BOL|QMW|M|0009.1 Ken King M
SPIRE-QMW-MOM-000100.1

Summary of the FIRST Bolometer Instrument Working Group meeting at QMW on December 6 1996

Dear Colleagues,

On behalf of the FIRST PWG, I would like to thank all those who attended this meeting, which I think was very successful in focusing attention on the essential work to be done, and in setting up teams of the relevant experts to look at the main issues. An impressive range of expertise can now be brought to bear on the job of studying and refining the basic instrument concept which the PWG has outlined.

Rather than produce a set of detailed minutes, I attach below:

(i) a summary of the main conclusions;

(ii) a list of the specialist teams which were formed at the meeting;

(iii) a list of the names of all those who attended (plus some others who were not able to be at the meeting);

(iv) copies of the viewgraphs presented at the meeting.

Best regards,

Matt

Matt Griffin
8th December 1996

Main conclusions of the meeting:

1. The instrument as specified in the PDD should be studied in more detail, with emphasis on the particular topics listed below. While the instrument may well be modified in the future for scientific, technical or financial reasons, we need to establish the feasibility of the current design as a starting point.

2. Working teams were set up to look at the various technical issues identified. These teams should work actively between now and next spring. Their main tasks are:

   - to examine the detailed technical feasibility of what is proposed in the PDD;

   - where possible, to produce a more detailed design/description of the relevant sub-system(s);

   - to investigate alternatives or specify more realistic parameters if the PDD assumptions are not realistic;

   - where possible, to identify and exploit the similarities between the BOL and the PHOC instruments, and between the BOL and the COBRAS/SAMBA HFI.

3. Each team has one or two "organisers". The main tasks of the organisers are:

   - to define and prioritise the essential tasks in more detail (the points listed below and on the viewgraphs should be taken only as a guide);

   - to co-ordinate (by e-mail and fax etc.) the activities of other members of the team (although there is no need for team members to delay in starting to think about the issues);

   - to produce summary of work in progress by 28 Feb. 1997;

   - to produce a summary of the team's work before the next meeting of the BOL Working Group (April 14th - see below).

   Note: Matt Griffin and Jean-Michel Lamarre have a lot of ESA and PWG-related documentation and other relevant paperwork which may be of use to the various teams, so please get in touch with one of them whenever more technical information or clarification is needed. I will in any case send to each of the team organisers a compilation of whatever I have that seems obviously relevant to their topics.

4. It was agreed that the group should meet again in Grenoble on April 14th (the day before the start of ESA's FIRST Symposium). Laurent Vigroux kindly offered to make the local arrangements for this meeting.

BOL Instrument Working Group Teams

Note: (i) As the meeting could not be attended by everyone with an existing or potential interest in these activities, it is possible that additional members may join the teams later.

(ii) I have tried to identify correctly the members of which team, but I have probably got it wrong in some instances. In some cases I have also tried to list those particular areas which some people have said they would look at, but again there may be errors (and the list is certainly incomplete). Please correct me if there are any mistakes, and get in touch with the relevant Team Organiser to clarify your interests.

(iii) Team membership should not be rigid or restricted, so please feel free to contribute to any activity if you think you can be useful. The only real requirement is that the work gets done in an organised way.

1. The Focal Plane Team

Sarah Church
Roger Emery
Walter Gear
H-P Gemünd
Matt Griffin (Joint Organiser)
Jean-Michel Lamarre ? (Joint Organiser)
Sye Murray
Louis Rodriguez
Laurent Vigroux

Main issues:

Bolometer technology (Murray, Vigroux)
- Spider-web bolometers are still the best option based on current/proven technology.
- Confirmation that operating temperature higher than 100 mK can be used.
- Evaluation of status and possible use of other bolometer technologies.

Array requirements for spectroscopy and photometry (Gear, Griffin)
- Same or different detector design?
- Same or different feed-horn design or pixel size?

Photometric modelling of the instrument (Murray, Gear)

Focal plane optics (Church, Gear, Gemünd, Lamarre, Rodriguez, Vigroux)
- Single vs. multi-mode
- Pixel sizes (different for spectroscopy and photometry?)

2. The Fabry Perot Interferometer Team

Len Culhane
Gary Davis (Organiser)
Roger Emery
H-P Gemünd
Ian Furniss
Francois Pajot
Albrecht Poglitsch (PHOC overlap)
Bruce Swinyard

Main issues:

Requirements for meeting scientific performance (Davis, Furniss, Swinyard)

- Feasibility of order-sorting/transmission efficiency
- Number of F-Ps needed to achieve PDD specifications
- Feasibility of large clear aperture (60 mm)
- Variation of spectral resolution across the array

Mesh design (Davis, Emery, Gemünd, Pajot)

- scientific performance
- mechanical mounting
- alternatives to free-standing meshes
- mesh manufacture techniques

Implementation (Davis, Culhane, Furniss)

- Digital servo
- Need for internal source for alignment?
- New magnet materials
- Electronics and cryo-harness requirements
- Power dissipation in the cryo-harness

3. The Cryogenic Mechanisms Team

Gary Davis
Roger Emery
Ian Furniss
Peter Hastings
Ian Hepburn (Organiser)
Laurent Vigroux
Albrecht Poglitsch (PHOC overlap)

Main issues:

ISO designs serve as starting point, but much re-engineering needed

- Minimisation of complexity
- Cryo-harness requirements
- Feasibility of meeting power dissipation limits (focal plane and harness), especially for the cryo-cooler option
  e.g.:
    - Flexible coupling between wheel and drive motor at higher temperature?
    - Continuous drive vs. free-running/ratchet system
    - Superconducting coils
- Reducing mass
- Mounting and alignment
- Reliability analysis

Bringing together the expertise of all of the ISO instrument teams on this issue (perhaps a meeting of some of the relevant people can be arranged)

CAM	Laurent Vigroux, Jacqi Cretolle
LWS	Ian Furniss, Ian Hepburn
PHOT	TBD
SWS	TBD

4. The Optical Design and Layout Team

Roger Emery (Joint Organiser)
Jean-Michel Lamarre
Albrecht Poglitsch (PHOC overlap)
Michel Saisse (Joint Organiser)

Main issues:

Detailed study and optimisation of the PDD design (Jean-Michel Lamarre's design)
Aberrations
Minimisation of mass/volume
Alignment tolerances
Mechanical requirements on the structures of the 4-K and 20-K boxes
Stray light and ambient background radiation suppression; diffraction within the instrument
Influence of optics chain on the propagation of the feed-horn beams through the system
Optics/baffling between the instrument and the telescope (PHOC overlap)

5. The Thermal/Mechanical Engineering Team

Matt Griffin (Organiser)
Jean-Michel Lamarre
Peter Hastings
Ian Hepburn
Tom Bradshaw
Albrecht Poglitsch
Michel Saisse

Main issues:

Practical demonstration of support of large mass/volume using Kevlar suspension or alternative (a study of the requirements for this should be the focus of the group's activity)
More detailed design and analysis of strength and resonant frequencies
Alternative materials
Design for ease of alignment and integration

6. The Operating Modes and Calibration Team

Emmanuel Caux
Walter Gear (Joint Organiser)
Ken King
Paolo Saraceno
Bruce Swinyard
Albrecht Poglitsch (PHOC overlap)
Tim Sumner
Laurent Vigroux (Joint Organiser)
+ Others who would be appropriate and should be asked to contribute:
  - Otto Bauer
  - Someone from the Heterodyne instrument group

Main issues:

Wheel movement requirements
Detailed definition of operating modes based on scientific requirements
Setting up of F-Ps
Instrument requirements for chopping, nodding, spatial scanning, rastering, F-P scanning, etc.
Implications for the spacecraft capabilities
Specification of standard observing sequences and AOTs
Implications for on-board S/W and telemetry
Wavelength and flux calibration methods

7. The Systems Engineering Team

Colin Cunningham	**(1, 2)**	**Joint Organiser**
Bruce Swinyard	**(1,2)**	**Joint Organiser**
CESR person (TBD)		
Ken King		
Albrecht Poglitsch (PHOC overlap)		
Otto Bauer ?		
Sye Murray	(2)	
Francois Pajot	(3)	
Emmanuel Caux	(3)	

1. **Electrical**

- Dependence on detector read-out electronics
- Overall grounding scheme
- EMC
- On-board processing requirements
- On-board autonomy

2. **Mechanical/thermal**

- Microphonics (from coolers and/or chopper)
- Optimisation of thermal balance/spectral filtering
  - Alignment and integration
  - Interfaces to coolers and other spacecraft systems

3. **Instrument system performance**
   + On-ground instrument calibration, testing and performance verification

FIRST BOLOMETER INTRUMENT WORKING GROUP

QMW Meeting December 6 1996

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FIRST Bolometer Instrument Working Group
QMW, 6th December 1996

Agenda

1. Introduction and purpose of the meeting
2. Current status and schedule of FIRST
3. Brief review of the BOL instrument concept
4. Review of main technical issues

   Under each of these headings, we should aim to:

   - Review the PDD assumptions and list the issues needing paper and/or experimental studies
   - Review progress since the February meeting
   - Identify commonality and possible collaboration with the PHOC instrument and with the COBRAS/ SAMBA HFI
   - Establish active working teams to carry out essential studies on the key technical issues

4.1 The focal plane
   - Presentations by: Sye Murray (Spider bolometers)
     Louis Rodriguez (LETI array programme)
     Ian Hepburn (MSSL ADR programme)

4.2 Fabry-Perot interferometers

4.3 Cryogenic mechanisms

4.4 Thermal/mechanical engineering

4.5 Instrument optical design and layout

4.6 Instrument operating modes

4.7 Systems engineering
   - Electrical
   - Mechanical
   - System-level testing and performance verification

FIRST Status and Schedule

Approximate schedule (will probably be revised soon)

• Cryostat vs. cryo-cooler decision	Early 1997
• Mission re-confirmation	Mid 1997
• Issue of AO	Late 1997
• Instrument selection	Mid 1998
• Launch	Early 2007 or Earlier ?*

* ESA are now examining the possibility of a launch in late 2005 or early 2006, and have asked the FIRST Science Advisory Group (SAG) and Payload Working Group (PWG) to look at the feasibility and implications. The SAG and PWG will be meeting next week to consider this issue.

FIRST Science Review by SAG + Experts

- Held at ESTEC on Sept. 23 1996

- Experts on
  Solar System
  Star formation
  ISM
  Galaxy formation/evolution
  Cosmology

- Conclusions:
  - Strong scientific case despite competition
  - Emphasis on key projects: surveys followed by detailed spectroscopy
  - Most important scientific aims of FIRST are

1. *Large-scale surveys for high-z galaxies (z = 1 - 4)*
2. H_2O, O_2, O_3, OI mapping
3. Cometary high-resolution spectroscopy
4. High-res. spectroscopy of protostars
5. *z > 4 galaxies*
   Quantitative astrochemistry
6. *CII in high-Z galaxies*
   Spectroscopy & mapping of star-forming regions
   ISO-follow-up spectroscopy of galaxies and AGN
7. *S-Z effect*
8. *Mapping nearby galaxies*
   Large-scale surveys of the galaxy for protostars & YSOs
   The outer planets and their moons
9. The inner planets

- No simplifications of payload recommended as yet

- Push to get HET to operate above 1 THz

- Desirable additional features:
  - Bigger detector arrays
  - Better sensitivity for moderate resolution spectroscopy (e.g., grating-mode)
  - $\lambda/\Delta\lambda \sim 30$ mode over whole 100-800 μm region

Scientific Requirements

- Wavelength range 200 - 900 μm
- Spectroscopy 200 - 400 μm
  $\lambda/\Delta\lambda \sim 3 \times 10^3$
  ($\sim$ 100 km s^{-1})
- Photometry 200 - 900 μm
  $\lambda/\Delta\lambda \sim$ 3-5
- Sensitivity

  Photometry: Limited by photon noise from telescope thermal background

  Spectroscopy: Detector noise limited

  ($\Rightarrow$ must use best possible detectors)

Summary of BOL Components

- Cold FPU bolting to a “15-20 K” plate provided by spacecraft
- Thermal strap to the 4-K stage provided by spacecraft
- Cold ($\sim$ 100-K) JFET module for detector read-out
- 0.1-K dilution refrigerator
- 4 warm electronics boxes:

  3 analogue boxes for science data, mechanism control, dilution refrigerator control

  Digital box for data processing, instrument control, telemetry
- Cryo-harness with $\sim$ 600 wires

Thermal Budget

- Spacecraft interface is 15 - 20 K plate

4-K: Provided by cryocoolers or vapour-cooled shields

Strict thermal budget:

~ 15 mW load at 4 K for all three instruments

For the BOL in operation:

- Conduction (mech. supports, wires)	2.8 mW
- Radiation from higher temps.	0.3 mW
- Dissipation	4.7 mW
Total:	7.8 mW

Support of the 4-K box (mass ~ 10 kg) inside instrument by Kevlar ties

- 2 K: Provided by spacecraft (cryostat)

  Provided by instrument (cryo-cooler)

Cooling power available:

~ 2 mW	(cryostat)
~ 0.5 mW	(cryocooler)

- 0.1 K: Provided by ^{3}He-^{4}He dilution fridge

Cooling power available ~ 100 nW

Optical Design

- Input optics to define field of view and collimate the beam
- 3 interchange wheels in series
  - Medium resolution Fabry-Perot (F-P) wheel at 20 K
    - 2 F-Ps + open position
  - Filter wheel at 4 K
    - 4 or 5 broad-band filters
  - Low resolution F-P wheel at 4 K
    - 2 F-Ps + open position
- f/5 final optics
- Dichroic beamdivider splitting 200 - 400 μm and 400 - 900 μm
- Two 0.1-K bolometer arrays

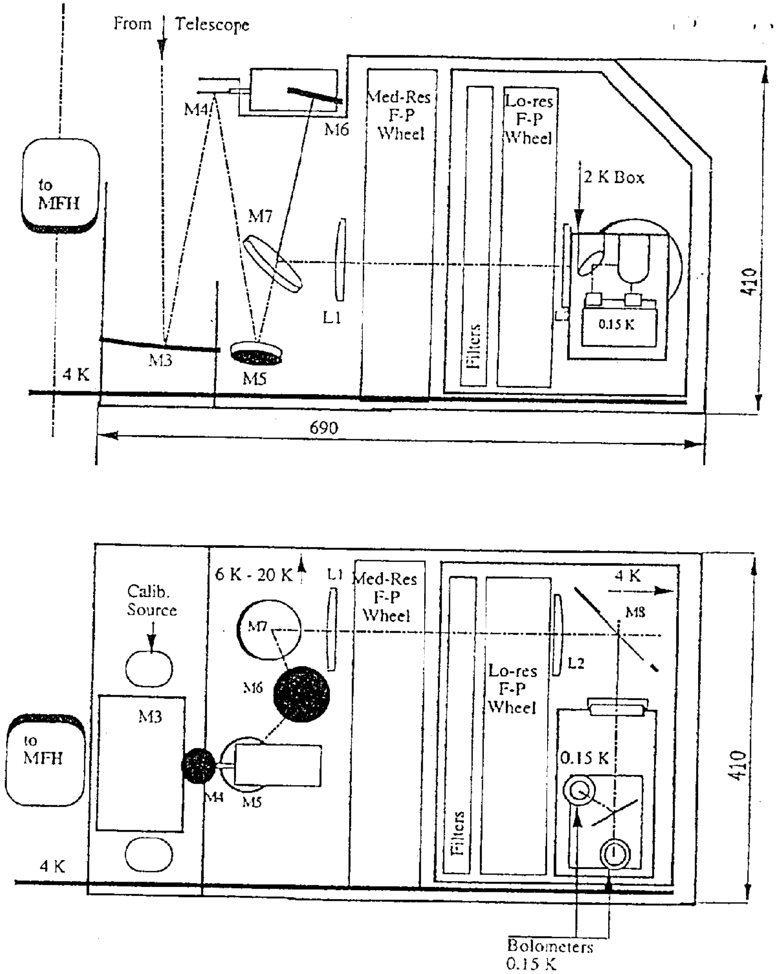


Figure 12: Optical scheme of the bolometer instrument

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.

Fabry-Perots

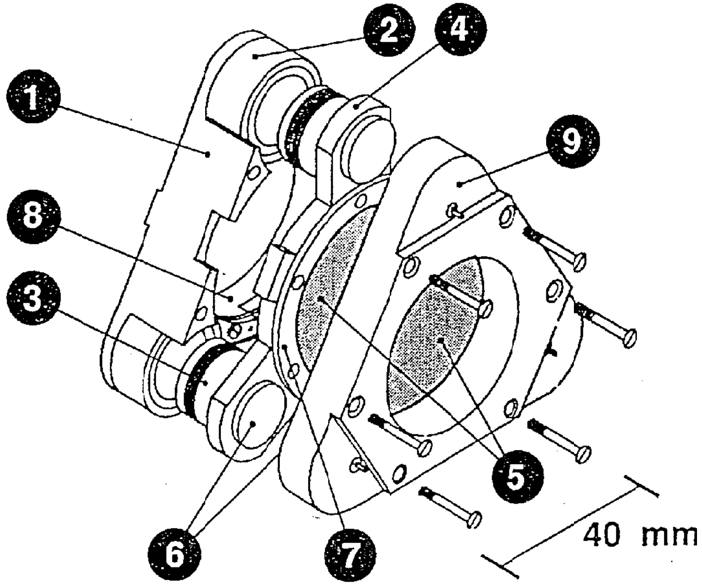
- Medium resolution spectroscopy

  Reqd. resolution $\lambda/\Delta\lambda \sim 3\text{x}10^3$ across the whole SW array

  $\Rightarrow$ Clear aperture $\geq$ 60 mm

- Two sets of F-Ps for 210 - 280 μm and 280 - 400 μm
- High resolution F-P is order-sorted by the low-resolution F-P
- F-P wheel and interferometer design based on ISO LWS F-P sub-system

LWS F-P Interferometer Unit



1. Back plate
2. Magnet housing
3. Drive coil
4. Moving plate
5. Metal meshes
6. Capacitance micrometer pads
7. Mesh mounting ring
8. Leaf spring
9. Fixed plate

Bolometer Arrays

- Short wavelength array
  - 200 - 400 μm
  - 61 bolometers,
    hex. close-packed
  - 25” pixel size
  - 35 detectors optimised
    for photometry
    - high background
    - $P_{det} = 5 - 25$ pW
  - 25 detectors optimised for
    spectroscopy
    - low background

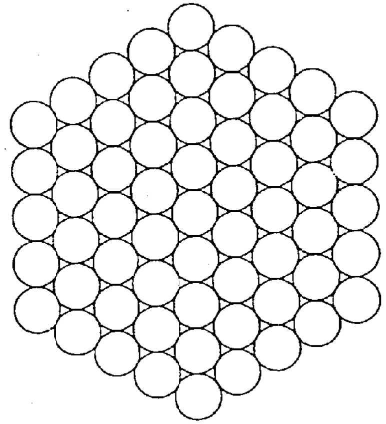
- Long wavelength array
  - 400 - 900 μm
  - 8 bolometers, optimised
    for photometry
  - 56” pixel size

SW array

61 detectors

2 mm pixel size

225" field of view

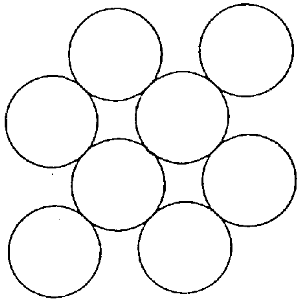


LW array

8 detectors

4 mm pixel size

200" field of view



Predicted Sensitivity

Photometry					
λ	(μm)	250	350	500	750
NEP$_{ph}$	(W Hz$^{-1/2}$ x 10^{-16})	2.2	1.2	1.3	0.62
NEFD	(mJy Hz$^{-1/2}$)	100	110	125	130
F(10-σ 1 hr)	(mJy)	12	13	15	16

⇒ Photon noise limited
Need detector NEP ≈ 5×10^{-17} W Hz$^{-1/2}$

Spectroscopy					
λ	(μm)	250	350	500	750
NEP$_{ph}$	(W Hz$^{-1/2}$ x 10^{-18})	3.9	2.1	2.4	1.1
NEFD	(Jy Hz$^{-1/2}$)	29	55	57	127
		15	28	29	64
F(10-σ 1 hr)	(W cm^{-2} x 10^{-21})	3.0	4.2	3.0	4.5
		1.6	2.1	1.5	2.2

Detector NEP = 2×10^{-17}
Detector NEP = 1×10^{-17}

⇒ Detector noise limited
Need detector NEP as low as possible

Key Technologies for Study and Development

- **Cryogenics**
  - Mounting and operating bolometer arrays with low cooling power
- **Mounting/alignment**
  - String support using kevlar or similar material
  - Integration and alignment with such a support system
  - Integration of the dilution system
- **Mechanisms**
  - Engineering for low mass, low power, high reliability
- **F-P/Filter combination**
  - Number of filters and F-Ps needed
  - Optimising for overall performance
- **Bolometers and read-out electronics**
  - Development of devices which meet sensitivity goals
  - Optimisation of feed optics and filtering
  - Can the nominal operating temperature be increased?
  - Low noise/low power cold electronics
  - Can planar bolometer arrays be developed?
  - Microphonics and EMI suppression
  - Alternative submm detector technologies (e.g. superconducting microbolometers)

Fundamental questions

- Is a dual F-P spectrometer the best option to meet the scientific goals?
- HOW CAN THE INSTRUMENT BE SIMPLIFIED WHILE STILL MEETING THE MOST IMPORTANT SCIENTIFIC GOALS

The Focal Plane

- Detector arrays
  - Spider-web bolometers are baselined
  - Other technologies are also being developed
    - Planar arrays
    - Superconducting transition edge sensors (TES)

  Issues:

  - Different arrays for spectroscopy and photometry ?
  - Numbers of detectors
  - Requirements on warm electronics
  - Numbers of wires/detector needed in the focal plane
  - Photometric model of the instrument
- Optics
  - Single mode (corrugated feeds) is base-line

  Issues:

  - Relative merits of single mode and multi mode optics
  - Possibility of using planar arrays with no feed optics
  - Spectral filtering and control of background radiation
- Cryogenics
  - 300 mK adequate for photometry but 100 mK needed for spectroscopy ?
  - TES sensor technology might work at higher temperature
  - Benoit dilution system is base-line
  - ADR is possible alternative

  Issues:

  - Space qualification of the dilution system
  - Large 4-K mass of ADR system
  - Temperature control
  - Required operating temperature
  - Thermal/mechanical architecture

Fabry-Perot Interferometers *

- Base-line is two pairs of F-Ps to cover the whole BOL wavelength range

Issues:

- Feasibility of order-sorting/transmission efficiency
- Number of F-Ps needed
- Feasibility of large clear aperture (60 mm)
- Variation of spectral resolution across the array
- Mesh design:
  - scientific performance
  - mechanical mounting
  - Alternatives to free-standing meshes
- Digital servo
- Need for internal source for alignment
- New magnet materials
- Electronics and cryo-harness requirements
- Power dissipation in the cryo-harness

* Italicised viewgraph title ⇒ great similarity between the Bolometer and Photoconductror instruments

Cryogenic mechanisms

- F-P wheels at 20 K and 4 K
- Filter wheel at 4 K
- Chopper at 20 K or 4 K
- ISO designs serve as starting point, but much re-engineering needed

Issues:

- Minimisation of complexity
- Cryo-harness requirements
- Feasibility of meeting power dissipation limits (focal plane and harness)

  e.g.:
  - Flexible coupling between wheel and drive motor at higher temperature?
  - Continuous drive vs. free-running/ratchet system
  - Superconducting coils
- Reducing mass
- Mounting and alignment
- Reliability analysis

Thermal/mechanical engineering

- Kevlar suspension base-lined for 20-K and 4-K boxes
- Mechanical/thermal analysis shows feasibility in principle

Issues:

- Practical demonstration of support of large mass/volume using Kevlar
- More detailed design and analysis of strength and resonant frequencies
- Alternative materials
- Design for ease of alignment and integration
- Integration of the dilution system with the spacecraft

Instrument optical design and layout

- PDD design is the base-line

Issues:

- Detailed study and optimisation of the PDD design
- Minimisation of mass/volume
- Alignment tolerances
- Mechanical requirements on the structures of the 4-K and 20-K boxes
- Stray light and ambient background radiation suppression
- Influence of optics chain on the propagation of the feed-horn beams through the system

---

Instrument operating modes and calibration

- Basic spectroscopic and photometric modes are defined in the PDD
- More detailed definition needed

Issues:

- Wheel movement requirements
- Setting up of F-Ps
- Requirements for chopping, nodding, spatial scanning, rastering, F-P scanning, etc.
- Implications for spacecraft capabilities
- Specification of standard observing sequences and AOTs
- Implications for on-board S/W and telemetry
- Wavelength and flux calibration methods

Systems Engineering

- Electrical
    - Depends critically on detector read-out electronics
    - Overall grounding scheme
    - EMC
    - On-board processing requirements
    - On-board autonomy
- Mechanical/thermal
    - Microphonics (from coolers and/or chopper)
    - Optimisation of thermal balance/spectral filtering
    - Alignment and integration
    - Interfaces to coolers and other spacecraft systems
- On-ground instrument calibration, testing and performance verification

Progress on 2-D monolithic silicon bolometer arrays at CEA-FRANCE

P. AGNÈSE*, L. RODRIGUEZ**, L. VIGROUX**

* LETI/LIR 38 GRENOBLE CEDEX
** SAp Bat 709 CE Saclay 91191 Gif/Yvette CEDEX

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◆ Report on progress in resonnant bolometer detectors.
- Overview
- Current status of micromachined resonnant structures.
- Status of Implanted Thermometer.

◆ Read Out Electronics
- CMOS follower (4 K)
- JFET (@ 60-90K)

◆ Application to Spider Web Manufacture
- Geometric limitations
- Thermometer
- Read Out Electronics

Reflection Filters : Brief overview

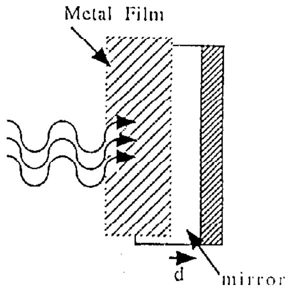
JOURNAL OF THE OPTICAL SOCIETY OF AMERICA VOLUME 37, NUMBER 6 JUNE, 1947

Reflection and Transmission Interference Filters

Part I. Theory

L. N. HADLEY AND D. M. DENNISON
University of Michigan, Ann Arbor, Michigan

(Received February 1, 1947)



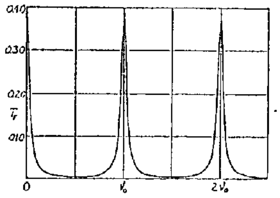


FIG. 4. Transmission coefficient *vs.* frequency of radiation for the transmission filter. The constants of the films are chosen such that the reflection and transmission coefficients for a single metal film are 0.80 and 0.122, respectively.

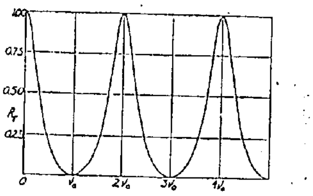
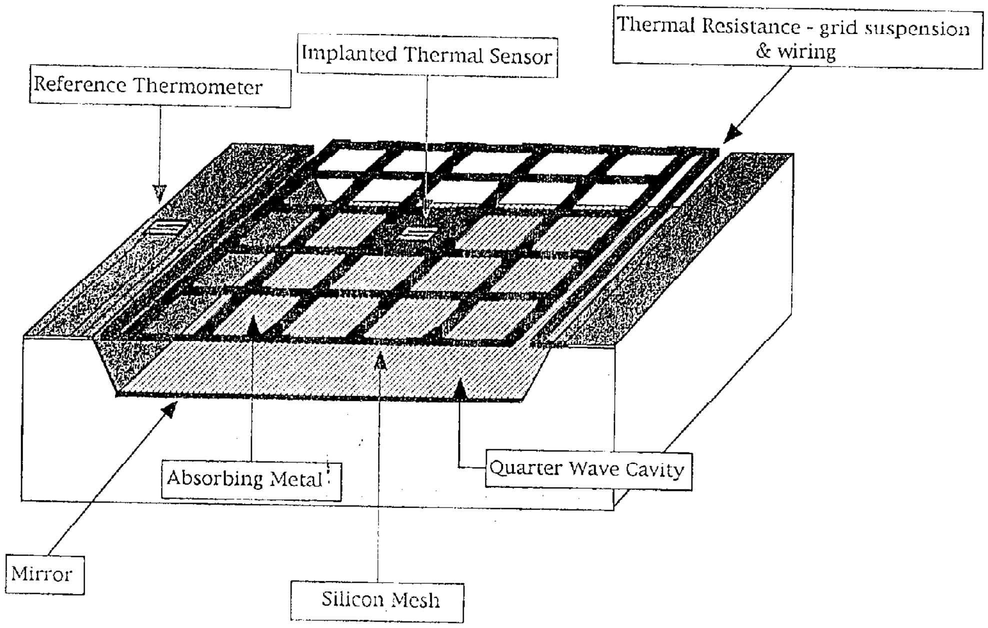


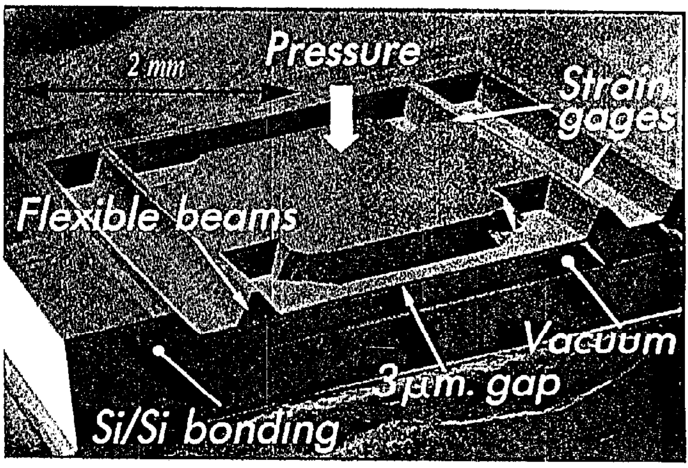
FIG. 3. Reflection coefficient *vs.* frequency of radiation for the reflection filter. Resistance of metal film is 377Ω/□, dielectric constant of dielectric layer is unity.

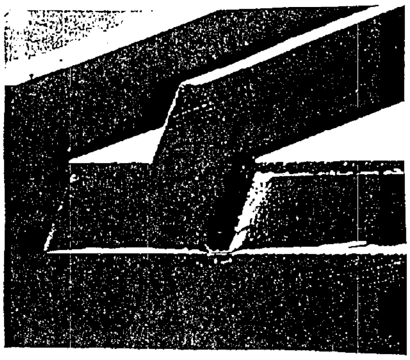
ELEMENTARY PIXEL (I)



EXEMPLE OF MICROMACHINED SENSOR

Pressure sensor manufactured at LETI





ELEMENTARY PIXEL (II)

Silicon grid

cristalline silicon
Standing mesh
to reduce heat capacity
and Ionizing radiations
sensitivity.

Thermal conductance
tailored in the silicon
suspension beams.

Micromachined by
LETI standard or
INOV silicon etching
technology

Thermometer

Implanted silicon
P compensated B (50%)

Near metal transition:
hopping conduction
Exponential behaviour
of the resistance with
temperature.

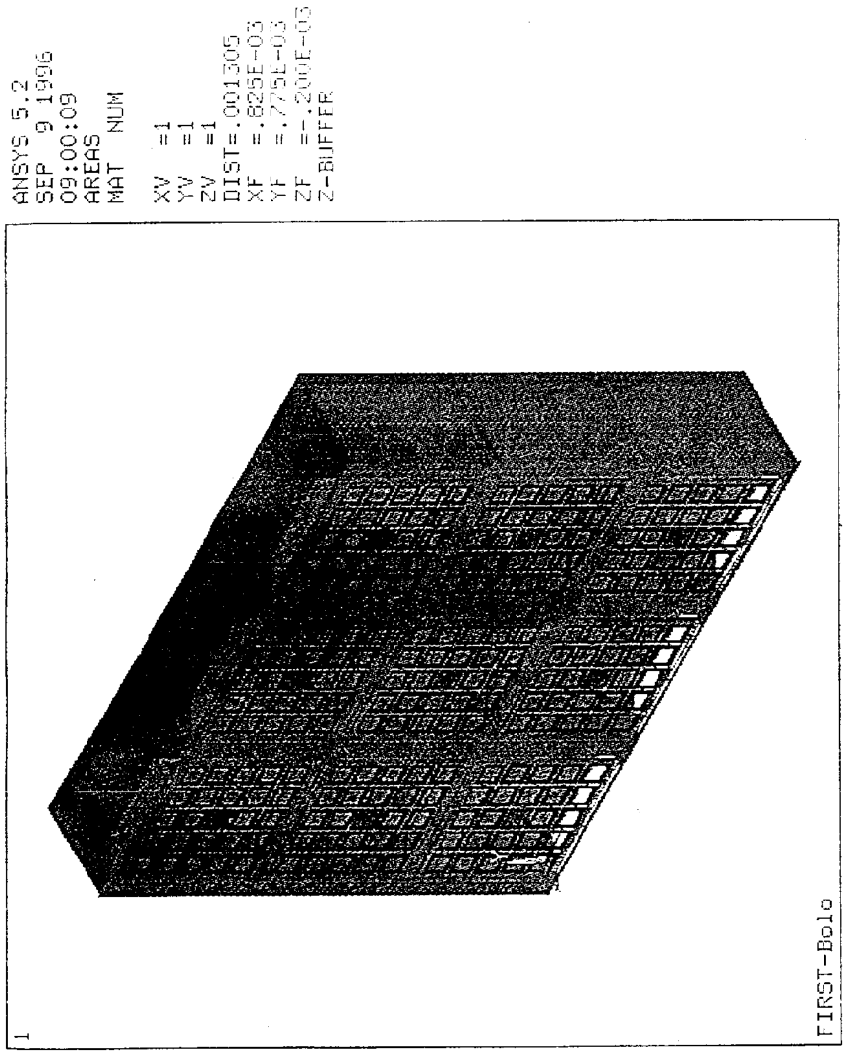
High impedance
differential measurement

Front Read Out Electronics:
CMOS FOLLOWER
@ 4 K

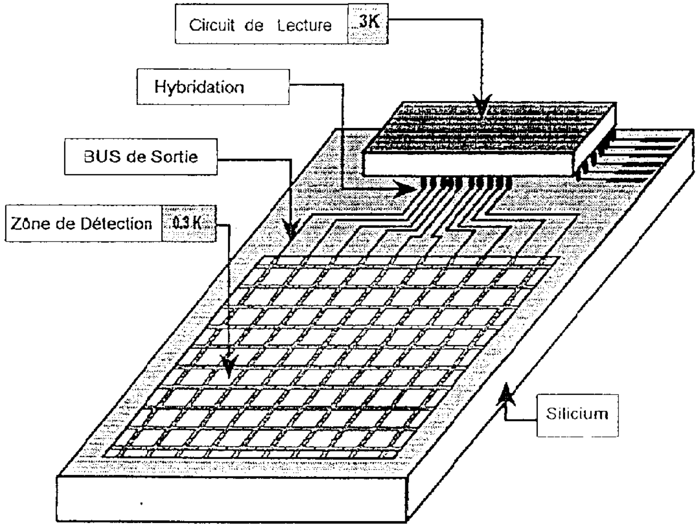
Sub-mm Wave Absorption

Resonnant metal absorption
layer matched to vacuum
impedance on a λ/4
reflecting cavity.

Horizontal metallic
resonnant pattern:
crosses, loops, tripods...
adjusted to
obtain (377 Ω/)
deposited on
the silicon mesh.



CONCEPT DU PLAN FOCAL



<u>Objectif:</u> réaliser une matrice bolométrique de NEP 10-17 W/$\sqrt{Hz}$ pour la détection des ondes submillimétriques (0.2-0.9 mm)

<u>Applications</u> astrophysiques en vol (FIRST) et au sol (IRAM)

<u>Moyens:</u>

Filières de micro-électronique silicium du LETI permettant une réalisation collective de structures matricielles. Possibilité de contrôler des structures microniques.

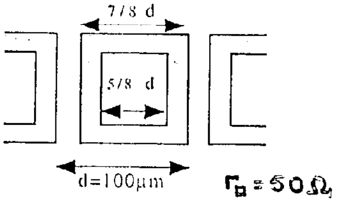
Circuiterie CMOS validée à 4 K pour le programme ISO (Infrared Satellite Observatory), hybridée sur le détecteur par billes d'indium -> Sensibilité à la microphonie réduite

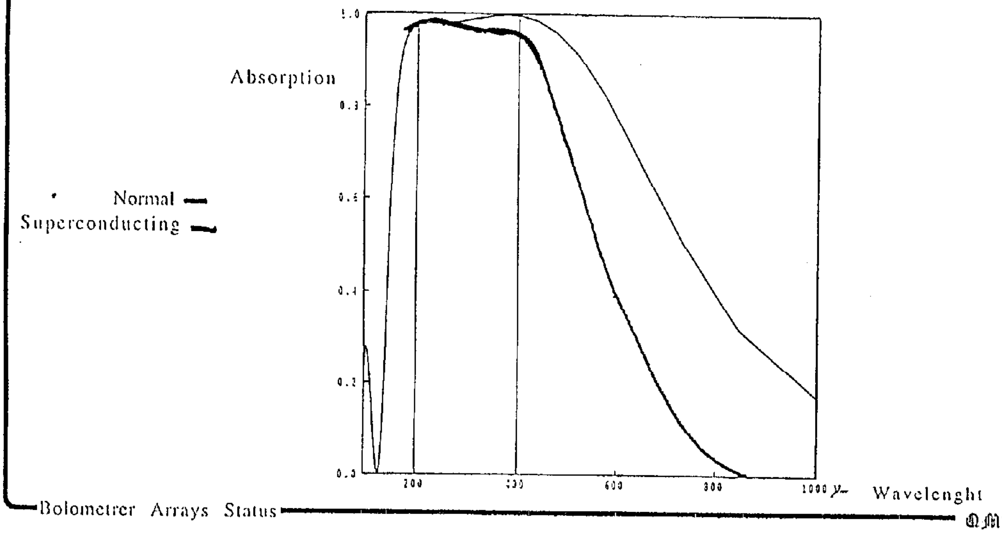
Moyens de caractérisation (2 cryostats) et de simulations (ANSYS)

Expertise de divers laboratoires (CEA/CNRS)

mm WAVE ABSORPTION

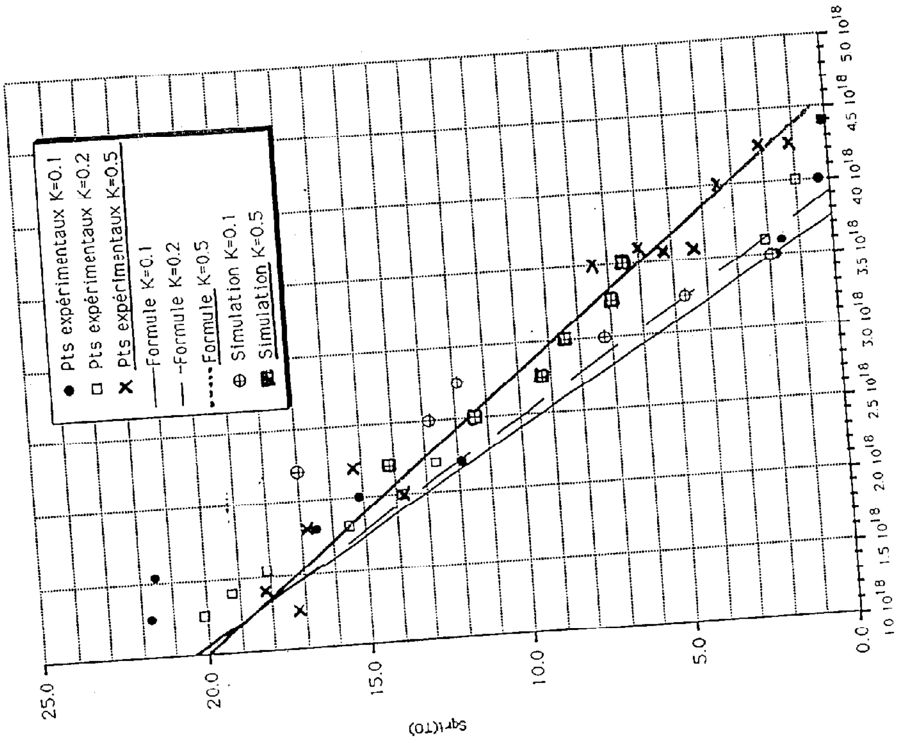
Calculations done for the 200-400 µm channel here:
-Capacitive Metallic loops in a 100 µm periodic pattern .
-Cavity 64 µm
Normal Metal and
Superconductive metal well below Tc to obtain a significant decrease of heat capacity.
(hν >> 2Δ) to have a good sub mm wave absorption.





$$\rho=\rho_0\exp\sqrt{\frac{T_0}{T}}$$

Sqrt(T0)=(28.494-5.7945*K)+Nd*(-7.9127e-18+4.6403e-18*K)



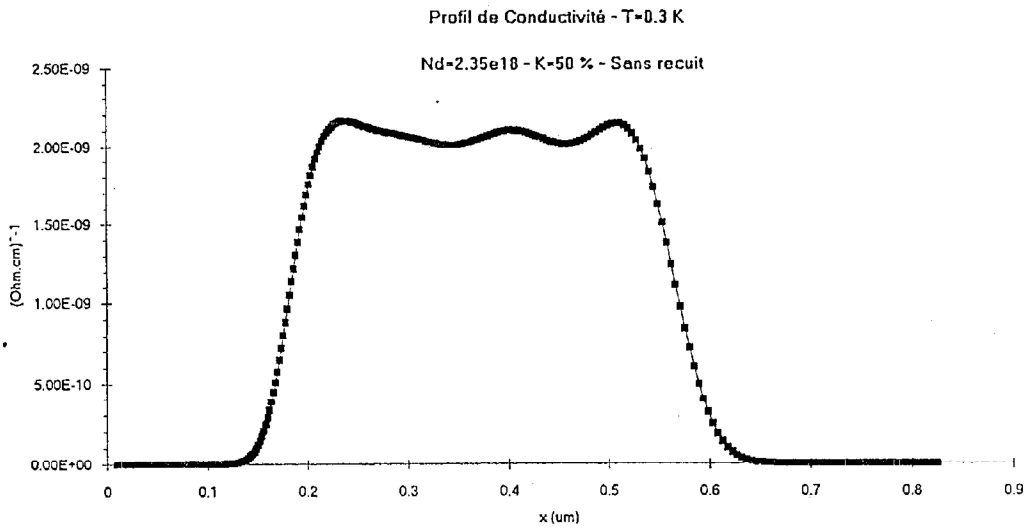
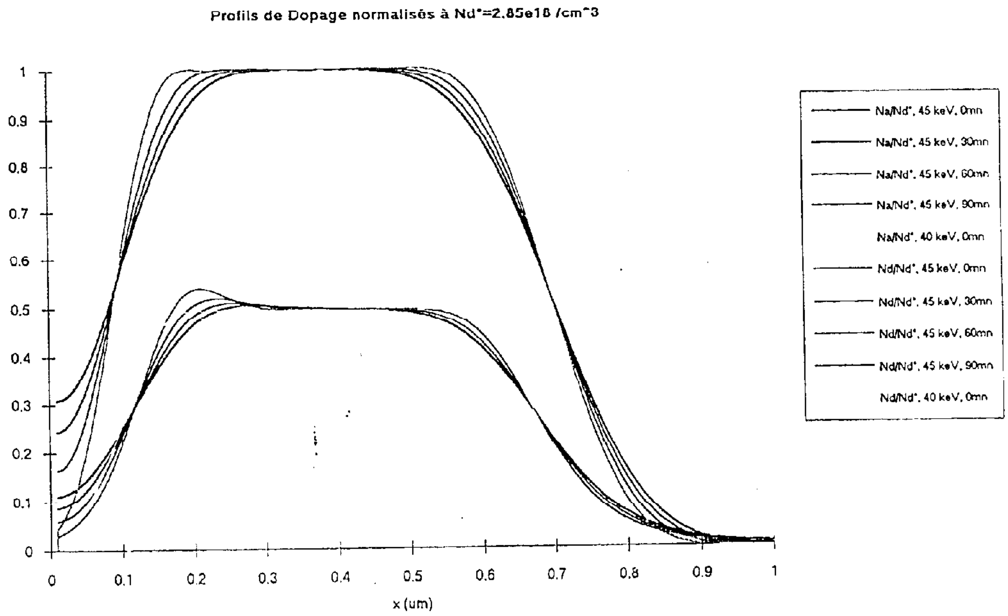

Profil de Conductivité - T=0.3 K
Nd=2.35e18 - K=50 % - Sans recuit
2.50E-09
2.00E-09
1.50E-09
1.00E-09
5.00E-10
0.00E+00
(Ohm.cm)^-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
x (um)

FIGURE 1


Profils de Dopage normalisés à Nd*=2.85e18 /cm^3
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
x (um)
Na/Nd*, 45 keV, 0mn
Na/Nd*, 45 keV, 30mn
Na/Nd*, 45 keV, 60mn
Na/Nd*, 45 keV, 90mn
Na/Nd*, 40 keV, 0mn
Nd/Nd*, 45 keV, 0mn
Nd/Nd*, 45 keV, 30mn
Nd/Nd*, 45 keV, 60mn
Nd/Nd*, 45 keV, 90mn
Nd/Nd*, 40 keV, 0mn

APPLICATION TO COLLECTIVE SPIDER WEB MANUFACTURE

Manufacture:
Integrated circuit Silicon etching can be applied very easily to manufacture many spider web bolometers at the time.

wafers can be hybridized on micromachined ceramic including metalised cavities.

We have not yet investigated the coupling to the telescope.

The low filling factor of conventional spider webs permits in principle high complexity pattern.
BUT
With our technique the maximum photographic pattern is only 14 x 14 mm^2 .

Thermometer:
Same problems and advantages in spider web and resonant absorption.

Absorption:
Spider webs need Winson cones or horns and integrating cavity.

Coupling to the preamplifier:
Same advantages.

Read Out Electronics

There is currently a large debate on bolometers read out electronics.
We have still to investigate the better way to bias bolometers and read the thermal information.

Taking in account that:
A bolometer is a very sensitive detector for microphonics and cosmic particles.

We propose in our solution a Front end electronics using CMOS Followers (ISO Heritage) fixed on the cold focal plane (100-300 mK) to avoid microphonic sensitivity, but working at 4 K thanks to a thermal link to the corresponding thermal shield.
This implies a large detector impedance, but no moving wires between detectors and preamplifiers few centimeters away.

The thermal decoupling of the follower Integrated Circuit from the focal plane is obtained by indium links (large thermal impedance).

The preamplifier and bias circuit can then be located on the warm shield.

Special care must be taken to study the electrothermal feedback circuit to reduce the sensitivity to energetic particles falling on the detector.

CONCLUSIONS

The resonnant absorption applied to the manufacture of 2-D bolometer arrays seems very promising.

In spite of everything, current techniques cannot open up the way to very high complexity focal planes (>16 x 16 pixels).

Simulations performed on compensated implantation thermometers are consistant with measurements done in other labs. Expected bolometer performances seem reachables with this technique.

Microphonics and high energy particles sensitivity will hopefully be reduced.

-> These techniques need sofisticated and expensive technology.
Most properties of the final component must be calculated or simulated before processing.

For cost and delay reasons the number of attempts will be drasticly reduced.

The first thermometric wafers are expected in Grenoble very soon.
These wafers with 50% compensation are designed to work at 300 mK .

Our optical test bench at 300mK is currently under manufacture. We already have two 300 mK refrigerator in ^{4}He cryostats.
Optical tests are planned to begin in March 97.

Performance testing of 100 mK spider-web bolometers

Sye Murray, Peter Ade, Ravinder Bhatia,
Matt Griffin, Bruno Maffei, Ramon Nartallo
QMW

Jeff Beeman
LBL

Jamie Bock, Hector Del Castillo
JPL

Andrew Lange
Caltech

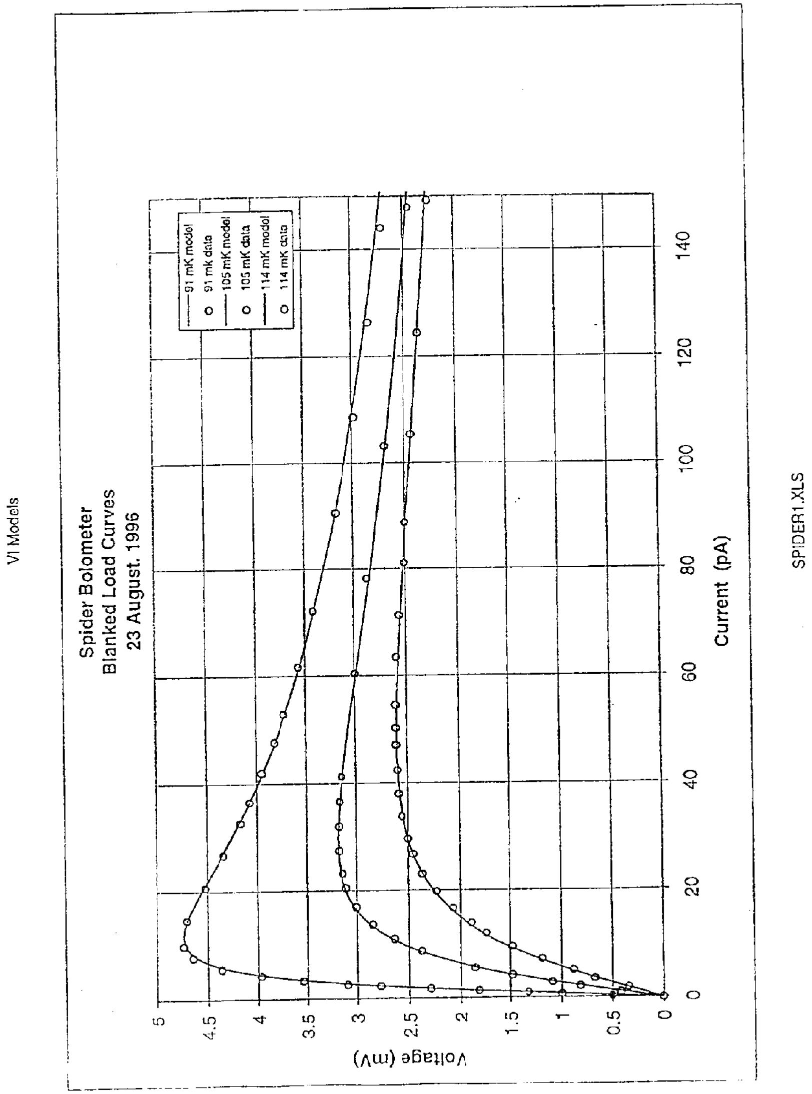
FIRST detector requirements

- $NEP_{opt} \sim 1 \times 10^{-17}$ W $Hz^{-1/2}$ for high-resolution spectroscopy
- $f_{3dB} \geq$ a few Hz
- Best candidate device based on current/existing technology is the spider-web bolometer

QMW tests

- Rationale
  - Aim initially for lowest achievable NEP
  - Determine the required characteristics of optimised devices
  - Evalute optimised detectors
- Characteristics of device tested:
  - NTD24 thermistor
    (100 x 300 x 50 µm)
  - Web geometry: d = 2·5mm
    g = 160µm
    5% filling factor

Fig. 2



Test results

- Blanked off tests:

Used to establish bolometer parameters:

$$R(T) = R_0 \exp\left[\frac{T_g}{T}\right]^n \qquad G(T) = G_0\left[\frac{T}{T_o}\right]^\beta$$

$T_g = 31.8$ K

$R_0 = 10.7\ \Omega$

$\beta = 1.7$

$n = 0.5$

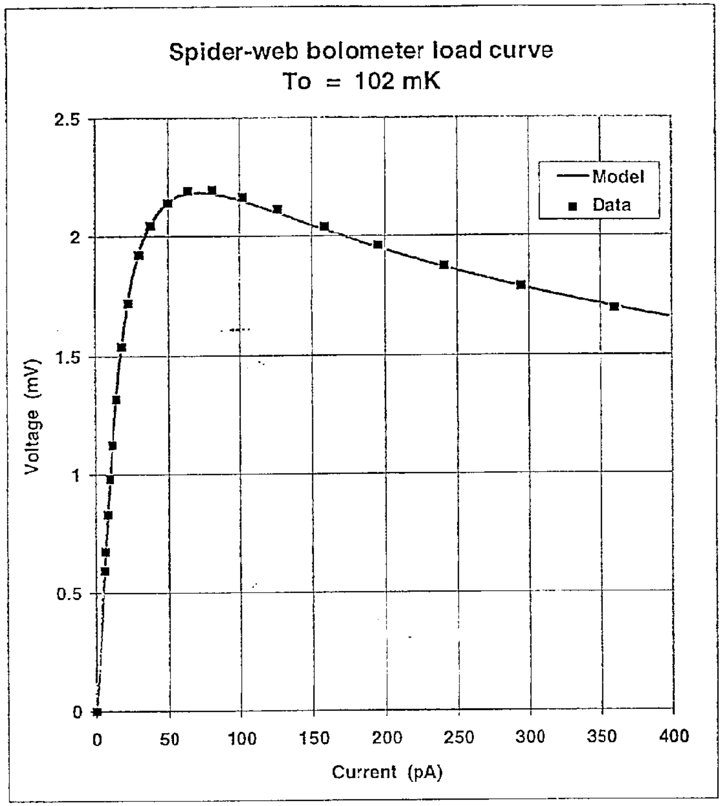
$G(100\text{ mK}) = 4.3\text{ pW K}^{-1}$

- Optical tests:
  - $\lambda = 850\ \mu m$
  - Background power ~ 0.1 pW
  - Measurement of NEP and speed of response vs. operating temperature

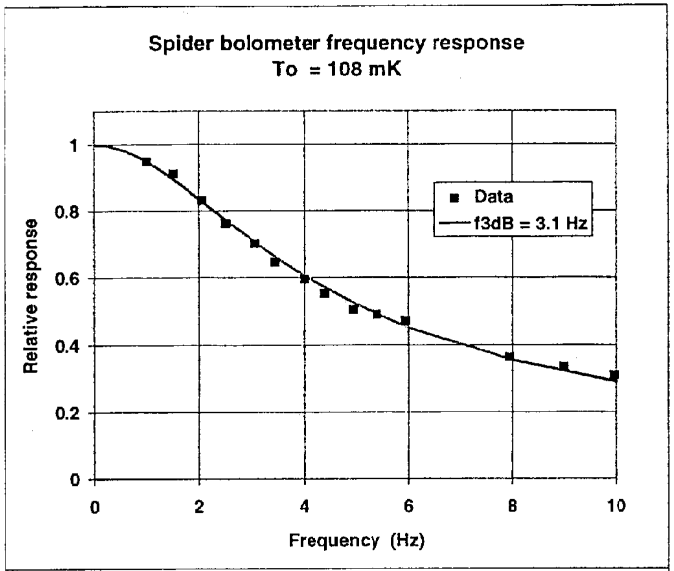
  - At T = 100 mK:

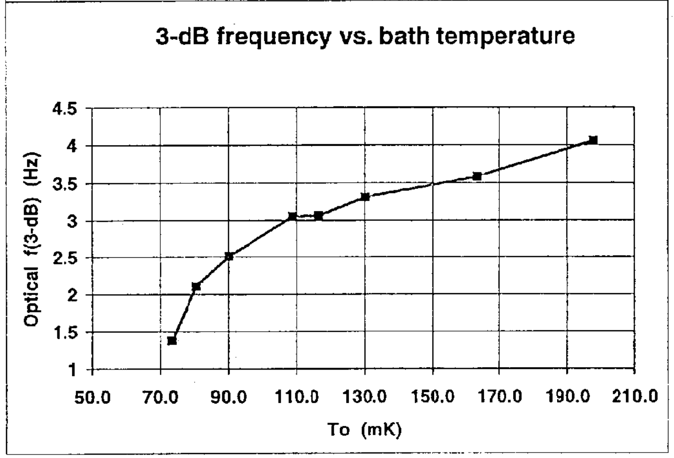
    $NEP_{optical}$: 1×10^{-17} W $Hz^{-1/2}$
    (photon noise limited)
    f(3-dB) : 3 Hz

- Extrapolation to device optimised for FIRST:
  - NEP = 10^{-17} (detector limited)
  - f(3dB) ~ 5 Hz
  - T_o = 150 - 200 mK

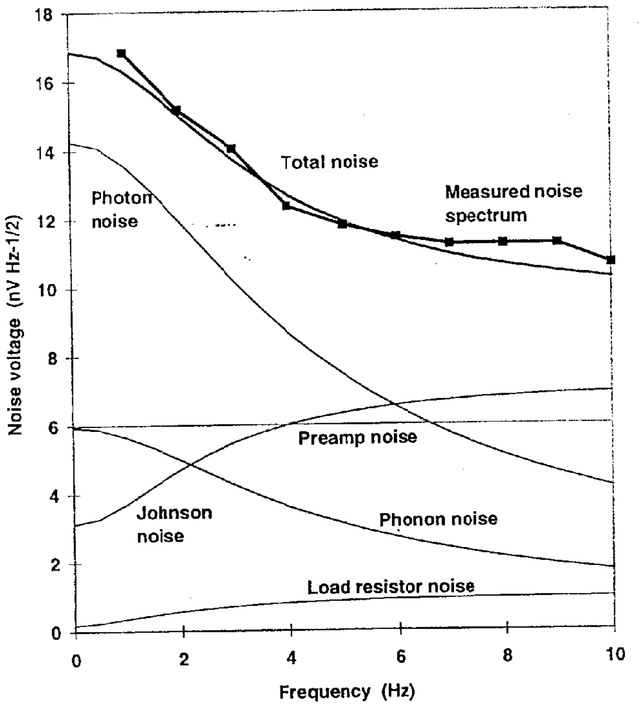


To	102	mK
β	1.7	
n	0.5	
Tg	31.8	K
Go	4.4	pW K-1
Q	105	fW
f3-dB	3.1	Hz
NEPdet	3.0E-18	W Hz-1/2
NEPph	8.0E-18	W Hz-1/2





Spider bolometer Nov. 5 1996
Measured and model noise spectra

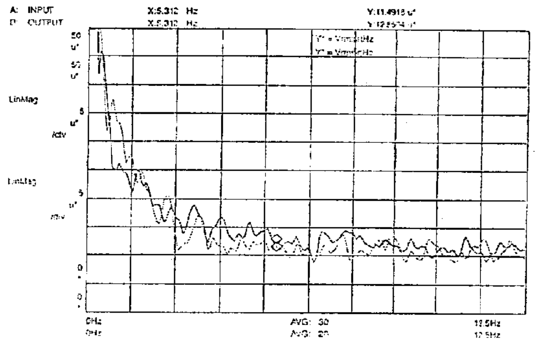


- DIFFERENTIAL READOUT
- 10 μW COOLING POWER
- BLANKED AT OUTER ⁴He SHIELD

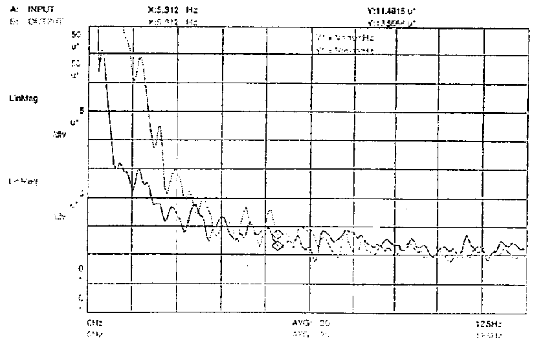
QUEEN MARY
AND WESTFIELD COLLEGE
UNIVERSITY OF LONDON

BLANKED SPIDER MICROPHONIC RESPONSE AT 100 mK

INPUT = 1.05 mg peak AT 32 Hz



INPUT = 1.12 mg peak AT 32 Hz



Conclusions

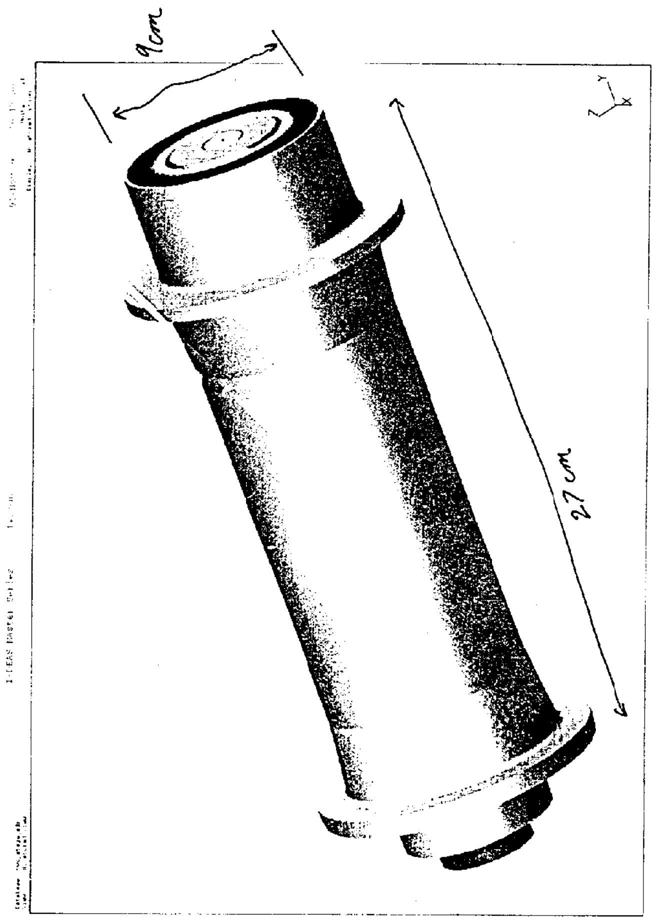
- Spider-web bolometers can meet the FIRST requirements
- Behaviour is close to that of an ideal bolometer
- Low cosmic ray cross section
- Suitable for making arrays and uniform mass production
- Operation at $T = 150\text{-}200$ mK should be possible
- Microphonics: much more to be done but indications are that the spec. can be met

Future Work

- Full characterisation (electrical and optical) of optimised devices
- Develop prototype single-pixel system for FIRST
  - Cold stage with representative cooling power
  - Appropriate filtering, field of view, photon background
  - Specified performance:
  - Optical NEP over required range of signal frequencies
  - Speed of response
  - Acceptable microphonic and EMI susceptibility
- Complete demonstrator system (4-K cooler) + dilution fridge + detectors

Ian Hepburn (MSSL)

ADR development status



Magnetic System

Standard conduction cooled superconducting magnets.

1 Tesla field

2 Amp current required at the moment. can be reduced to 1 Amp.

Nulling coils cancel the magnetic field at sensitive points e.g. detector plane.

Completely shield by passive shielding.

Thermal

dADR housed in a 5-4 K environment.

Thermal load dominated by magnet current leads.

Only current technology used.

Maximum loads at present

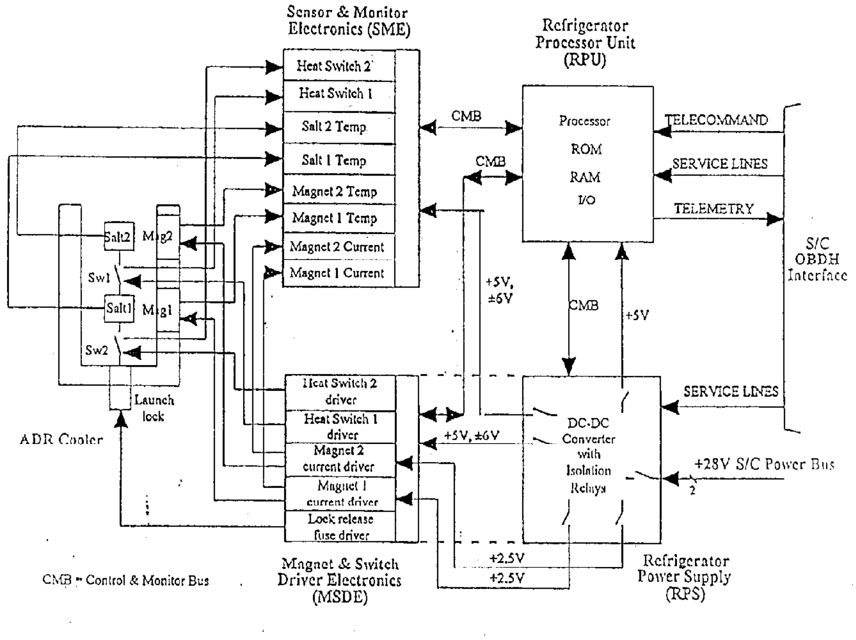
5-4 K	10mW
20 K	15mW
65 K	74mW
150 K	120mW

Electrical System.

Comprises 4 sub-units

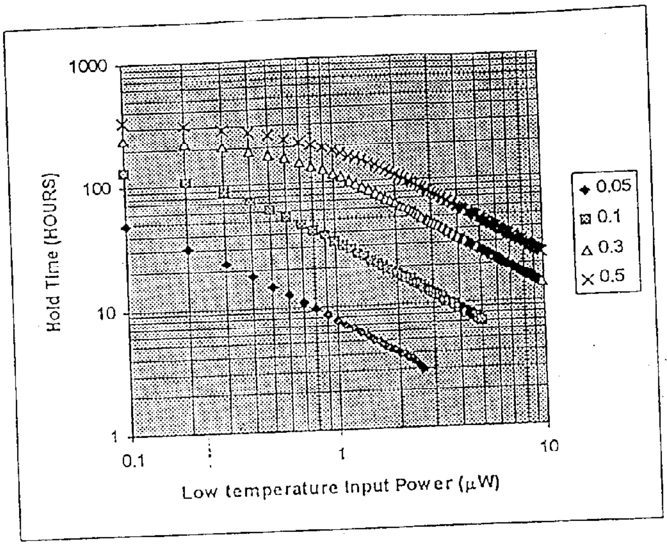
1. Refrigerator Power supply
2. Sensor and Monitor electronics
3. Magnet and Switch Driver Electronics
4. Refrigerator Processing Unit

Power 24 Watts



Mass Break Down

Sub-System			Mass (kg)
dADR	Paramagnetic Materials	Material 2 Assembly	0.16
		Material 1 Assembly	0.98
	Supports and Heat switches		1.36
	Magnets	Wire	6.7
		Former	5
Electronics			7.0
Total			**21.2**



High temperature Paramagnetic material Testing

Experiments so far performed on high temperature materials agree with theory and show that further reduction in magnetic field may be possible.

Proto- Type

Both the dADR and 3rd Stage are under construction.

Testing of both will take place ~July 1997

Conclusion

A new form of ADR has been presented which is under construction.

This ADR can produce temperatures down to 0.01K.

Operate from a 5-4 K environment

Very suitable for use with mechanical coolers

Experimentation with the proto-types is likely to lead to further reduction in magnetic field and thermal load.

⇒ Reduced Mass

MATERIAL THERMOPHYSICAL
MEASUREMENT PROJECT

- Measure Thermal conductivity from
  10mK → >4K
- Measure Heat Capacity
  10mK → >4K

For a selection of materials

FUNDED by PPARC PIPSS grant in association with Oxford Instruments.

Project start date : April 1997
Duration : 2 yrs

Results of thermal conductivity measurements could be released to FIRST teams.