calibration Source(s) Test Requirements
- **T-08.06.03** Specification of Warm Electronics Interfaces

BOL-WP-09 - Digital Processing Unit (DPU)

This unit includes the instrument power supply and digital electronics. It does not include provision of the harness between the DPU and S/C.

T-09.01 DPU Design
- **T-08.01.01** Power Supply design
- **T-08.01.02** Digital Electronics design
- **T-08.01.03** Mechanical design
- **T-08.01.04** Instrument Grounding design
- **T-08.01.05** DPU/APU interface definition
- **T-08.01.06** S/C Interface design
- **T-08.01.07** Provision of DPU Development Model

T-09.02 Qualification Model (QM) DPU
- **T-09.02.01** Provision of QM DPU
- **T-09.02.02** Vibration test of QM DPU
- **T-09.02.03** Thermal Vacuum test of QM DPU
- **T-09.02.04** Calibration of QM DPU
- **T-09.02.05** Provision of QM DPU delivery documentation

T-09.03 Flight Model (FM) DPU
- **T-09.03.01** Provision of FM DPU
- **T-09.03.02** Vibration test of FM DPU
- **T-09.03.03** Thermal Vacuum test of FM DPU
- **T-09.03.04** Calibration of FM DPU
- **T-09.03.05** Provision of FM DPU delivery documentation

T-09.04 Flight Spare (FS) DPU
- **T-09.04.01** Provision of FS DPU
- **T-09.04.02** Vibration test of FS DPU
- **T-09.04.03** Thermal Vacuum test of FS DPU
- **T-09.04.04** Calibration of FS DPU
- **T-09.04.05** Provision of FS DPU delivery documentation

T-09.05 Ground Support Equipment
- **T-09.05.01** Provision of Mechanical Ground Support Equipment
- **T-09.05.02** Provision of Electrical Ground Support Equipment

T-09.06 Management
- **T-09.06.01** Management
- **T-09.06.02** Definition of DPU Test Requirements
- **T-09.06.03** Specification of Warm Electronics Interfaces

BOL-WP-0010 - Analogue Processing Unit (APU)

This subsystem includes any interconnecting harnesses between the DPU and APU.

T-10.01 APU Design
- **T-10.01.01** Analogue Electronics design
- **T-10.01.02** Harness design
- **T-10.01.03** Mechanical design
- **T-10.01.04** APU/Subsystem Interface Definition
- **T-10.01.05** Provision of APU Development Model

T-10.02 Qualification Model (QM) APU
- **T-10.02.01** Provision of QM APU (inc harness)
- **T-10.02.02** Vibration test of QM APU
- **T-10.02.03** Thermal Vacuum test of QM APU
- **T-10.02.04** Calibration of QM APU
- **T-10.02.05** Provision of QM APU delivery documentation
- **T-10.02.06** Integration of QM Warm Electronics
- **T-10.02.07** EMC Test of QM Warm Electronics
- **T-10.02.08** Provision of QM Warm Electronics delivery documentation

T-10.03 Flight Model (FM) APU
- **T-10.03.01** Provision of FM APU (inc harness)
- **T-10.03.02** Vibration test of FM APU
- **T-10.03.03** Thermal Vacuum test of FM APU
- **T-10.03.04** Calibration of FM APU
- **T-10.03.05** Provision of FM APU delivery documentation
- **T-10.03.06** Integration of FM Warm Electronics
- **T-10.03.07** EMC Test of FM Warm Electronics
- **T-10.03.08** Provision of FM Warm Electronics delivery documentation

T-10.04 Flight Spare (FS) APU
- **T-10.04.01** Provision of FS APU (inc harness)
- **T-10.04.02** Vibration test of FS APU
- **T-10.04.03** Thermal Vacuum test of FS APU
- **T-10.04.04** Calibration of FS APU
- **T-10.04.05** Provision of FS APU delivery documentation
- **T-10.04.06** Integration of FS Warm Electronics
- **T-10.04.07** EMC Test of FS Warm Electronics
- **T-10.04.08** Provision of FS Warm Electronics delivery documentation

T-10.05 Ground Support Equipment

- **T-10.05.01** Provision of Mechanical Ground Support Equipment
- **T-10.05.02** Provision of Electrical Ground Support Equipment

T-10.06 Management

- **T-10.06.01** Management
- **T-10.06.02** Definition of APU Test Requirements
- **T-10.06.03** Definition of Instrument Parameters
- **T-10.06.04** Definition of Instrument Functions

BOL-WP-11 - On Board Software (OBS)

T-11.01 OBS Implementation

- **T-10.01.01** OBS Requirements Definition
- **T-10.01.02** OBS design
- **T-10.01.03** OBS coding and test
- **T-10.01.04** Provision of OBS development version
- **T-10.01.05** Provision of OBS final version
- **T-10.01.06** Provision of OBS documentation

T-11.02 OBS Maintainance and Validation

- **T-10.01.01** OBS Maintainance and Validation Facility design
- **T-10.01.02** Provision of OBS Maintainance Facility

T-11.03 Software Instrument Simulator

- **T-11.03.01** Instrument SimulatorRequirements Definition
- **T-11.03.02** Instrument Simulator design
- **T-11.03.03** Instrument Simulator coding and test
- **T-11.03.04** Integration of Instrument Simulator with Satellite Simulator
- **T-11.03.05** Maintainance of the Software Instrument Simulator

T-11.04 Management

- **T-11.04.01** Management
- **T-11.04.02** Definition of OBS Test Requirements
- **T-11.04.03** Definition of Instrument Commands
- **T-11.04.04** Definition of Instrument Telemetry

BOL-WP-12 - Electronic Ground Support Equipment (EGSE)

T-12.01 EGSE Design

- **T-12.01.01** EGSE/ESA Interface Definition
- **T-12.01.02** EGSE Requirements Definition
- **T-12.01.03** EGSE hardware design
- **T-12.01.04** EGSE software design

T-12.02 EGSE Implementation

- **T-12.02.01** Provision of EGSE Computer Hardware
- **T-12.02.02** Provision of custom interface electronics
- **T-12.02.03** Software coding and test
- **T-12.02.04** EGSE Integration and Validation

T-12.03 Management

- **T-12.03.01** Management
- **T-12.03.02** Definition of EGSE Test and Validation Requirements
- **T-12.03.03** Specification of EGSE Interfaces

BOL-WP-13 - Assembly Integration Verification (AIV)

T-13.01 AIV Facilities

- **T-13.01.01** AIV Facilities Requirements Definition
- **T-13.01.02** AIV Facilities design
- **T-13.01.03** Provision of AIV Facilities
- **T-13.01.04** Test of AIV Facilities

T-13.02 Qualification Model (QM) AIV

- **T-13.02.01** QM Optical Alignment Check (cold)
- **T-13.02.02** QM Optical througput check (cold)
- **T-13.02.03** Integration of Instrument QM
- **T-13.02.04** Vibration Test of Instrument QM (cold)
- **T-13.02.05** Execution of QM Instrument Level Test Plan
- **T-13.02.06** Execution of QM System Level Test Plan

T-13.03 Flight Model (FM) AIV

- **T-13.03.01** FM Optical Alignment Check (cold)
- **T-13.03.02** FM Optical througput check (cold)
- **T-13.03.03** Integration of Instrument FM
- **T-13.03.04** Vibration Test of Instrument FM (cold)
- **T-13.03.05** Execution of FM Instrument Level Test Plan
- **T-13.03.06** Execution of FM System Level Test Plan

T-13.04 Flight Spare (FS) AIV

- **T-13.04.01** FS Optical Alignment Check (cold)
- **T-13.04.02** FS Optical througput check (cold)
- **T-13.04.03** Integration of Instrument FS
- **T-13.04.04** Vibration Test of Instrument FS (cold)
- **T-13.04.05** Execution of FS Instrument Level Test Plan
- **T-13.04.06** Execution of FS System Level Test Plan

T-13.05 Management

- **T-13.05.01** Management
- **T-13.05.02** Definition of Instrument Integration Plan
- **T-13.05.03** Definition of Instrument Level Test Plan

- T-13.05.04 Definition of Instrument Level Test Plan
- T-13.05.05 Provision of Instrument delivery documentation

BOL-WP-14 - Ground Calibration

T-14.01 Calibration Facilities

- T-14.01.01 Calibration Facilities Requirements Definition
- T-14.01.02 Calibration Facilities design
- T-14.01.03 Provision of Calibration Facilities
- T-14.01.04 Test of Calibration Facilities

T-14.02 Calibration

- T-14.02.01 Defnition of Ground Calibration Plan
- T-14.02.02 Execution of QM Ground Calibration Plan
- T-14.02.03 Execution of FM Ground Calibration Plan
- T-14.02.04 Execution of FS Ground Calibration Plan

T-14.02 Management

- T-14.02.01 Management

BOL-WP-15 - Instrument Control Centre

T-15.01 Infrastructure

- T-15.01.01 Definition of ICC infrastructure requirements
- T-15.01.02 Provision of ICC infrastructure

T-15.02 FINDAS

- T-15.02.01 Definition of Instrument data to be stored in archive
- T-15.02.02 Definition of Instrument Data model
- T-15.02.03 Provision of FINDAS related hardware
- T-15.02.04 Implementation of FINDAS software

T-15.03 Computer Systems

- T-15.03.01 Commonality/Interface definition
- T-15.03.02 ICC Computer Systems Requirements Definition
- T-15.03.03 ICC Computer Systems Design
- T-15.03.04 Provision of Hardware to support Commissioning and PV phases
- T-15.03.05 Provision of ICC Operational Hardware

T-15.04 Management

- T-15.04.01 Management
- T-15.04.02 Computer System Management
- T-15.04.03 Operations Systems engineering
- T-15.04.04 Software Systems engineering
- T-15.04.05 Provision of Quality Assurance Plan
- T-15.04.06 Monitoring of commonality/Interface adherence
- T-15.04.07 S/W Configuration Control
- T-15.04.08 H/W Configuration Control
- T-15.04.09 Provision of ICC documentation

BOL-WP-16 - Instrument Operations

T-16.01 Instrument Commanding

- T-16.01.01 Definition of Instrument Modes
- T-16.01.02 Definition of TM and TC packets
- T-16.01.03 Definition of Instrument Command Sequences
- T-16.01.04 Definition of Permanent Command Sequences
- T-16.01.05 Definition of 'TDATA' commands
- T-16.01.06 Provision of inputs to Instrument Command Translator
- T-16.01.07 Definition of Astronomical Observation Templates
- T-16.01.08 Provision of Instrument Time Estimator

T-16.02 Instrument Monitoring

- T-16.02.01 Definition of Instrument Health and Safety Parmeters for MOC

T-16.03 Operating Procedures

- T-16.03.01 Generation and validation of 'nominal' Instrument Flight Operating Procedures
- T-16.03.02 Generation and validation of 'contingency' Instrument Flight Operating Procedures

BOL-WP-17 - ICC Operations

T-17.01 ICC Setup

- T-17.01.01 Provision of TM/TC database
- T-17.01.02 Generation and Validation of ICC Operations Procedures
- T-17.01.03 Generation and Validation of Ground Segment related ICC Operations Procedures
- T-17.01.04 Provision of inputs for Ground Segment Integration and Validation tests
- T-17.01.05 Participation in pre-launch Ground Segment Integration, Validation tests and Simulations
- T-17.01.06 Setup and training of Operations Team
- T-17.01.07 Training of FSC and MOC staff

T-17.02 Operations Software

- T-17.02.01 Provision of Low Level analysis tools
- T-17.02.02 Provision of Real Time Assessment Software
- T-17.02.03 Provision of Trend Analysis Software
- T-17.02.04 Provision of Calibration Analysis Software
- T-17.02.05 Provision of Interactive analysis software

T-17.03 Science Processing Software

- **T-17.03.01** Definition of Instrument Calibration Plan
- **T-17.03.02** Setup and maintainance of the Instrument Calibration Database
- **T-17.03.03** Definition of requirements on FSC for support calibration activities
- **T-17.03.04** Provision of Science Processing software
- **T-17.03.05** Provision of Science analysis software

T-17.04 Operations

- **T-17.04.01** Provision of staff to support Commissioning and PV phase operations at MOC
- **T-17.04.02** Calibration Database Management
- **T-17.04.03** Execution of Commissioning Phase
- **T-17.04.04** Execution of PV phase
- **T-17.04.05** Instrument Monitoring
- **T-17.04.06** Instrument Calibration
- **T-17.04.07** Instrument Data Processing and Quality Control
- **T-17.04.08** Instrument Data Analysis
- **T-17.04.09** Trend Analysis

BOL-WP-18 - Post Operations

T-18.01 Post Operational Phase

T-18.02 Archive Phase

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Matt Griffin

Summary of meeting

SUMMARY:

- MERGER STUDY UNDERWAY AND WILL DOMINATE ESA WORK / SCHEDULE FOR $\gtrsim 1$ YEAR
- GRATING SPECTROMETER:
  - INCORPORATE AS MUCH IMAGING ACROSS THE SLIT AS CAN BE ACHIEVED (CONSTRAINTS: - NO. OF DETECTORS
    - IMAGE QUALITY)
  - WHAT'S ACHIEVABLE $\lambda/\Delta\lambda$?
- DETECTOR ARRAYS
  - SPIDER OR EQUIVALENT BOLOMETERS + FEED HORNS = BASELINE
  - CLOSE PACKED ABSORBER ARRAY DEVELOPMENT OFFERS PROSPECT OF MORE DETECTORS ETC ⇒ BETTER PERFORMANCE, SIMPLICITY OF FOC. PLANE
  - FOR ANY DESIGN, STRAYLIGHT IS A HUGE PROBLEM
- PHOTOMETER DESIGN
  - ESSENTIALLY AGREED
  - BANDS TO BE OPTIMISED

MAJOR CHALLENGES

- THERMAL / MECHANICAL ENGINEERING
- STRAYLIGHT SUPPRESSION
- CRYOGENICS / OPERATING TEMP.

IMPORTANT / URGENT TASKS

- DEFINE MASS / POWER BUDGET REQUIREMEN
- DEFINE BASELINE OPTICAL DESIGN(S) AI SPE
- CARRY OUT DETAILED STRAY LIGHT (DIFFRACTION) ANALYSIS
- DEFINE THE CORE OF AN INSTRUMENT CONSORTIUM TO RESPOND TO LETTER OF INTENT / AO

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Matt Griffin

Copies of viewgraphs from BOL talk at Grenoble FIRSU symposium

FIRST MODEL PAYLOAD

THE BOLOMETER INSTRUMENT

Matt Griffin
QMW, London

- Key scientific projects for this instrument
- The "Red Book" instrument
- The revised instrument design
- Performance goals
- Technical challenges

BOLOMETER INSTRUMENT WORKING GROUP

Peter Ade	QMW
Patrick Agnese	CEA
Eli Atad	ROE
Jean-Paul Baluteau	LAS
Alain Benoit	CRTBT
Ravinder Bhatia	QMW
Jamie Bock	Caltech/JPL
Emmanuel Caux	CESR
Sarah Church	Caltech
Len Culhane	MSSL
Colin Cunningham	ROE
Gary Davis	Saskatoon
Kjetil Dohlen	LAS
Roger Emery	RAL
Ian Furniss	UCL
Walter Gear	ROE
H-P Gemund	MPIfR
Peter Hastings	ROE
Ian Hepburn	MSSL
Ken King	RAL
Andrew Lange	Caltech
Jean-Michel Lamarre	IAS
Bruno Maffei	QMW
Sye Murray	QMW
Ramon Nartallo	QMW
Renato Orfei	IFSI
Francois Pajot	IAS
Albrecht Poglitsch	MPE
Jean-Loup Puget	IAS
Louis Rodriguez	CEA
Michael Rowan-Robinson	IC
Michel Saisse	LAS
Paolo Saraceno	IFSI
Tim Sumner	IC
Bruce Swinyard	RAL
Laurent Vigroux	CEA

SCIENTIFIC DESIGN DRIVERS FOR THE BOL

- Deep photometric surveys of high-Z galaxies
- Follow-up spectroscopy of high-Z objects (redshifted FIR lines)
- Survey of the galaxy for protostars and YSOs
- Concentrate on capabilities unique to FIRST

THE RED BOOK INSTRUMENT

- **Tandem Fabry-Perot spectrometer + filter-wheel photometer**
- **Photometry** $\lambda = 200\text{-}900\ \mu\text{m}$
- **Spectroscopy** $\lambda = 200\text{-}400\ \mu\text{m}$

  $\lambda/\Delta\lambda = 3000$

THE REVISED BOL INSTRUMENT

- **Designed for**
  - key scientific goals
  - simplicity of operation
  - low risk
  - affordability
- **Photometer and spectrometer optical chains separated near instrument input**

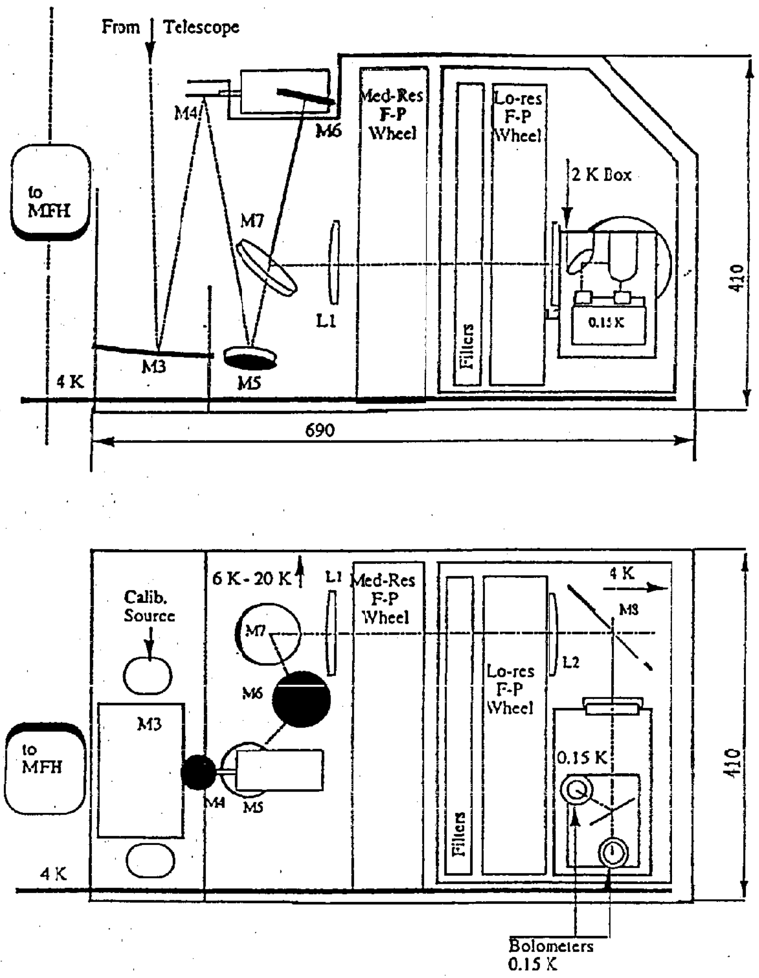


Figure 12: Optical scheme of the bolometer instrument

Schematic figure of the BOL instrument. The f/10 beam from the telescope secondary is incident on M3. Sky chopping is effected by the wobbling mirror M4. The beam is collimated, passed through the Fabry-Pérot and filter wheels, and re-imaged onto the detector arrays with a final focal ratio of f/4.5. The detector arrays are contained in a 2 K enclosure, and maintained at 0.1 K by the dilution refrigerator.

ADVANTAGES OF GRATING SPECTROMETER

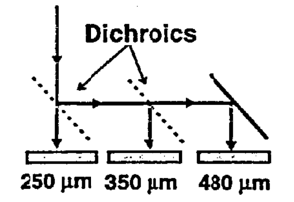
- Simpler instrument construction and operation
- Higher reliability (F-P has mechanisms in series)
- Less development effort
- Lower cost
- Higher efficiency
- Better instrument response function
- More suited to spectral survey work
- Can more easily separate photometry and spectroscopy and optimise both

DISADVANTAGES OF GRATING

- Not optimised for 2-D imaging spectroscopy
- Cannot easily get $\lambda/\Delta\lambda > 1000$

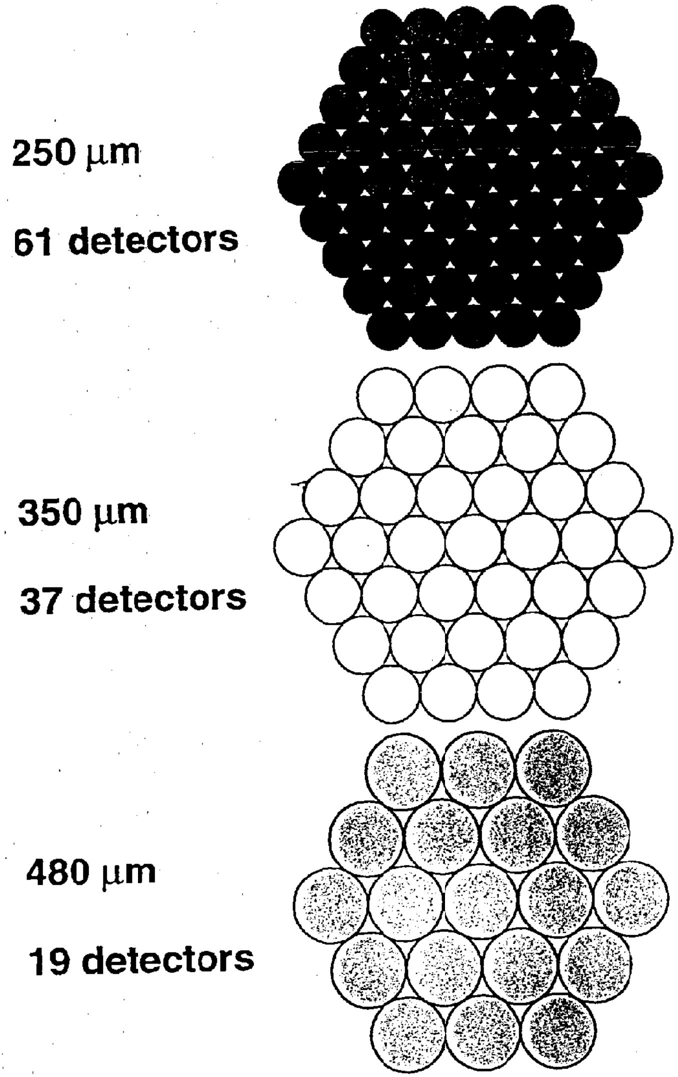
IMAGING PHOTOMETER

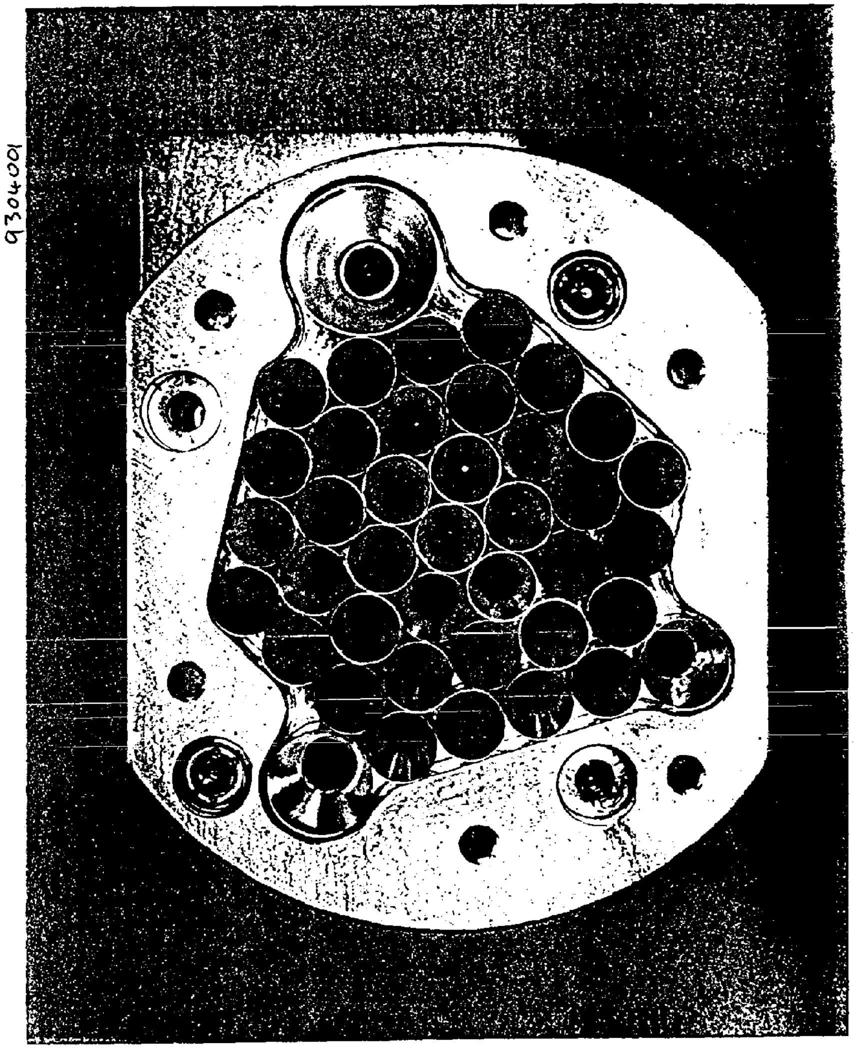
- $\lambda = 250 - 500\ \mu m$
- $\lambda/\Delta\lambda \sim 3$
- Background limited by telescope thermal emission
- No filter wheel
  - simplicity, reliability
  - better observing efficiency
  - better stray light rejection
  - filters can be at 2 K
- Three hexagonally close-packed bolometer arrays
- Simultaneous observation of same ~ 6 arcmin field of view



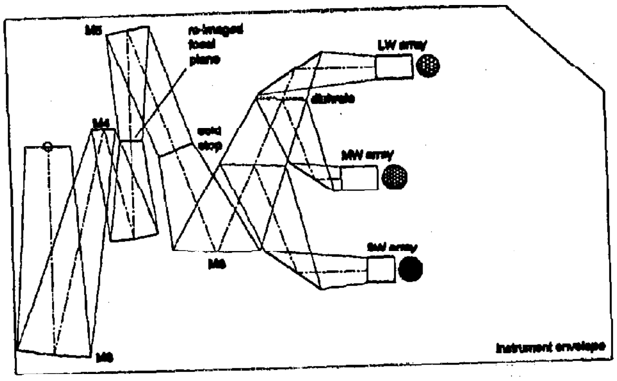
SCHEMATIC

λ_o (µm)	No. of pixels	Beam width (arcsec.)
250	61	21
350	37	29
480	19	40


250 µm
61 detectors
350 µm
37 detectors
480 µm
19 detectors

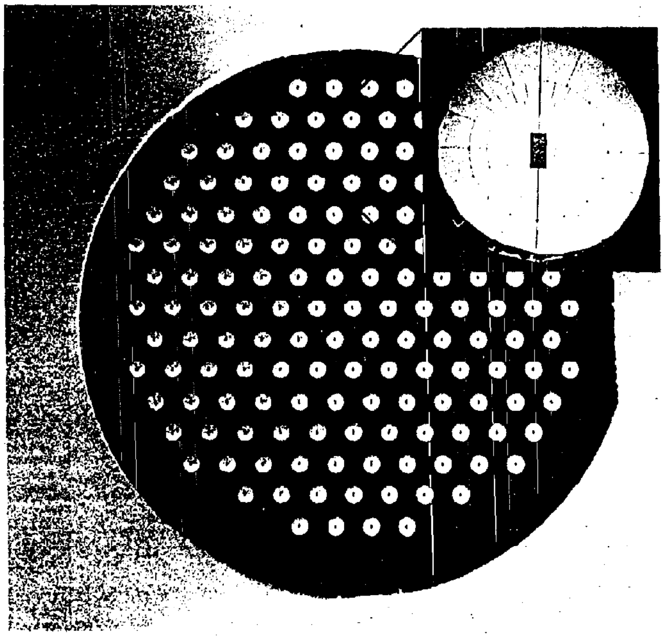

9304001

PHOTOMETER OPTICAL LAYOUT



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

JPL Silicon Nitride Micromesh Bolometer Array

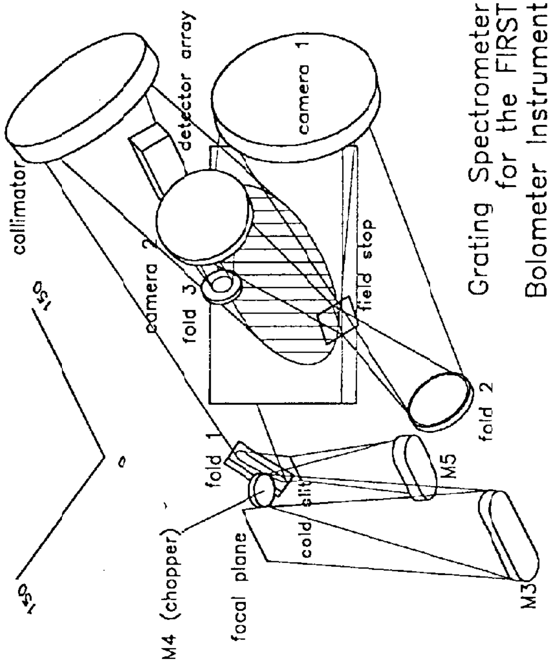


J. J. Bock / JPL & A. E. Lange / CIT 1/97

GRATING SPECTROMETER

- $\lambda = 200 - 350\ \mu m$
- $\lambda/\Delta\lambda \sim 1000$
- **Optimised for spectral multiplexing**

  ⇒ measurement of whole spectrum in shortest possible time
- **Imaging spectroscopy not a high priority**
- **Littrow or concave grating design**
- **Linear array of ~ 20 detectors**



Grating Spectrometer for the FIRST Bolometer Instrument

SENSITIVITY ESTIMATION

- **Main assumptions:**

Telescope D=3 m T=80 K ε=4%
Optics efficiency η = 30% (photometry)
η = 20% (spectroscopy)
Detector NEP 1×10^{-17} W Hz$^{-1/2}$
Throughput $A\Omega = \lambda^2$

Photometry and mapping

λ	(μm)	250	350	480
NEFD	(mJy Hz$^{-1/2}$)	61	64	64
Point source	ΔS (1-σ 1 hr) (mJy)	0.71	0.76	0.76
6' x 6' map	ΔS(1-σ 1 hr) (mJy per pixel)	4.0	4.3	4.3

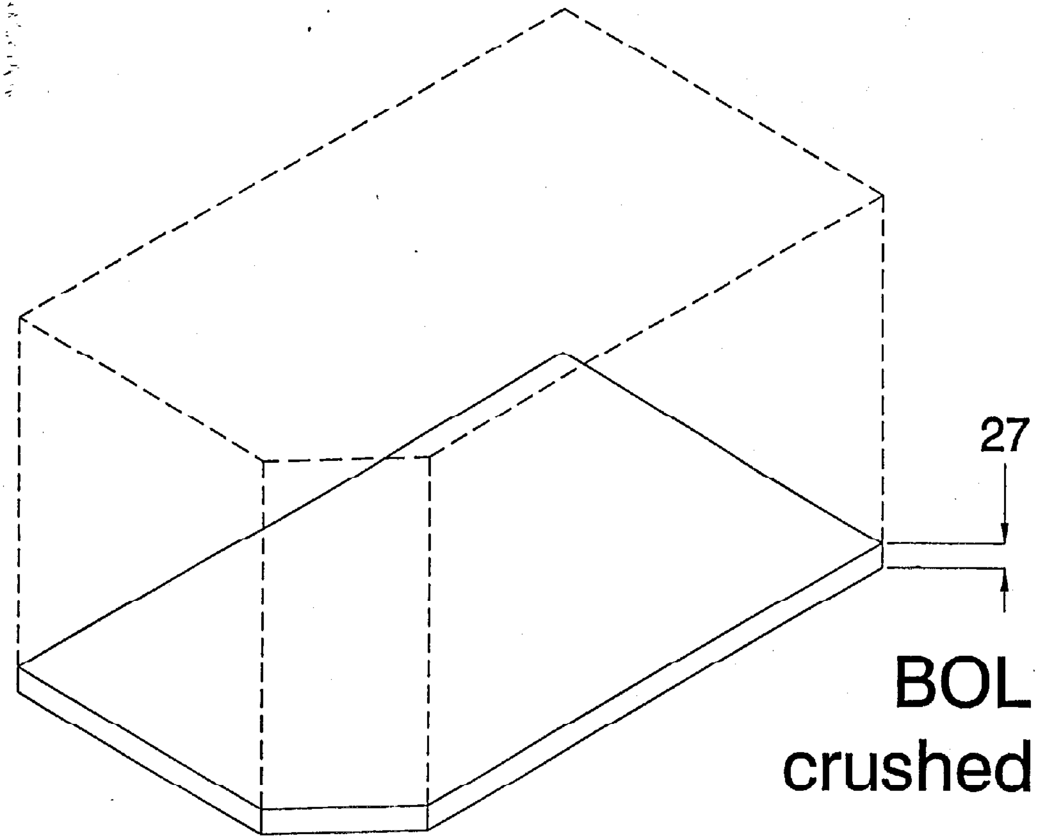
All three bands observed simultaneously

Spectroscopy

Full spectrum	F(1-σ 1 hr) (W m^{-2} x 10^{-18})	3.4 (R = 1000) 2.4 (R = 400)
Known line	F(1-σ 1 hr) (W m^{-2} x 10^{-18})	1.4 (R = 1000) 1.7 (R = 400)

TECHNICAL CHALLENGES

- Thermal/mechanical engineering
- Stray light control
- Cryogenics and bolometer operating temperature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BOL
crushed