SPIRE Bolometer Array Technology Meeting
NASA GSFC, 17, 18 September 1998

PROVISIONAL AGENDA SPIRE/NASA/M/0049.10

Day 1: Thursday September 17

1.	09.00	Welcome, logistics	Moseley
2.	09.15	Introduction • Review/revision of agenda • Status of FIRST and SPIRE • Aims of the meeting	Griffin
3.	09.30	Schedule for detector evaluation, SPIRE PDR, CDR, and QM manufacture	King
4.	10.00	Actions from Saclay meeting	Swinyard
5.	10.30	Qualification programme	Swinyard
6.	11.00	Systems design and interface specifications • Goddard/NIST • Caltech • Saclay	Array teams (30 min. each)
7.	12.30	Evaluation criteria and plan and future meeting schedule	Griffin
	13.00	**Lunch**	
8.	14.00	Array development progress reports and qualification plans • Goddard/NIST • Caltech • Saclay	Array teams (30 min. each)
9.	15.30	BACUS status and array test plan	Hargrave
10.	16.00	Presentations on technical issues: • TES and semiconductor bolometer design for uncertain photon background • Simulations of SPIRE observations	 Griffin Vigroux
11.	17.00	Discussion following day 1	All
12.	17.45	Summary of day 1	Griffin
	18.00	End of day 1	

Day 2: Friday September 18

13. 09.00 Review of agenda; splinter meeting organisation — Griffin

14. **Parallel splinter sessions**

09.30	1.	Array test plan Hargrave, Maffei, Irwin, Rodriguez, Caltech, Goddard, Ade, Swinyard + others	Hargrave
09.30	2.	Array sensitivity and operating modes Bock, Vigroux, Griffin, + others	Vigroux
10.30	3.	Feedhorn option Cunningham, Bock, Duncan, Swinyard, Ade, + others	Bock
10.30	4.	Front-end electronics for US options Rodriguez, Caltech, Goddard, NIST, + others	Rodriguez

15. 11.30 Reports from splinters (~ 10 min. each)

1. Array test plan — Hargrave
2. Sensitivity and operating modes — Vigroux
3. Feedhorn option — Bock
4. Front-end electronics — Rodriguez

16. 12.30 Review of actions from this meeting — Swinyard

17. 12.45 Summary and conclusions — Griffin

- Mid-term assessment of progress and likelihood of
  - (i) meeting the performance requirements on schedule;
  - (ii) establishing the systems design on schedule;
  - (iii) meeting the requirements of the qualification programme and the CQM schedule.
- Division of effort on the different options between now and selection
- Details of test plan
- Other issues . . . .

13.30 End of meeting

-- -- ARRAY MEETING GSFC 17 Sept. 9

	Name	Institute	Fax	E-mail
1)	Terry Cafferty	JPL/TC Technology	2136534726	tctech@earthlink.net
2)	BRUNO MAFFEI	QMW	(44) 181 980 0986	B.Maffei@qmw.ac.u
3)	WILLIAM DUNCAN	UK ATC	44 131 668 8264	william.duncan@roe.ac.uk
4)	PETER ADE	QMW	44 181 980 0986	P.A.R.ADE@QMW.AC.UK
5)	PETER HARGRAVE	QMW	44 181 980 0986	P.HARGRAVE@QMW.AC
6)	Laurent VIGROUX	CEA	33 1 69 08 65 77	lvigroux@cea.fr
7)	Louis RODRIGUEZ	CEA/SAp	"	lrodriguez@cea.fr
8)	Patrick AGNESE	CEA/LIR	33 4 76 88 51 67	agnese@lirsew.cng.ce
)	Christophe CARA	CEA/SAp	33 1 69 08 46 35	ccara@cea.fr
	Juan Roman	GSFC	301-286-0318	Juan.Roman@gsfc.nasa.gov
)	Phil Mauskopf	UMass	413-545-3192	mauskopf@fcrao1.phast.umass.edu
2)	Christopher Paine	JPL	818 393 3566	cpaine@squid.jpl.nasa.gov
13)	CARL REINTSEMA	NIST	303 497 5092	reintsema@boulder.nist.gov
14)	ERICH GROSSMAN	NIST	303 497-5102	grossman@boulder.nist.gov
15)	JASON GLENN	Caltech	626 584-9929	jg@astro.caltech.edu
16)	BILL GRAY	JPL	818 354-1090	wbgray@jpl.nasa.gov
17)	ANTHONY TURNER	JPL	818 393 4420	adturner@pop.jpl.nasa.gov
18)	Hien Nguyen	JPL	818 354-0560	hien@cougar.jpl.nasa.gov
9)	Jamie Bock	JPL	626-584-9929	jjb@astro.caltech.edu
20)	COLIN CUNNINGHAM	UK ATC	44-131-668-8223	CRC@ROE.AC.UK
21)	Andrew Lange	Caltech	626 584 9929	ael@astro.caltech.edu
22)	BRUCE SWINYARD	RAL	(44) 1235 446667	B.M.SWINYARD@RL.AC.UK
23)	Harvey Moseley	GSFC	301-286-2347	moseley@stars.gsfc.nasa.gov
	[illegible] King	RAL	(44) 1235 446667	[illegible]
	[illegible]	QMW	(44) 181 980 0986	[illegible]
6)	Bob Baker	GSFC	301-286-9082	baker@lheapop.gsfc.nasa.gov
7)	Rick Shafer	GSFC	301-286-3463	rick.shafer@gsfc.nasa.gov
8)	[illegible] Bergman	GSFC	[illegible]	[illegible]

2.

INTRODUCTION

MATT GRIFFIN

Status of FIRST and SPIRE

FIRST

- Carrier is favoured option of ESA's SPC

  But ESA still have to fit FIRST and PLANCK into something not much more than 650 MAU

- Final mission confirmation and payload approval in February 1998

- Funding status was reviewed at special meeting in July

- Another one planned for October

SPIRE

- Double-pass FTS option being studied as alternative to classical MP as in proposal
  - Decision in January

- Still need to convince Mission Scientists of wisdom of FTS choice

- Funding problem in the UK (Structure and Systems Engineering) needs to be sorted out by October

- First formal meeting with ESTEC project took place on July 29 – many actions on us to be completed by October 9 ⇒ not long after this meeting

- SPIRE project now needs to establish more formal and reliable lines of communication and reporting

Main aims of this meeting

1 Review the schedule and requirements for SPIRE detector array selection and qualification

2 Establish the system design for each option

3 Plan the testing and evaluation programme

4 Review progress on array development since the Saclay meeting in May

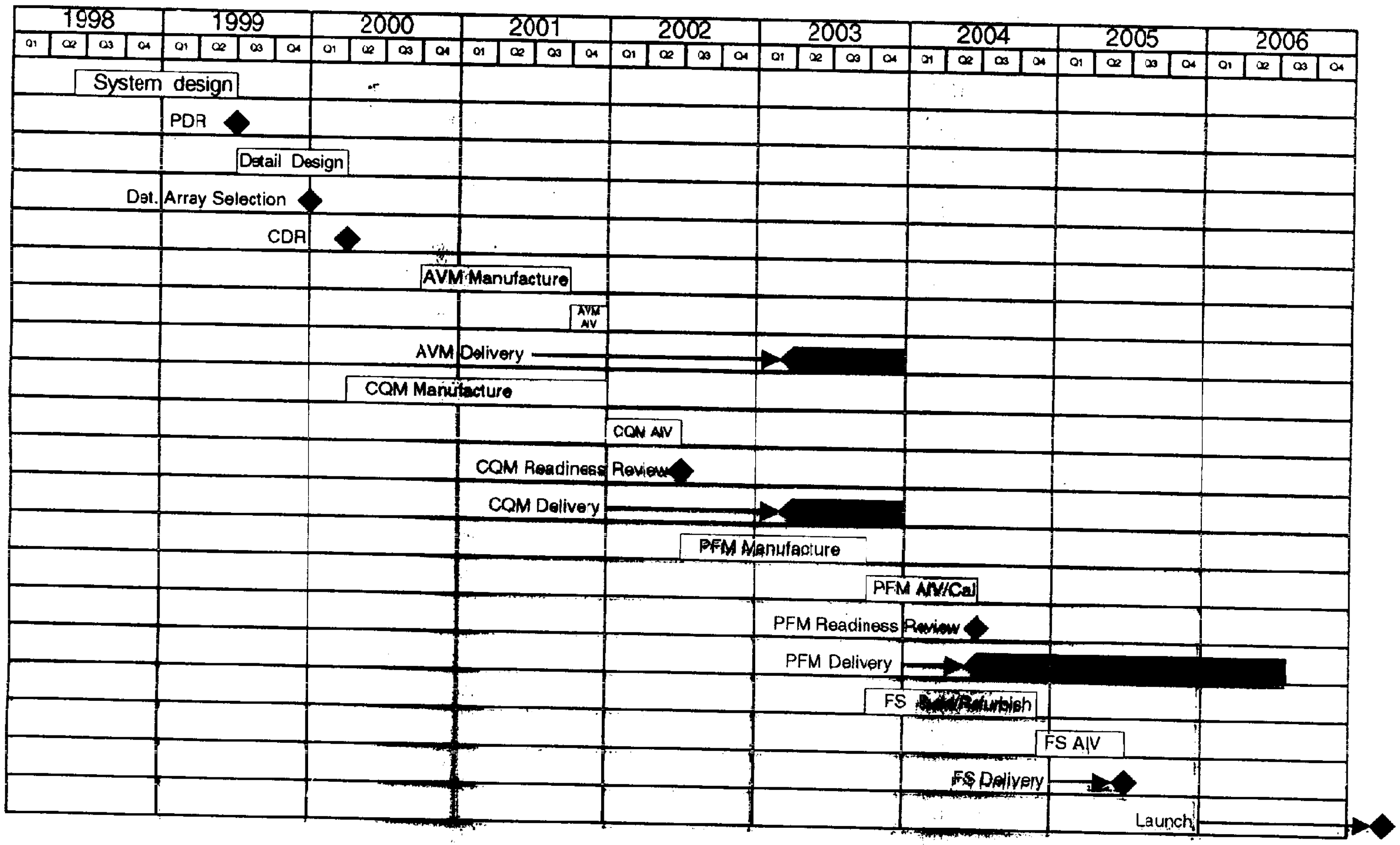
5 Mid-term assessment of how well the array programme is going: are we being realistic?

3

SPIRE SCHEDULE

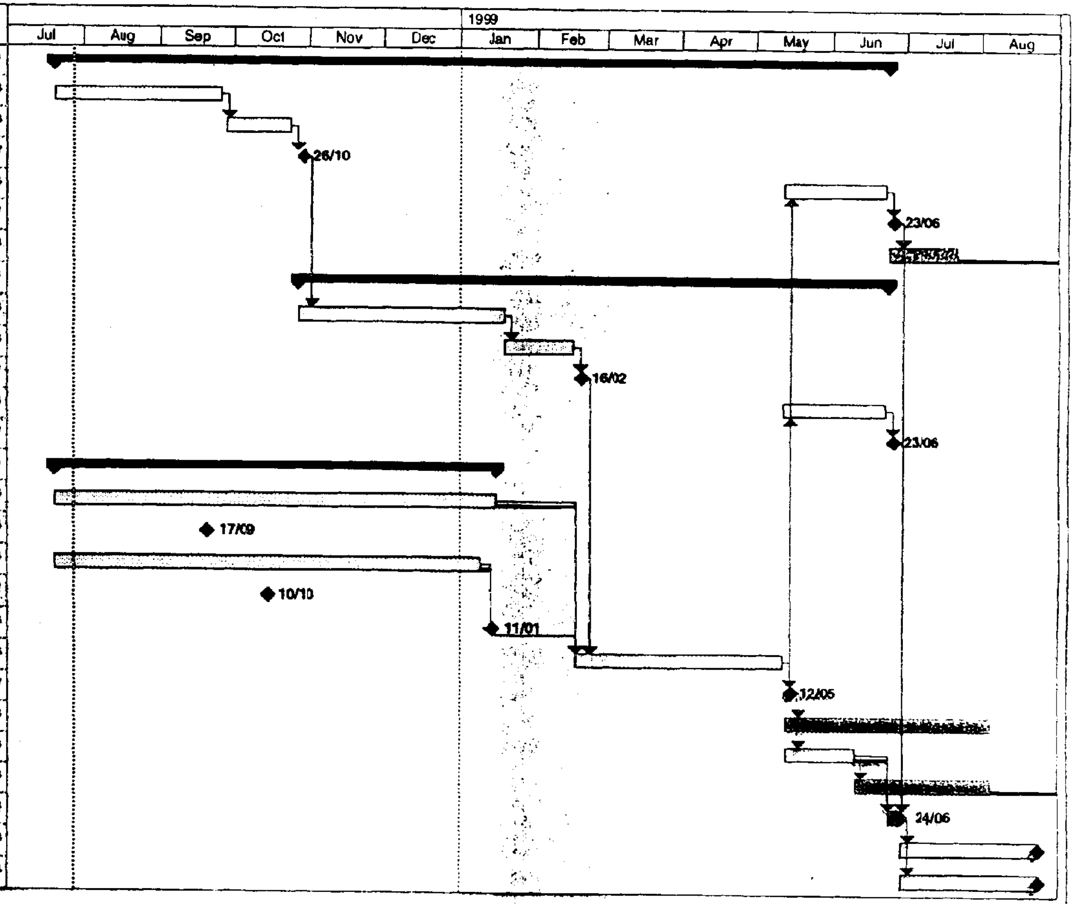
KEN KING

SPIRE Instrument Development Schedule



29th July 1998

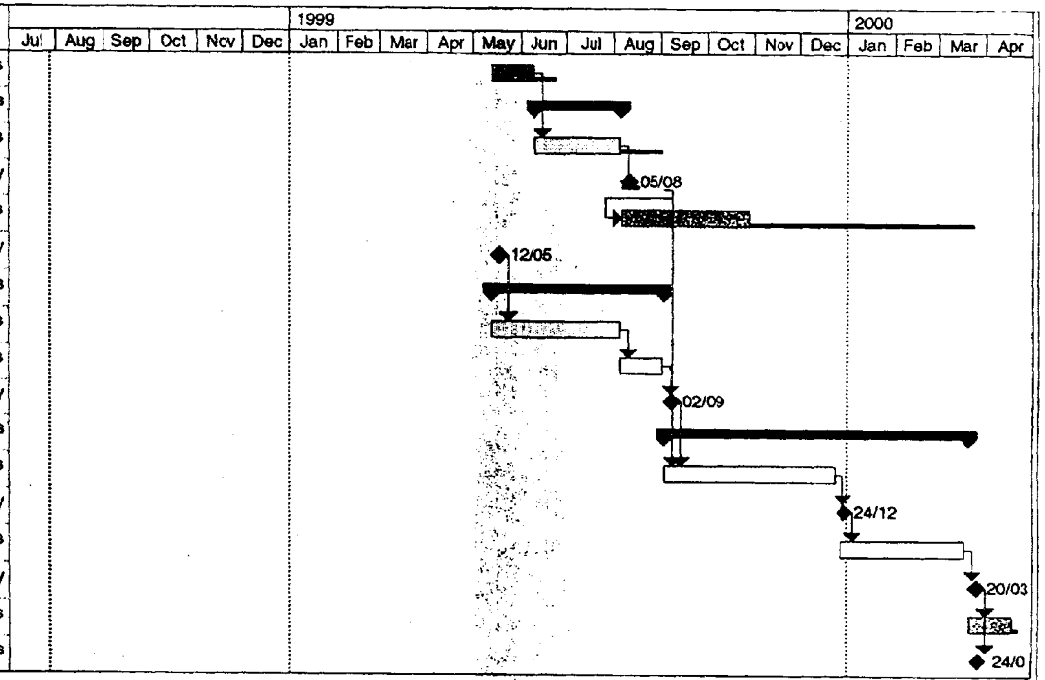
ID	Task Name	Duration
1	**Science Requirements Document (SciRD)**	243 days
2	Write draft SciRD	10 wks
3	Review draft SciRD	4 wks
4	Issue draft SciRD	1 day
5	Update SciRD to Issue 1	6 wks
6	Issue Scientific Requirements Document	1 day
7	Definition of Scientific Calibration Requirements	4 wks
8	**Engineering Requirements Document (EngRD)**	172 days
9	Write draft EngRD	12 wks
10	Review draft EngRD	4 wks
11	Issue draft EngRD	1 day
12	Update EngRD to Issue 1	6 wks
13	Issue Engineering Requirements Document	1 day
14	**System Design development**	130 days
15	Detector design development	26 wks
16	Detector Meeting	2 days
17	FTS design development	25 wks
18	FTS meeting	1 day
19	FTS Design Selection	2 days
20	System Design Definition	12 wks
21	Issue System Design Document (SysDD)	1 day
22	Write draft SubRD	12 wks
23	Allocation of Budgets	4 wks
24	Write draft SubICD	8 wks
25	Instrument Preliminary Design Review	3 days
26	Provision of Mathematical Optical Model	8 wks
27	Provision of Mathematical Thermal Model	8 wks



Project: System Design
Date: Tue 28/07/98

Task		Summary		Rolled Up Progress		Milestone Slack	
Critical Task		Rolled Up Task		External Tasks		Milestone	◆
Split		Rolled Up Split		Project Summary			
Progress		Rolled Up Milestone ◇		Slack			

ID	Task Name	Duration
1	Allocation of Budgets	4 wks
2	Subsystem Interfaces Document (SubICD)	41 days
3	Write SubICD	8 wks
4	Issue SubICD	1 day
5	EGSE Design	12 wks
6	Issue System Design Document (SysDD)	1 day
7	Subsystem Requirements Document (SubRD)	81 days
8	Write draft SubRD	12 wks
9	Review draft SubRD	4 wks
10	Issue SubRD	1 day
11	Subsystem Design Document (subDD)	142 days
12	Write draft SubDD	16 wks
13	Detector Technology Selection	1 day
14	Update SubDD	12 wks
15	Issue SubDD	1 day
16	Definition of Instrument Integration Plan	4 wks
17	Instrument Critical Design Review	4 days



Project: Detailed Design
Date: Tue 28/07/98

Task	Rolled Up Task	Project Summary	
Critical Task	Rolled Up Split	Slack	
Split	Rolled Up Milestone ◇	Milestone Slack	
Progress	Rolled Up Progress	Milestone	
Summary	External Tasks		

5.

QUALIFICATION PROGRAMME

BRUCE SWINYARD

Detector Qual Programme

- Assumption is that at least one dedicated model of the complete detector sub-system will be passed through a qualification programme - this is to be termed the "Type Approval Model".
- In a "classical" space project this will have happened BEFORE the instrument CDR. [OR WITH A DEDICATED QM]
  - Not possible for the detector sub-system. [ON SPIRE]
- As much as possible of the detector sub-system qualification must be done before the CDR
  - Freeze interfaces as early as possible
- The arrays and cold readout electronics qualification programme won't really start until after array selection.

Detector Qual Programme

- Need to identify:
  - What is to be done
  - When it is to be done in the qualification programme
  - How representative the components need to be for the test in question
  - Who is going to do it

Detector Qual Progr[redacted]

Detector Qual Prog[redacted]

Detector Qual Progr[redacted]

How representative:

When:

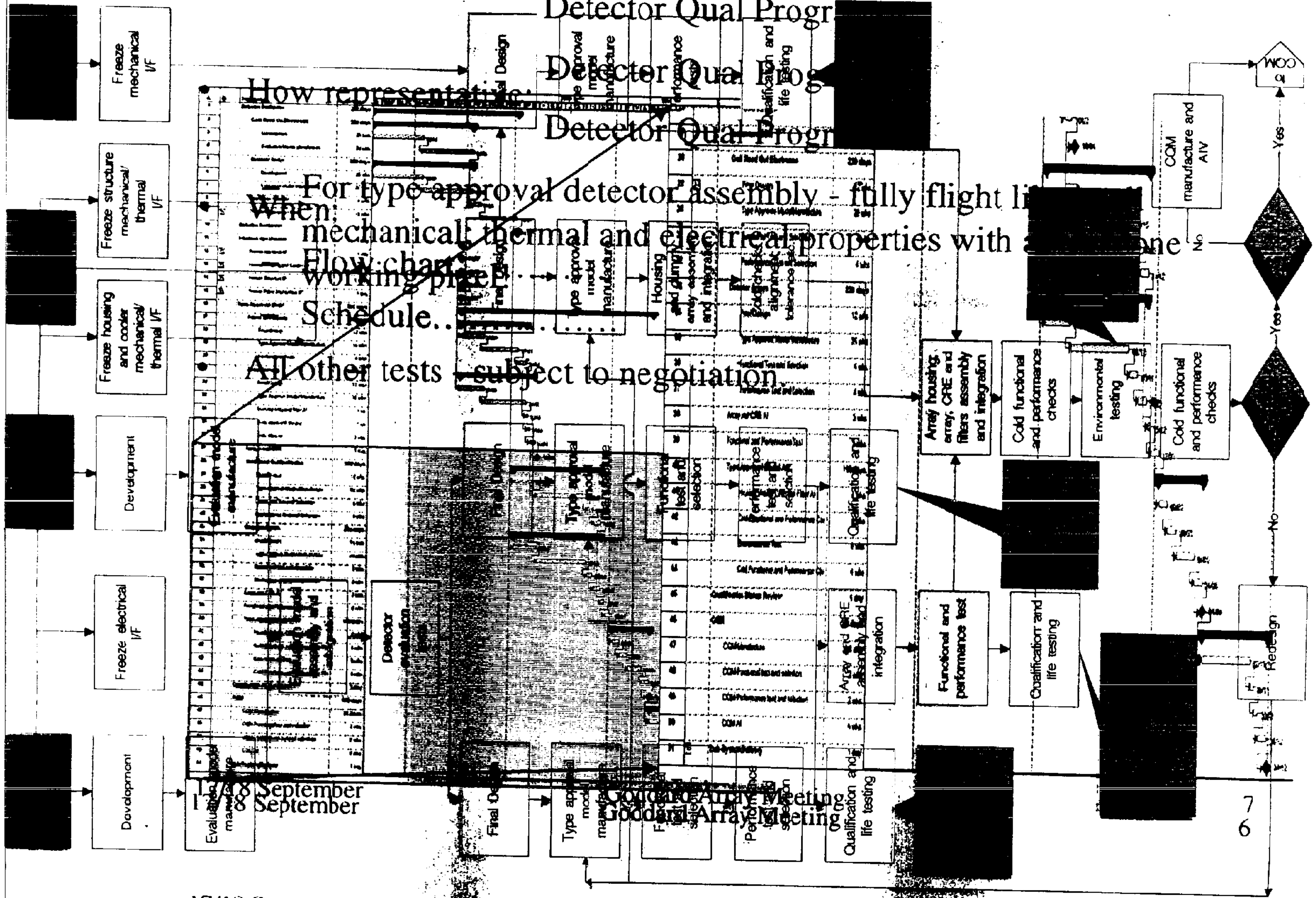
For type approval detector assembly - fully flight li[redacted]
mechanical, thermal and electrical properties with a[redacted]one

Flow chart

working plan

Schedule...

All other tests – subject to negotiation.



17/18 September
17/18 September
Goddard Array Meeting
Goddard Array Meeting
7
6

Detector Qual Programme

- What:
  - Vibration
  - Thermal Cycle
  - Vacuum Cycle
  - Lifetime
  - Soak and operationally cycle
  - Radiation tolerance
  - Thermal range
  - Thermal stability
  - Microphonics
  - Ionising Radiation
  - EMI
  - EMC
  - Materials conformance

- What now:
  - Draw up agreed list of tests - array groups to respond to list given here and fill in pro-forma test sheets (1 month/next meeting)
  - Systems team to specify levels for qualification tests - prompting information from ESA as appropriate (next meeting)
- Who:
  - Array groups to identify what tests can be done before array selection and/or CDR (next meeting)
  - Array groups to identify level of component representation required for all tests (next meeting)
  - QMW to identify level of component representation required for filter and housing tests (next meeting)
  - QMW (+BMS) to draw up proper qualification plan (1 month before PDR)

- Good question! No point in duplicating effort during array development and some facilities are very expensive.....
- Some large facilities required:
  - ☹ Cold vibration
  - ☹ Proton beam capable of taking cryostat without making it radioactive or melting the electronics!!)
  - ☹ Cryostat(s) and calibration facility for array evaluation before/after each test
  - ☹ Facility for evaluation of microphonic response
- Some facilities needed for a long time:
  - ☹ Cryostat for lifetest
  - ☹ EGSE for soak; operational cycle and lifetest
  - ☹ Folk to carry out and monitor the tests

☺ Remember ☺

A qualification plan is a requirement for detector technology selection

☹

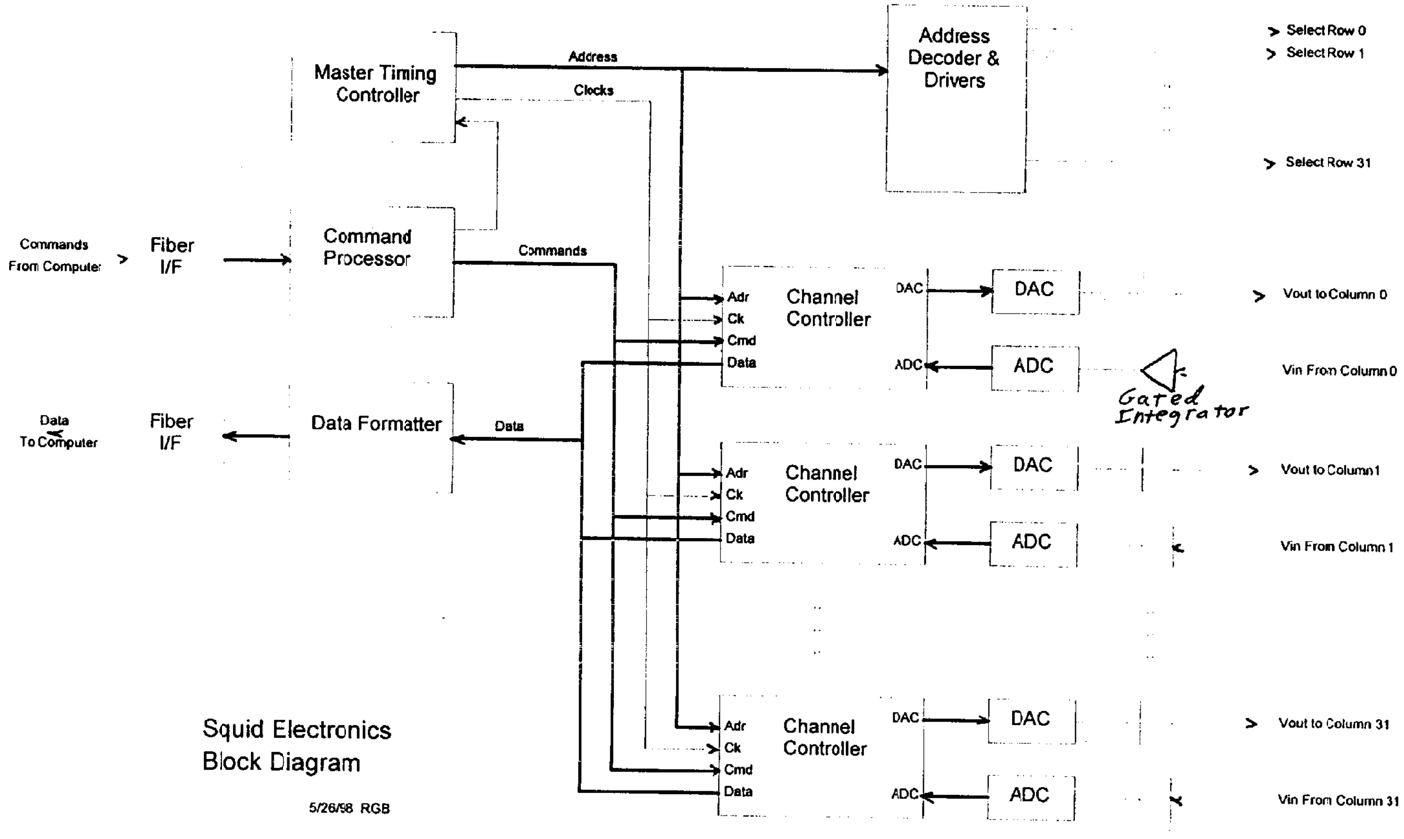
6a

SYSTEMS DESIGN : GSFC /N

BOB BAKER

RICK SHAFER

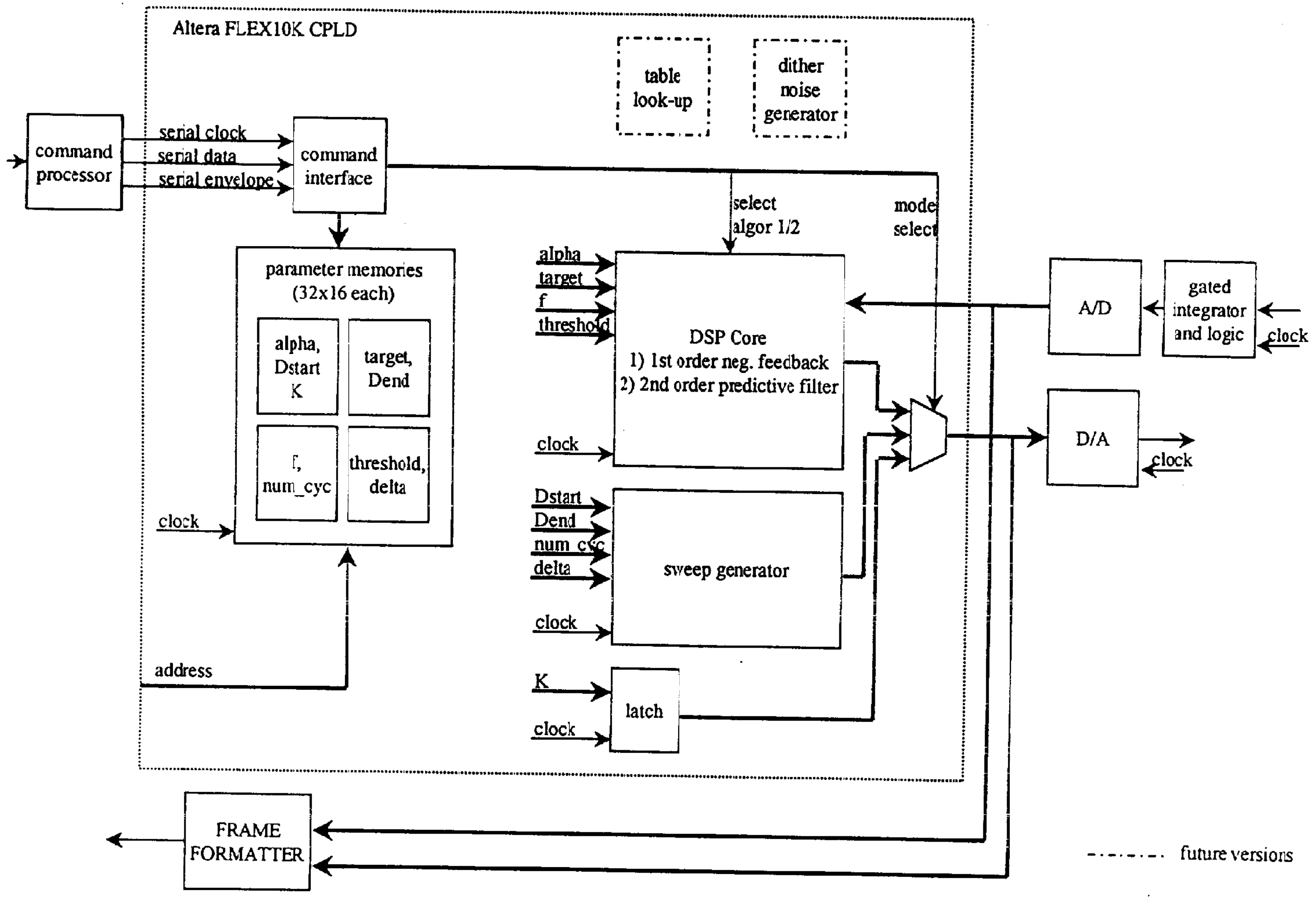
DAVID BERGMAN



Squid Electronics
Block Diagram

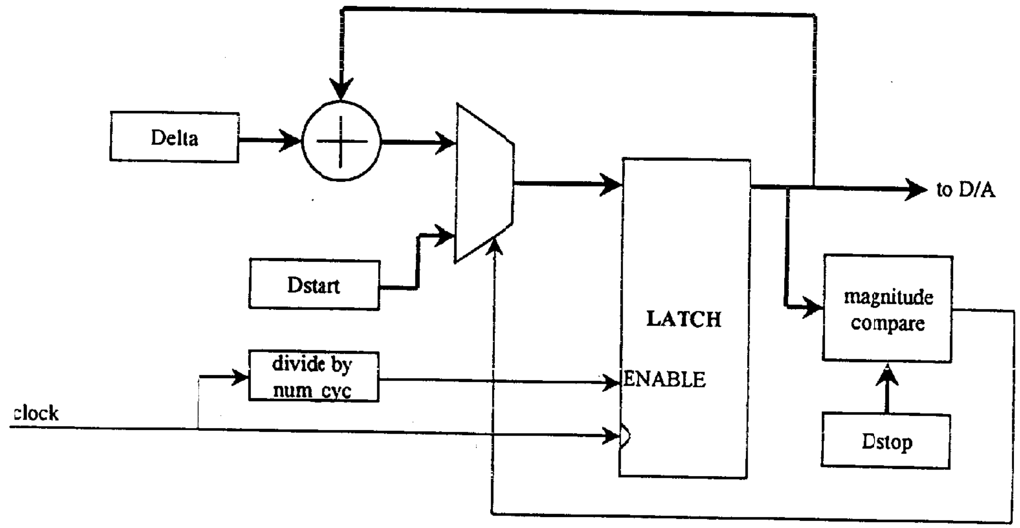
5/26/98 RGB

SPIRE MARK 2 COLUMN CONTROLLER BLOCK DIAGRAM



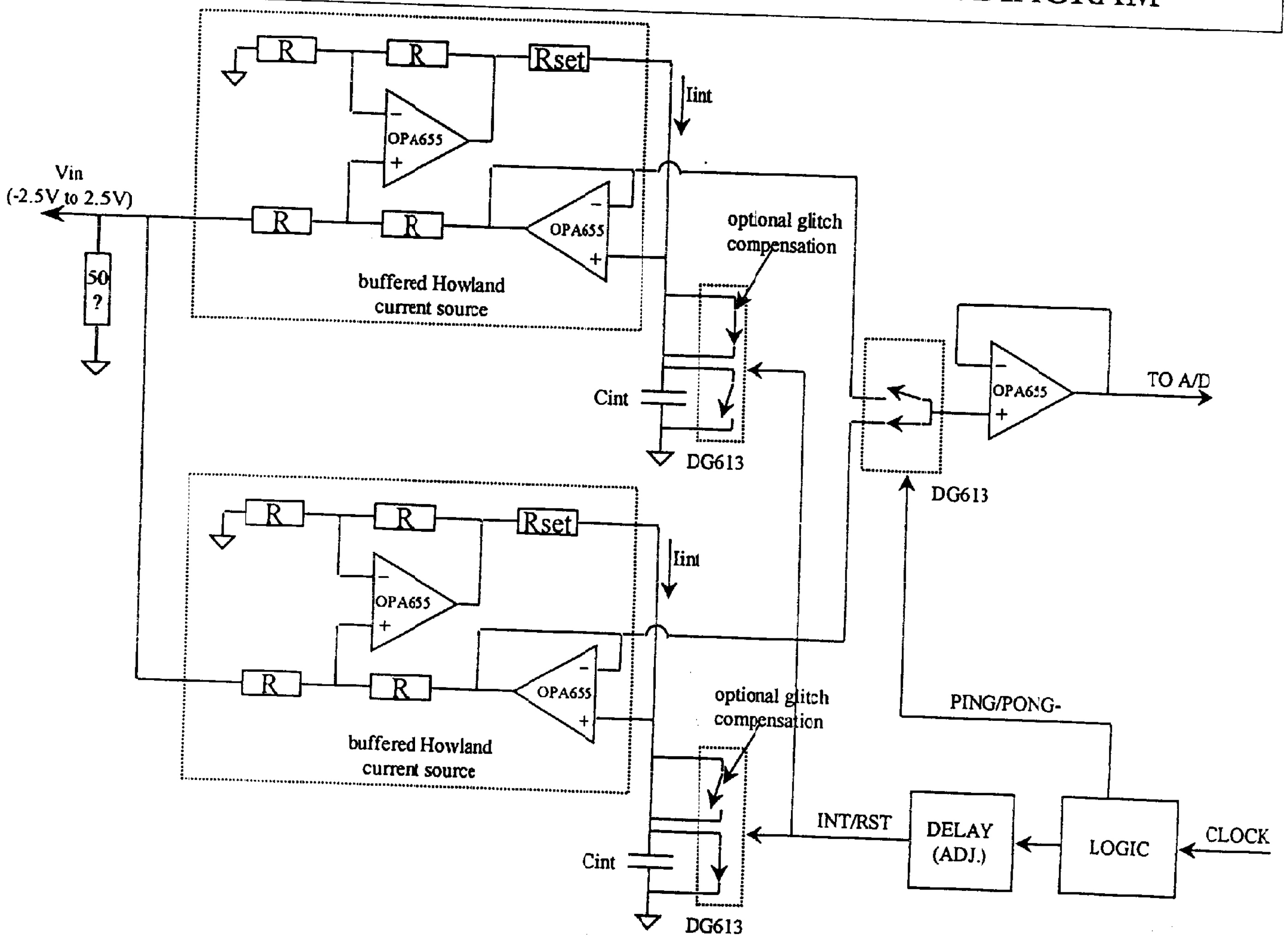
D. Bergman/564

SWEEP GENERATOR [IV Curves]



D. Bergman/564

PING PONG GATED INTEGRATOR BLOCK DIAGRAM



D. Bergman/564

SCHEDULE

- COMPLETE MARK 1.8 FABRICATION BY THANKSGIVING
  - A/D, D/A EVALUATION BOARDS, GATED INTEGRATOR PROTOTYPE BOARD, DSP PROTOTYPE BOARD
- TEST ELECTRONICS WITH SQUIDS AT GSFC LATE NOVEMBER, EARLY DECEMBER
- TEST ELECTRONICS WITH TES's AND SQUIDS AT COLORADO MID-LATE DECEMBER
- COMPLETE MARK 2 FABRICATION (4 COLUMN) BY LATE JANUARY, EARLY FEBRUARY

6 A B

SACLAY ARRAYS

SYSTEM DESIGN + PROGRESS REPORT

LOUIS RODRIGUEZ

CEA
BOLOMETER ARRAYS
PROGRESS STATUS

TO BUILD BOLOMETER ARRAYS

TO HAVE ACCESS TO A TECHNOLOGY :HERE AT CEA/LETI
Manufacture of integrated electronic circuits,
and microsensors for industry.

TO HAVE KNOWLEDGE OF CRYOGENIC DETECTORS FOR SCIENTIFIC SPACE PLATFORMS: ISO and CASSINI.

TO HAVE ACCESS TO PH[illegible]ROPERTIES:

OPTICAL ABSORPTION DA[illegible]

THERMAL CONDUCTANCES [illegible]TERIALS:
Si, metal wires, others.

SPECIFIC HEAT DATA to [illegible] capacity of the bolometer.

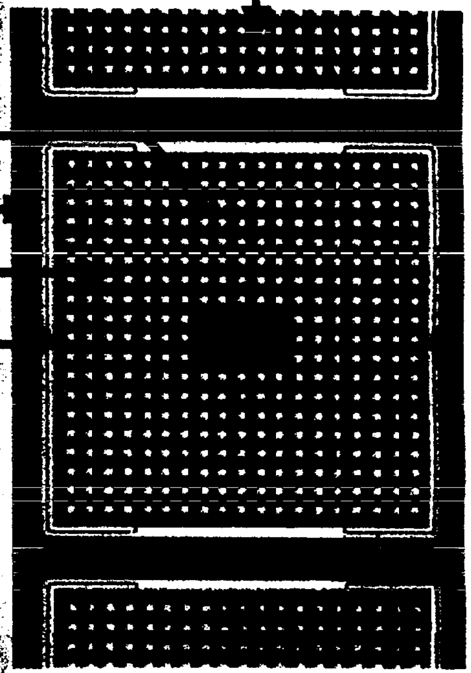
A THERMOMETER with [illegible] and noise density
to compute SENSITIVITY.

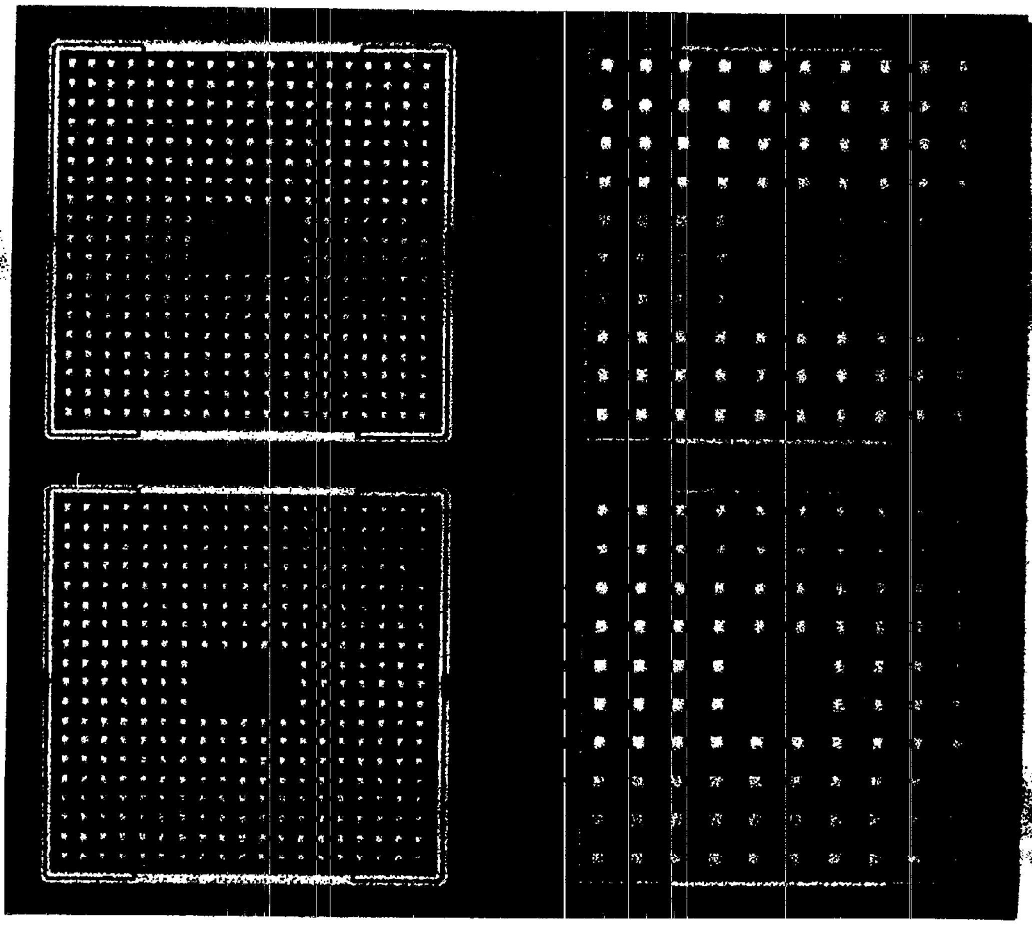
TO DEVELOP MODELS [illegible]

For observations [illegible]

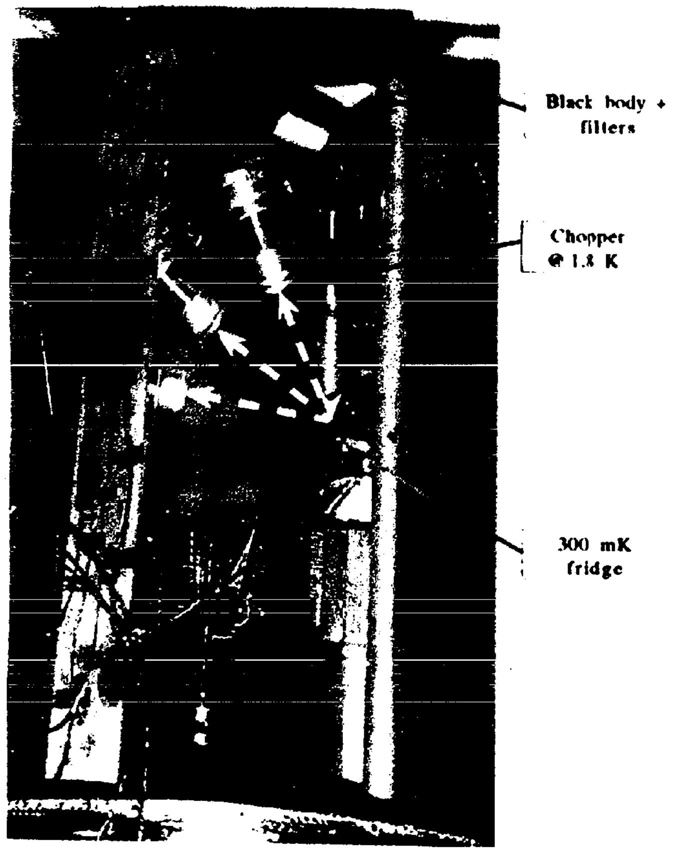
For optical absorption [illegible]
For thermal [illegible]
For [illegible]
For [illegible]

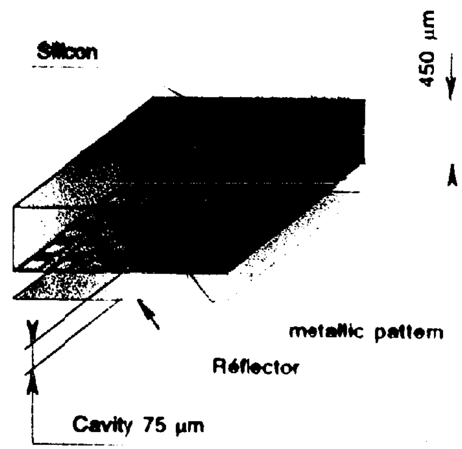
TO ENSURE THAT SOL[illegible]
AVIABLE TECHNOLOG[illegible]
OBSERVATIONS.

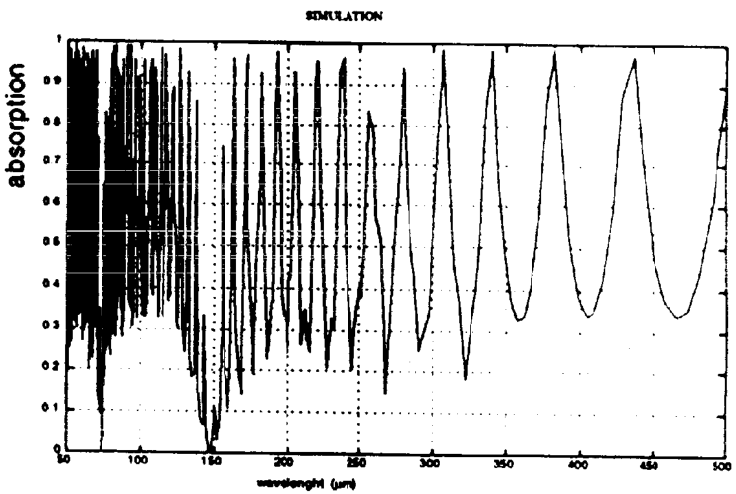




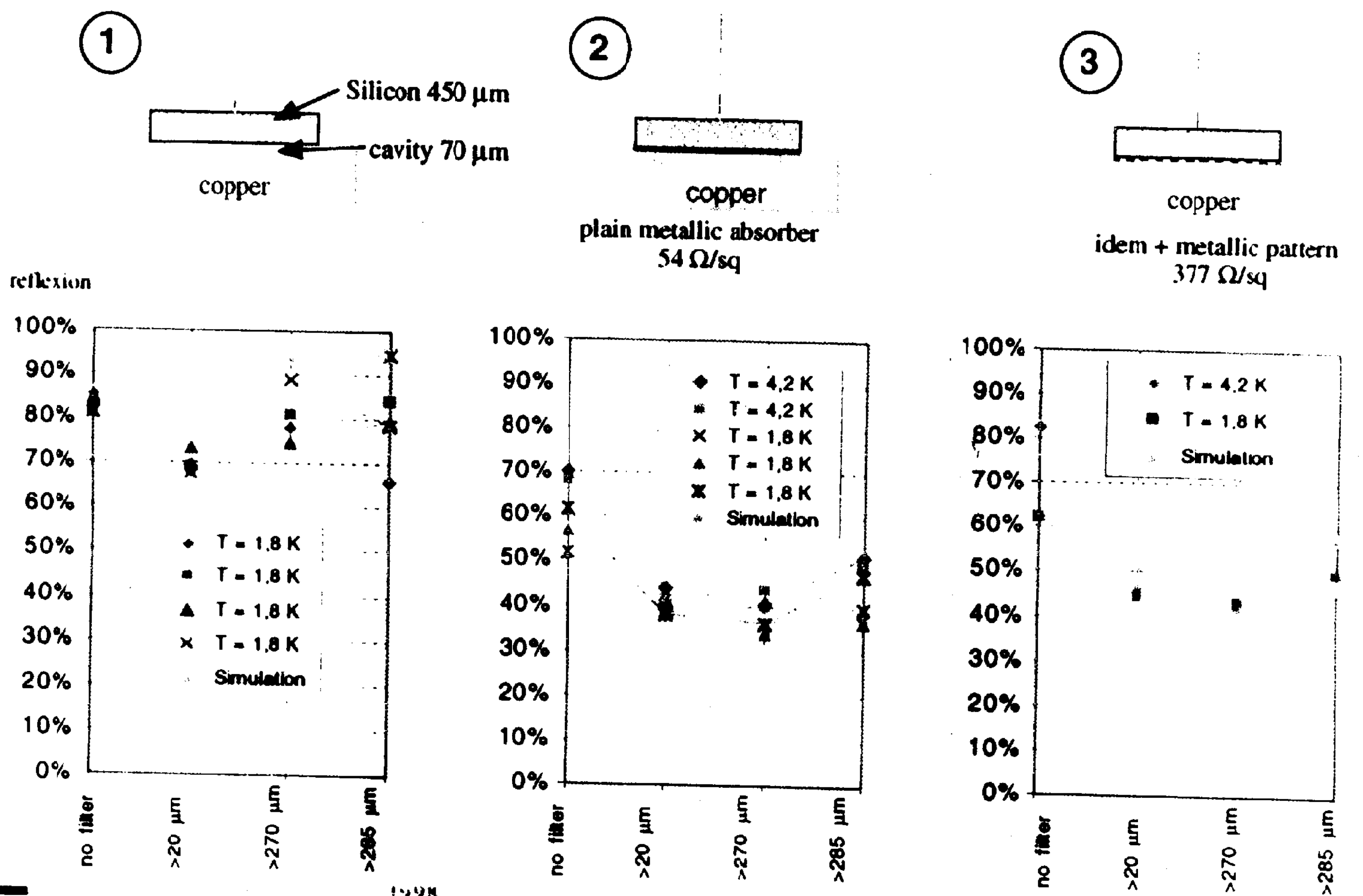
OPTICAL ABSORPTION MODEL (I)

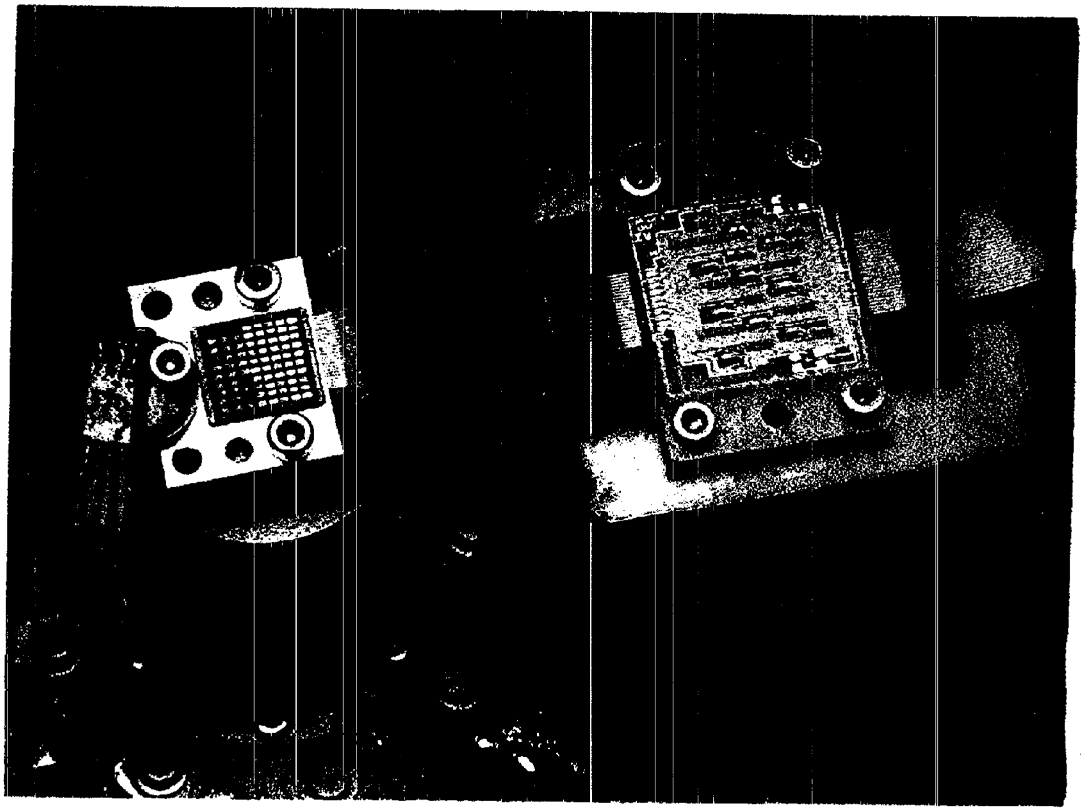






OPTICAL ABSORPTION MODEL (II)





THERMAL PROPERTIES OF THE BOLOMETERS (I)

THERMAL CONDUCTIVITY (SAp & LETI+SBT)

1) CARACTERIZATION OF THERMOMETERS

Calibration of reference thermometers in the temperature range 300 à 900 mK, and for bias range10->1000 mV :

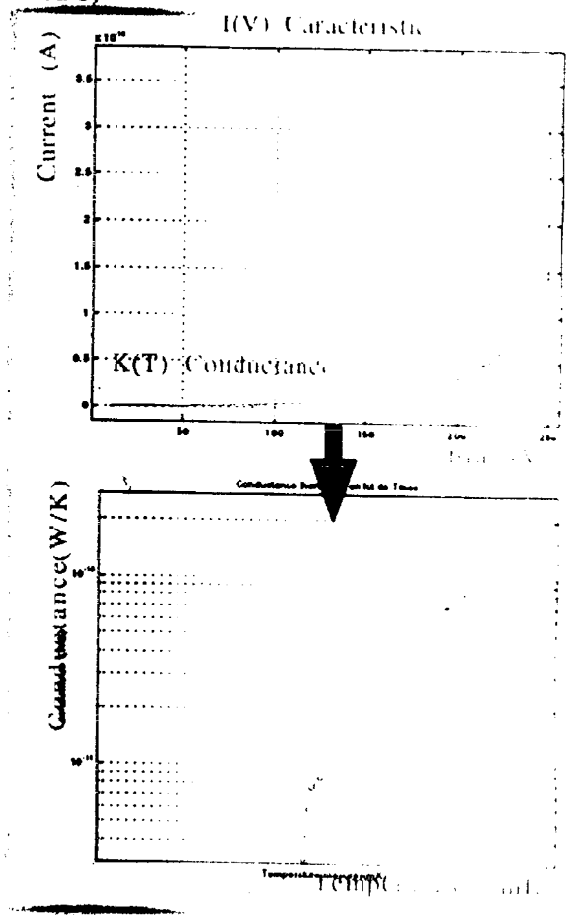
$$R(T) = Ro.\exp[(\frac{T}{To})^{1/2}].\exp(-\frac{q(aT^2+bT+c)E}{kT})$$

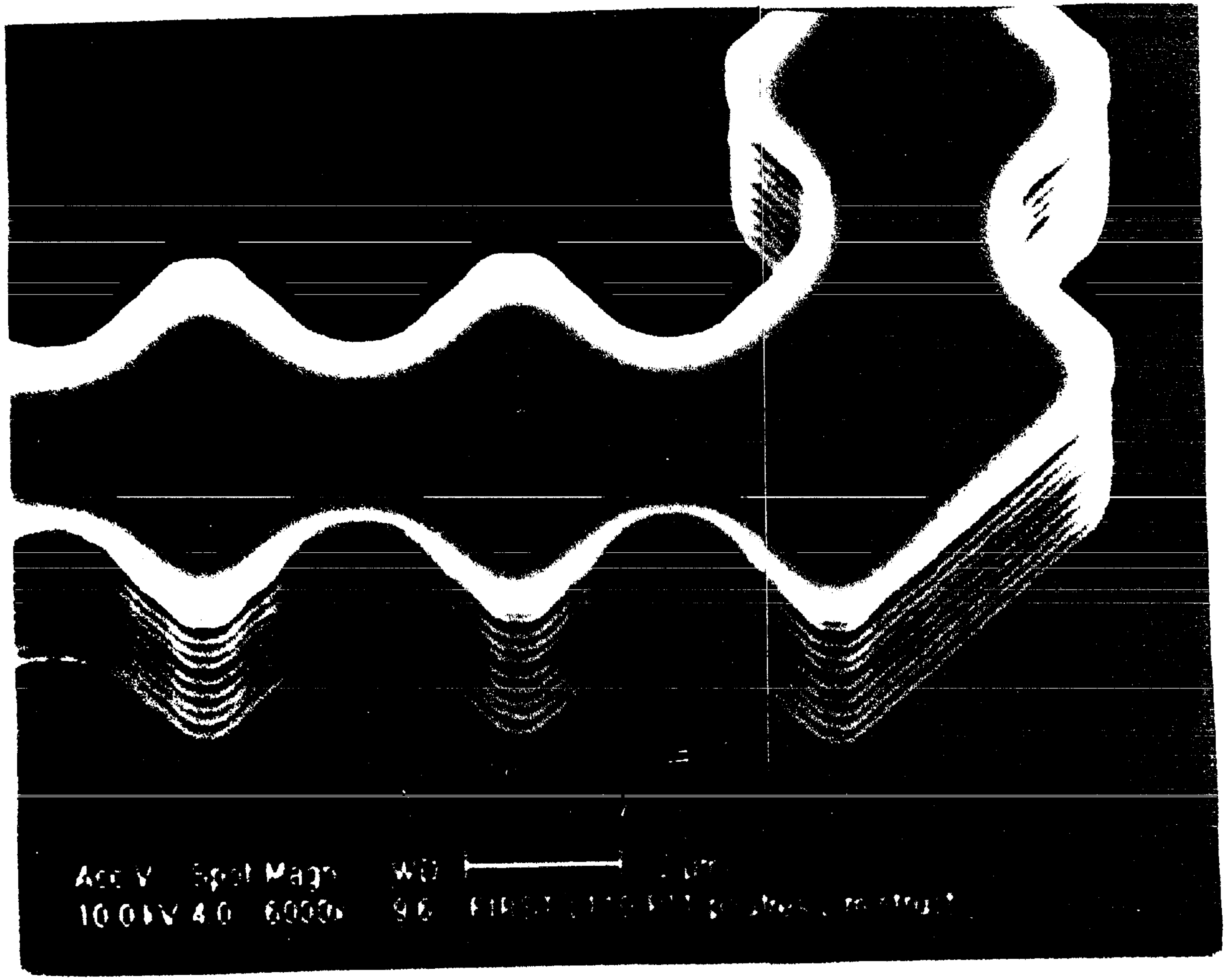
2) APPLICATION TO BOLOMETERS

Result: **for straight "beams", the resuslt is close to Casimir law, with a contribution of the metal passivation layer. For wiggly beams, silicon contribution remains identical with a strong decrease of conduction of the passivation layer.**

Measured conductivity for these beams

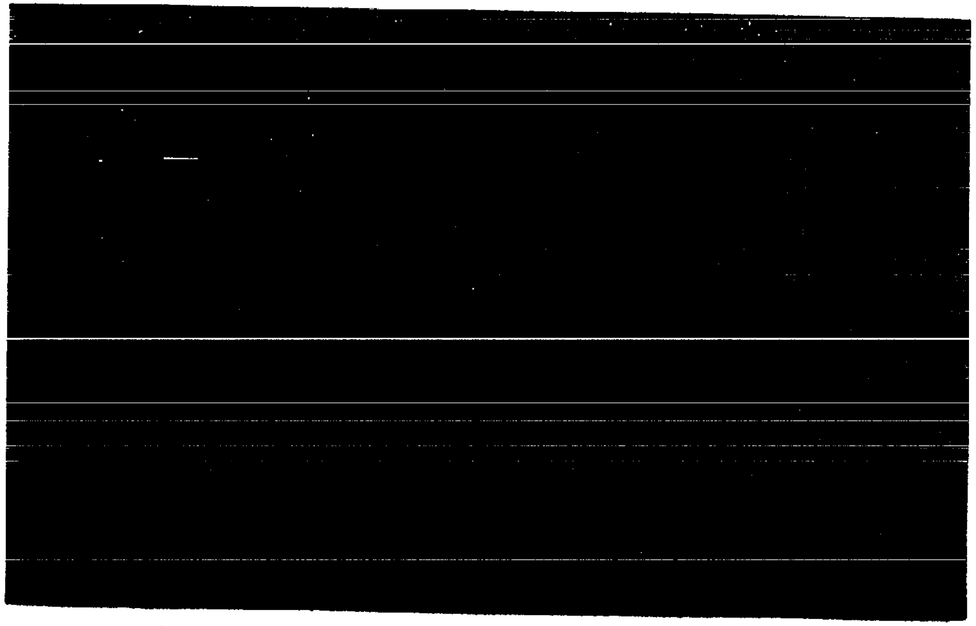
$$G_0(T) = (0.2497 \pm 0.06).10^{-9}T^3 + (0.009 \pm 0.002).10^{-9}T$$





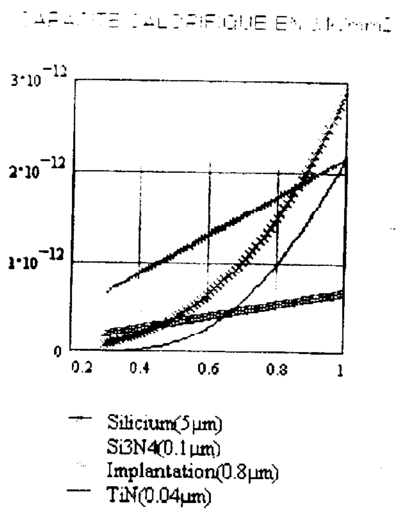
Acc.V Spot Magn WD
10.0 kV 4.0 6000x 9.6

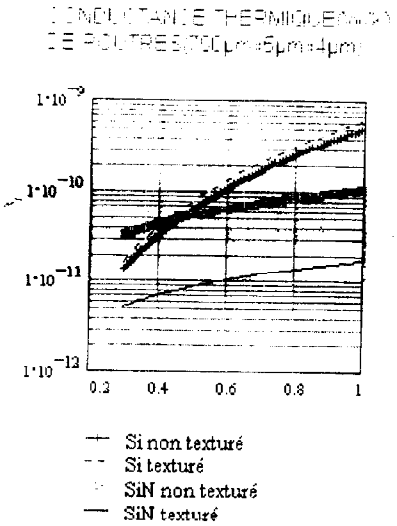
THERMAL CONDUCTANCE (II)

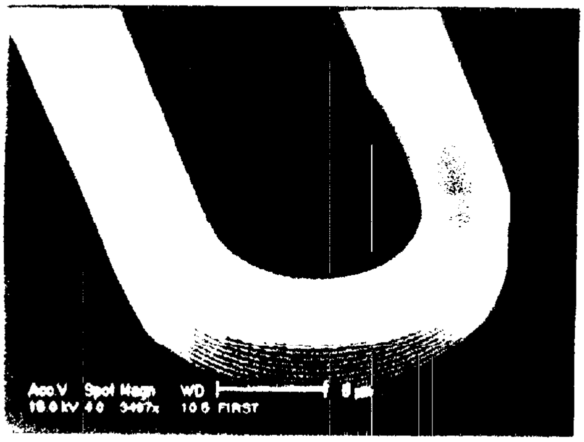


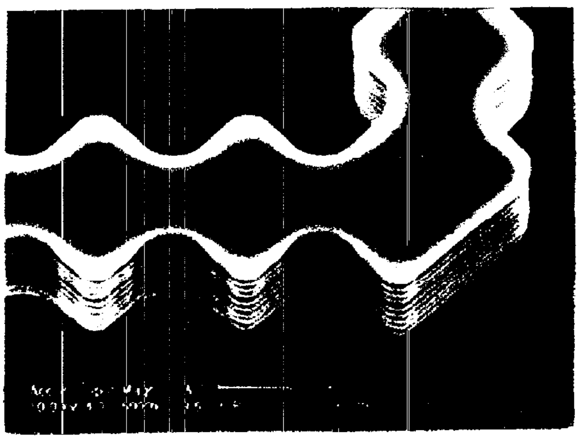
CEA/LETI/LIR, le 11/09/98

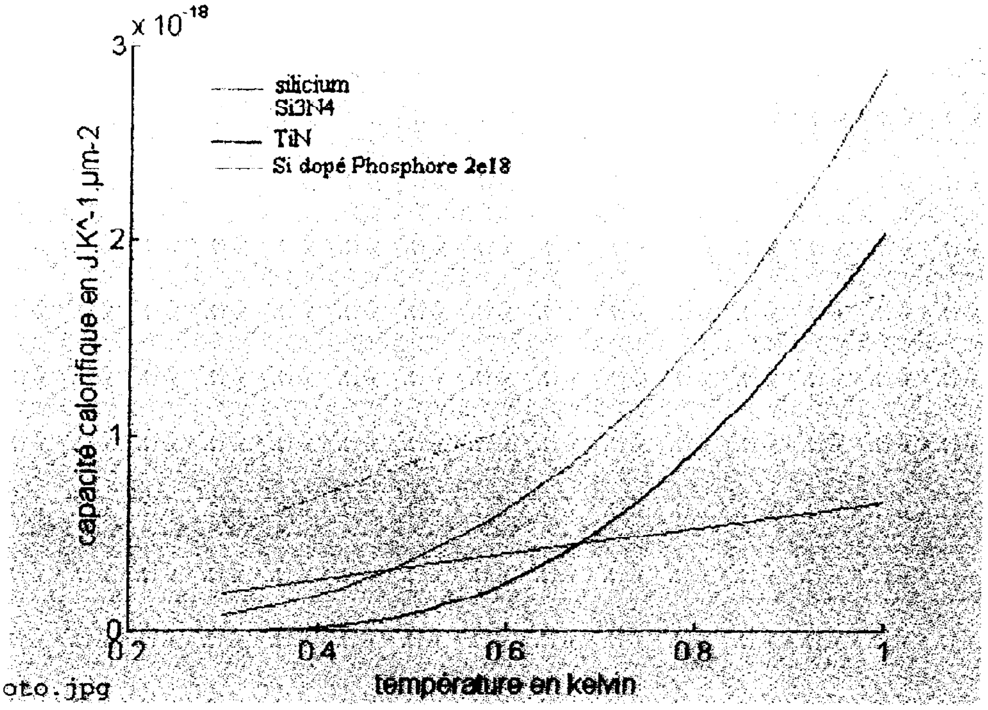
MODELES THERMIQUES SUB-KELVIN DU BOLOMETRE FIRST



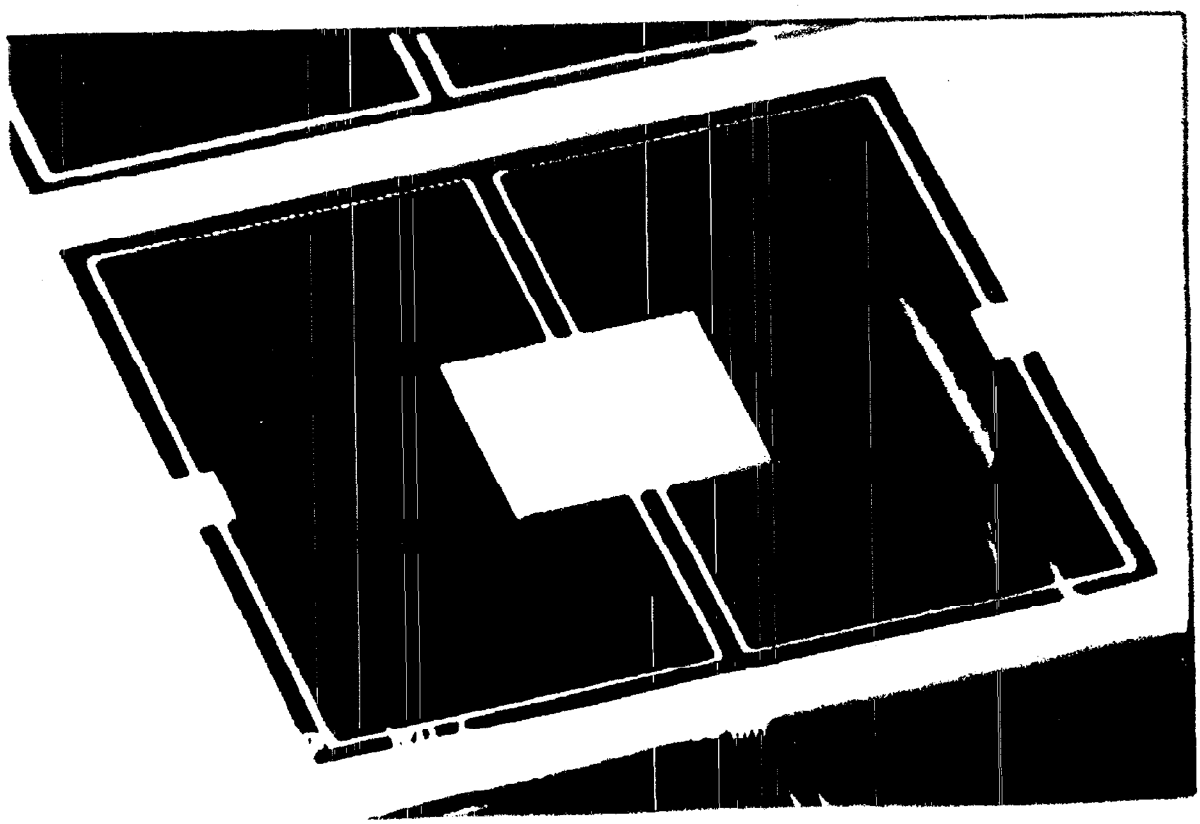






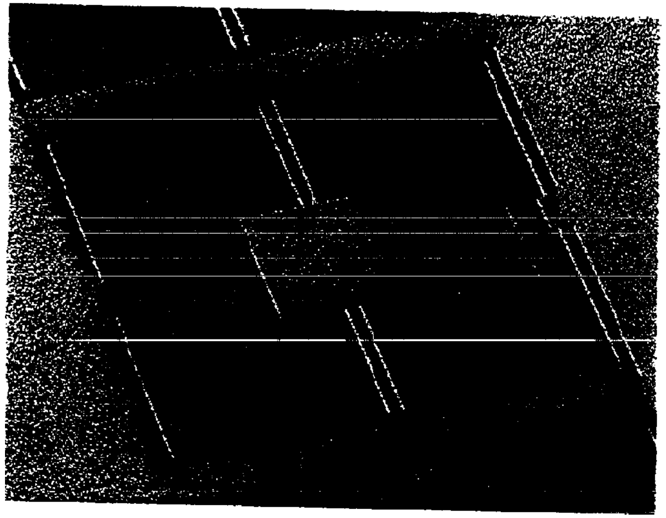


bolo-photo.jpg



THERMAL PROPERTIES OF THE BOLOMETERS (II)

SPECIFIC HEAT & HEAT CAPACITY (LETI+SBT)



ON DEDICATED PIXELS (Fig.)

A power step is injected in one of the thermometers and we measure the temperature decrease :

-2 thermometers 40*40*0,8 μm^3
-2 thermometers 100*100*0,8 μm^3
+absorbing metal layer
+passivation TEOS
+passivation Si3N4 (metal protection).

Knowing the thermal conductance we deduce by differnce the heat capacity of bolometer components with T .

Heat capacity of Si $C(T)=5,8(\pm1,3)10^{-7}\ T^3$ $J/K/cm^3$. Close to predicted values (Casimir 1938)

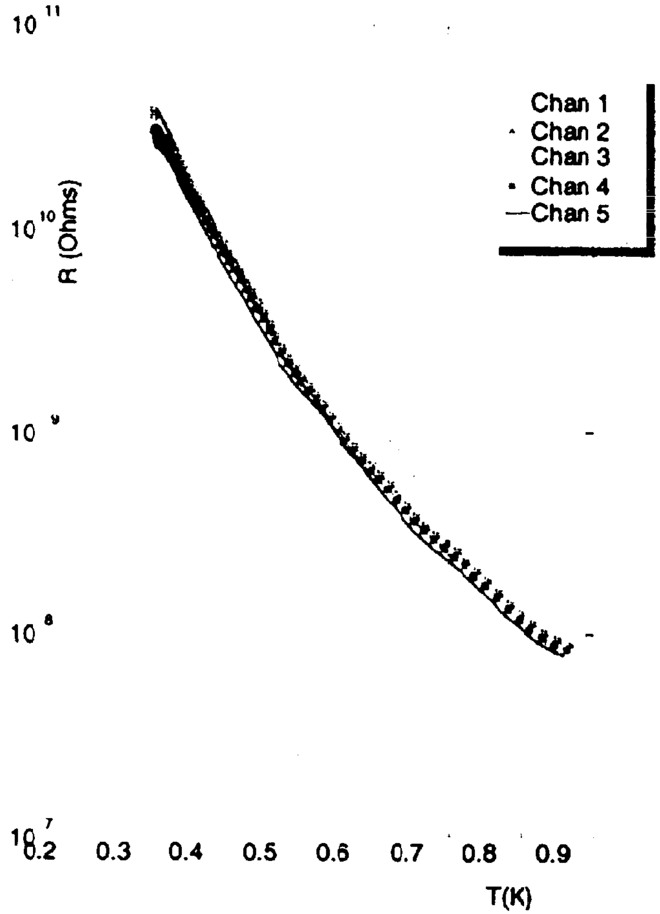
- TEOS and implanted Boron at 4E12 at/cm^2 not measurable.
- Passivation Si3N4 : $C(T)=2,156(\pm0,32)10^{-5}\ T^3$ $J/K/cm^3$.
- Implantation P+,B+ $C(T)=8,25(\pm1,23)10^{-7}\ T^3$ $J/K/cm^3$
- Metal TiN $C(T)=5.81\ 10^{-4}\ Tc\ \exp(-1,44Tc/T)$ $J/K/cm^3$

GOOD NEWS: The most important contribution is passivation Si3N4 used to protect the metallic absorbing layers. Other contributions will be negligible compared to silicon. Silicon contribution is consistant to the Casimir model used for predictions.

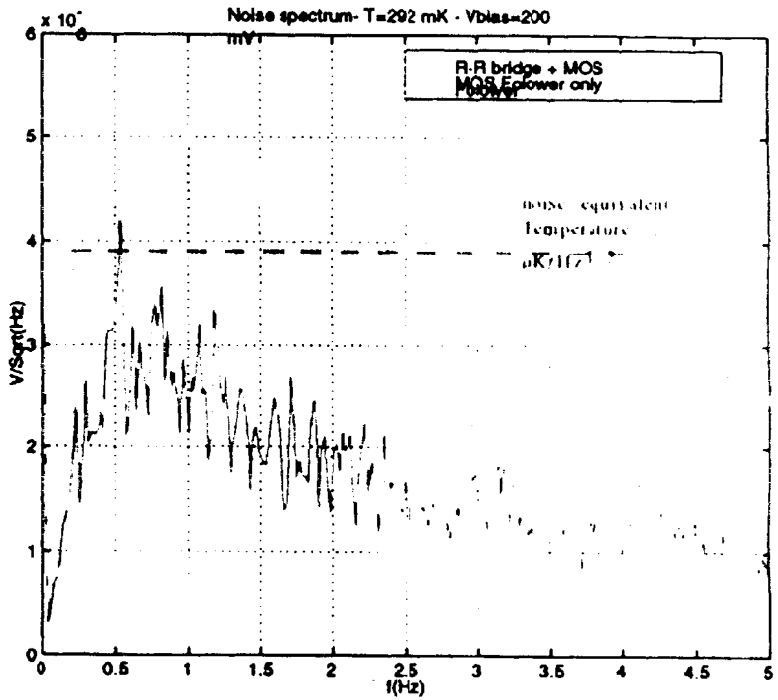
CONSEQUENCES: The thermal response will be faster than forseen: :-10 ms

THERMAL RESPONSE OF BOLOMETERS

These results have already been presented



These characteristics are checked with every new array tested.



L. Rodriguez

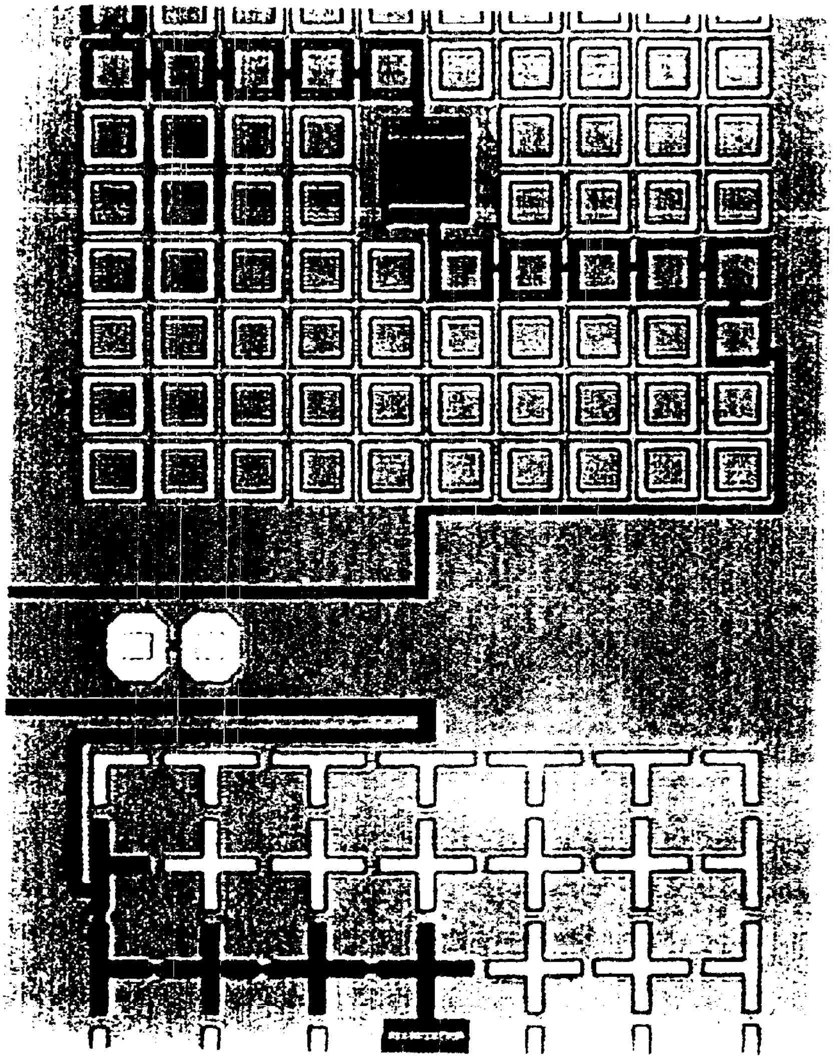


Photo d'ensemble d'un bolomètre montrant que les pistes WN connectées aux plots TiNiAu d'hybridation se sont oxydées (bleuissement) alors que les motifs WN (carrés ou croix) utilisés comme absorbeur n'ont visiblement pas évolué

MAIN UNEXPECTED PROBLEMS SOLVED SINCE 1996

MANUFACTURE OF SELF STANDING STRUCTURES IN COLLECTIVE PROCESS

BOLOMETER ARRAYS proceed from superposition of 3 thechnologies:

-Standing sensors at DMITEC

-Indium hybridization by bumps

- Deep implantation of P & B and metallization with exotic alloys (TiN,WN).

Ensure compatibility of these technologies was less straightforwad than foreseen.

-Manufacture yield was low: often broken pixels were found at grid liberation step .

-Residues were found between beams and grids.

Chemical reaction of WN with solutions used for grid liberation converted metallic contacts in "isolating contacts"

THERMOMETERS MANUFACTURE

Deep implantation was poorly controled some wafers were lost .

THERMAL INSULATION OF READ OUT CIRCUITS

The thermal insulation of read out circuit (2K) from 300 mK interconnection circuit was devoted to the superconducting indium bumps (90).

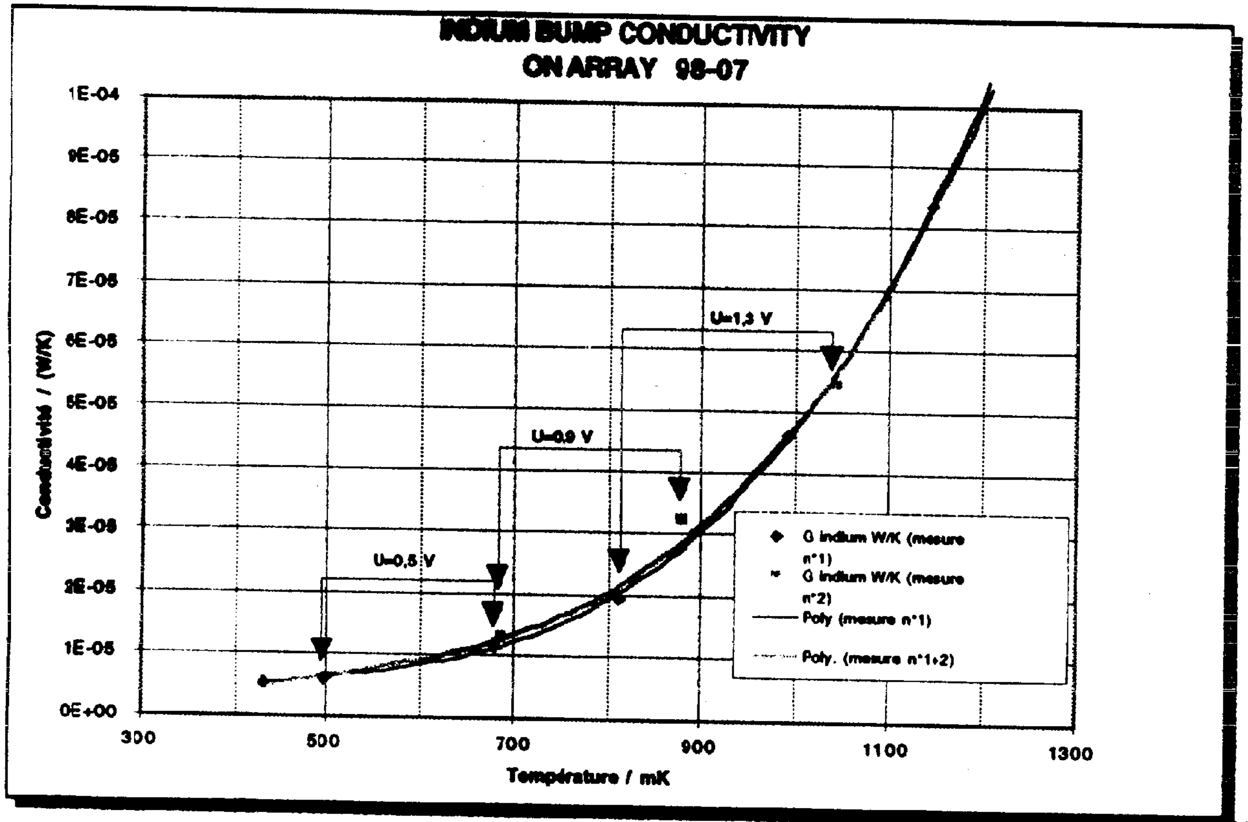
This problem is not yet solved, we will test new solution by early 99. We need a waiver on this parameter for the selection process: the new arrays under manufacture will use the same decoupling scheme

L. Rodriguez

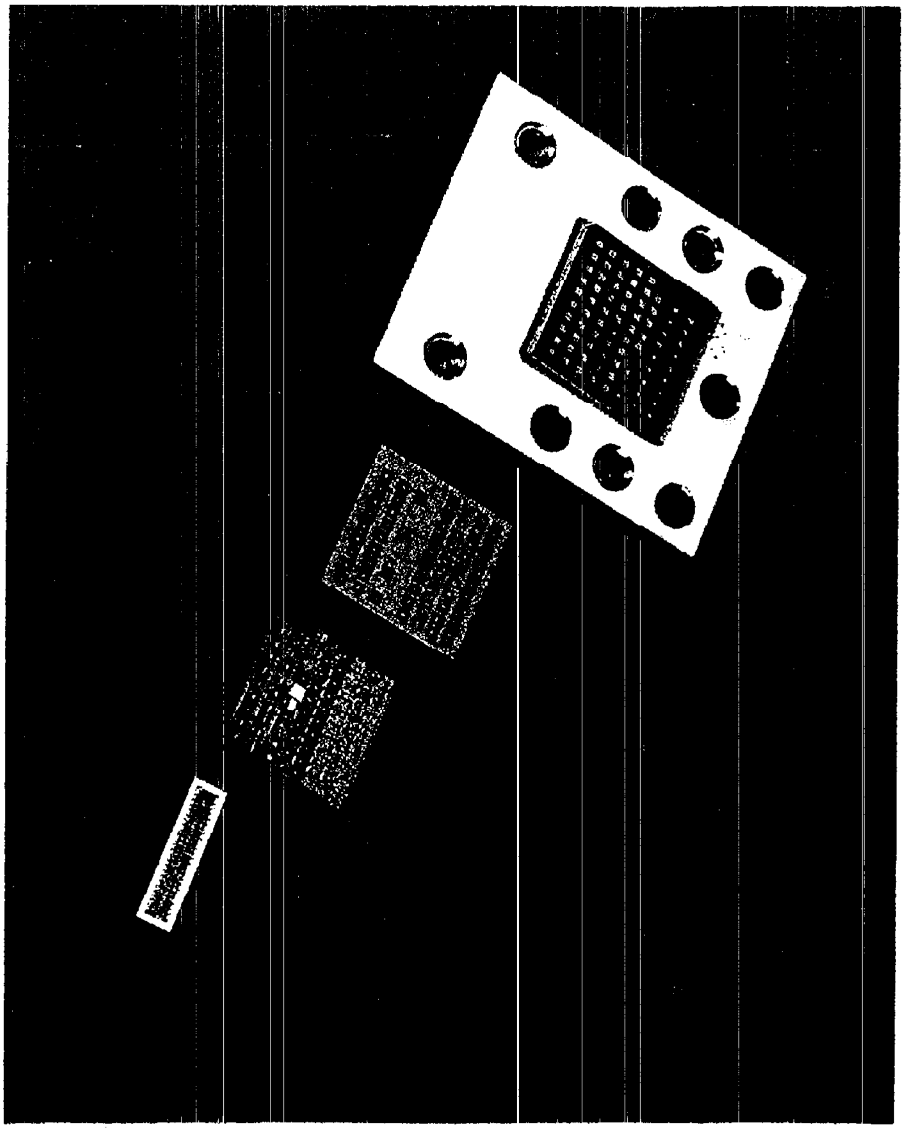
INDIUM BUMPS THERMAL CONDUCTIVITY

Using high power dissipation on bolometers and measuring substrate (reference) temperature, we deduced the thermal conductivity of the indium bumps. They were supposed to isolate the cold read out circuit at 1,8 K from the 300 mK stage .

We measured a conductivity variation with T^3 in place of T, incompatible with admitted thermal load on the ^3He fridge.



CEA/DSM/DAPNIA/SAp



CURRENT SITUATION

THE MANUFACTURE OF ARRAYS FOR THE SELECTION PHASE STARTED IN JUNE.

GEOMETRICAL AND THERMAL PARAMETERS FIXED IN THE DESIGN PHASE - ITEMS [illegible]

HOMOGENEOUS ARRAYS16 x 16 pixels. STEP 750µm.

MUX 8->1 SUBSTRATE TEMPERATURE 300 mK under a 1pW background.

MUX and read out circuits will be integrated to the arrays

32 array types will be manufactured. They differ from:

-the absorbing pattern (crosses, capacitives loops, grids).

-Thermometer: implanted or mesa (double SOI wafer and thermal diffusion).

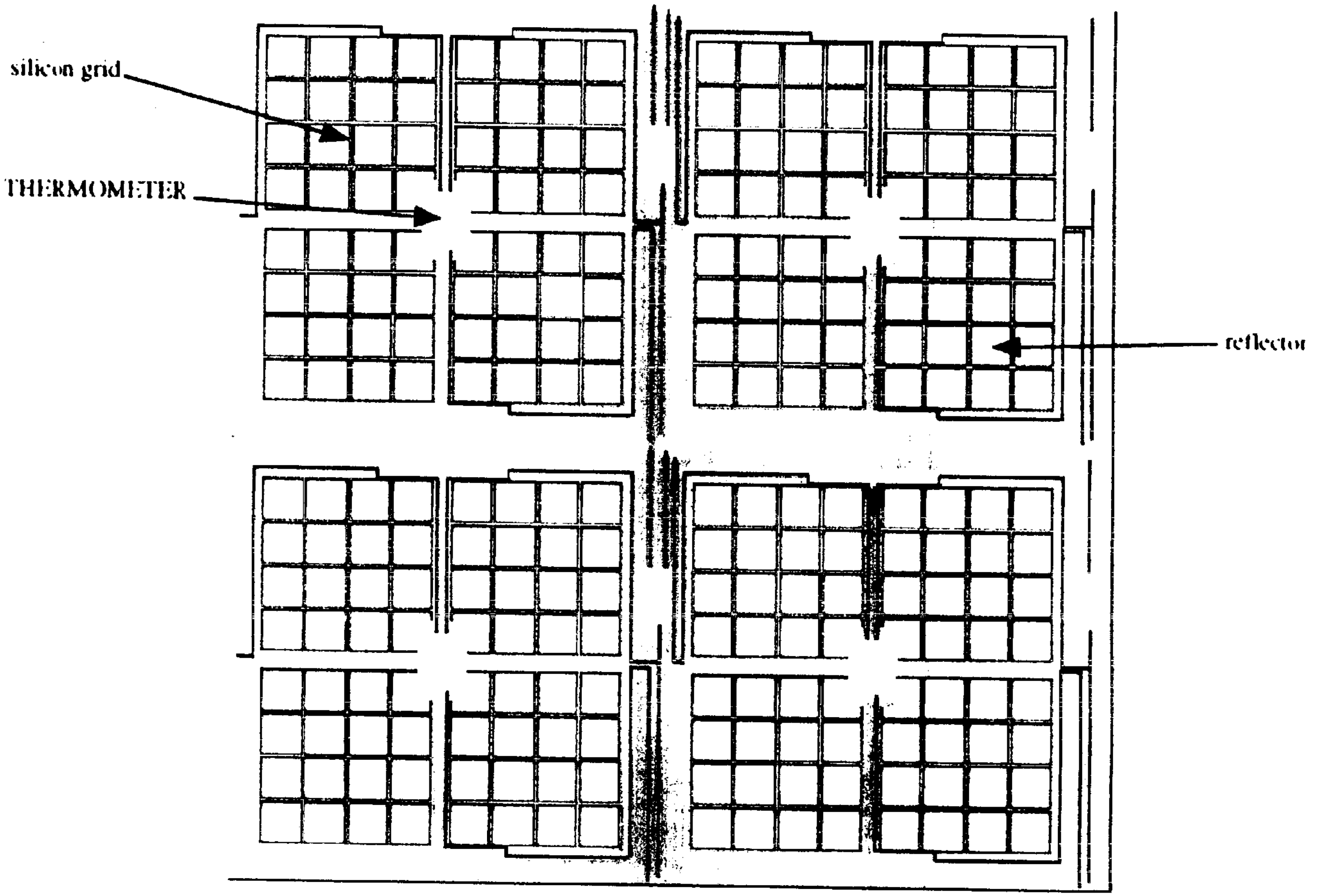
-absorbing metal(TiN or WN)

-Independent bias of the thermometers grids or not.

-Reflector type.

OTHER CONCERN : HOW TO CONNECT THE FIVE FOCAL PLANES TO THE DISTANT ELECTRONICS. 500 WIRES REPRESE A SUM OF MECHANICAL AND THERMAL DIFFICULTIES. WE WORK TO INCREASE THE MUX SCHEME

1999 BOLOMETER DESIGN



L. Rodriguez

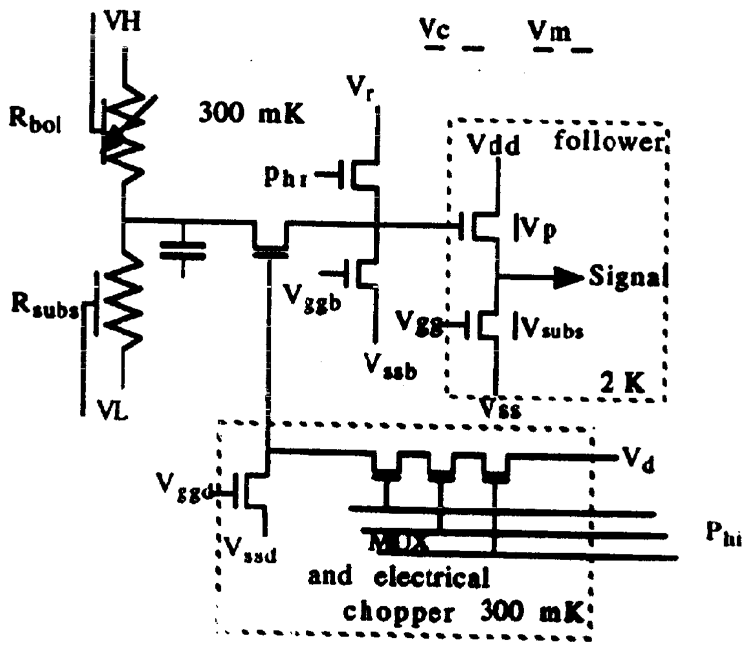
SITUATION PRÉSENTE

ELECTRONIQUE:

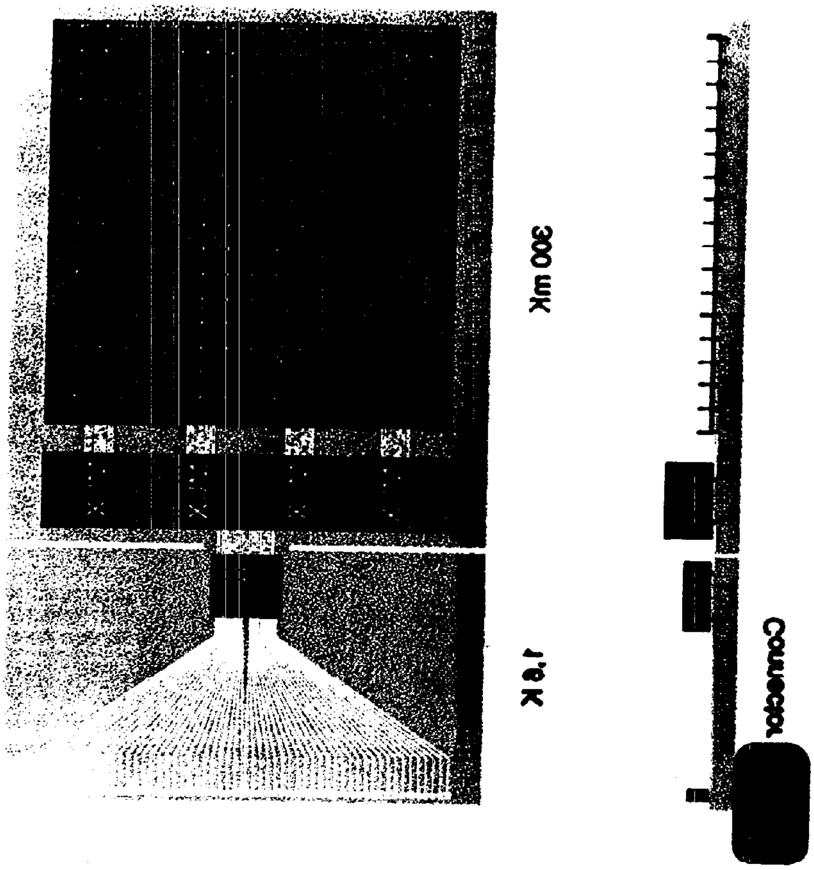
Le schéma de l'électronique froide (0,3-2K) est maintenant bien avancé. Il comporte un multiplexeur/hacheur à 300 mK qui sera testé prochainement au SAp (8->1/1 kHz). Un suiveur à 2K en cours de tests a Saclay.

Le principal effort sur l'électronique de proximité est déployé pour augmenter la bande passante électrique dans les mêmes proportions que la bande passante thermique.

La prochaine génération de détecteurs permettra l'accès à la grille de résistance des thermomètres.



Un schéma de l'électronique chaude de traitement du signal est en cours de maquettage. Il comprend un ensemble de détection synchrone analogique.



300 mK
1.8 K
Connector

6. C

CALTECH [FEEDHORN ARRAYS]

SYSTEMS DESIGN

JAMIE BOCK

FEEDHORN - COUPLED ARRAYS

INTERFACES

17 SEPTEMBER 1998

MECHANICAL

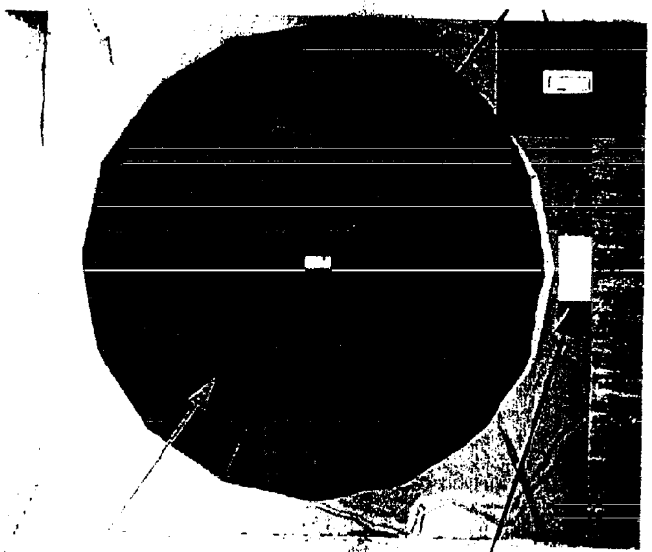
[redacted]

WIRING

READOUT

[redacted]

Silicon Nitride Micromesh Bolometer

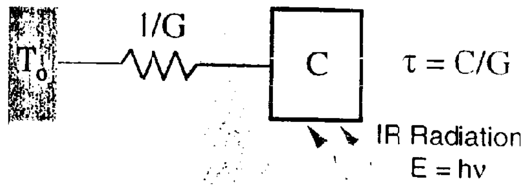


Silicon Nitride Micromesh Bolometer with Indium Bump-Bonded NTD Ge Thermistor

dimensions:
5.6 mm
400 μm
1.5%

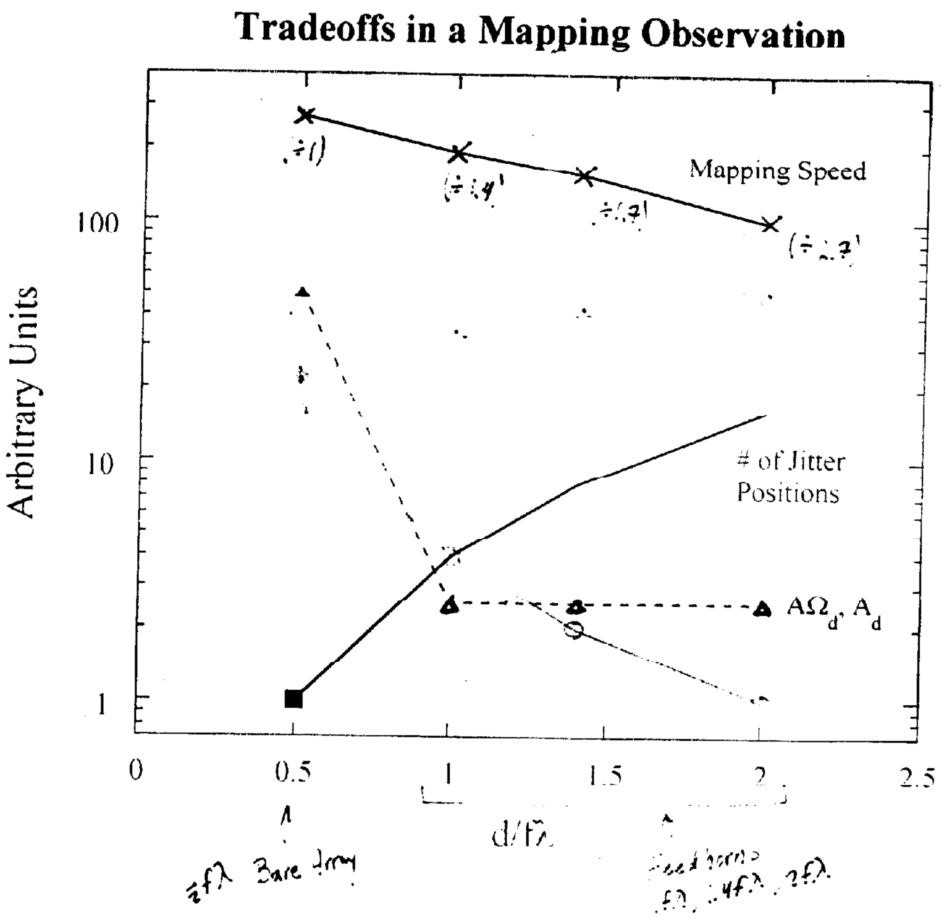
Principle of Operation:

- Incident **infrared radiation** is absorbed by silicon nitride **micromesh**.
- Absorber **temperature changes**.
- Temperature **change is** detected by neutron-transmutation **doped** (NTD) Ge thermistor.

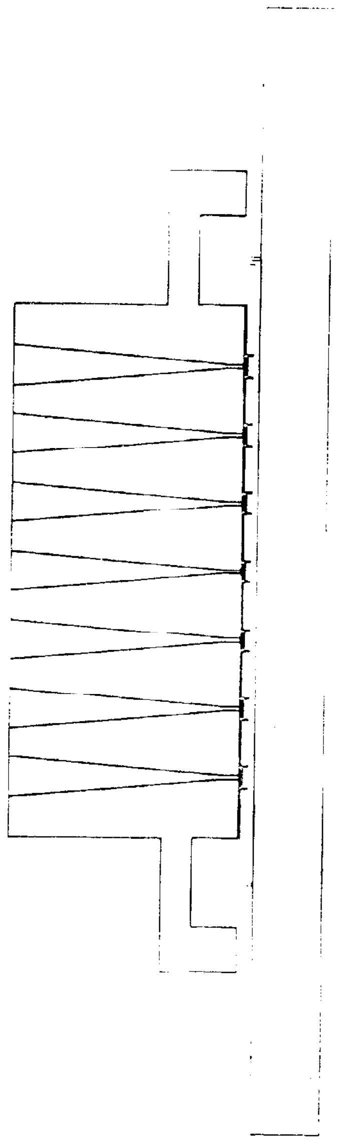


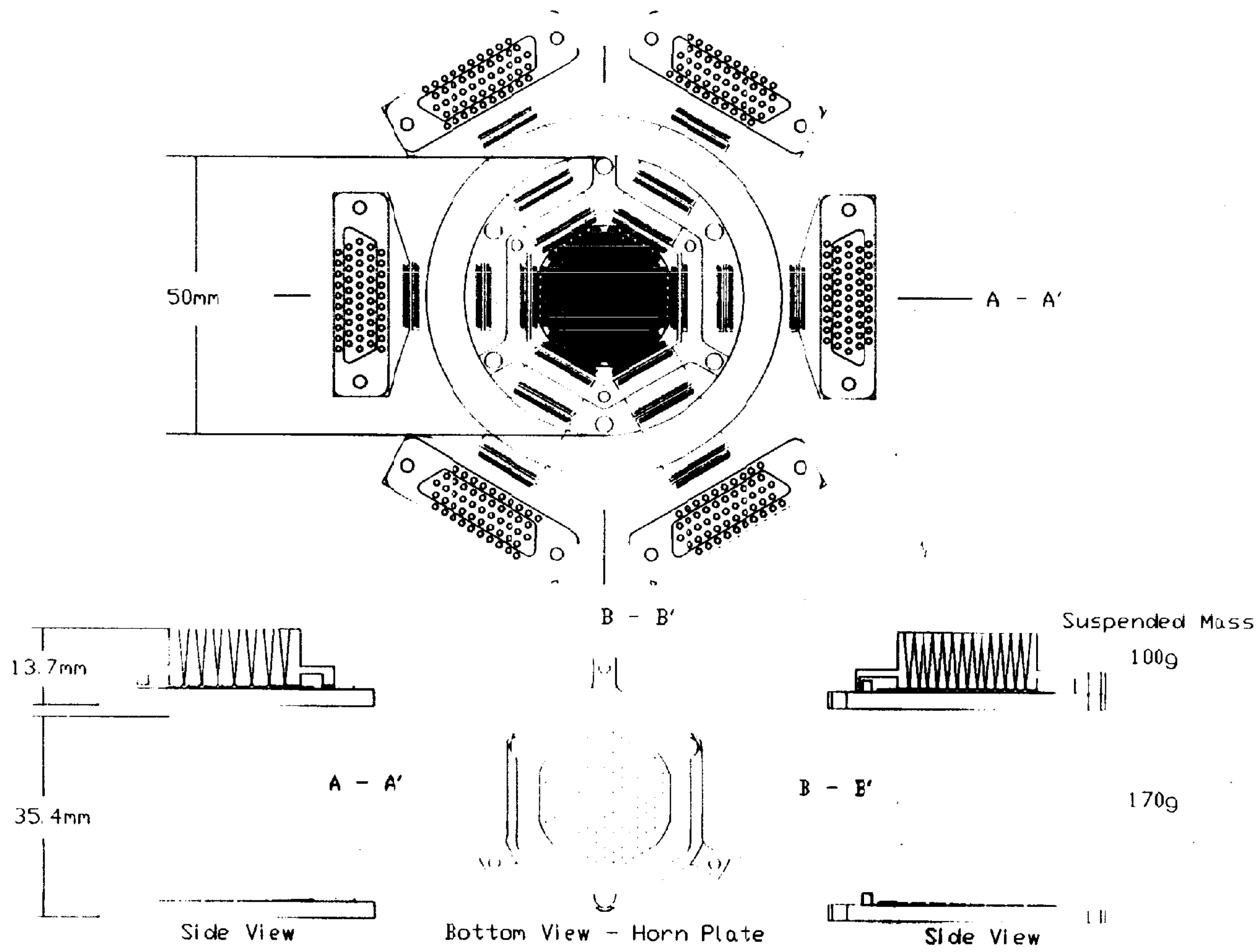
Advantages:

- Low G → high sensitivity
- Low C ⇒ fast response
- Small mass ⇒ reduced microphonic response
- Mesh absorber ⇒ small cosmic ray cross section
  ⇒ short λ rejection
- Excellent DC stability
- 2D array compatible



· Background-limited case




50mm
A - A'
B - B'
13.7mm
35.4mm
A - A'
Side View
Bottom View - Horn Plate
B - B'
Side View
Suspended Mass
100g
170g

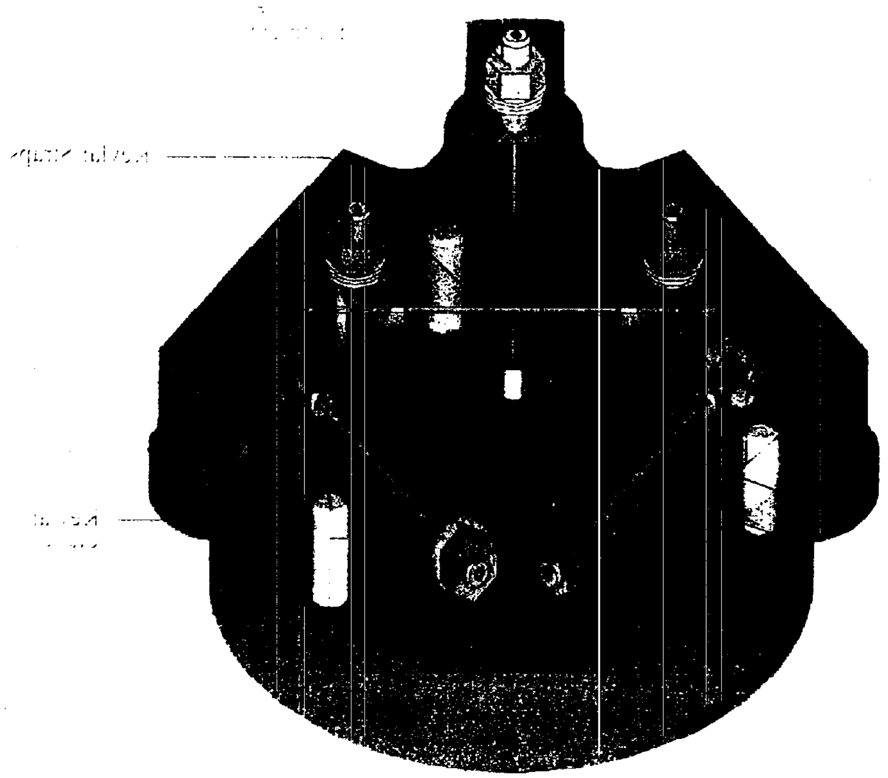
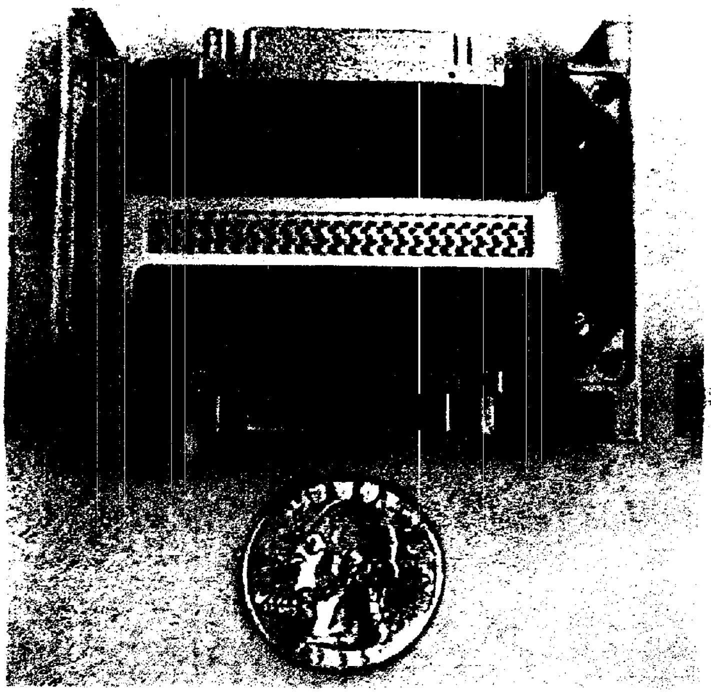


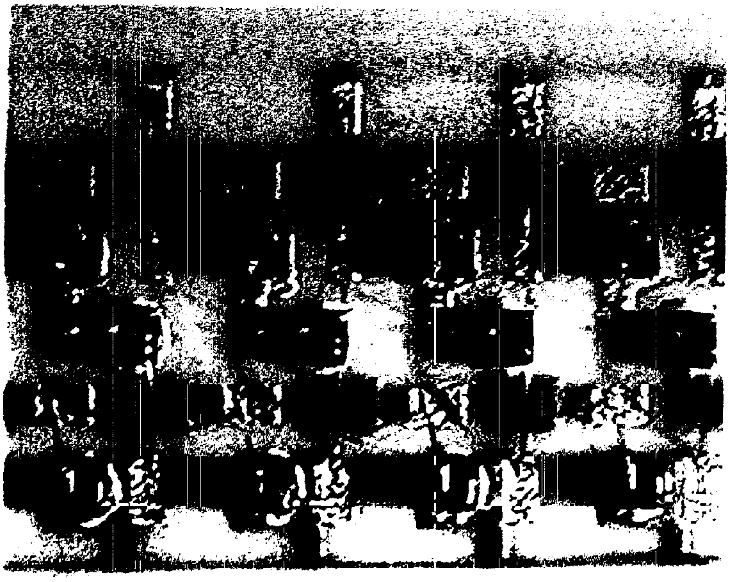
Figure 2: Detector Mount Housing with Kevlar Straps

horns =	2	Ω
Rbol =	5	MΩ
C0 =	1	pJ/K
[illegible]	[illegible]	

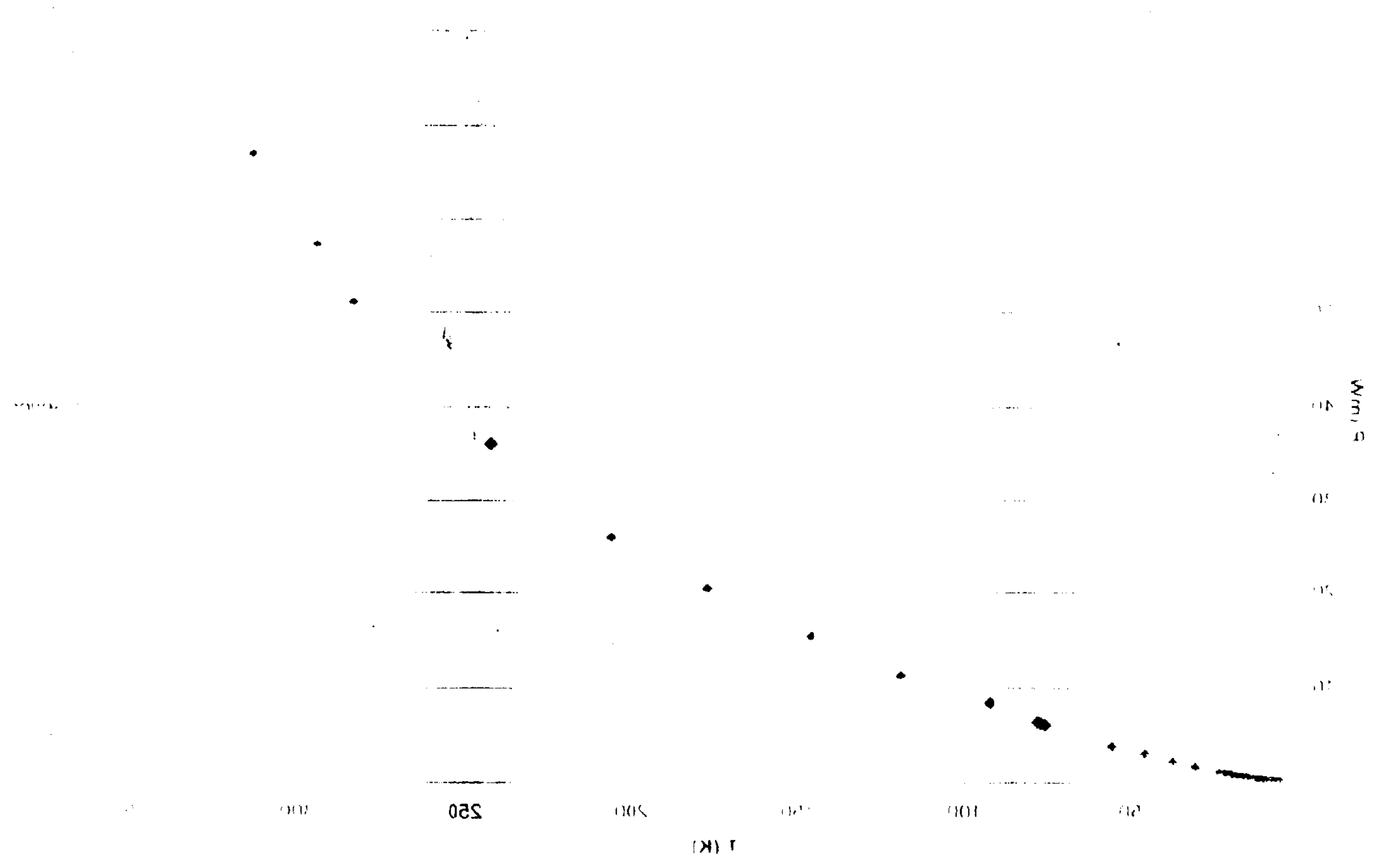
[illegible]	[illegible]	Q (pW)	NEPphoto	G (pW/K)	NEPbolo	Top (K)	Pe (pW)	[illegible]
[illegible]	[illegible]	9	[illegible]	[illegible]	[illegible]	0.40	[illegible]	[illegible]
Phot 350	350	7	8.92	233.33	4.46	0.40	13.25	3.34
[illegible]	500	6	6.91	200.00	4.12	0.40	11.36	[illegible]
[illegible]	[illegible]	4	[illegible]	[illegible]	[illegible]	0.40	[illegible]	[illegible]
FTS 450	450	2.8	4.97	93.33	2.82	0.40	5.30	8.35

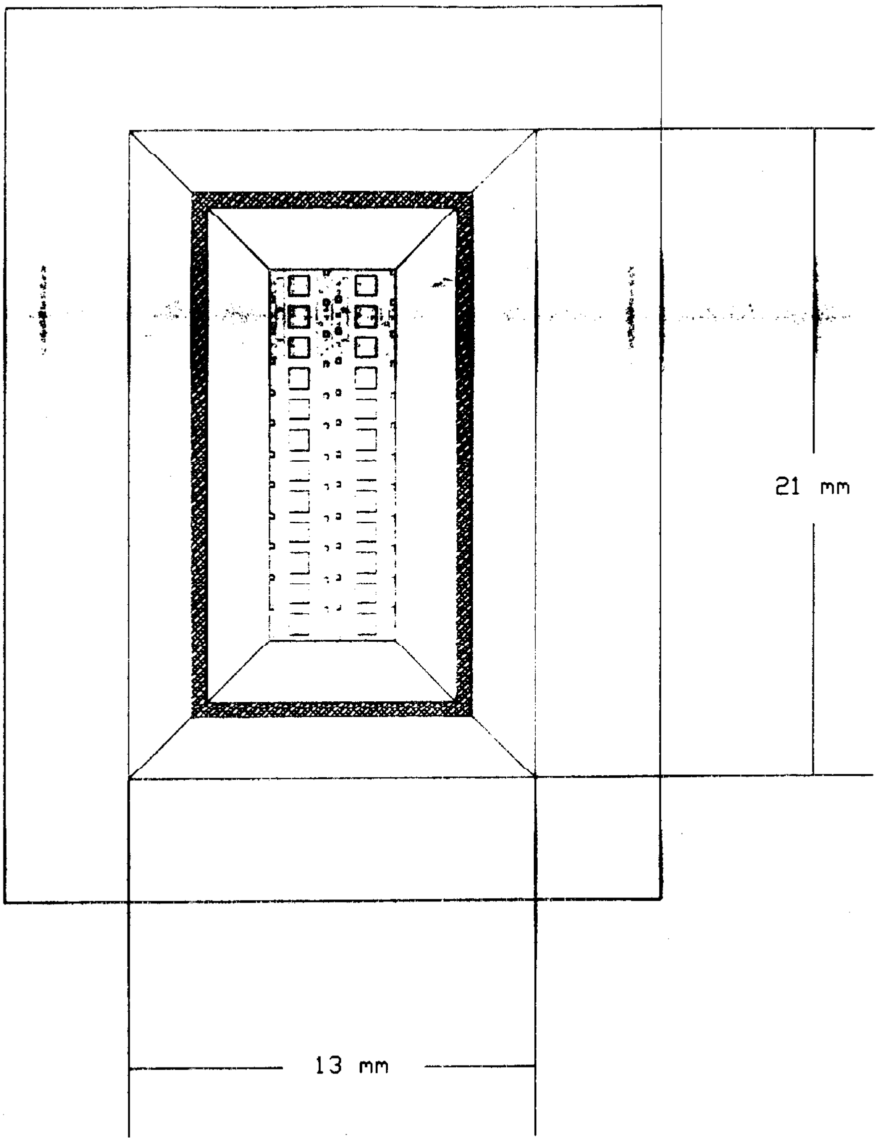
Channel	Vn,bol (nV/rtHz	Vn,tot (nV/rtHz)	Voffset (mV,rms)
Phot 250	11.50	29.56	9.229223772
Phot 350	11.50	25.73	8.139410298
Phot 500	11.50	22.43	7.535629654
FTS 250	11.50	29.56	6.152815848
FTS 450	11.50	23.33	5.14781507



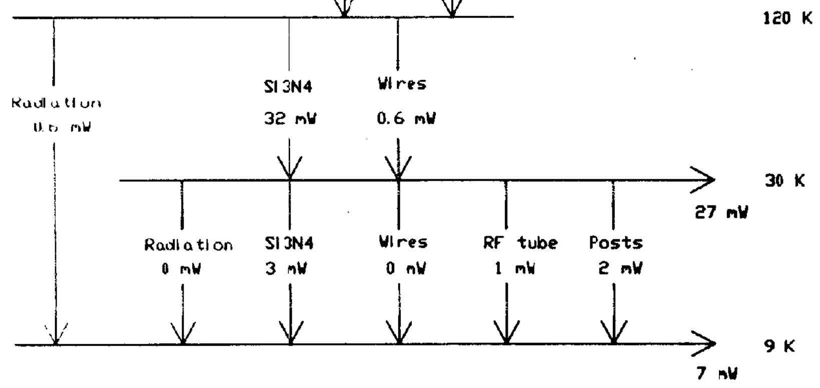


double thick membrane LHe

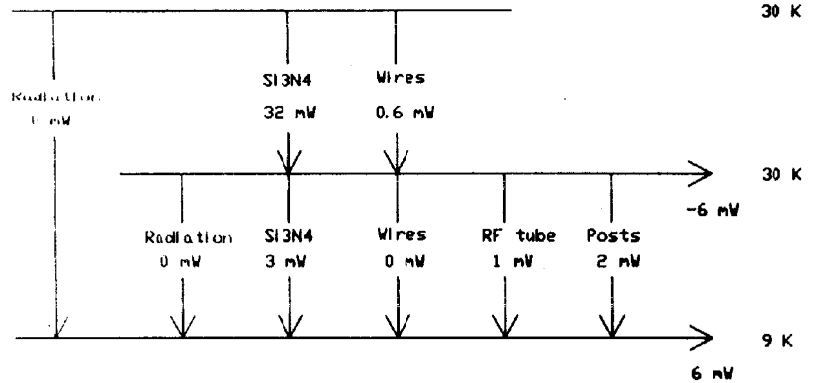



21 mm
13 mm

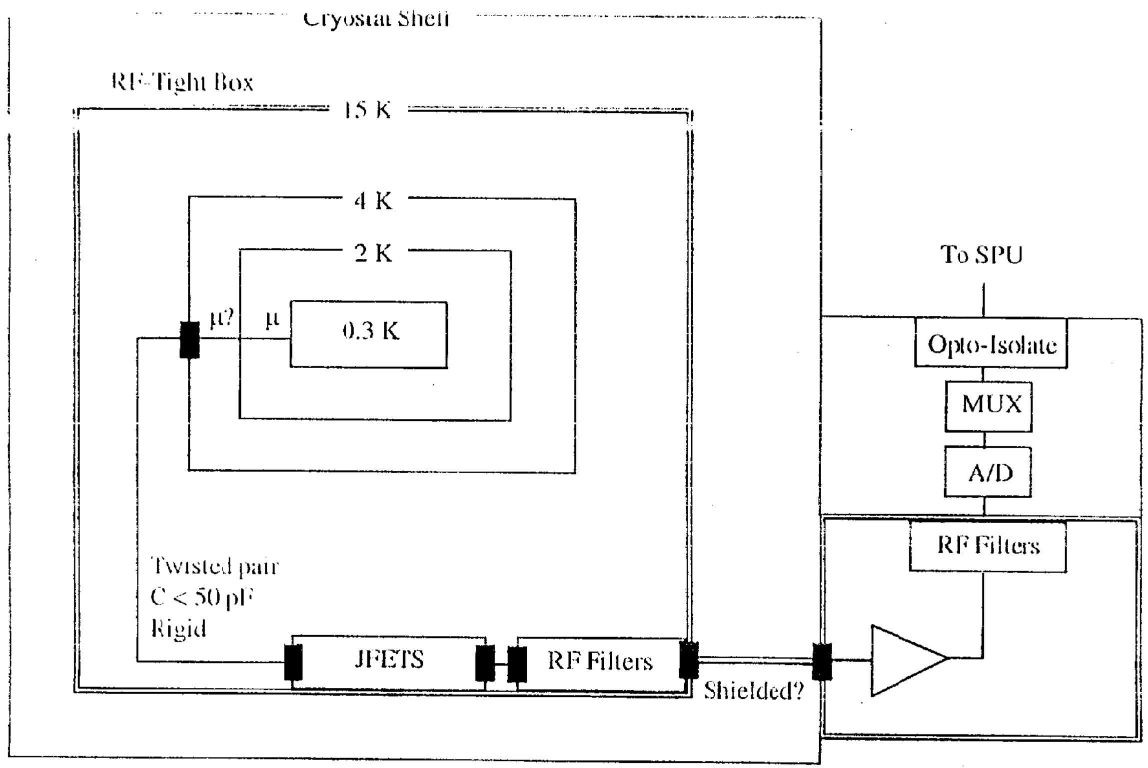
ON STATE

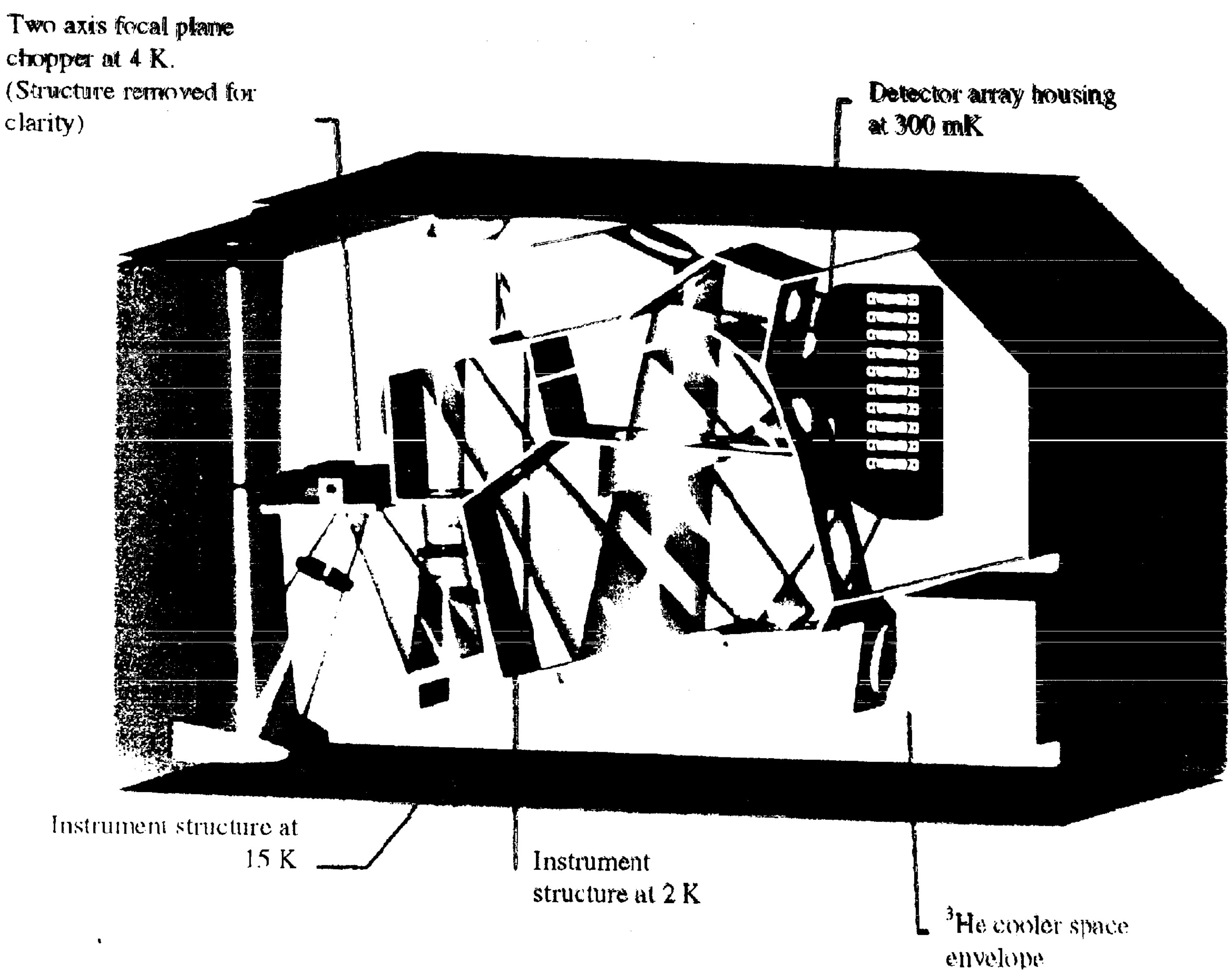


OFF STATE



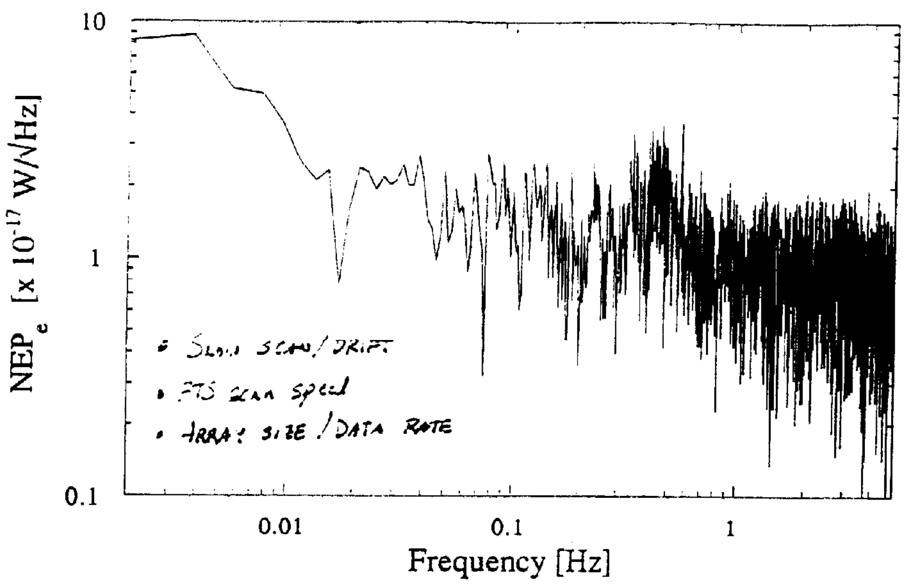
SPIRE Wiring - 2fλ Feedhorns

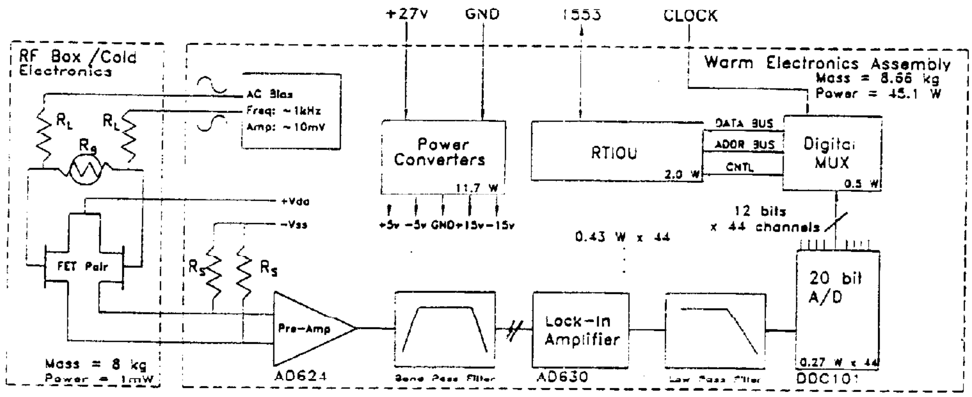




Two axis focal plane chopper at 4 K. (Structure removed for clarity)
Detector array housing at 300 mK
Instrument structure at 15 K
Instrument structure at 2 K
^{3}He cooler space envelope

DC-Stable Readout





Measured noise spectrum of a micromesh bolometer operating from a 300 mK cold stage using a DC-stable total-power readout circuit. Low frequency noise stability is required to produce accurate maps using the slow-scanning strategy employed in many space-borne observations (e.g. COBRAS/SAMBA). The slow rise in the noise spectrum at low frequencies is caused by drifts in the voltage reference in the 20-bit A/D converter; the feature at 0.5 Hz is due to the response time of the thermally regulated cold stage.

READOUT

[illegible]

$[illegible] = \frac{[illegible]}{2\pi} \frac{\theta_{FWHM}}{\dot{\theta}}$

$\dot{\theta} > 21.3\, \theta_{FWHM} \approx [illegible]$ for $\tau = [illegible]$ ms

scan time ~ 100 s ⇒ scan length < 10°

Max data rate ~ 50 Hz · 18 bits · 150 = 135 kbps

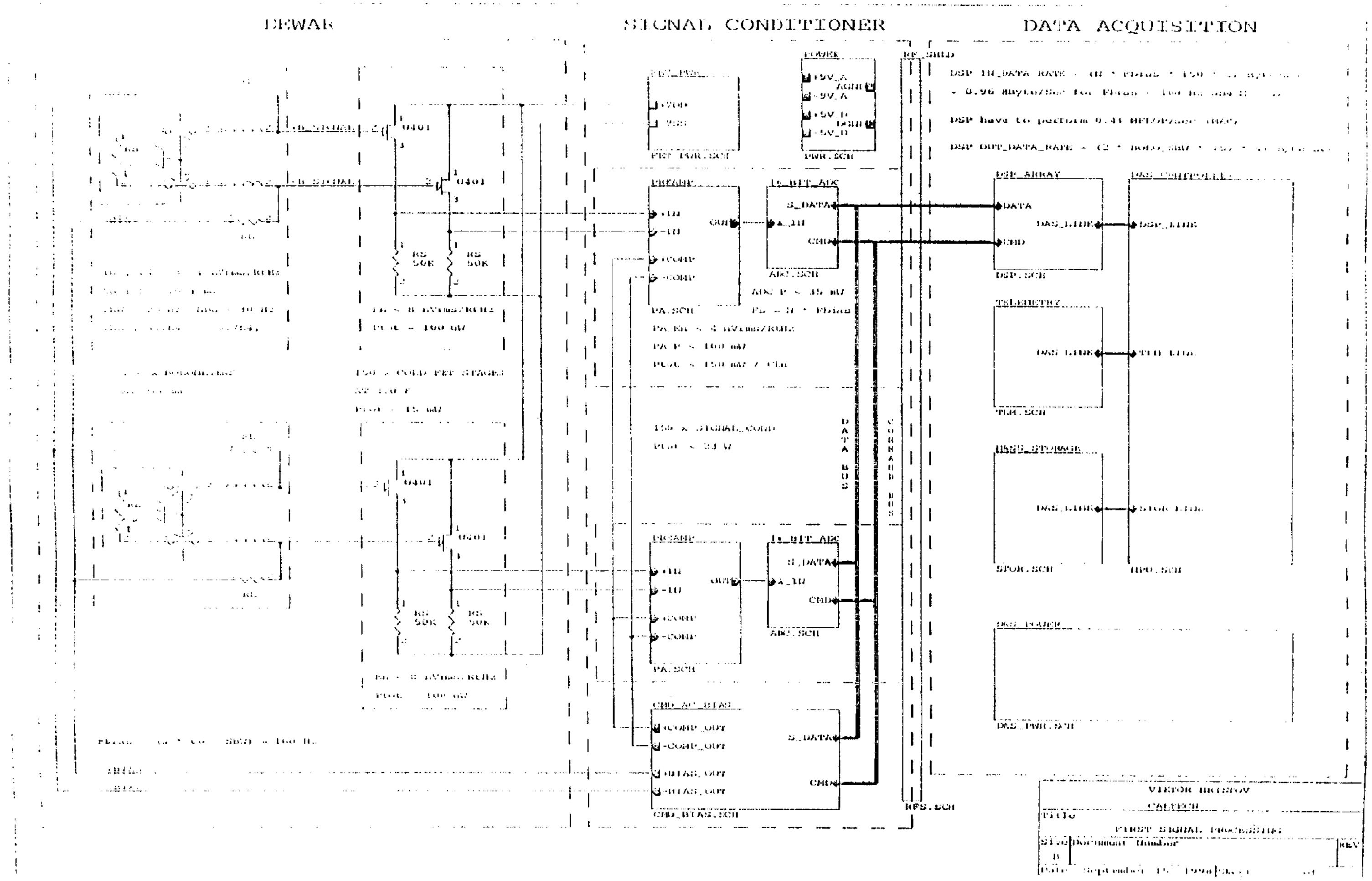
[illegible] SAMPLED MAP IN 1 SCAN

[illegible] OFFSET, ABERRATIONS

[illegible] RESOLVED

[illegible] TO [illegible]

[illegible]


DEWAR
SIGNAL CONDITIONER
DATA ACQUISITION
Q401
RS
50K
PREAMP
PA.SCH
16_BIT_ADC
S_DATA
A_IN
CMD
ADC.SCH
150 x COLD FET STAGES
150 x SIGNAL_COND
CMD_AC_BIAS
+COMP_OUT
-COMP_OUT
+BIAS_OUT
-BIAS_OUT
CMD_BIAS.SCH
POWER
+9V_A
-9V_A
+5V_D
-5V_D
AGND
DGND
PWR.SCH
DATA BUS
CONTROL BUS
RF_SHLD
RFS.SCH
DSP_ARRAY
DATA
DAS_LINK
DSP.SCH
DAS_CONTROLLER
DSP_LINK
TELEMETRY
TLM.SCH
MASS_STORAGE
STOR.SCH
DAS_POWER
DAS_PWR.SCH
VIKTOR HRISTOV
CALTECH
FIRST SIGNAL PROCESSING
Title
Document Number
REV
Date: September 1998

6 D

SUMMARY OF SYSTEM DESIGN AND INTERFACE STATUS

BRUCE SWINYARD

8a

ARRAY DEVELOPMENT PROGRESS REPORT : GSFC/NIST

HARVEY MOSELEY

Draft performance requirements for evaluation tests

Nominal operating conditions	
Bath temperature	300 mK
Incident background power (pW)	Filled array: 1.3 2Fλ feedhorn: 5.3
Photon noise NEP (W Hz$^{-1/2}$)	Filled array: 3.8 2Fλ feedhorn: 7.7
Central wavelength (μm)	350
λ/Δλ	3

Requirements on measured performance	
Detector optical NEP (W Hz$^{-1/2}$) (a) (excluding photon noise)	Filled array: 2.0×10^{-17} 2Fλ array: 4.0×10^{-17}
3-dB freq. of responsivity roll-off (b)	≥ 20 Hz
Maximum pixel-pixel variation	Noise: 20% Responsivity: 20%
Yield (good pixels) (c)	> 50% (for demonstration arrays only)
Crosstalk	TBD
Ionising radiation response	Shall be characterised with γ-rays and avg. projected area (cosmic ray cross section) shall be quoted for all proposed array types
Pixel angular response	Shall be characterised or modelled
EMI susceptibility	Shall be characterised or modelled
Thermal and vacuum cycling	TBD

criteria

Draft note has been circulated – will be updated in response to written/e-mailed comments

Some important points:

- We must have absolute confidence at time of selection that chosen option will work
- A full system design document shall be produced by each array group, compliant with SPIRE design, spacecraft resources and IID-A requirements.
- A detailed array fabrication, test and delivery schedule shall be provided (at least up to CQM)
  - Including relevant warm electronics
  - Consistent with the SPIRE schedule
  - Realistic
- Credible space qualification programme and schedule shall be provided

7

EVALUATION CRITERIA

&

FUTURE MEETING PLAN

MATT GRIFFIN

* WIRE CCULT

TES - NOT YET
JFET - NOT YET
CEA - NO CHANGE (REDUCED?)

* SPU REQUIREMENTS

TES - INTERNAL TO READOUT?
WHAT ARE REQS ON 'EXTERNAL'
SPU - PROCESSING SPEED?
MEMORY REQS?

JFET - 1MFLOP/S O.K.
MEMORY REQS?

CEA - ?

* OPTICAL - NOT ADDRESSED

* EMI - ~~NOT ADDRESSED~~

JFET - RF SHIELD FROM CVV → 300mK
DETAILED IMPLEMENTATION?
CEA/TES ?

PROGRESS ON INTERFACES (?)

* MECHANICAL:

PLAUSIBLE SUSPENSION SCHEME PROPOSED FOR 2K/300mK SUSPENSION

⇒ IT LOOKS TOO BIG!

WILL WORK FOR SQUID/TES + FEEDHORN [CEA?]

JFET BOX STILL LOOKS BIG (160 x 326 mm)

* ELECTRICAL:

TES: COMPLEX ELECTRONICS BASED ON ADVANCED FPGA's AND ADC's
SYSTEM DESIGN WILL NEED TO BE BASED ON MORE CONSERVATIVE COMPONENTS
[illegible]
[illegible]

JFET: RELATIVELY STRAIGHTFORWARD ELECTRONICS
⇒ 18 BIT A/D NOT APPROVED PART
~~BUFFER~~ ~~ANALOGUE~~ FILTER. IS REQUIRED ON SVV

CEA: NO CHANGE — BAU DETAILS.

* THERMAL:

TES ⇒ NO ISSUE? (AT FPU) WARM ELECTRONICS??

CEA ⇒ 'UNPROVEN' THERMAL SEPARATION OF 300mK/2K

JFET ⇒ NEW DESIGN ALLEVIATES MANY OF THE PROBLEMS
⇒ [illegible]

8b

ARRAY DEVELOPMENT PROGRESS REPORT : CALTECH

JAMIE BOCK.

TES/Pop-Up Array Progress

SPIRE Quarterly Meeting

GSFC

Sept 17-18, 1998

Oct. - Dec. Continued

- SQUID Mux work
  - Test with pop-up array
  - Evaluate performance with filter inductor
  - Operate with Mark 1.8 electronics
  - Finalize design for downselect array (if changes are required)

Schedule for Oct. - Dec.

- Detector Work
  - Fold previously tested pop-up, retest
  - Microwave design of pixel
  - Definition of pixel design for downselect array
  - Test of absorber concepts in FTS
  - Complete process design for TES/PUD integration
- Complete and Test Mark 1.8 electronics
- Receive and test cryostat

Detector Tests

- TES (T_c=440 mK) applied to pop-up detector.
  - Conductance ~ 30 pW/K , just about right
  - NEP ~1.2 x 10^{-17} W/$\sqrt{Hz}$
  - τ_{eff} ~ 2 ms

SQUID Multiplexer

- Multiplexer improvements planned
  - Input circuit includes coupling inductor plus filter inductor. Filter being developed.
- Test anticipated for Fall, test with Mark 1.8 electronics by Dec.

Mechanical Design

- Mechanical design for detector mounting nearly complete
  - Structural support
  - Thermal isolation
  - Electrical interconnections
  - Fab of model to begin in Oct.

Test Cryostat

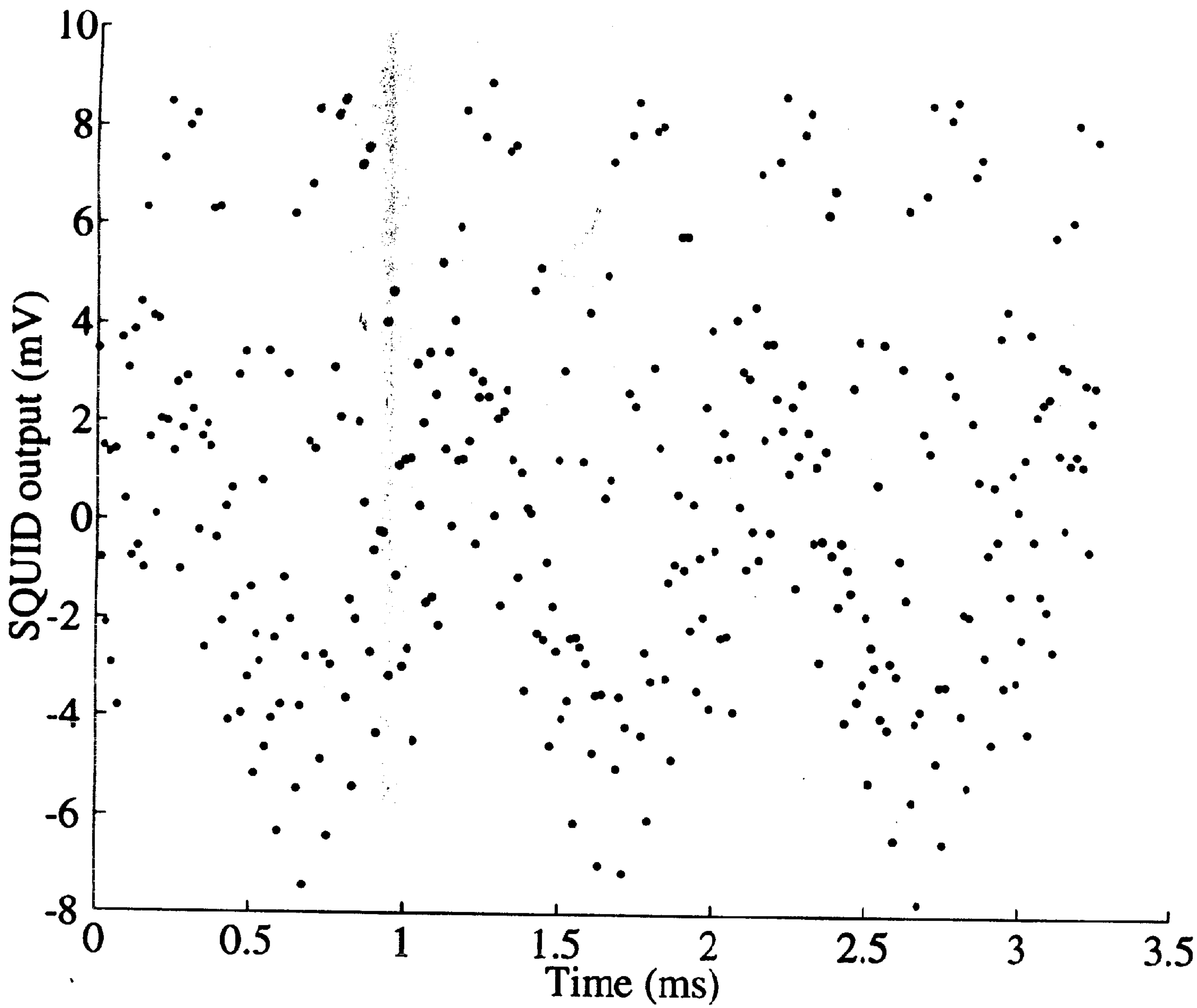
- Cryostat of QMWC design ordered from Precision Cryogenics
- ^{3}He system ordered from Simon Chase

Detector Electronics

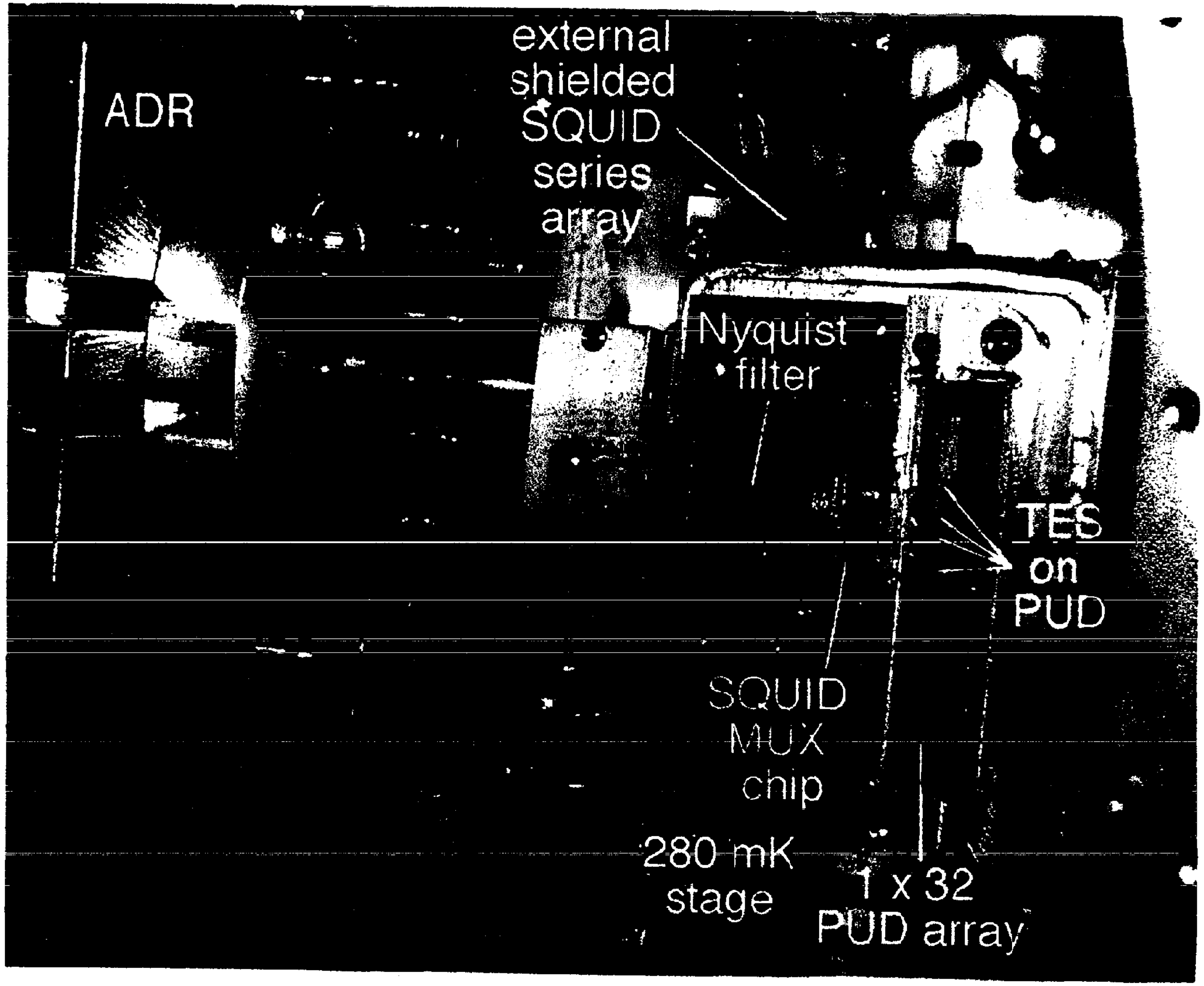
- "Mark 1.8" electronics completed by Nov. 20
- Software for control and operation by Nov.20
- Test with SQUID mux by Dec. 10
- Test with pop-up arrays Dec. 20

Progress Since Last Meeting

- Procurement of test Cryostat initiated
- Mark II (1.8) SQUID readout requirements established, design developed,parts procured
- Mechanical design for Pop-Up array structure developed.
- Pop-Up detector tested with TES

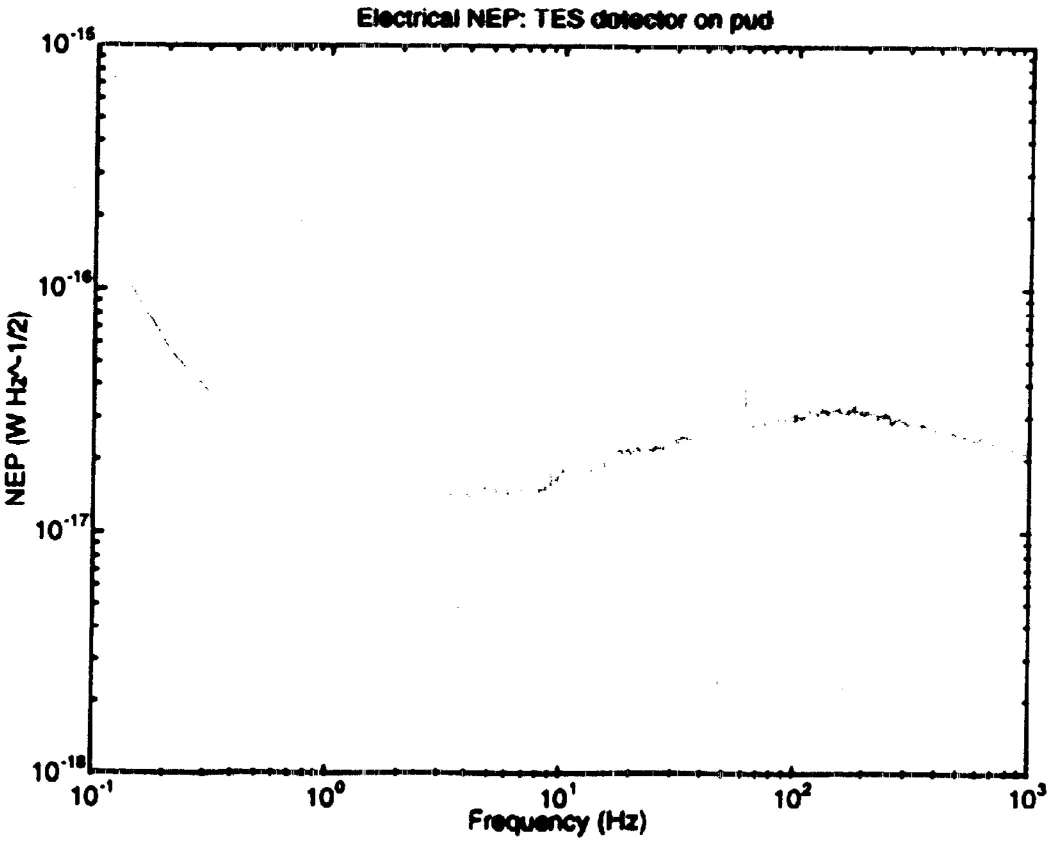


SQUID output (mV)
Time (ms)

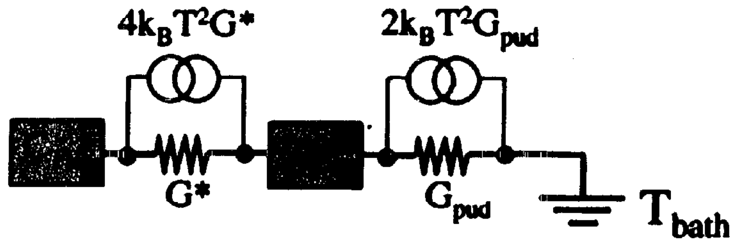

ADR
external shielded SQUID series array
Nyquist filter
TES on PUD
SQUID MUX chip
280 mK stage
1 x 32 PUD array

TES Bolometer on Popup Structure

- Bath temperature 280 mK
- Transition temperature 450 mK
- Thermal conductance 30 pW/K
- Signal bandwidth about 100 Hz
- Maximum power 3 pW
- 1/f knee < 1 Hz
- Electrical NEP
  - 1-10 Hz: 1.5e-17 WHz^-1/2
  - 10-100 Hz: < 3e-17 WHz^-1/2



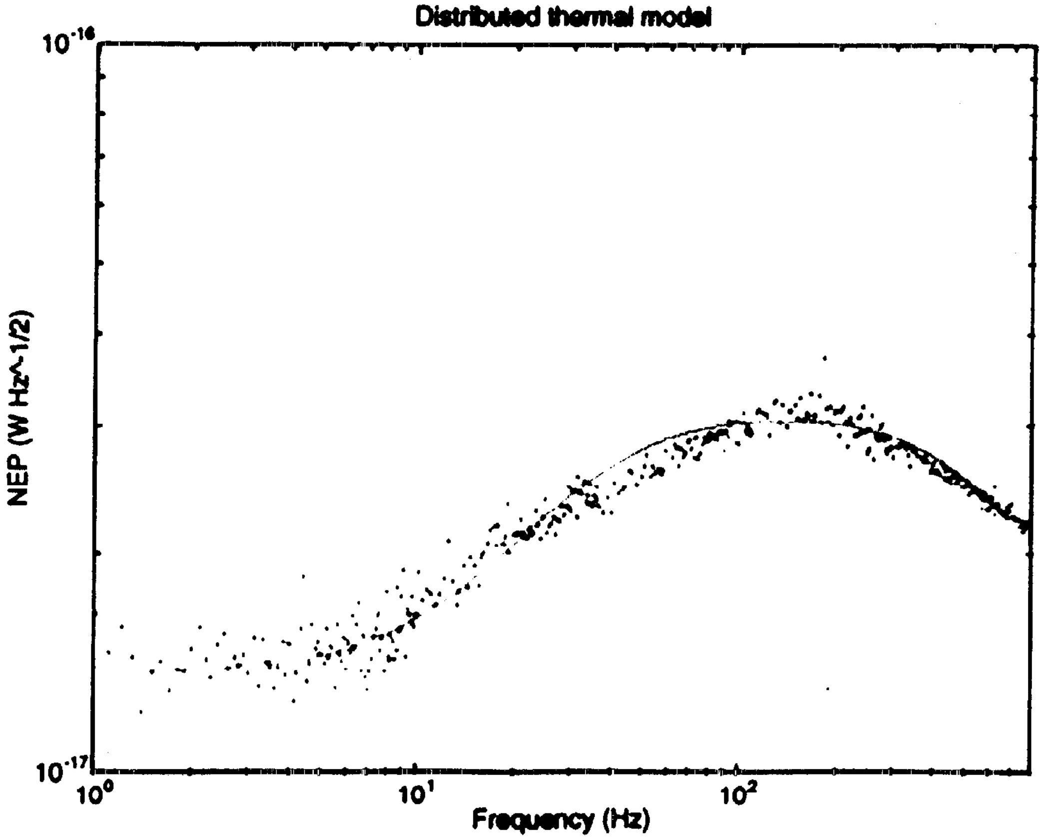
Thermal Circuit Model



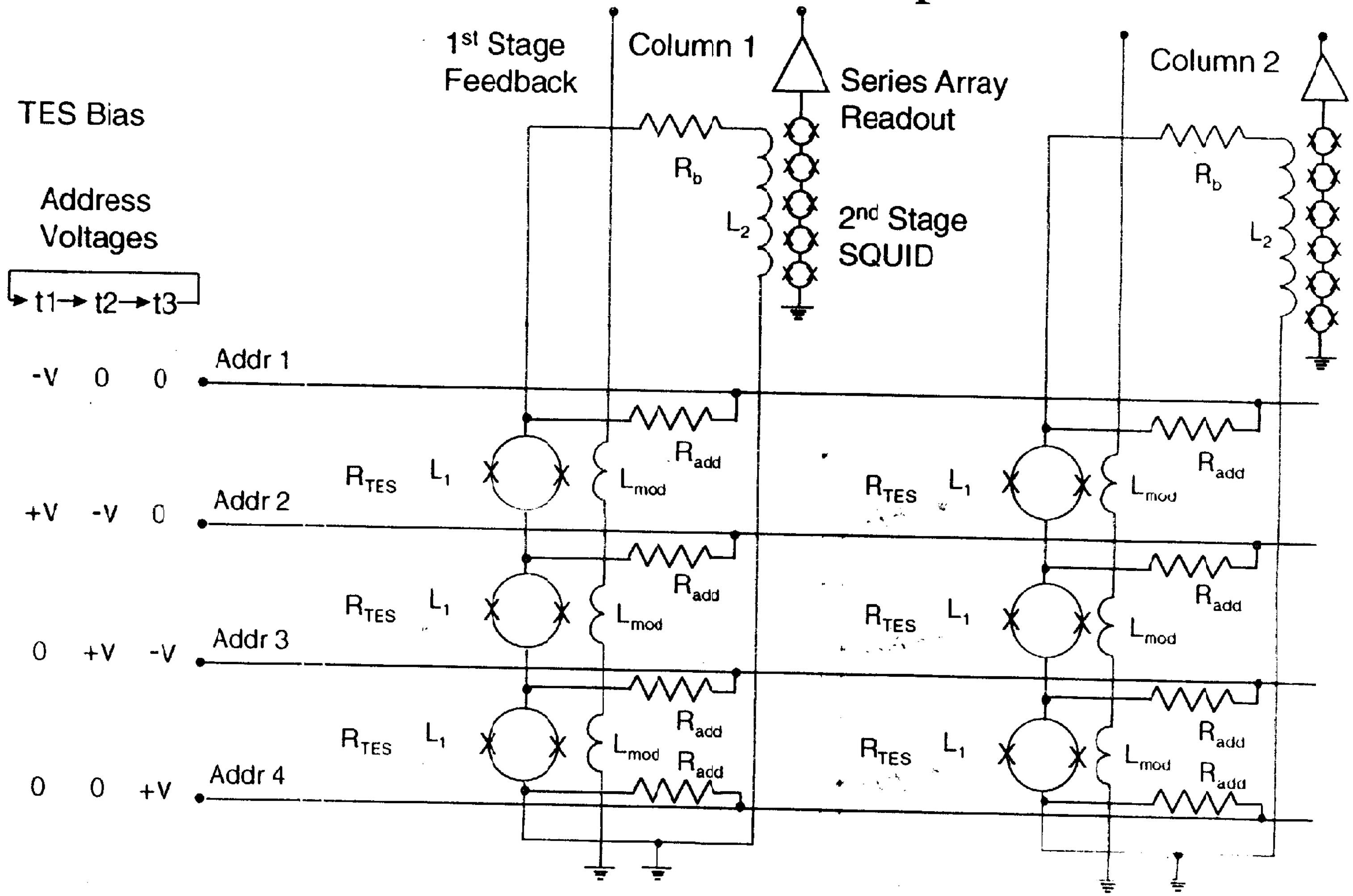
Fit to two free parameters:

$G^* = 300\ G_{pud}$ Thermal conductance within pud

$C^* = C_{TES}$ Extra heat capacity (from granular Al or Al diffused into silicon?)



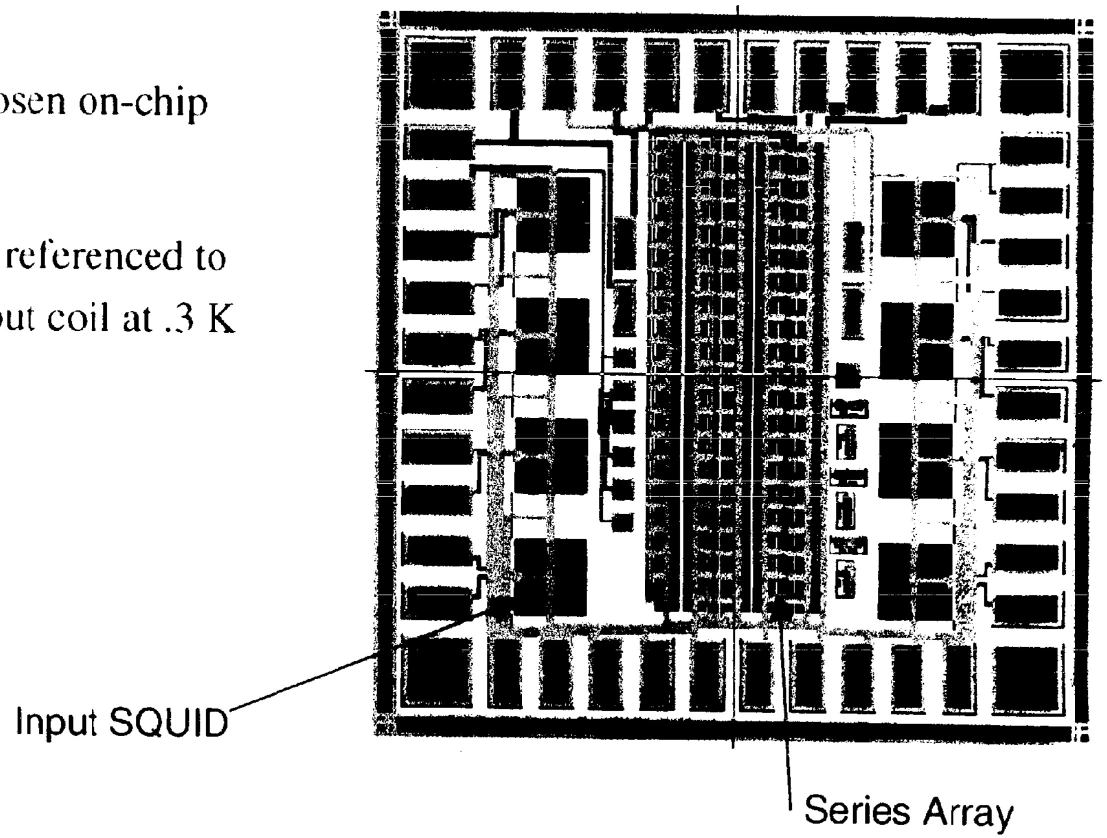
Analog 2x3 SQUID Multiplexer

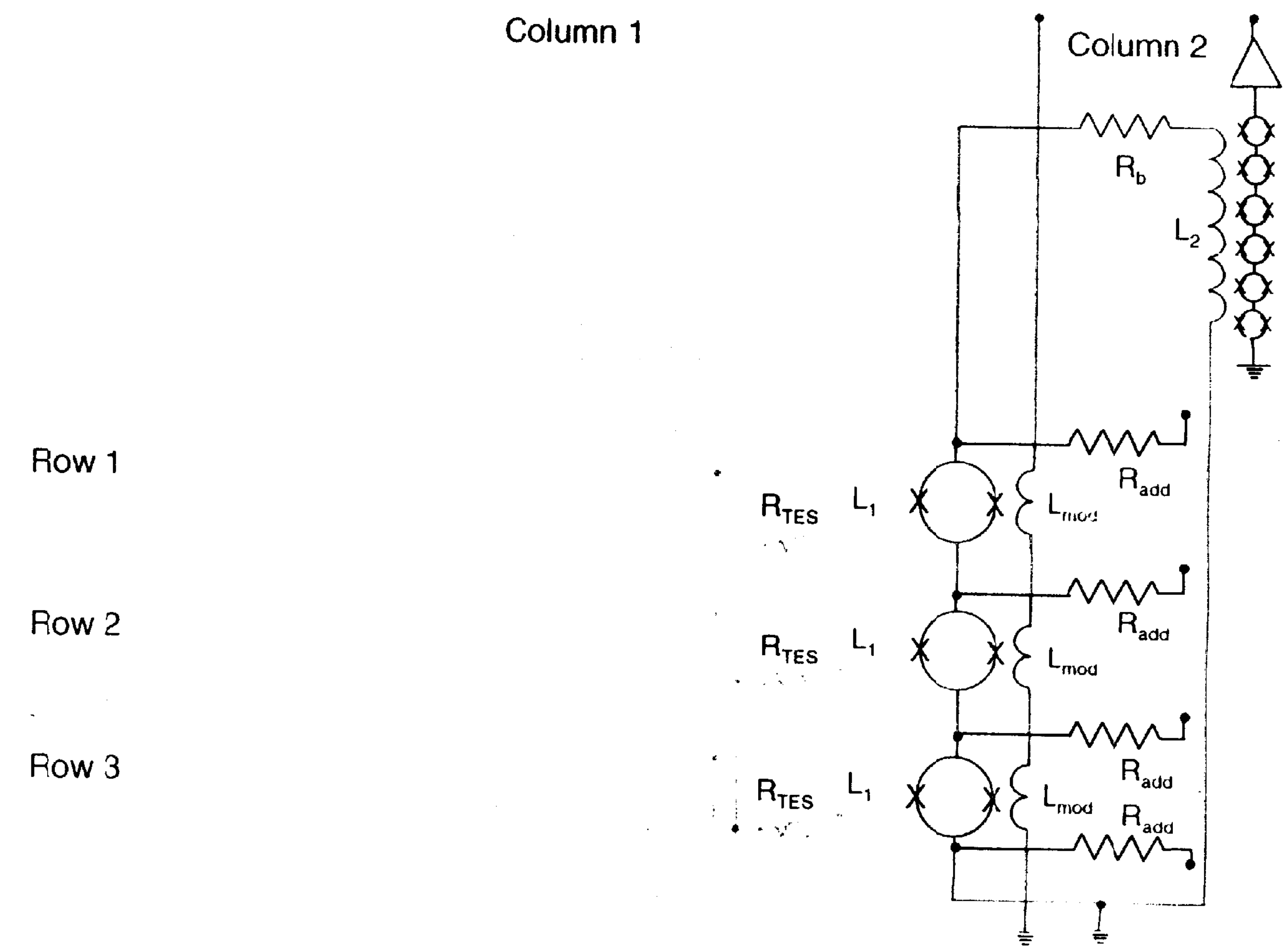


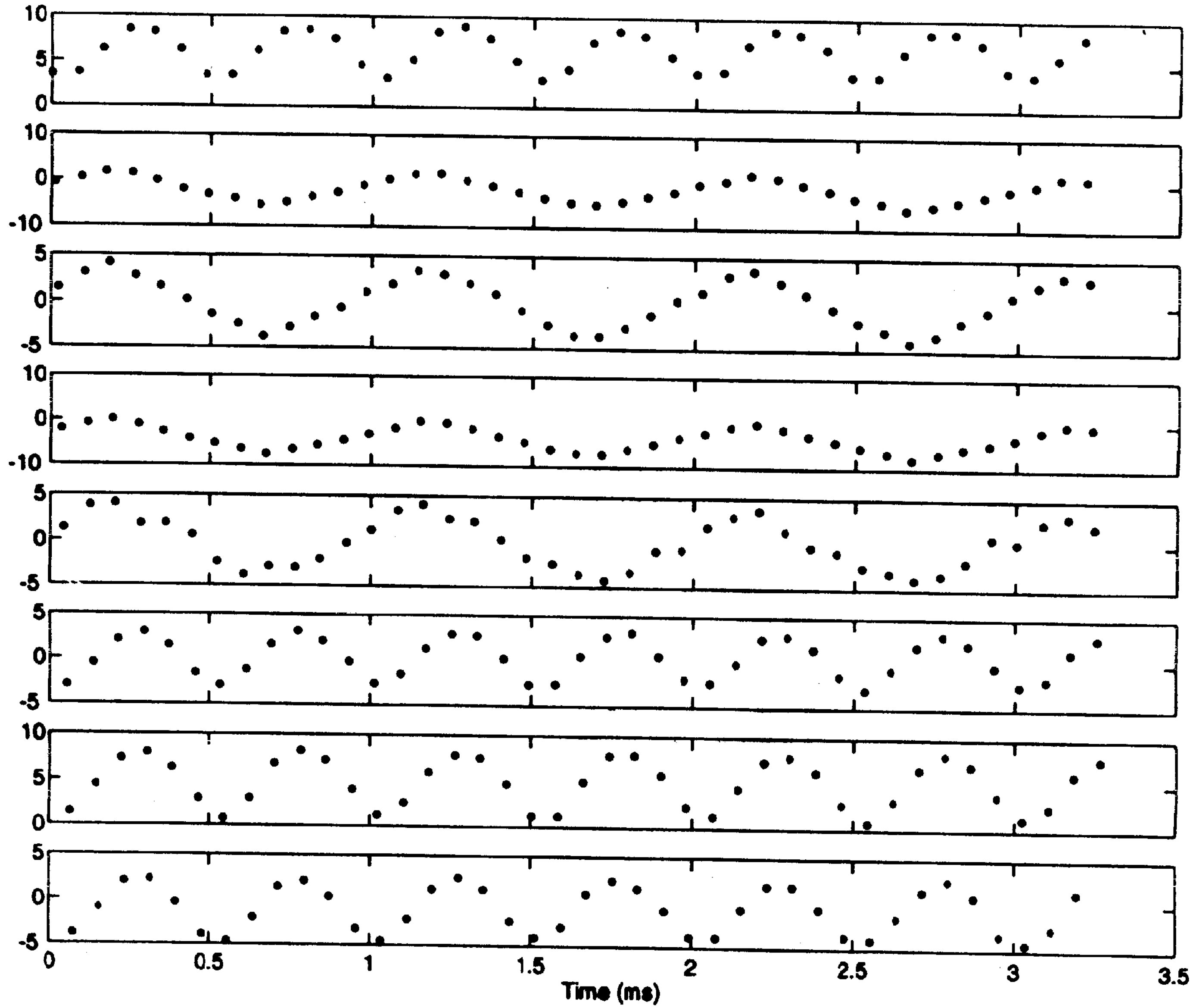
1x8 SQUID Multiplexing Chip

L_2 and R_b chosen on-chip

1.3 $\mu\phi_0/Hz^{1/2}$ referenced to first stage input coil at .3 K




Column 1
Column 2
R_b
L_2
Row 1
Row 2
Row 3
R_{TES}
L_1
L_{mod}
R_{add}



Time (ms)

9.

BACUS STATUS

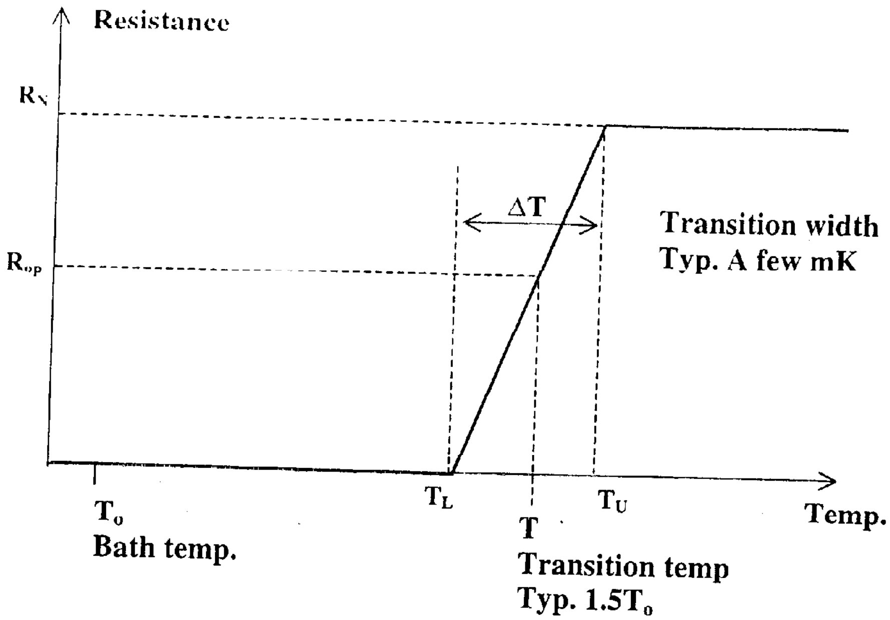
PETER HARGRAVE

10a.

TES OPTIMISATION FOR SPIRE

MATT GRIFFIN

TES detector optimisation for SPIRE



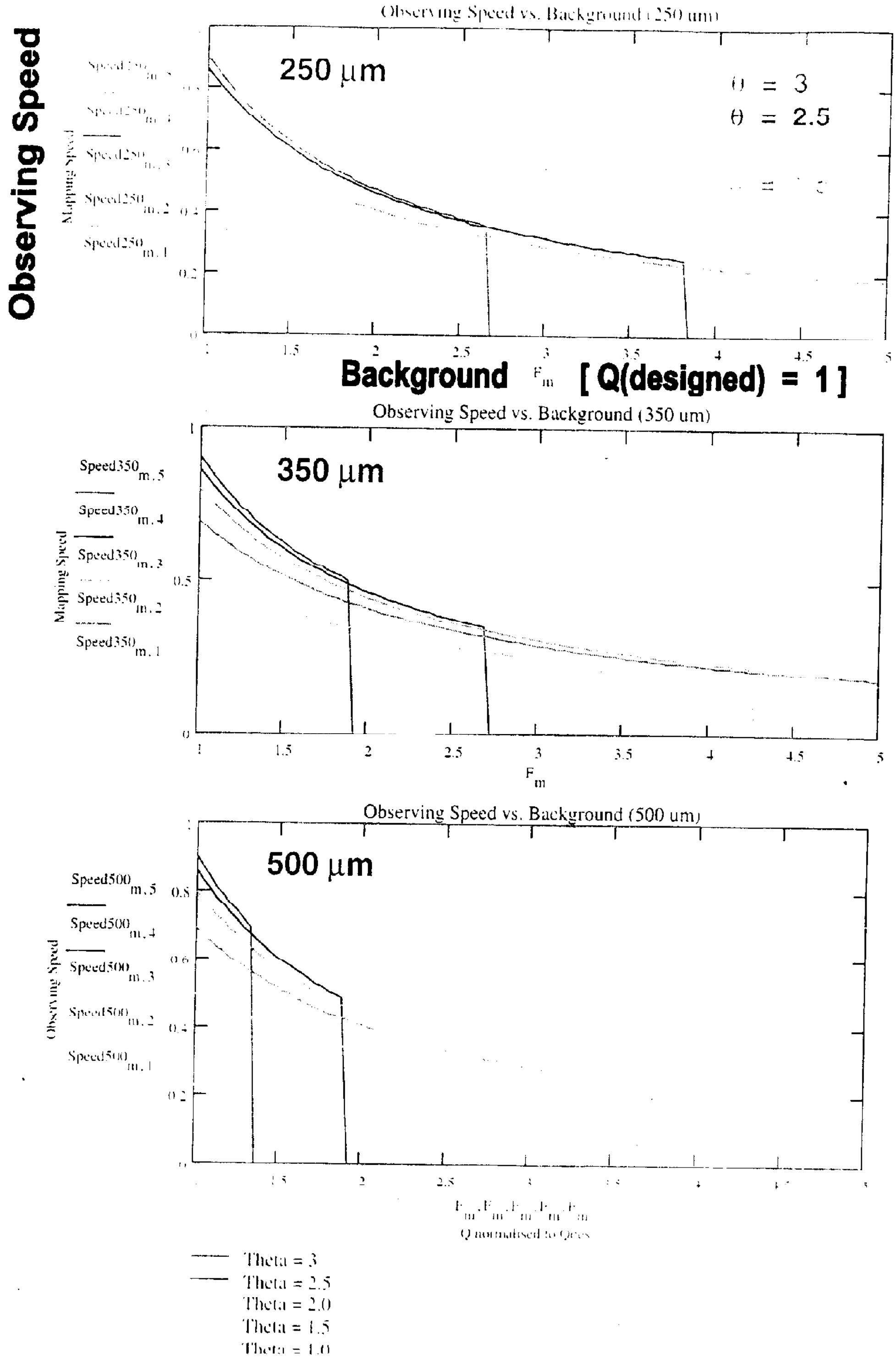
- Bias power + absorbed power $P + Q = W = \text{Const.}$
- As Q is altered, P alters to keep W, T_{op} constant
- $W < G_s(T - T_o)$
- T and G_s are fixed by design
- T_o is fixed for ^{3}He system
- If Q is unexpectedly high, then equilibrium temperature even with zero P could be $> T_u$
  $\rightarrow$ detector does not work at all

  Maximum tolerable background: $Q_{max} = G_s(T - T_o)$
- Solution: insure against high Q by making G_s large
- But $NEP_{det} \propto G_s^{1/2}$, so this degrades sensitivity

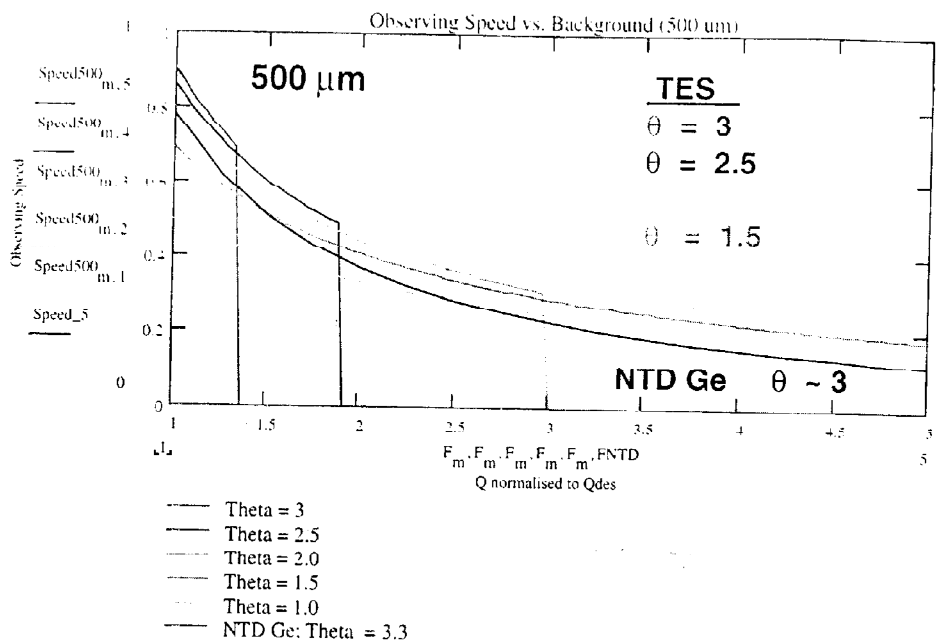
- Assumptions for TES:
  - Thermal conductance $G_d \propto T^{\beta}$ $\beta = 3$
  - Bath temperature $T_o = 300$ mK
  - Transition temperature $T = 450$ mK
  - Temp. coeff. of resistance $\alpha = (T/R)(dR/dT) = 300$
  - $NEP_{det} = (NEP_{ph\text{-}des})/\theta$ $\theta = 2$
  - NEP_{det} dominated by the phonon noise term

- Assumptions for NTD Ge:
  - Ideal NTD Ge bolometer (Johnson and phonon noise only)
  - $T_o = 0.3$ K
  - $P_b = 4$ pW (SPIRE 500 μm channel; feedhorn option)
  - $R_{op} = 5$ MΩ
  - $G_{so} = 25$ pW K-1 (G_s at T_o)
    ($\Rightarrow \theta = 3.3$ - i.e., strongly photon noise limited if $Q = Q_{des}$)
  - Signal chain input short noise = 6 nV $Hz^{-1/2}$
  - Load resistance $R_L = 30$ MΩ
  - Bias voltage adjustable

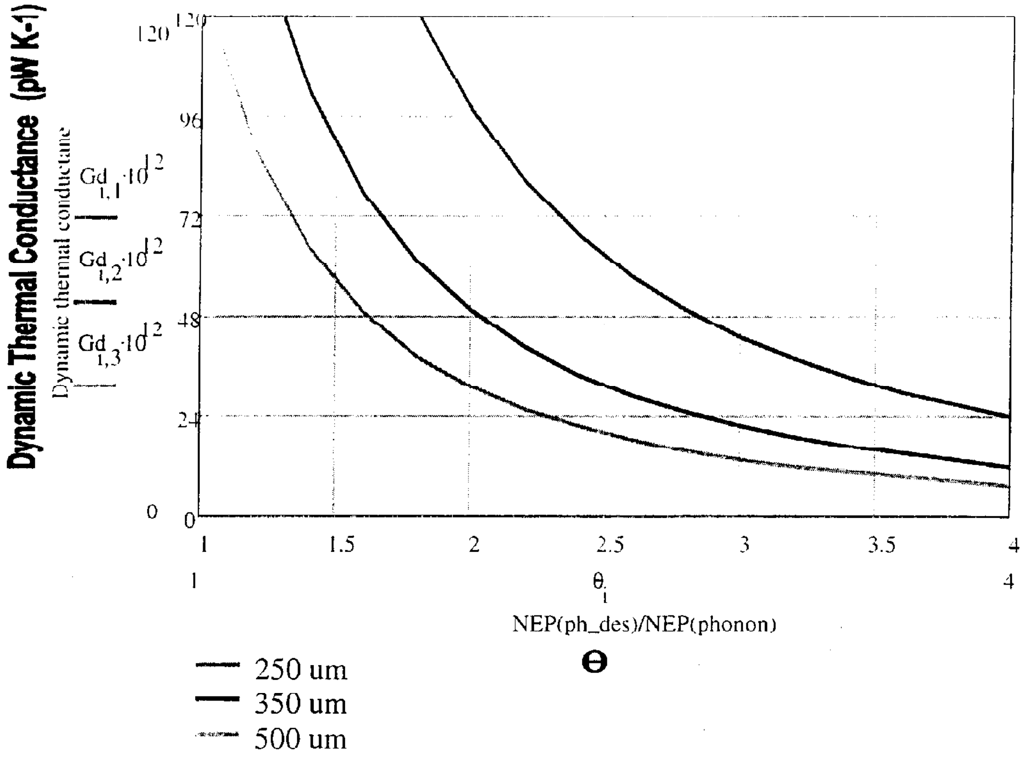
Observing speed vs. background for TES



Observing speed vs. background for NTD Ge and TES at 500 μm



TES thermal conductance for SPIRE bands vs. insurance factor θ



Conclusions

- For TES sensors, we need an "insurance factor" θ to make sure the arrays work in the instrument. I suggest minimum of ~ 2.
- Required TES dynamic thermal conductances for SPIRE (with $\theta = 2$ are):

λ (μm)	G_d (pW K^{-1})
250	100
500	50
350	30

- Semiconductor bolometers are not susceptible to complete saturation at higher than expected background levels
- Background during satellite ground tests may be too high to operate TES bolometers unless we incorporate a cold shutter
- This analysis should be checked and refined and may be corrected. But the issue must be addressed by TES groups for array selection.

10b.

SIMULATIONS OF SPIRE

OBSERVATIONS

LAURENT VIGROUX

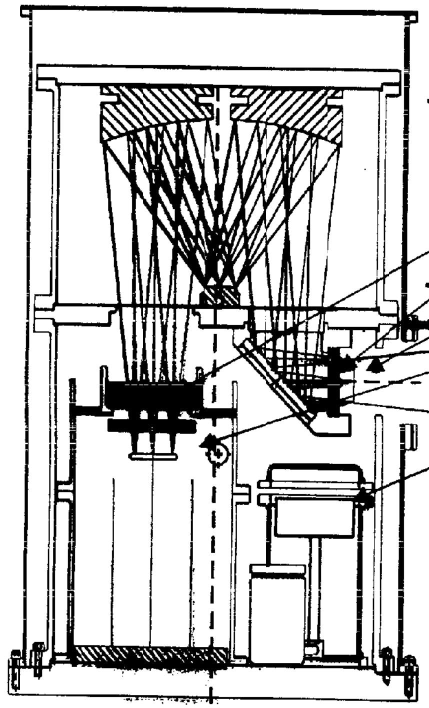
QUEEN MARY
AND WESTFIELD COLLEGE
UNIVERSITY OF LONDON

BACUS Status & Array Test Plan

P.Hargrave, B.Maffei, F.Gannaway,
M.Griffin & P.Ade

QUEEN MARY
AND WESTFIELD COLLEGE
UNIVERSITY OF LONDON

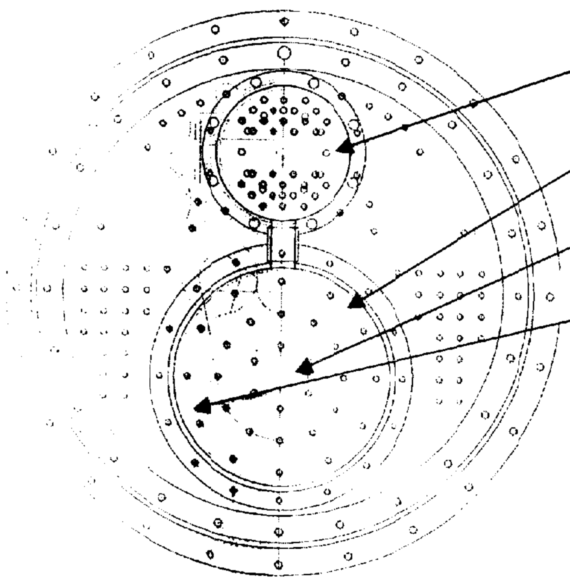
Design of BACUS Module



- F5 Offner Relay
- Filters
- Illuminators
- Detector Module & Shields
- He-3 Fridge & Shields

QUEEN MARY
AND WESTFIELD COLLEGE
UNIVERSITY OF LONDON

BACUS Design



- He-3 Fridge & Shields
- Detector Module
- Detector Array
- Blanking/Flat-Fielding Plate

QUEEN MARY
AND WESTFIELD COLLEGE
UNIVERSITY OF LONDON

Cryogenics

- Cryostat from Precision Cryogenics (Indiana)
- Optics at 1.5K (Pumped L^4He Bath)
- Detector stage at 300mK - Kevlar isolated stage linked to ^3He fridge (Chase Research)

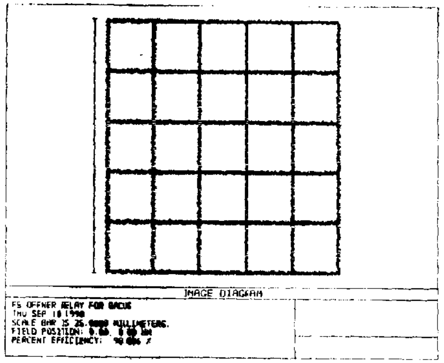
QUEEN MARY
AND WESTFIELD COLLEGE
UNIVERSITY OF LONDON

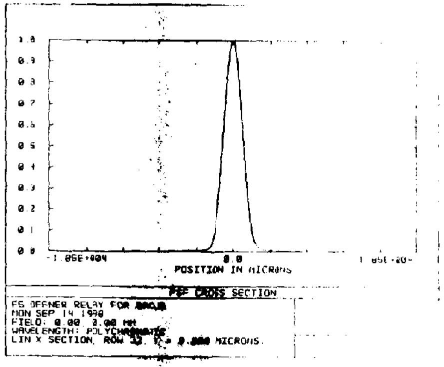
Optics

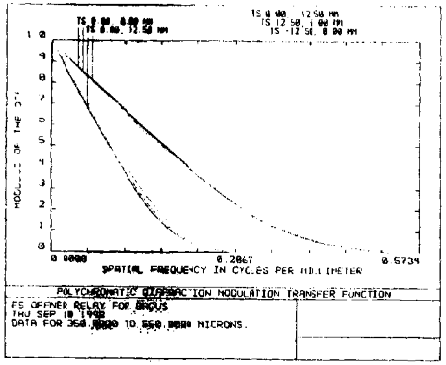
- F5 Offner Relay
- Mirrors from Symons Mirror Technology (diamond turned Al-6061)
- All optics at 1.5K
- Baffling scheme needs finalising

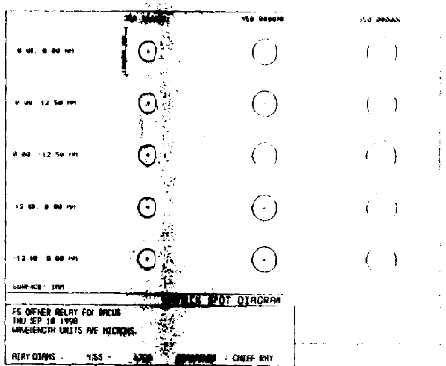
QUEEN MARY
AND WESTFIELD COLLEGE
UNIVERSITY OF LONDON

Optics





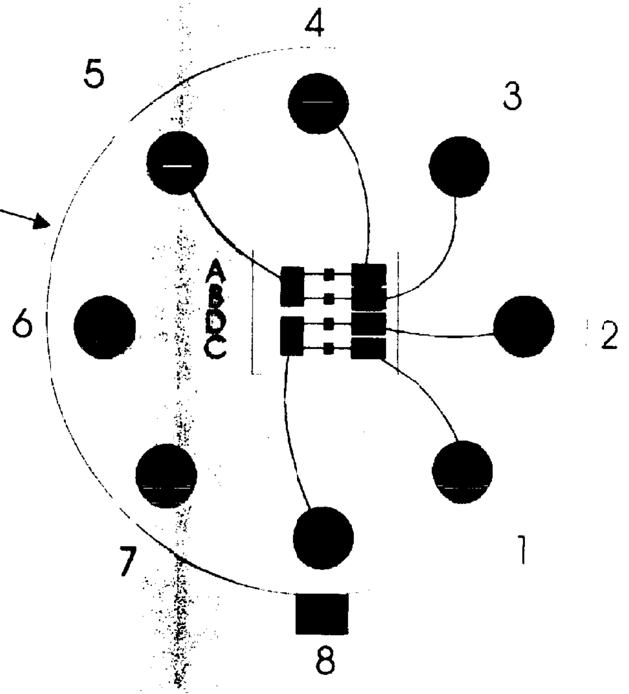




QUEEN MARY
AND WESTFIELD COLLEGE
UNIVERSITY OF LONDON

Illuminators

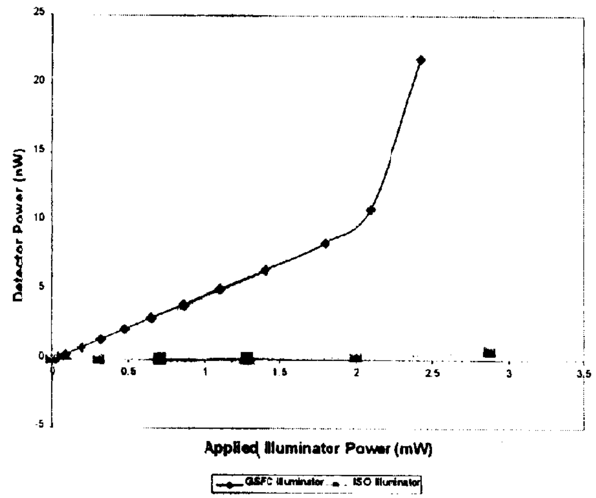
- ND + Edge filters for work in R-J region
- GSFC being evaluated
- Need to be modulated > 10Hz
- Uniform source plate - variable temp.
- QMW dewar will have window to outside



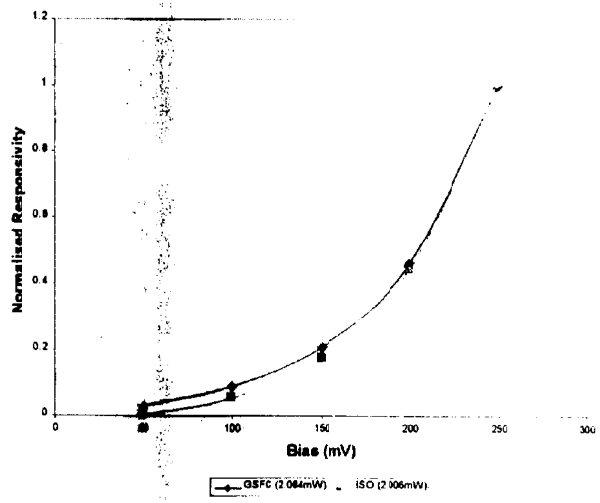
QUEEN MARY
AND WESTFIELD COLLEGE
UNIVERSITY OF LONDON

Illuminators

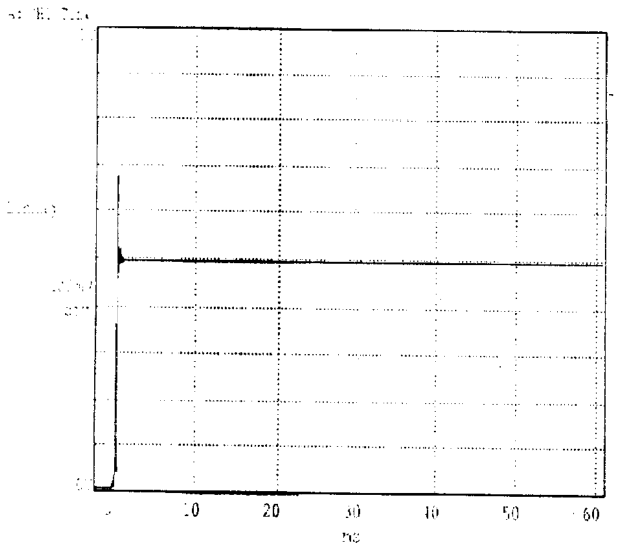
Comparison of ISO & GSFC Illuminators at 150mV Detector Bias

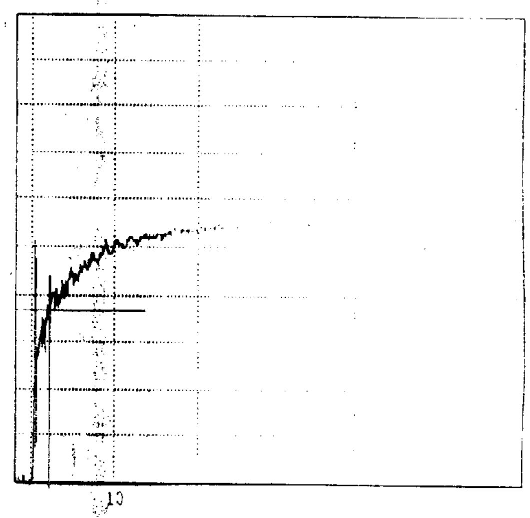


Normalised Responsivity vs Bias for Illuminator Power of 2mW



GSFC Speed of Response





Risetime=2.007ms

QUEEN MARY
AND WESTFIELD COLLEGE
UNIVERSITY OF LONDON

Connectors

- 1x79 way - for detector arrays
- 1x32 way - for illuminators
- 1x26 way - for housekeeping
- All connectors are box flange mount conforming to MIL-C-38999

QUEEN MARY
AND WESTFIELD COLLEGE
UNIVERSITY OF LONDON

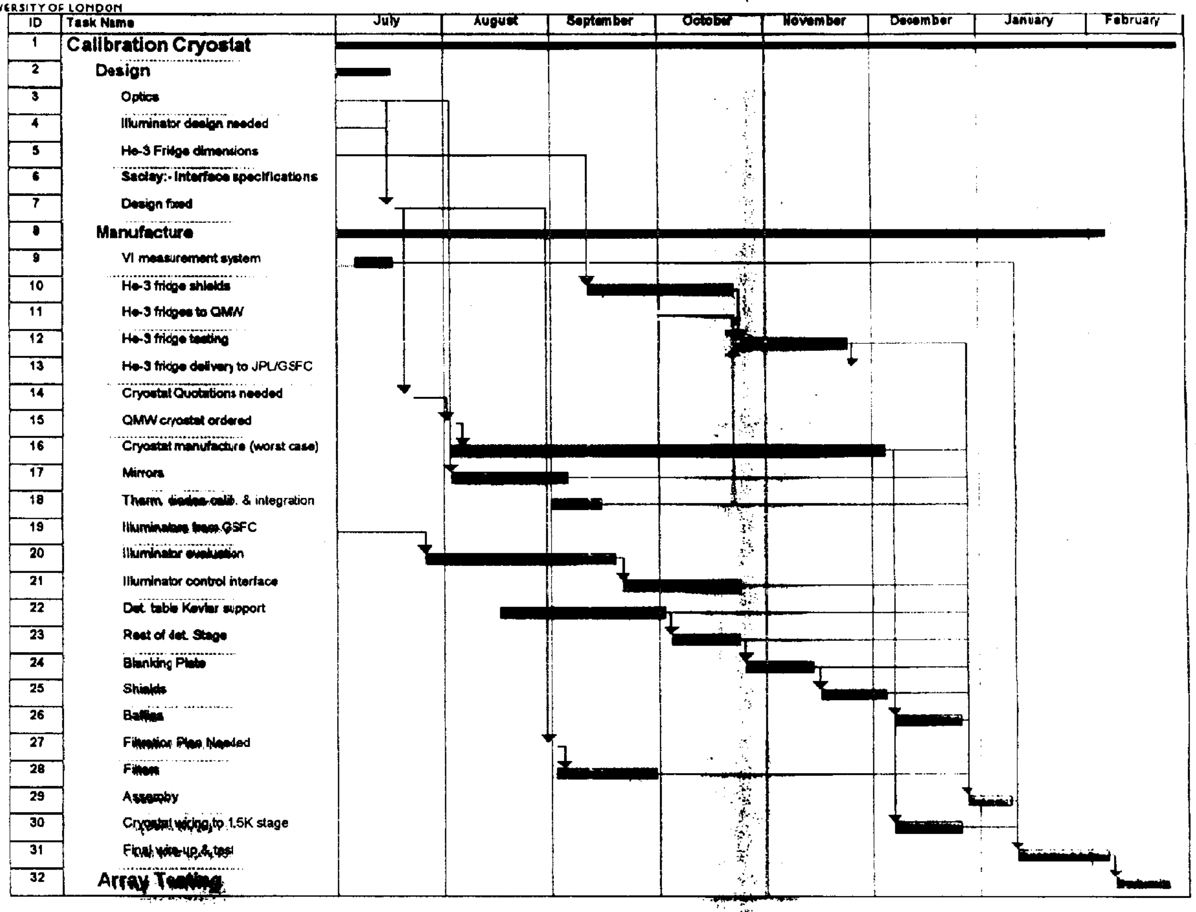
BACUS Capabilities

- V-Is - blanked or with uniform background (not CEA)
- Speed of response
- Flat fielding / array uniformity
- Cross talk
- Sensitivity
- Dynamic Range
- Linearity

- Optical NEP
- Spectral response
- Fringing between optical elements
- Calibration of detector responsivity (external black body)
- Connection to telescope simulator

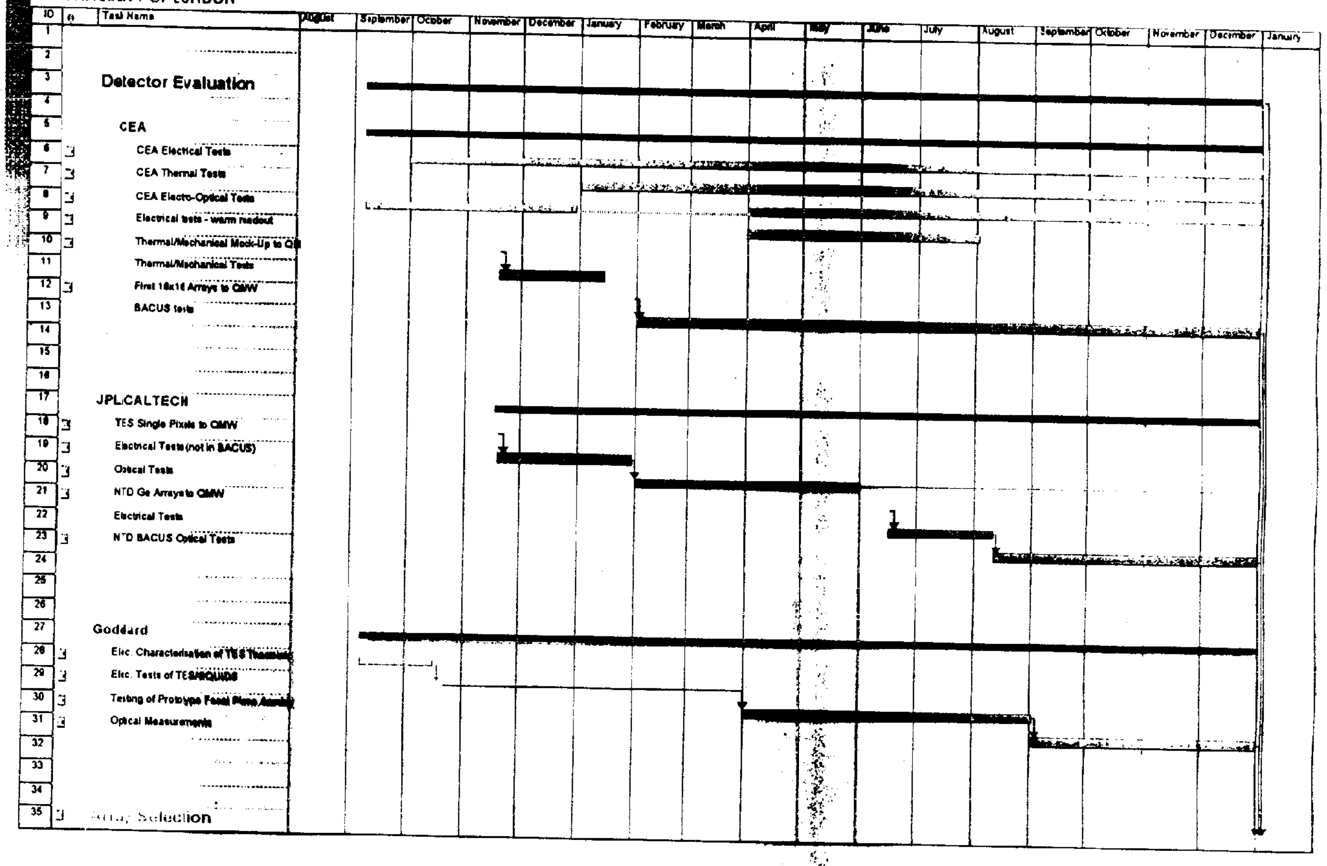
QUEEN MARY
AND WESTFIELD COLLEGE
UNIVERSITY OF LONDON

BACUS Schedule



QUEEN MARY
AND WESTFIELD COLLEGE
UNIVERSITY OF LONDON

Array Testing Plan



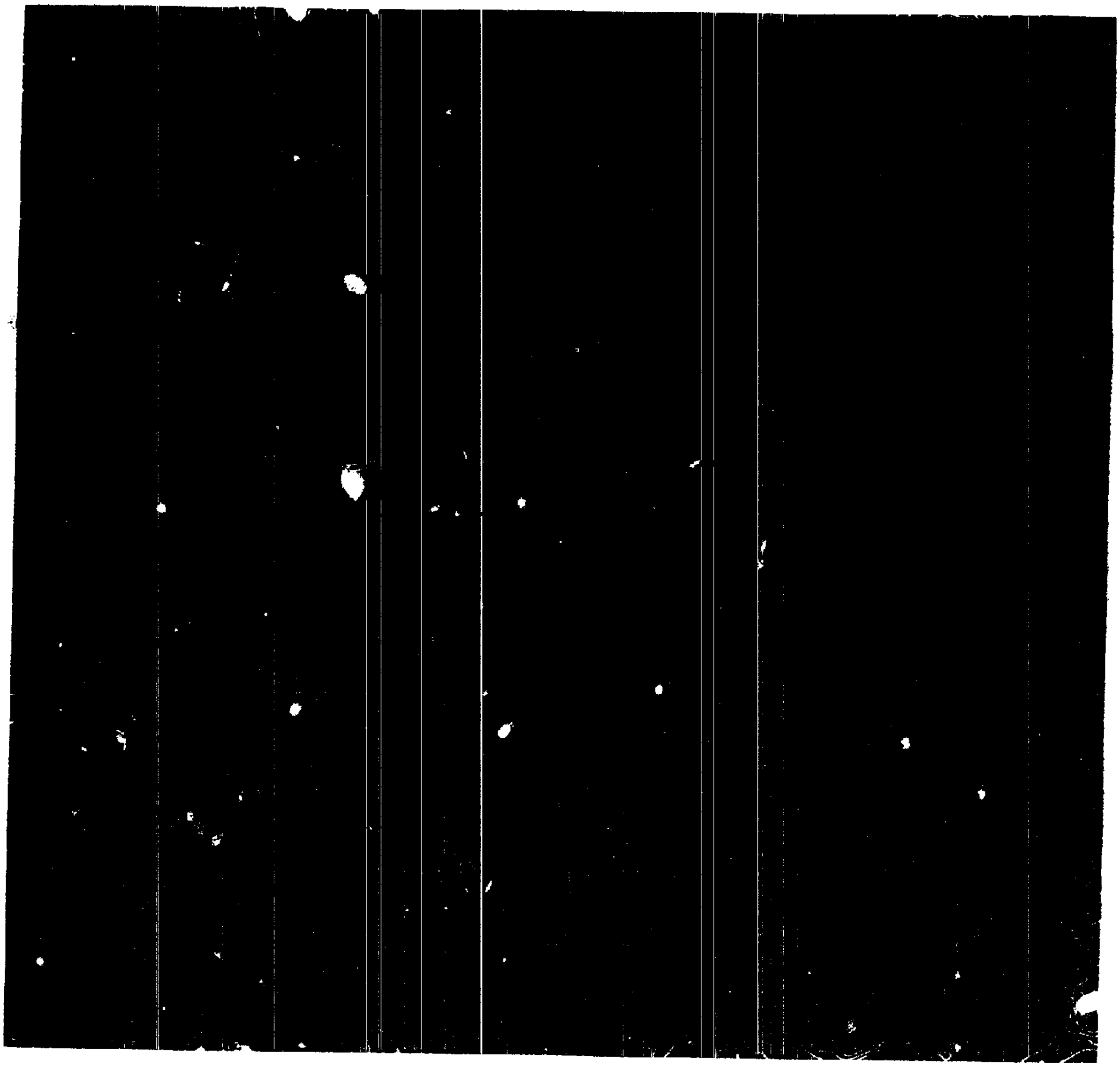
QUEEN MARY
AND WESTFIELD COLLEGE
UNIVERSITY OF LONDON

Summary

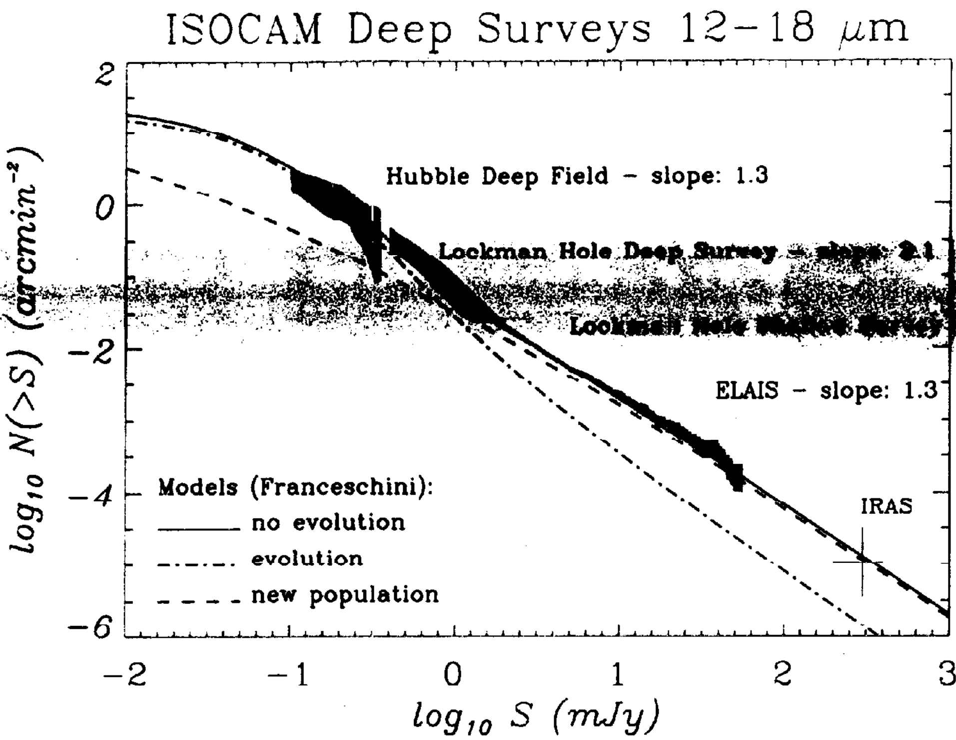
- BACUS should be operational by end January 1999
- Preliminary tests can be carried out in another dewar once He-3 fridges & shields are ready (mid-November)
- Schedule is very tight - we need realistic estimates for when we can expect devices at QMW
- "Pre-prototype" devices could be sent to QMW for pre-tests to familiarize QMW staff and avoid subsequent delays.
- 3 × BACUS MODULES ? – TBD

ISOCAM 7 μm ( ) and 15 μm ( )

superimposed with Hubble Space Telescope image



Visible light : NASA/ESA/HST and R. Williams and the HDF Team (STSCI)
Infrared : ESA/ISO/ISOCAM. CEA-Saclay and H. Aussel et al.



ISOCAM Deep Surveys 12−18 μm
Hubble Deep Field − slope: 1.3
Lockman Hole Deep Survey
Lockman Hole
ELAIS − slope: 1.3
IRAS
Models (Franceschini):
no evolution
evolution
new population
log10 N(>S) (arcmin−2)
log10 S (mJy)
2
0
−2
−4
−6
−2
−1
0
1
2
3

Models for SPIRE surveys

3 detectors are tested

1. Fλ square pixels with flat transmission :

   16 × 16 array of 18"×18" pixels at 250 μm.

   8 × 8 array of 36"×36" pixels at 500 μm

2. Fλ/2 square pixels with flat transmission :

   32 × 32 array of 9"×9" pixels at 250 μm.

   16 × 16 array of 18"×18" pixels at 500 μm

3. 2Fλ horns (backup option) with gaussian transmission (FWHM = Fλ) :

   61 horns of 18" of radius at 250 μm.

   27 horns of 36" at 500 μm

Sources

Number counts prediction of Franceschini et al. (97) are used to simulated a 20'×20' field, diffracted by the circular aperture of the telescope (3.5 m).

Observations

All detectors are tested with :

- Same surveyed area (10'×10' by 4 patches of 5'×5')
- Same observation time : 1.07 hour by patch
- Same final resolution.

Two resolutions are tested :

1. $\lambda/2$ at 250 μm $\longrightarrow$ $\lambda/4$ at 500 μm
2. $\lambda/4$ at 250 μm $\longrightarrow$ $\lambda/8$ at 500 μm

Noise model

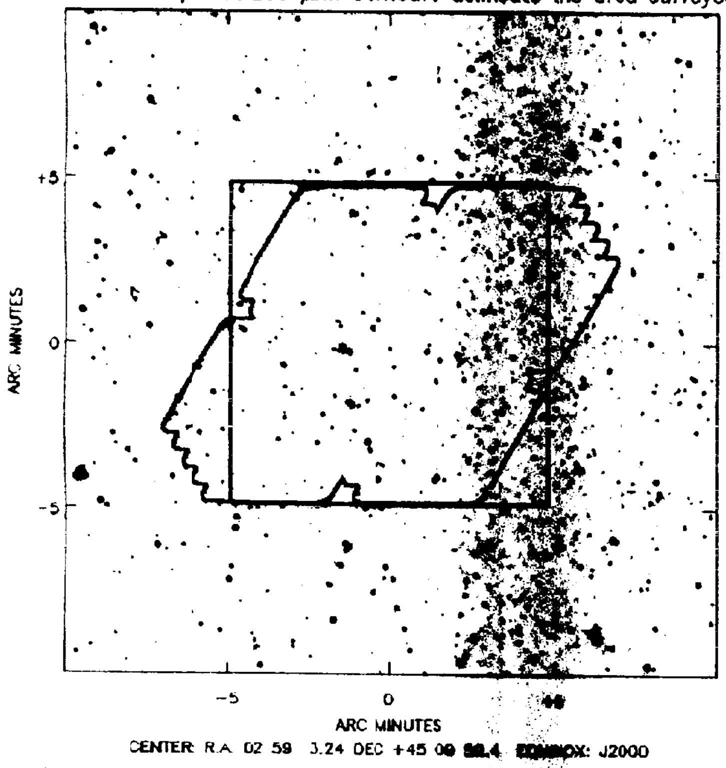
- Detector. **NEP =** $3 \times 10^{-17} W.Hz^{-1/2}$ **for all detectors.**
- Photon **noise. Origin** : the telescope mirror at **80 K. Varies** with wavelength and detector **throughput.**

Noise level **(mJy/pixel/hour)**

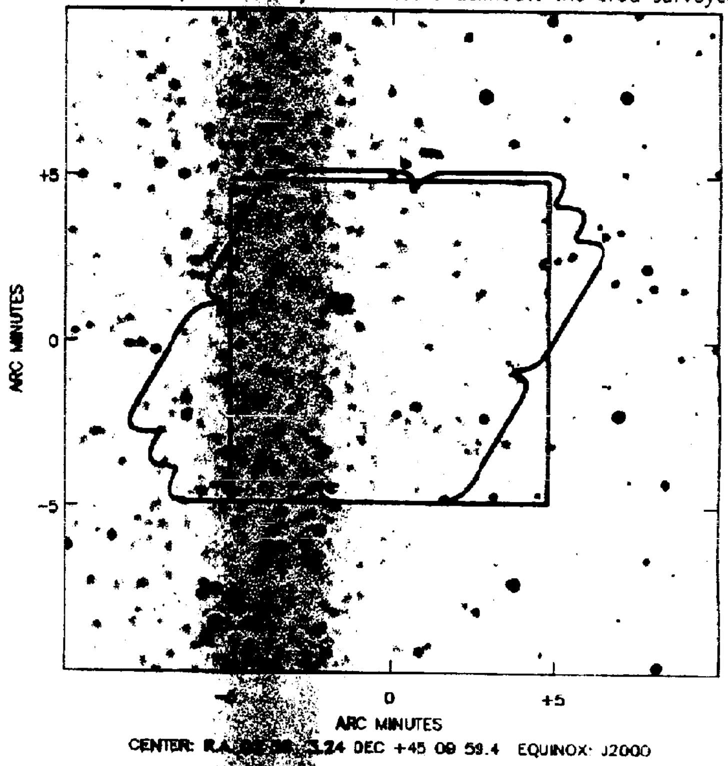
	Fλ	**Fλ/2**	**2Fλ**
250 μm	0.8	0.64	**0.42**
500 μm	0.8	0.73	**0.76**

Input field of the simulations, using counts prediction of Franceschini et al. (97)

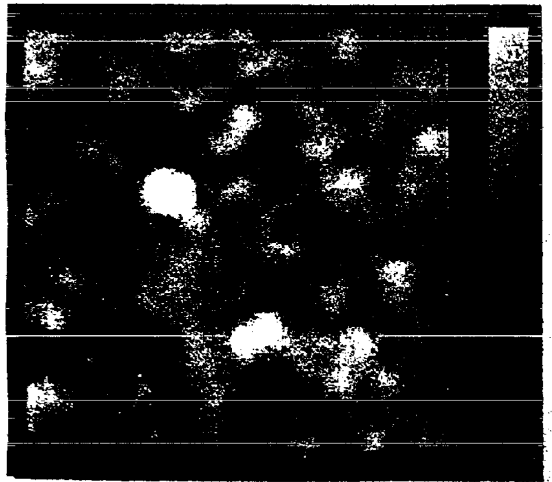
Simulation input at 250 μm. Contours delineate the area surveyed



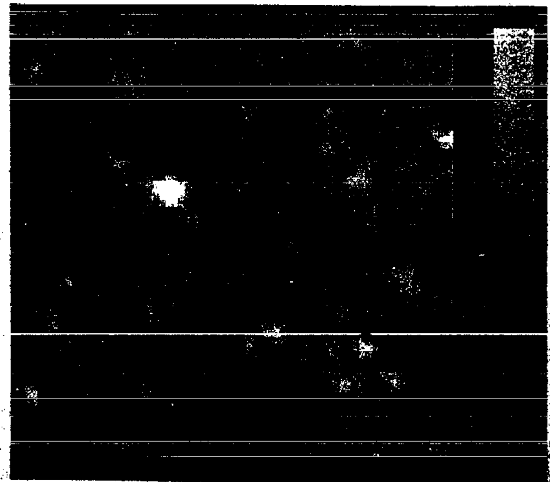
Simulation input at 500 μm. Contours delineate the area surveyed



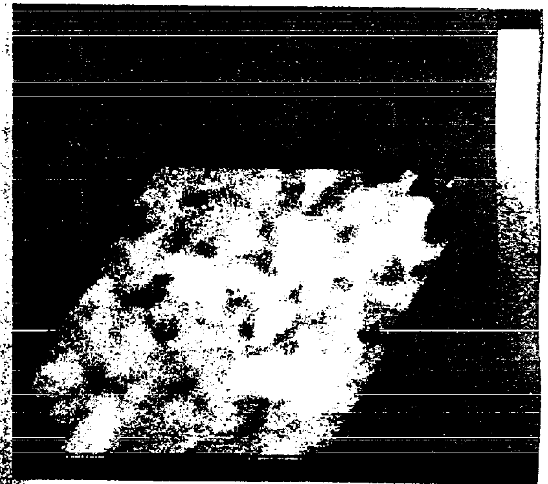
Result at 500   m for a $\lambda/4$ resolution



F λ Square pixels



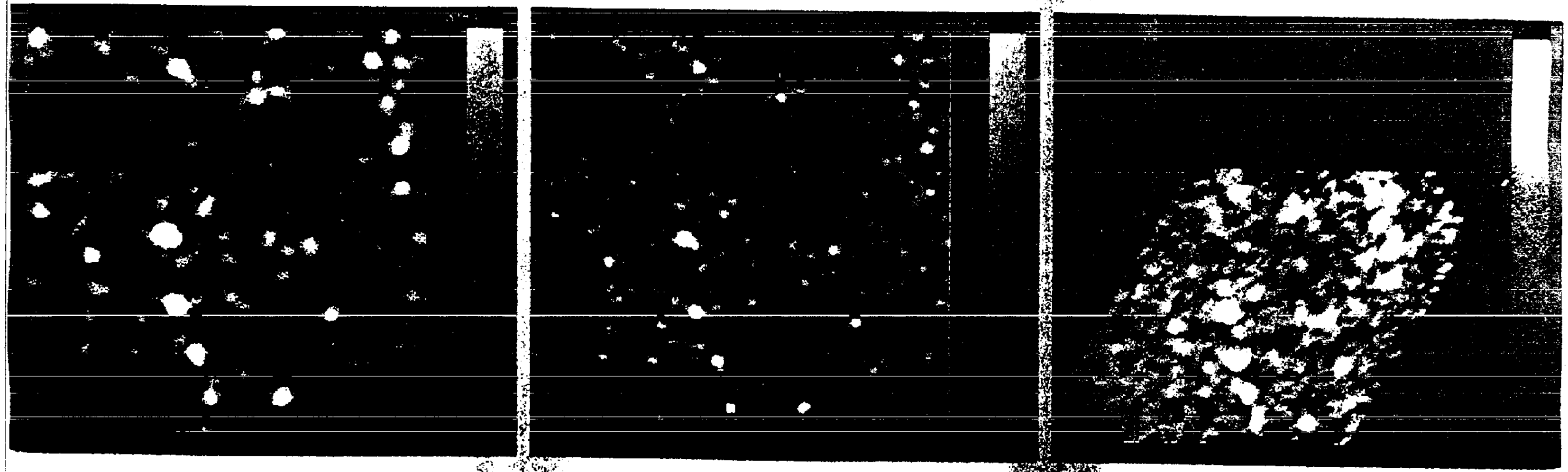
F λ/2 Square Pixels



2 F λ Horns

Displays are Log (f mJy/pixel)

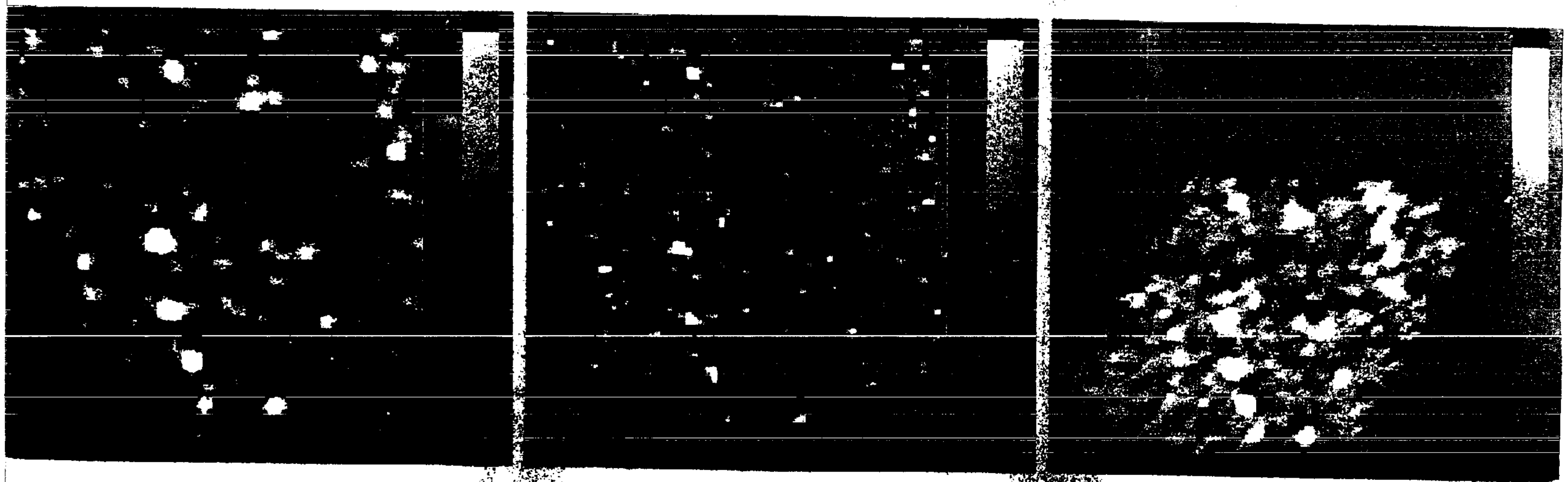
Result at 250 m for a λ/4 resolution



F λ Square pixels | F λ/2 Square Pixels | 2 F λ Horns

Displays are Log (f mJy/pixel)

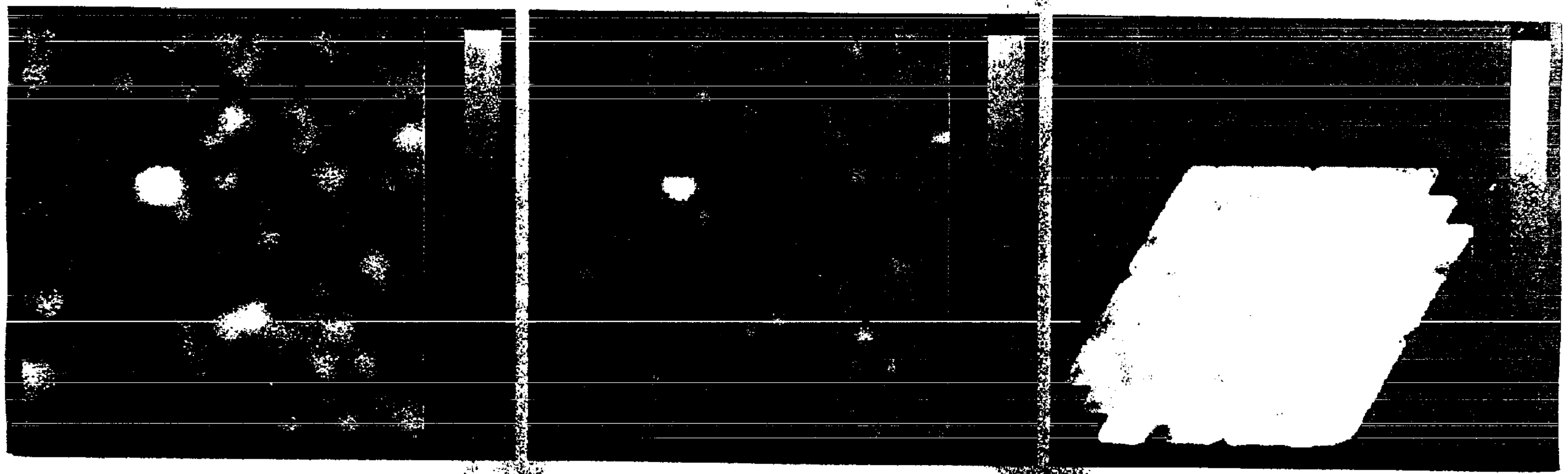
Result at 250 m for a $\lambda/2$ resolution



F λ Square pixels — F $\lambda/2$ Square Pixels — 2 F λ Horns

Displays are Log (f mJy/pixel)

Result at 500 m for a $\lambda/8$ resolution

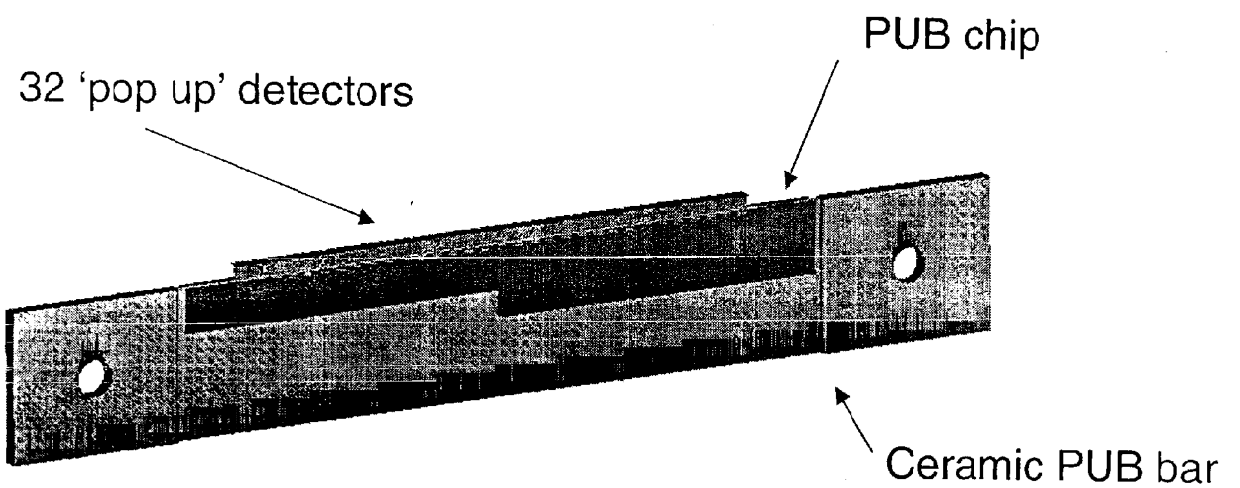


F λ Square pixels | F $\lambda/2$ Square Pixels | 2 F λ Horns

Displays are Log (f mJy/pixel)

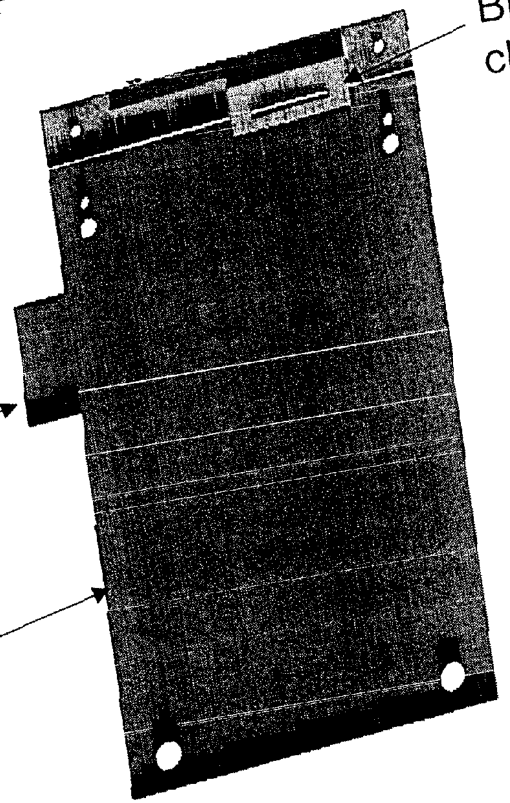
Detectors

- The PUB chips are folded and epoxied to the PUB bars.



Detectors

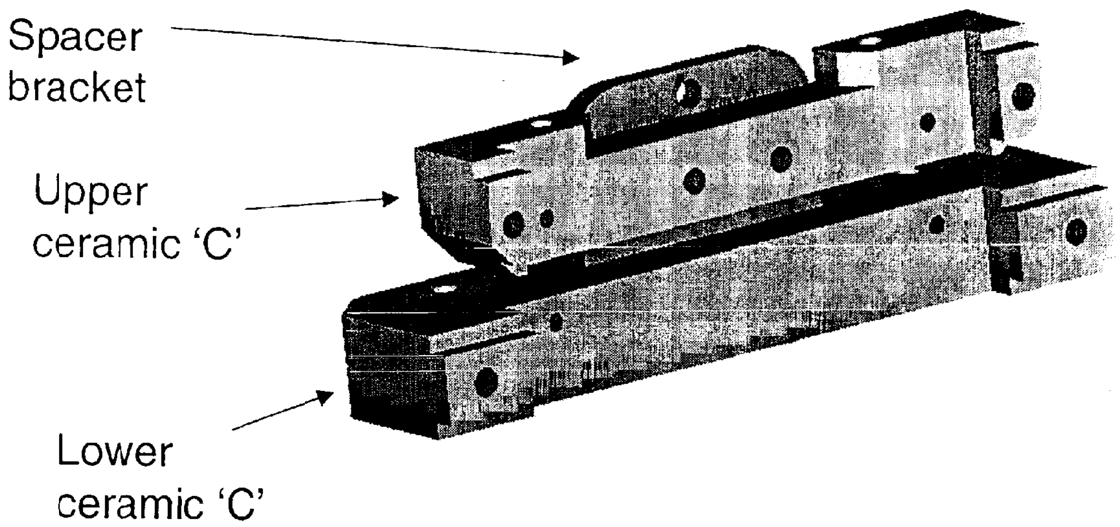
- The bridge chips are epoxied to a PUB bar and a fanout board.



Michael Amato

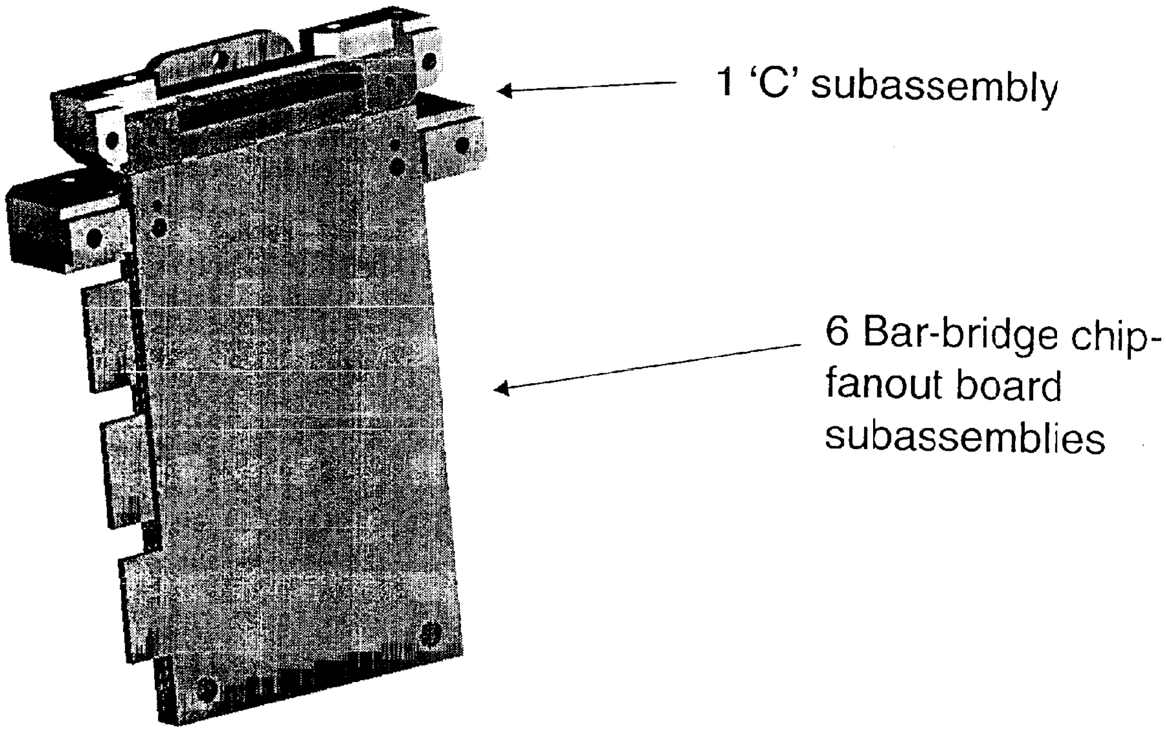
Detectors

- The upper and lower ceramic ‘C’ parts are aligned and assembled into two ‘half C’ subassemblies.



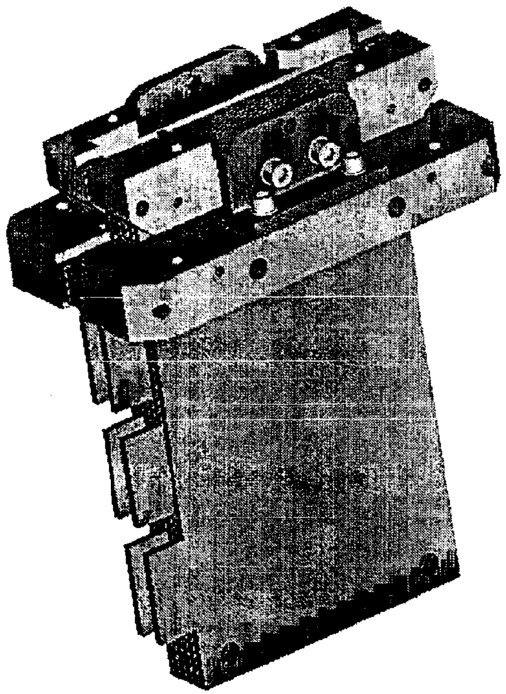
Detectors

- Six PUB bar-bridge chip-fanout board subassemblies are aligned and epoxied to each ceramic 'C' subassembly.



Detectors

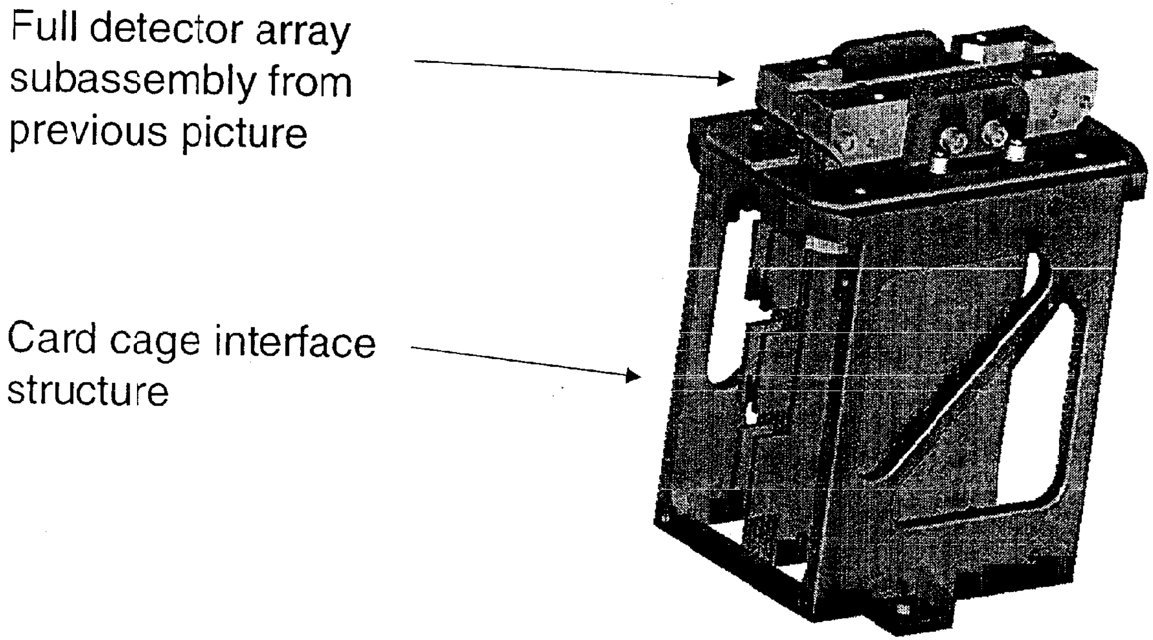
- Two of the resulting subassemblies are aligned and bolted together to form a 12X32 array.



Two half detector subassemblies joined into one full detector array subassembly

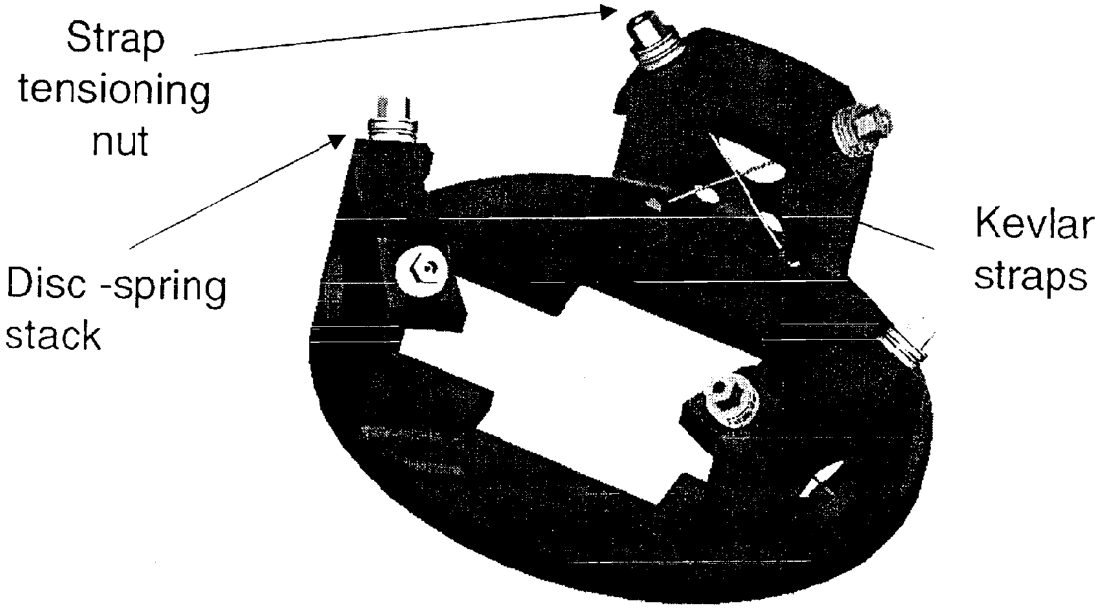
Detectors

- The resulting 12X32 detector assembly is lowered into and bolted to the card-cage interface structure.



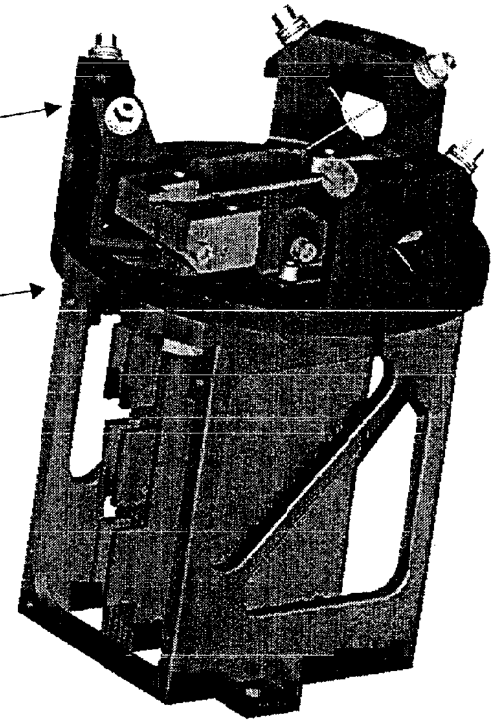
Detectors

- The six kevlar straps are epoxied to end hardware and tensioned into the claw with a Belleville spring stacks on the top ends.



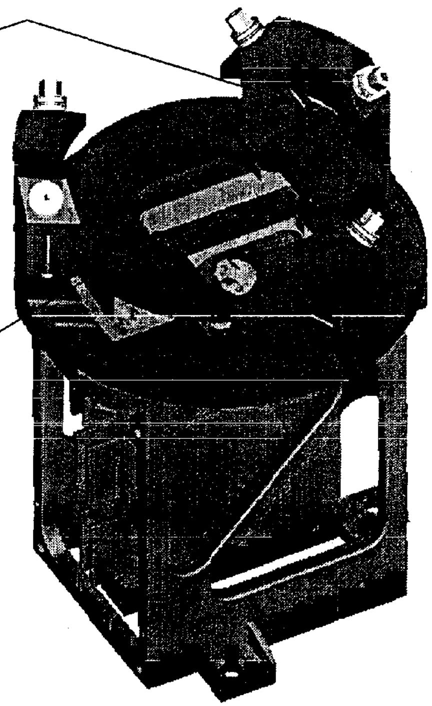
Detectors

- The claw is lowered over the detector array and bolted to the lower ‘C’s



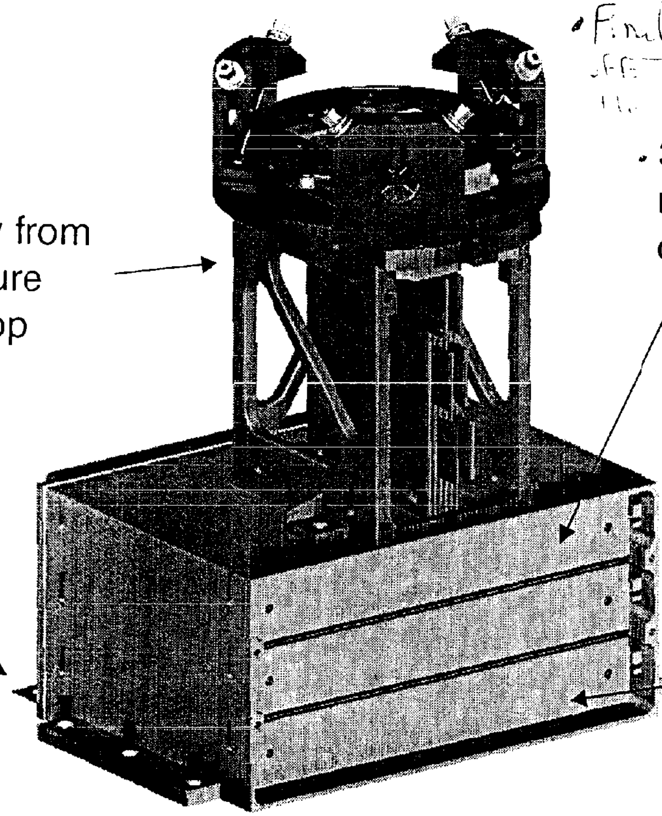
Detectors

- The cold plate is lowered, twisted into position with its 'hooks' or 'grooves' at the kevlar straps, and bolted or epoxied to the upper 'C's.



Detectors

- The assembly is mounted to the top of the JFET box.



Subassembly from previous picture mounted to top of JFET box

JFET heat straps

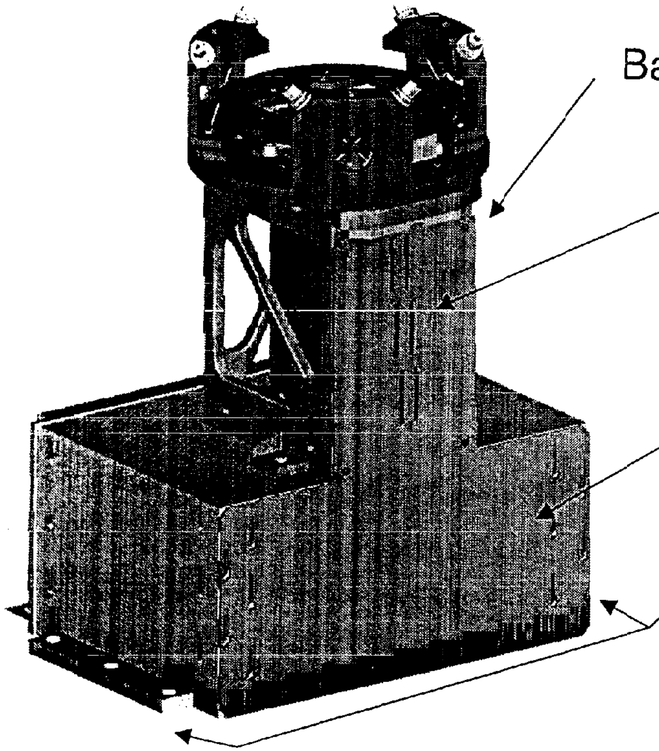
- 3 JFET electronics modules on card guides

- Not shown high density connectors are on both ends of the modules

Michael Amato

Detectors

- The back plane board is aligned to the fan out board tabs and attached to the card cage structure and the JFET box.



Detectors

- The ADR heat strap is attached to the suspension cold plate and the suspension brackets which suspended the detectors during the assembly are removed.