

Visits to SCUBA 2 and GISMO teams, and topics of interest from the LTD 12 conference.

Samuel Leclercq. 09/08/07.

This document presents a summary of the missions I did to SCUBA 2, GISMO and the LTD 12 conference. For the visit to SCUBA 2 and GISMO the summary is presented in the form of a question-answer interview, and for LTD 12 as short presentations of the talks I found interesting for bolometer arrays and regarding IRAM activities. **To ease fast reading the key words are in bold characters.**

SCUBA 2. 10-11 May 2007.

For a presentation of SCUBA 2 and a correct understanding of the interview the reader is invited to read the following paper (astro-ph June 2006):

“SCUBA-2: a 10,000 pixel submillimeter camera for the James Clerk Maxwell Telescope”

<http://arxiv.org/ftp/astro-ph/papers/0606/0606338.pdf>

*1) What were the more important **specification constraints** that drove the instrument design ?*

Wayne Holland:

4 constraints drove all the subsequent design engineering of the instrument:

- The **number of pixels** necessary to sample the JCMT field of view.
- The pixel **efficiency** > 85 %.
- The **photon noise** as an instrumental limitation.
- The **power load level and dynamic**.

These constraints serve the goal of the instrument to reach the **confusion limit** in a timely manner.

*2) What is the **reason of the cold optics choice**; namely this **big 4K box** including 3 mirrors, knowing that the gain of background power (justification in the article) is negligible compared to the atmospheric background ? Isn't it a big heavy instrument, expensive in money and cryogenics, for a small gain ?*

WH, Mike MacIntosh ; Peter Ade, Rasmi Sudiwala:

From the JCMT geometry, the 50 sq-arcmin Field-Of-View (8 arcmin FOV diameter) at the focal plane is 650 mm in diameter whereas the instrument size is 120 mm in diameter; it was therefore necessary to build a re-imaging system to match the 2 sizes. The instrument size was driven by the compromise of the minimum focal plane size possible in order to minimize microfabrication cost while avoiding losses due to diffraction on pixels. It was found that 1.1 mm pixels was the limit to get negligible losses at 850 μm wavelengths. Due to space limitation, the re-imaging mirrors had to project the beam through the telescope bearing and re-image the focal plane with negligible aberration. All the mirrors were needed to obtain a small aberration free image without using lenses which would have brought too much additional background. But why build a big cryostat including the 3 last mirrors ?

3 reasons:

- Most important: **minimizing the stray lights** polluting the signal. Actually even with this huge cryostat creating a complicated way for the stray lights to reach the pixels, they still got 2× more power from stray lights than expected, so they needed to add an extra filter after the entrance of the cryostat to get rid of this excess power (10 filters in total).
- The position and shape of this cryostat minimizes the size of the entrance window, therefore minimizes the background flux (from the window itself and again from stray lights). Even with the small size of the window (<30 cm diameter) 8mm thickness was necessary to insure no vacuum leak.
- This cryostat shape creates a physical support that would have been necessary anyway to place the pulse tube for 4 K and 1 K boxes and for the readout electronics.

The additional power that would be delivered if the 3 last mirrors were warm is not an argument (negligible compared to the atmosphere and other mirrors).

On one hand WH agreed that all these arguments may not be strong enough to fully justify the huge cryostat, there was maybe some over cautious over engineering decisions made to insure the minimum background and reach the confusion limit the fastest possible. On the other hand PA said the JCMT was not designed for SCUBA 2 and there was no other way than doing this big 4K box to reach the specifications of photon noise limitation, negligible aberrations, full sampling at the diffraction limit and negligible stray light. Any other decision would have screwed everything, and in particular the stray light problem.

*3) Why **Zemax** was used only for the initial concept, then **Code V** for the actual optics design ? (I thought Zemax could do it.)*

WH ; PA, RS:

Actually **GRASP** and **ASAP** were also used ! Each one of these 4 optical design programs had some advantages in some domains that others hadn't. This was several years ago, maybe now with the new packages and new versions not all of this commercially available software would be necessary.

Zemax was easy to use for the first design, **ASAP was good for the stray lights** modeling, the others were used for forgotten reasons... (the best would be to ask the question to the SCUBA 2 optical engineer).

*4) **How many filters** are used in the SCUBA 2 beam path ?*

PA:

There are **10 filters in series**. Only the last one is used to define the 2 bands windows (dichroic). The purpose of all the others is to **fight against stray light and thermal emissions** from optical elements. The many filters stages purpose is mainly to cut the emissions from the filters themselves, which have a huge temperature gradient between the borders and the center. Even with a 4 K ring attach, the equilibrium temperature at the center of the filter may reach >10 K due to the load power and the filter absorption coefficient. So it is necessary to cut the thermal Infra Reds with several stages: 5 μm, 20 μm, ... Fortunately with the big 4 K box there is enough space to put all these filters !

One SCUBA 2 **TES efficiency is 85 %** (→ no feed horn needed !), **with all the filters** and dichroic the total efficiency is lowered to **40 %**.

5) How can you propose a **spectroscopic mode** of observation with only 2 bands ?

WH: Put an interferometer (**Martin Puplett**) in the optical path to select wavelengths in a band. This can be used to scan each band in frequency (wavelength).

6) How the **cold shutter** will be used and at which frequency ?

WH:

It will be used to take dark frames. The time to **move** the shutter, take the frame and move it back is about **30 seconds**. No data will be recorded when the step motor is running. The step motor is a bit slow, but it is small, creates few vibrations and works at 4 K. One dark frame will be taken maybe **every few minutes**, but it has to be adjusted from experience, depending on the homogeneity of the array and its evolution with time.

7) What was the main motivation in the **choice of the array size** ? Was it constrained by the optics, cryogenics, absorption efficiency or others ?

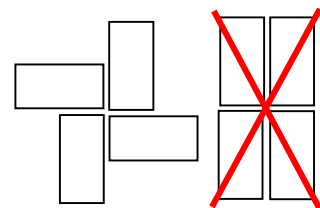
WH ; PA, RS:

The optics and cryogenics are not a big issue, but the microfabrication is the key element. the **minimum pixel size is driven by the wavelength** (must be $> \lambda$), this gives the minimum wafer size. The **maximum wafer size is driven by the microfabrication** tools, that is to say 3 inches in the labs involved. Hence this design with 4 sub arrays which are already the maximum size possible to put all that they contain. Doing more than 4 sub arrays would have been very difficult. In addition NIST SQUIDS process is well adapted to the chosen size; it would have been more expensive to up scale the multiplexer. Another argument for small wafers is the necessity to use wafers as flat as possible to perform a correct fusion bond of the 2 wafers used for the TESs and the hybridization of the TESs wafers to the MUX wafer. This flatness is better achieved with small wafers (3 inches) than bigger ones.

8) Why the **arrangement of the 4 arrays** on the focal plane is like a mill, and not like a big rectangle ?

WH:

Each individual array is rectangular because the SQUID array fabrication at NIST is limited to 3 inches wafers. The readout wires had to be put on the side, thus forcing the rectangle geometry. The 4 individual arrays were arranged in a mill shape and not in a big rectangle in order to maximize the sky coverage, in particular for **the DREAM operating mode where the star pattern allow to fill the gaps of the mill**.



The DREAM mode is obtained with the secondary mirror moving very fast in a star pattern; 40 ms is spent per branch.

9) What was the key **technology choice for the bolometers** ?

WH, Walter Gear:

The **Transition Edge Sensors (TESs)** were chosen, not the Neutron-Transmutation-Doped germanium bolometers (NTDs) or other semiconductors, nor other technologies (Superconducting Tunnel Junctions, Hot Electrons Bolometers, etc.), because only the TESs **looked ready** (or feasible) at the time of decision to build big arrays of photon noise limited bolometers.

WG: For **new arrays**, new emerging technologies may be very interesting, in particular **Kinetic Inductance Devices (KIDs)**.

10) How did you chose the different **microfabrication procedures** (choice of material, etching process, resists, etc.) ?

WH ; PA:

NIST people are working for a long time on their SQUID process. They **built** some **models** to predict the behavior of different layers depending on microfabrication choices (resists, deposition process, etching). Many wafers were worked, using models and **measurements** to diagnose wrong things and test new choices to **improve the processes**. It took a long time to get everything working properly. It was also a big investment for the TESs (which have much less layers than the SQUIDs) to get them reproducible without default and working well.

PA would like to reuse the technology for other applications. This could be done at much lower costs than this first development for SCUBA 2. He expect than any laboratory who would want to develop again a similar technology from scratch would face similar expenses as they did !

11) What is the meaning of “**sacrificial wire**” and “**etch handle**” in the process flow chart, and “**MCE**” in the article text ?

WH:

- Sacrificial wire: one additional wire bonding at the side of the detector wafer was connected to wires only (on electrical components) just to **test the electrical continuity** after the microfabrication process, then this bonding was cut (“sacrificed”) to limit the heat flux.
- Etch handle: remove the excess silicon from the 2 glued **wafers** used for the detector (TES) so that the **final thickness is $\lambda/4$** . The 2 glued wafers are thick enough to be handle easily during the hibridization process which is delicate. Indeed, the TES wafer and MUX wafer are bonded thanks to indium bumps requiring high precision to make contact at the right place and avoid to slip and break the wafers.
- **MCE = Multi Channel Electronics.**

12) Why do you use **2 wafers** glued together instead of a thicker one **for the TESs** substrate ?

WH:

The goal is to create a $\lambda/4$ cavity below the TESs to optimize the absorption, but a standard commercial wafer is thinner than $850/4 \mu\text{m}$. Though it adds an additional delicate microfabrication process to stick 2 wafers together very cleanly and etch them is **cheaper than** buying a **unique wafer with the correct thickness**.

13) Why did you choose a **hairbrush shape** for the focal plane holder and how is it **attached to the wafers** ?

WH ; PA, RS:

The **thermal link** between the detectors wafer and the dilution bath is done through this copper hairbrush. Its shape **maximizes the heat flow** from wafer to bath (vertical) and minimizes the heat flow in the perpendicular plan (horizontal).

It was difficult to **glue** the wafers to the hairbrush. After several tries, it appeared that a thin layer of **epoxy** was a good solution insuring a good thermal contact. With one spike per pixel on the hairbrush and the need to put epoxy only on the spikes, it was impossible to bond manually the complete area before the epoxy became solid. In the end a **robot** was bought and installed in Cardiff to **perform this specific task**.

14) What is used to **attach the dilution stage to the 4K box** ?

WH, Adam Woodcraft:

There is **no Kevlar string** (traditional method in other instruments) because it is not rigid enough for SCUBA 2 focal unit. Still it was necessary to get some attach points other than the dilution fridge cold finger alone. The objective was to attach the dilution unit the most rigidly possible to avoid vibrations and thermal constriction that would misalign the arrays. This was a big problem to solve and several solutions were considered. For instance a waived net Kevlar cloth was tested to hold the unit, but it was difficult to access the screws to mount all the elements of the arrays to the holders and the PCB boards. Finally the project team invented a mechanical **block made of sapphire washers and a ball-shaped copper link** with holes for screws. Several of these blocks are mounted on the 4K aluminum holder on one end and on the copper wafer holder on the other end.

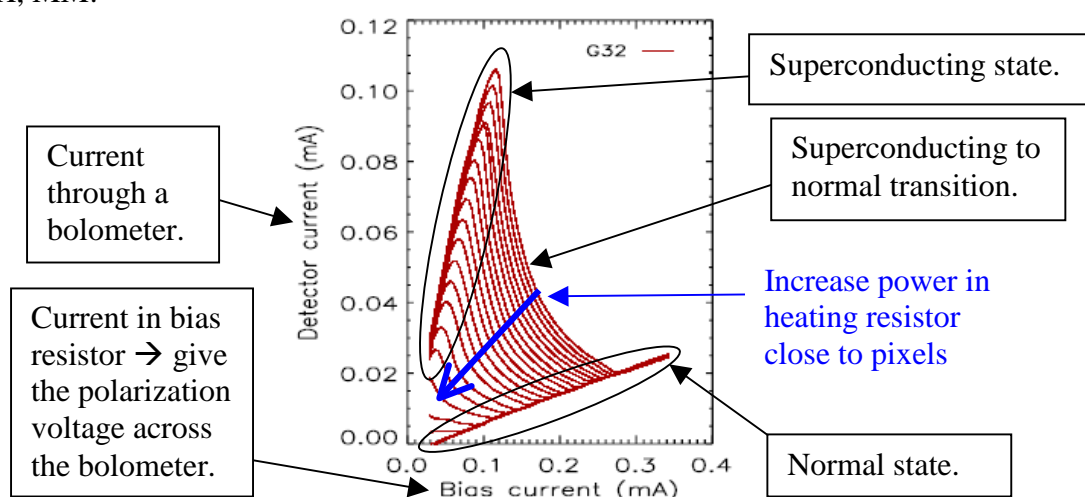
15) What were the most difficult parts for the construction of the instrument ?

WH, MM ; RS:

Cryogenics. Characterization of all pixels. Microfabrication. Many difficult parts...

16) Can you explain the **load curve** Fig.8 from the paper ?

WH, MM:



17) Why in the Table 2 of the paper, the **T_c** of the 450 μm bands and **NEP** of the 850 μm band are **higher for a single pixel than for the array** (NEP of the array should be higher because of the multiplexing dead time) ? And what is the **compromise** in the choice of **high T_c versus low T_c** ?

WH:

- For the 450 μm band the **T_c was lowered** from 193 mK for the single pixel to 173 mK for the more recent array in order to allow the TES to **respond to a bigger total power** (more dynamic). The ratio of Mo vs Cu is used to adjust the T_c. The compromise is that if the T_c is **too high** the pixel is **too noisy** and the “head room” (maximum load power before transition and therefore saturation) is too low, but if the T_c is **too low** the **heat capacity is too small** and creates a time constant too short for the multiplexing.
- For the 850 μm band the **NEP** of the **array** is a bit **better** than for the single pixel **because** the **microfabrication** process was **improved** (for example the shape of the heater resistors was redesign to be less noisy) **and a dark pixel**

was used in the array to subtract the systematic noise. The gain from these 2 improvements is more important than the loss due to the dead time of the multiplexing. Note that there is no leaking noise from the other pixels in a multiplexed row because there is no leaking current in the SQUIDs used as switches, unlike the transistors used to multiplex high impedance bolometers.

18) *Do you have any problem of **microphonic noise from the pulse tube** on the pixels signal ?*

WH, MM:

Yes, there was some microphonics problems to solve with the cryocoolers. **Deporting the moving parts** away from the cryostat 1 K box **fixed most of it**. Vibrations from cryocoolers were not causing too microphonics because the cryostat and all the system (cryocooler handlers and interface with the cryostat mainly) was designed to minimize this problem. Actually the vibrations from the cryocoolers created another problem not foreseen in the design process. It was **oscillations in the ^3He - ^4He dilution** (exchangers in resonance with vibrations). Once this problem was identified, moving parts away solved it.

Having all the cryogenic system working well took a long time. In addition to fixing leaks, many new things needed to be well tuned to optimize this new (and first in the world) commercial cryogen free dilution fridge. For example of the big problems to face was the absence of a 1 K pot, indeed the **cryocoolers limit is 3 K**, therefore some new special **additional heat exchangers** needed to be realized.

19) *What is your **procedure to measure the intrinsic noise** of all these pixels?*

MM:

The noise is measured with the usual **Fourier Transform** (FT) of the signals. **VI curves** are taken (see question 2), then a computer program performs the FTs.

The number of pixels was indeed a big and complex thing to face. There was an obvious need for a good **automated electronics** including addressing, feedback, bias, etc. There is still a need (SL: at the time of my visit in May) for some firmware improvement for the automation of unusual modes. One of them is the configuration and **reprogramming through fiber optics, rather than the usual Altera plug**, in order to make it evolve while the instrument is working. This would **avoid switching off the instrument**, warm it up and dismount it partially to access the programming socket.

With the electronics not totally completed, it was tricky to do characterizations with “pre-boards”. At first only few pixels were measured and the wires were switched by hand. The different elements of the detectors were characterized separately first, then together. This allowed the identification of the noise sources.

20) *Can you explicit the **different kinds of SQUIDs** used in the instrument ?*

WH, MM:

There are 3 stages using SQUIDs:

- 1 SQUID per TES is used for **pre-amplification**.
- 1 SQUID per column of pre-amplifier SQUIDs is used as a **multiplexer** switch.
- About 100 SQUIDs in series are used per column as an **amplifier** stage in the readout module.

The SQUIDs designed by NIST had no noise problem and were not a limiting factor. In particular the geometry of the SQUIDs wafer was designed to **minimize the cross-talk** between pixels.

21) How many pixels will be **multiplexed on a SQUID line** ?

MM:

40 pixels, this is roughly the limit where the pixel noise \times dead time (not reading) factor is low enough to meet the photon noise limit requirement. (For N pixels the additional noise due to the multiplexing dead time is roughly $\sqrt{N} \times$ one pixel noise on the amplification stage.)

22) Can't you use the fact that the time multiplexing acts as a lock-in, therefore shift the signal at a higher frequency domain, to fight against your **1/f noise limitation** ?

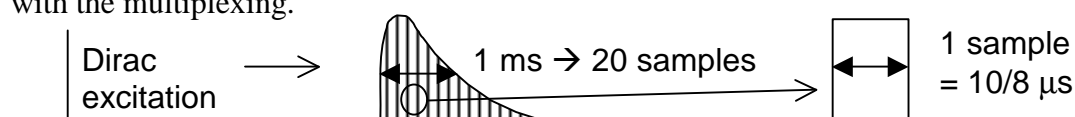
WH, MM:

The 1/f noise from electronics and/or(?) TESs indeed dominates the other noise sources and the multiplexing is indeed used as a lock-in. The **1/f noise knee is less than 1 Hz, but the tail at higher frequencies is big** enough to be a non negligible part in the remaining instrumental noise. There was a real fight in the microfabrication process to minimize this 1/f noise.

23) What is the **multiplexer integrator** and what is the **timing scheme** ?

WH, MM:

The TES **bolometer time constant is ~ 1 ms**; it is used as the integrator. The "switch" SQUID is turned on when the pixel is read and off the rest of the time. A **pixel is read at a frequency of 20 kHz** (inverse of time between 2 readings of the same pixel), and since there are **40 pixels** per MUX line, the rate of the pixel **switching** is $20 \times 40 = 800$ kHz (inverse of a pixel reading time). Note that $20 \text{ kHz} > 1/\tau = 1 \text{ kHz}$, so the pixel loading curve is well sampled and therefore no signal is lost with the multiplexing.



After amplification, the **samples** of a pixel are pre-processed (de-spiking, re-gridding, and other noise reduction tools) and **co-added** together by packets of 100 in a dedicated data acquisition computer, which **output a 200 Hz digitized signal** that is recorded into files.

24) What were the **unexpected causes of delay in the realization of SCUBA 2** ?

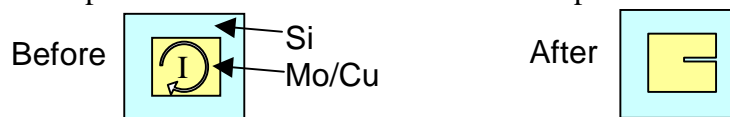
WH, MM:

A significant part of the delays was due to the **microfabrication of the SQUID multiplexer (MUX)**, mostly shorts in the tiny wiring. There is about 100 microfabrication steps to build the MUX ! There were also some problems in the TESs wafer, like shorts or pollutions. The **yield of good pixels** for the prototype array was about **50 %**, for the pre-commissioning array it reached 75 %, and for the **science grade array > 90 %** is expected.

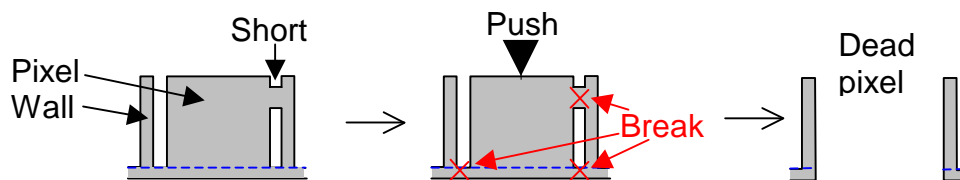
The main cause of the delays though was the **characterization of the instrument** (establish the good procedures and perform them).

Examples of problems that caused delay:

- Finding good **folding wires** between the TES plus SQUID arrays and the SQUID amplifiers and cold electronic module PCB took more time than expected.
- Mastering the **hybridization** of the TESs array and the SQUIDs array (bonding the indium bumps is a cold welding, everything sticks thanks to Van Der Waals forces, and it acts as an electrical link) was very delicate. For example once some pollution got between the 2 wafers and a huge part was etched out.
- For some time the electrical measurements showed a mysterious **excess noise** that seemed to come from the SQUIDs only when the TES were superconducting. Several tests led to the conclusion that the excess noise was due to magnetic perturbations created by a **current loop** in the pixel. The solution was to create a new mask for the TESs where a slot without metallic deposition prevented the formation of current loops.



- Diagnose and remove **shorts that occurred between a pixel and the wall frame**. This kind of problem is annoying because it almost kills a complete multiplexed row. From the pulses anomaly it is possible to locate roughly the wrong pixel. The solution is to remove the bad pixel so that the other pixels are not affected by the short. The bad pixel is pushed with a twister to break the sapphire thermal link at the bottom of the wafer, then it is removed thanks to a stick with some glue on one end. Afterward new electrical checks are performed to see if the pulses shapes are corrected.



24) *When SCUBA 2 will be working on JCMT ?*

WH:

Officially during summer 2007. Unofficially **winter 2007** is more likely.

About IRAM bolometer project:

All the members of SCUBA 2 team I met looked interested by our project of a new big field of view bolometer array on the 30m. Yet they seemed doubtful about the time remaining for us before new competitor telescopes better than IRAM are ready...

GISMO. 17-19 May 2007.

For a presentation of the technology used to built GISMO pixels and a correct understanding of the interview the reader is invited to read the various reports emailed by Johannes Staguhn about the progress in GISMO development, and the following papers (astro-ph June 2006):

“Thousand-element multiplexed superconducting bolometer arrays”

http://www.sofia.usra.edu/det_workshop/papers/session5/3-31benford_cr.pdf

&

“Characterization of TES bolometers used in 2-dimensional Backshort-Under-Grid (BUG) array for far-infrared astronomy”

http://safir.gsfc.nasa.gov/safire/SAFIRE_SciencePage_files/2006_NIMPRA_Staguhn_BUGs.pdf

0) Status of GISMO during my visit and general related information.

Mostly Johannes Staguhn and Dominic Benford:

Several **months ago** they did some tests with the **4K stage blanked off**, without filters underneath. They proved that their **TESs array worked perfectly**. **From electrical tests and behavior at low T** (IV curves and response time at different bias, and FFT noise study), **they are “incredibly” homogeneous and reproducible** (much better than SHARC).

During my visit the instrument was cooling down. They did another cool down between the last teleconference meeting and my visit, and they still had a **problem of excess power load on the detectors**.

The first measure they took was to add some **super-insulation** (many thin Mylar and Teflon intercalated sheets) between the 300K and 77K stages and between the 77K and 4K stages to reduce the stray light from 300K and 77K. It removed totally the THz leak from the 77K stage, but there was still some excess power.

To **diagnose** the origin of this excess power, **they blanked the 300 K entrance window with Al foils** for their following cold tests. In the run preceding my visit they added a **Cu plate with 1 cm wide holes** was added **on the 4 K stage**, close to the optical stop, to reduce the power load from the upper stages. The diagnostic was still going on.

For the **17/05/07 cool down**, even with pumping on the bath, the detectors were 20 mK higher than expected, meaning that the package in front of them was too hot. The Si lens thermometer indicated 3 K whereas the bath was pumped at 2 K. So **100-500 pW were in excess on the focal plane**.

A “crisis” meeting with all the GISMO team (~ 8 persons) was organized in Samuel Harvey Moseley office for a brain storming on the possible causes. Short summary to get a flavor of the spirit of the meeting:

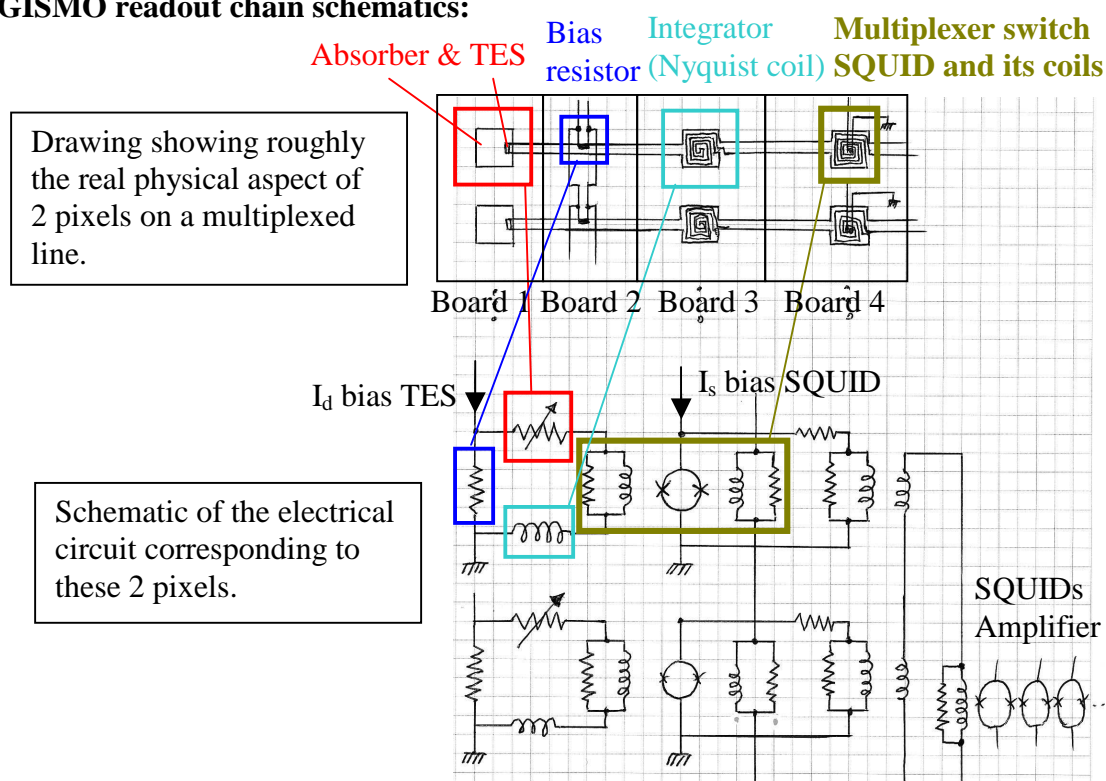
Could be Macor filter not thermalized ... but it was inconsistent with its own thermometer ... but the thermometer could be badly coupled to the Macor ... or have a problem ... unlikely from previous runs ... or it could be a heat load on the “package” (BP + array holder) due to a screw with a wrong thermal contact ... or

could be stray light from upper stages ... but the previous tests with the Cu plate full of holes and liquid helium in the liquid nitrogen compartment made no difference, so it is unlikely that the problem comes from the 77 K stage, neither the 300 K since the window was blanked off with Al foils ... puzzling ... strategy to find out: warm up, blank off the 4 K stage ... put a thermometer at the center of the Macor ... eventually trash all the density filters !

For information, at the time of LTD 12 they decided to trash every filter that was not from Cardiff; so they kept only the Edges, TB, and BP (and the Teflon window, baffles and Si lens of course).

Some other groups in LTD 12 suggested to use vacuum grease to improve the thermal contact between thermal bath and filters, other groups suggested to use screws into the filter edges to improve even more the thermal contact. Currently the contact is done through tight clamps.

GISMO readout chain schematics:



1) What **materials** is used to make the **TESs** ?

JS:

The TESs are **Mo/Au**, and not the usual Mo/Cu. The Cu is very sensitive to acid and oxidize very quickly. This was bad for a good homogeneity and reproducibility. Now with Au it is much better because Au is very inert.

2) Why did you thought **deep RIE** was not good for the microfabrication of 2mm pixels and why did you though **XeF₂** would be better ?

Christine Allen:

With **deep RIE** it is **difficult to have a good control of the slopes** and edges when etching “big” structures like the 2 mm pixels. The fact that XeF₂ is more aggressive can make think it would be better to etch big structures. But after several months of

tries, it turned out that **XeF₂** was **definitively too aggressive** and some parts of the wafers were systematically over etched. Finally it was decided to go **back to deep RIE** (with Ar⁺ ?) and thanks to a very meticulous protocol it was eventually possible to **control** very well the **slopes**, even on big structures.

3) *Is there a microfabrication process to optimize the **efficiency of the pixels** ?*

JS:

The commercial **Si wafers they use are 0.5 mm thick**, so exactly the right thickness to have $\lambda/4$. They are perfect (thickness, but also flatness) directly from the factory !

4) *How did you **glued the chip board to the ceramic wafer** ?*

JS, DB:

A very thin layer of **H74** was used. H74 is a kind of stycast **glue**.

4) *What is a **Nyquist inductor** ?*

JS:

This is a coil used in the TES electrical loop to **integrate the signal between 2 readings** of the multiplexer (RL circuit). It acts also as a filter due to the integrator bandwidth.

5) *What is the **breakout board** ?*

JS:

This is the **amplification** system made of hundreds of **SQUIDs** in series contained in a **box shielded by μ -metal** on the 4K stage.

6) *What is the **T_c of the TESs** and why did you change it from previous versions to the current one ?*

JS:

Originally it was about 450 mK, but it was lowered around **280 mK** to increase the dynamic range of the TESs. Actually it now reaches the limits of the ³He pump. Going at lower T_c would require either a dilution fridge or an adiabatic demagnetization fridge (ADM). The latter one is favored because it has potentially less cryogenic problems.

7) *What **limits the number of pixels that can be multiplexed** by a SQUID (typically 40 pixels) ?*

JS:

The working **bandwidth of the SQUID** increases with the number of pixels to multiplex. The 1/f and with noises are integrated over the complete bandwidth, therefore limit the number of pixel for a given signal to noise ratio. This is equivalent to say that the time lost not reading a pixel is time spent reading noise.

8) *What do you use to **monitor the temperatures** of the different stages of the instrument ?*

DB:

The thermometry used is diodes for the upper T stages, and **Cernox** for the intermediate and cold stages. Cernox have very good sensitivity coefficient ($\alpha \approx 1$) in a wide range of temperature (see <http://www.lakeshore.com/temp/sen/crtd.html>), they are much better in that respect than the RuO₂ traditionally used in low temperature

experiments. About 20 thermometers with 4 wire-bridges readout are used in the cryostat. Some of them are multiplexed.

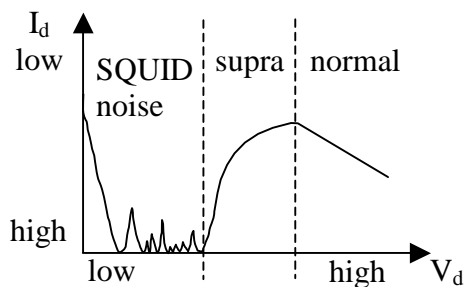
9) *How is done the wiring of the 100s of connections between the TES wafer, the bias resistors board, the Nyquist coils board and the SQUIDs board ?*

JS:

Everything is done by hand (there is no robot !), but as can be seen from microscope pictures, this is nicely done.

10) *Can you explain the **behavior** at low V of the **IV curve** you showed at the 23/04 meeting, and why it is inverted (low I is at the maximum of the y axis) ?*

JS:



The y axis represent the detector current feedback (I_d), the x axis represent the voltage into the dewar (V_d). At low V_d , the voltage is not high enough to bias the detector and the amplification SQUID read only the noise from the SQUID AC bias. Once V_d is high enough the SQUID commutes and amplifies I_d . **The direction of I_d is given by the direction of the AC at**

the time the SQUID commuted. So the direction of I_d is totally random, **what counts is the absolute slope change between the superconducting region and the normal region.**

11) *Do you have **heaters on the pixels** for a better characterization of electrical versus thermal effects ?*

DB:

No, we hope the pixels work as intended and no debugging would be necessary. If needed, it will still be possible to play with the thermal bath temperature and analyze the system response in the frequency domain.

12) *How do you characterize the noise of the instrument and the thermal conductivity of the different elements ?*

JS:

Done through electrical measurements at different bias, and FFT on signals.

13) *Are the **RF and magnetic problems** solved ?*

JS:

Yes, better shielding solved these problems. The optical shielding was improved with the **baffles and the super-insulator** between the different temperature stages, the electrical shielding was improved with a better cabling, notably **flexible cable in kapton ribbon**, the magnetic shielding was improved with solid **μ -metal** around the SQUID box and around the focal plane.

14) *You use **CMOS** in the **address board**, but aren't they too **noisy** and usually used for high impedance circuits ?*

JS:

They are just used as **switches** to control the SQUIDs states (on/off), and since the **SQUIDs have no leakage current**, the CMOS have no effect on the noise.

15) What are the different **noise components** of the instrument and their respective power ?

DB:

The objectives for the noise components are:

- higher = **photon noise** from atmosphere + optics.
- much lower = **phonon noise** from detectors.
- much much lower = **SQUID and readout chain** (1/f noise, SQUID flux noise,...)

The **phonon noise in the TESs dominates the instrumental noise**, it is $\approx \sqrt{2} \times$ the Johnson noise and $\approx 10 \times$ the SQUID readout noise. The additional noise due to multiplexing N pixels is $\approx \sqrt{N} \times$ the noise of a SQUID reading 1 pixel. The 1/f noise knee is about 2 Hz, and the tail is negligible in the system bandwidth.

16) How was done the **absorption tests of the TESs** with a light source ? What is the result ?

JS:

A resistor was attached to a plate on the **4 K stage** which **was blanked off** to higher temperature stages. The results gave a **90% efficiency** for the pixels ! These are very good news; the only problem remaining is to fix the excess power from high temperature stages and do the test with the cryostat window open to external world.

17) How many **filters** are in the optical path ?

JS:

There were **about 12 filtering elements** in the cryostat optical path for the 17/05/2007 cool down:

- 300 K \rightarrow the Teflon window and a Thermal Blocker (TB) at 300 K.
- 77 K \rightarrow a polypropylene (PP) layer supporting a Zitex layer (white Teflon foam used as a neutral density filter), a low-pass Edge filter (multi layers of Cu meshes in a PP substrate), and a low-pass Thermal Blocker (TB) (same as Edge but with a less constrained transmission function).
- 4 K \rightarrow a PP + Zitex layer, followed by a several centimeter long black painted baffles tube, followed by another Zitex layer on the Si lens, an Edge and a Macor plate (glassy ceramic used as a neutral density filter).
- 0.3 K \rightarrow the Band-Pass filter and the detectors.

Peter Ade from Cardiff sold them the Edges, TBs and the BP. He told them their optical design was good for their needs.

The Macor seems to pose problem, it will be removed and replaced by a quartz window or nothing. The **total efficiency of the filters is about 50%**.

18) Was the **Si lens** optically tested ?

JS:

Yes, and it is **very good**; no problem at all from that part.

19) What is the status of the **77K THz leak** evocated during 23/04 meeting ?

JS:

The **super-insulator** was used to **fix this THz leak**. To check its efficiency a test was done putting liquid He in the liquid N₂ tank; no effect was seen on the pixels response, meaning that there was no more radiative leaks from the 77K stage...

But there was still some unexpected excess power on the detectors. So another cool down was done, using the Cu plate with 1cm diameter holes on the 4K stage. The plate was close enough to the pupil (the cold Si lens) to act as a stop (decrease only the power from upper stages, the holes are not imaged on the detectors). There was still some excess power during the 17/05 run, meaning that something was wrong with the optical elements of the 4K stage (one or several filters would not thermalize).

20) *Will it be necessary to use the wobbler (M2) during observations with GISMO ?*

JS, DB:

Yes because that permits to remove efficiently most of the sky noise.

The best observing mode for noise reduction would be to do **Lissajou** figures with the telescope while mapping. The Lissajou pattern covers a maximum space with a minimum jerk (derivative of acceleration).

21) *How is the **chopper** that will be used to the **simulation of the wobbler** ?*

DB:

This is a **metallic disk, 10 cm in diameter**, with 2 holes of a $\frac{1}{4}$ turn each acting as **top hat function**, thus creating a crenel transfer function. It will be used in front of the cryostat window for the optical test. It has never been done yet for GISMO, but the chopper is ready to be used.

22) *What is the status of the **data acquisition and data processing** ?*

JS:

Edward Wollack gave a modified version of the **SHARC acquisition program**; this GISMO version is almost ready. Somebody else gave a modified GUI from the **SHARC “astro package” for the data processing**.

23) *Is the access to documentation and discussion with IRAM people about telescope parameter files as you wish ?*

JS:

It was long to have the correct persons talking fruitfully to each other, in particular to get the necessary information about the data stream and correct interface with the telescope control flow. But everything looks OK now, the work on the data acquisition system interface is in progress.

LTD 12. 22-27 July 2007.

The Low Temperature Detector is held every 2 years in different parts of the world. For this edition the talks were divided into 21 sessions:

1. Session A: Tutorials
2. Session B: General detector physics
3. Session C: TES detectors (Transition Edge Sensors detectors): Physics
4. Session D: TES detectors: Fabrication
5. Session E: STJ detectors (Superconducting Tunnel Junctions)
6. Session F: MMC (Metallic Magnetic Calorimeters)
7. Session G: Thermistor detectors
8. Session H: Studies on detector absorbers
9. Session J: Instrumental design
10. Session K: KIDs (Kinetic Inductance Detectors)
11. Session L: Nanowires, Hot electron bolometers
12. Session M: Neutrino physics
13. Session N: Cryogenic techniques and materials
14. Session P: Astronomy, from microwaves to gamma rays
15. Session Q: Material analysis and life science
16. Session R: Dark matter search
17. Session S: Detectors with background rejection capabilities
18. Session T: SQUIDs, electronics and multiplexing
19. Session U: Signal readout and processing
20. Session V: Quantum electronics
21. Session W: Atomic, nuclear and particle physics

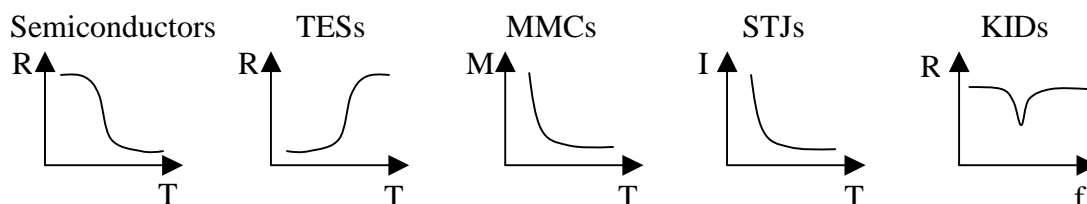
In the following I give few words overviews of the talks that I think interesting regarding IRAM activities. More information can be found in the abstract booklet available on the conference website (<http://www.ltd12.org/>) or in the IRAM library and in the conference proceedings that would be in the library this autumn 2007.

Session A, tutorials:

Physical principles of LTDs. D.McCammon (University of Wisconsin). Talk A01.

Advantages of LTDs over ionization detectors. Applications: dark matter, solar neutrino, microwaves, X-rays & gamma rays, nuclear physics, biology.

Calorimeter (bolometer) principles



Electron-phonon coupling, fundamental noise, fundamental equations for the different kinds of LTDs.

Session B, detectors physics:

PACS bolometer arrays for ground-based telescope. V.Reveret (ESO). Talk B02.

PACs instrument on Hershel space telescope. $\lambda = 60 - 200 \mu\text{m}$.

Pixel design: Si semiconductor, grid, $\lambda/4$ cavity. $\text{NEP} \approx 10^{-16} \text{ W}/\sqrt{\text{Hz}}$.

Ground study ARTEMIS:

$\lambda [\mu\text{m}]$	200	350	450	865
P [W]	70	34	40	8
beam [arcsec]	4	8		

Absorption: 2D resonance depending on ν thanks to an absorption layer above the grid. Laboratory spectral measurements agree with simulations.

Solutions for 3 simultaneous bands = project ARTEMIS. Prototype tested on APEX:

$\text{NEFD} \approx 6 \text{ Jy} \cdot \sqrt{\text{s}} \rightarrow$ factor 3 to gain to reach the goals.

NbSi bolometers: a versatile approach for large arrays. P.Camus (CNRS/Institut Nee). Poster B04.

NbSi can be used as a semiconductor or a TES depending on Nb ratio.

2 major problems in the actual status of semiconductor NbSi arrays: high R anomaly is back (it was a problem during my thesis, they though they found a solution last year, but it is back on some samples); antenna absorber are not so good \rightarrow development in progress, lack of manpower, no clear schedule.

A.Benoit: but 3 test cryostats ready, electronics ready, optical design ready.

Session C, TES physics:

Introduction to TES physics. B.Cabrera (Stanford University). Talk C01.

3 types of TESs:

Direct operation



With absorber



Large mass absorber



Basic concepts: coefficient of temperature α , dissipation power P_J , Bias voltage V , SQUIDs readout.

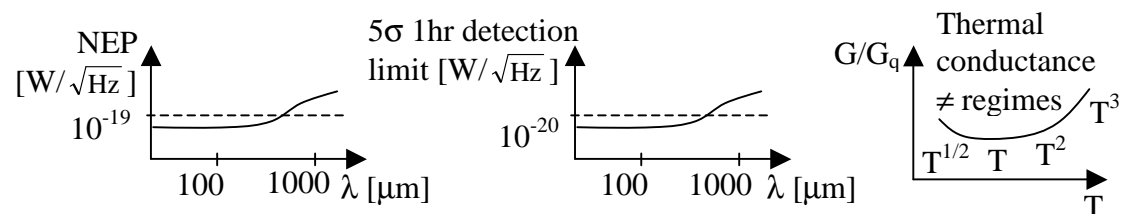
Electrothermal feedback, electron-phonon coupling \rightarrow energy equation.

Time response, sensitivity, IV curves, E saturation.

Adjustment of T_c . 3D plots (R,T,V). Excess noise study.

Electrical properties of background limited membrane-isolated TES bolometers for IR/submm spectroscopy. M.Kenyon (JPL). Talk C05.

Mo/Au bilayer TESs with a transition temperature $T_c \approx 70 \text{ mK}$, patterned onto a suspended Si_3N_4 membrane.



Thermal conductance model with ballistic 1D transport: $G_q \sim 4\pi^2 k_B^2 T/3h$.

$NEP \sim \sqrt{4k_B T^2 G}$ very low thanks to very low thermal conductance $G \approx 10^{-19}$ W/K.

Price to pay: effective time constant slow $\tau \approx 200$ ms.

1D and 2D arrays (32×32 pixels) built. Application: Background Limited far-IR and Submillimeter Spectrometer (BLISS, JPL) on the SPICA 3.5m 4.5K space telescope (JAXA).

Minimizing excess noise in Au/Ti TESs. I.Maasilta (University of Jyväskylä). Talk C06.

For X-ray application, but interesting effects of TES geometry on excess noise figures.

Sensitivity measurements of a TES hot-electron microbolometer for millimeter-wave astrophysical observations. E.Barentine (University of Wisconsin-Madison, NASA GSFC). Poster C16.

Goddard (Moseley team) development for future Cosmic Microwave Background polarized observations with 1000s of bolometers.

Accurate thermal conductance and impedance measurements of TESs. M.A.Lindeman (University of Wisconsin). Poster C17.

New technique to measure the thermal coupling of superconducting TESs on SiN membranes. The other techniques usually employed are too susceptible to current dependence of the phase transition of the TESs.

Session D, TES fabrication:

Excess voltage noises at the superconducting transition of Tin films. F.Zuo (University of Miami). Talk D01.

Excess noise was observed for several years in TESs, but it was still unexplained during LTD 11. Now several groups found explanations for this excess noise:

Goddard: Johnson noise from non-ohmic parts of their TESs.

SRON: Internal fluctuations in their TESs.

This talk: evidences of Kosterlitz-Thouless transitions in Tin Mo/Au TESs argue in favor of vortex noise.

Material development for auxiliary components for large compact Mo/Au TES arrays. J.Chervenak (NASA GSFC). Poster D13.

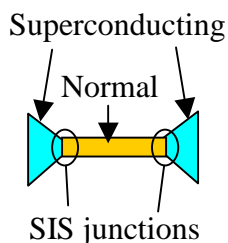
For X-ray application, but interesting studies in microfabrication processes for Mo/Au TES bolometers.

Design and fabrication highlights enabling a 2 mm, 128 element bolometer array for GISMO. C.Allen (NASA GSFC). Poster D16.

Presentation of the Backshort-Under-Grid (BUG) superconducting bolometer array architecture. 3 year program to build 1000 pixels arrays. Validate design with 128 Mo/Au pixels for 2 mm wavelength instrument called GISMO. Presentation of the microfabrication process for high pixel yield, low noise, and high uniformity.

Session E, STJ:

A superconducting Cold-Electron Bolometer (SCEB) with SIS tunnel junction and Josephson junction for cosmology instruments. L.Kuzmin (Chalmers University of Technology). Talk E03.



Technology chosen for Boomerang 3, dedicated to CMB polarized observations:

$n = 350$ GHz, 90 channels, 0.3 K pumped ^3He fridge, 5 pW/channel, $\text{NEP} = 5 \times 10^{-17} \text{ W}/\sqrt{\text{Hz}}$, polarization resolution = 40 dB.

The SIS junctions create problems for the SQUID readout. Different asymmetric design tested: SN-SIS, SI-SII with JFET readout. Under development.

Realization of submillimeter-wave imaging array with superconducting direct detectors. H.Matsuo (National Astronomical Observatory of Japan). Talk E05.

SIS photon detectors in development. theoretical $\text{NEP} \approx 3 \times 10^{-17} \text{ W}/\sqrt{\text{Hz}}$, but current 6×6 array at 0.3 K has $\text{NEP} \approx 10^{-16} \text{ W}/\sqrt{\text{Hz}}$, leakage current ≈ 10 pA/junction, efficiency ≈ 20 -60%, dynamic range $\approx 10^7$, $\tau < 1$ ns. GaAs JFET readout.

Future instrument: SISCAM-9 ($\nu = 650$ GHz) on ASTE (10m telescope in Atacama).

Session G, Thermistor:

Fabrication and optical characterization of antenna bolometer arrays. T.Durand (CRNS Institut Neel). Poster G04.

Progress in the fabrication of NbSi antenna bolometers. Martin-Puplett interferometer developed and used to measure the pixels responsivity from 60 GHz to 3000 GHz. Disagreement with simulations.

Session J, instrumental design:

My bolometer is running a fever (...) very low noise requires careful design. D.Yvon (CES Saclay DAPNIA/SPP). Talk J01.

Target $\rightarrow 5$ arcmin, 5 μK noise, $2 \times 10^{-18} \text{ W}/\text{pixel}$ sensitivity.

Problems: pick-up noise (microphonics, tribo-electric, ...), bad environment (power supply, ...), EMI/EMC.

Solutions: Differential readout, grounding, shielding, cabling, contacts, cryogenics, mechanics.

Application: Planck satellite.

GISMO: a 2 mm bolometer camera optimized for the study of high redshift galaxies (was originally scheduled in session P). J.Staguhn (NASA GSFC). Talk J02. Presentation of the BUG technology for the TESs developed in GSFC. Instruments: FIBRE, SHARC II, GISMO.

Photon noise on the 2mm pixels of GISMO: $\text{NEP} \approx 10^{-16} \text{ W}/\sqrt{\text{Hz}}$.

TESs have background-limited sensitivities, high filling factor and $\lambda/4$ reflective backshort grid providing high optical efficiency, bump-bonded SQUIDs multiplexed readout.

Objective for GISMO: 1 source at 5σ for 4 hours integration time.

Presentation of the optics, focal plane integration, Si lens, filters, and electronics.

Laboratory tests: IV curves, optical tests at 300 K (moving hand), and with closed window and warm baffles.

Short presentation of the acquisition software.

Indium hybridization of large format TES bolometer arrays to readout multiplexers for far-IR astronomy. T.Miller (NASA GSFC). Poster J09.

Demonstrating electrical connectivity of a 32×40 element of TES detectors on a mock NIST multiplexer, thanks to hybridization with 10-12 μm indium bumps.

Superconducting TES bolometer with integrated electron-tunneling refrigerators. R.Silverberg (NASA GSFC). Poster J10.

Development of TES bolometers for millimeter wavelength, using integrated Normal-Insulator-Superconductor (NIS) refrigerators to cool each bolometer 100 mK below the 280 mK of the ^3He pumped reference bath. NIS are placed at the base of the 4 suspension legs controlling the thermal conductance of a bolometer, and the cooling effect is obtained by removing hot electrons thanks to quantum mechanical tunneling. A prototype will be used for 3mm observation on the Green Bank Telescope.

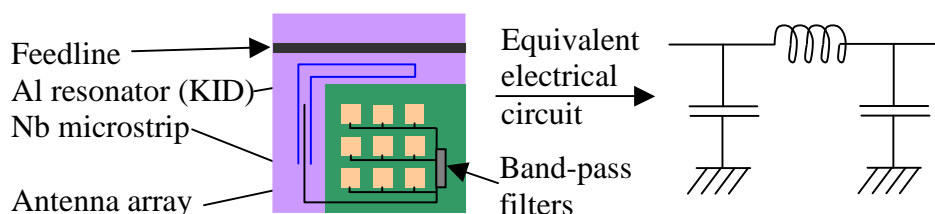
Large bolometer array with superconducting NbSi sensors for future space experiments. F.Pajot (CNRS-IAS). Poster J14.

The required sensitivity to study the polarized optical component of the CMB is 2 orders of magnitude better than the Planck mission. This can be obtained by large arrays of a few 10000 pixels fully covering the telescope focal plane. NbSi alloy superconducting thermometers are being studied and characterized to build such an instrument.

Session K, KID:

Antenna-coupled Kinetic Inductance Detectors for millimeter and submillimeter imaging. A.Vayonakis (Caltech, JPL). Talk K01.

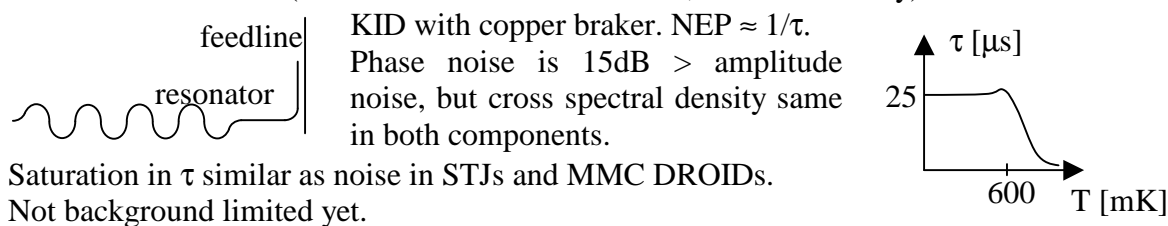
Antenna-coupled Microwave Kinetic Inductance Detectors (MKID) are easily fabricated and many detectors can be frequency multiplexed through a single feedline with a lot of bandwidth using a cryogenic microwave amplifier and warm electronics.



The quasiparticles are created in the KID either by microwave power absorbed by the antenna or by change of temperature of the thermal bath (tests from 200 to 800 mK).

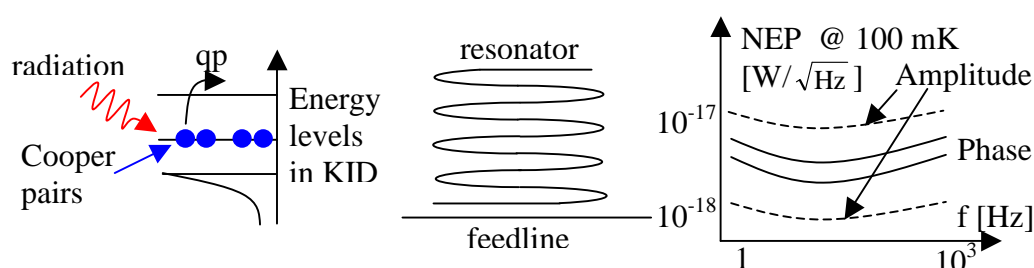
A 6×6 pixels demonstrator has been tested on a telescope in the 150-250 GHz range: picture of Jupiter.

Quasiparticle lifetime and noise in tantalum high Q superconducting resonators for KIDs. R.Barends (Kalvi Institute of Nanoscience, Delft University). Talk K02.



Noise and sensitivity of Al KIDs for sub-mm astronomy. J.Baselmans (SRON). Talk K03.

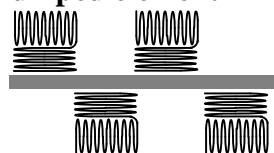
Study of MKIDs with thin Al film $\lambda/4$ coplanar waveguide resonator of different deposited thickness. NEP measurement as a function of temperature and power;



depends on quasi-particle (qp) density and lifetime.

Phase NEP limited by excess noise, amplitude NEP limited by setup noise (readout electronics).

Lumped element KIDs. S.Doyle (Cardiff University). Talk K04.



LeKIDs are like usual KIDs, but much smaller with more meanders in the resonator. No antenna is needed with this design, a high filling factor and multiplexing are possible, with the same responsivity as usual KIDs.

Session L: Nanowire, Hot electron bolometer:

Superconducting hot-electron bolometer (HEB) mixers for THz low noise heterodyne receivers. S.Cherednichenko (Chalmers University). Poster L04.

HEB mixers for low noise heterodynes using planar antennas for both the signal and the Local Oscillator (LO). At 2 GHz Intermediate Frequency (IF) the double sideband noise temperature of 350 K to 1100 K is achieved for LO frequencies from 500 GHz to 2.5 THz. Temperature model of the bandwidth, materials to increase the bandwidth and micromachining techniques to create HEB arrays are discussed. Application in the Herschel Space Observatory,

Session N: Cryogenic:

Development of superconducting coaxial cables for cryogenic detectors.

A.Kushino (Asahikawa National College of Technology, Coax.Co.LTD). Poster N05

A completely self-contained cryogen-free dilution refrigerator, the TritonDRTM. V.Mikheev (Oxford Instrument). Poster N08.

Session P: Astronomy

Astronomy: individual photon detection from IR to X-rays. P.Verhoeve (ESA ESTEC). Talk P01.

Goal for 2015-2020: multiplexed kilopixel 2 eV resolution in 0.1-10 keV range.

TES: GSFC, NIST, SRON, JAXA → active groups close to goal.

MMC: pioneered at Heidelberg → no bias, no dissipation, but slow.

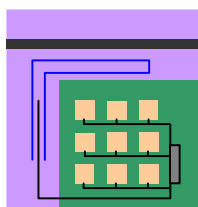
STJ: → best resolution @ 6 keV, but non-uniform, no progress since few years.

MKID: → great potential.

LTDs γ -rays: some developments going on → ~30 eV @ 60 keV.

LTDs UV/Vis/IR: some niches → fast photometry & spectroscopy.

A millimeter and submillimeter KID camera. J.Schlaerth (California Institute of Technology). Talk P02.



Antenna coupled MKID, for $\nu \approx 240$ and 350 GHz. 16 antenna DemoCam tested on Jupiter, and raster scan on Saturn. $\text{NEFD}(240\text{GHz}) \approx 1.5 \text{ Jy}\sqrt{\text{s}}$, $\text{NEFD}(350\text{GHz}) \approx 10 \text{ Jy}\sqrt{\text{s}}$. The sensitivities are limited by the optical efficiency (filters, antenna coupling), and the detectors need a higher Q. A better instrument is in progress.

The final camera will have 576 antennas feeding 4 different wavebands - 0.75, 0.85, 1.1 and 1.3 mm – providing ≈ 2400 detectors read out simultaneously. This instrument is planned to be the successor of Bolocam on the CSO by 2010.

A kilopixel array of TES bolometers for ACT: development, testing and first light. M.Niemack (Princeton University). Talk P03.

Science case: CMB, SZ, lensing, neutrinos...

The mm Bolometer Array Camera (MBAC) will contain 145 GHz diffraction-limited 1024 TES pixels (largest Pop-Up-Detector array ever fielded). It will be mounted on the 6m Atacama Cosmology Telescope (ACT). The parameters driving the design are the noise, power saturation, and time constant. There will be time domain multiplexing with SQUIDs. The SQUID flux noise $\approx 0.5 \mu\Phi/\sqrt{\text{Hz}}$, creating a current noise $\approx 4\text{pA}/\sqrt{\text{Hz}}$, for a total multiplexed pixel $\text{NEP}_{10\text{Hz}} \approx 2\text{-}6 \times 10^{-17} \text{ W}/\sqrt{\text{Hz}}$. Evanescently coupled Si layers match the bolometers impedance to the sky, providing a 80% efficiency. The good pixel yield is 90%. Nyquist inductors minimize the aliasing. Time constants are tested with a chopper. CCam prototype on ACT.

TES bolometer array for the APEX-SZ camera. J.Mehl (University of California Berkeley). Talk P05.

Instrument characteristics: 320 pixels, SQUID frequency domain multiplexing, pulse tube cooling, feed horns, spider-web absorbers, Al/Ti TES, $R_n = 1.2 \Omega$, $\tau = 9 \text{ ms}$, $T_c = 450 \text{ mK}$, $G = 200 \mu\text{W/K}$, Si wafers, $\lambda/4$ cavity, AC bias of bolometers in 200 kHz – 1 MHz range.

Problems with $\tau \rightarrow$ play on heat capacity.

Session T, SQUIDs and multiplexing:

Readout of large-format low-temperature detector arrays. K.Irwin (NIST). Talk T01.

Evolution 1960-2000: sensitivity $\times 10^8$, number of pixels $\times 10^2$, speed (mapping) $\times 10^{18}$, all following Moore's law with doubling every 18 months !

Multiplexing: limited bandwidth, filters (L/R or RC low-pass, or LC resonators), signal modulation, signal addition, demultiplexing. 2 methods: time multiplexing and frequency multiplexing. SQUIDs can be used for both. Filters limiting the bandwidth are needed to limit the noise, otherwise aliasing (folding noise) dominates.

NIST provided SQUIDs multiplexers: time domain for SCUBA 2, frequency domain for instruments on APEX, from Berkeley and SRON.

Goal for the future: multiplexing ~ 250000 pixels. How ? \rightarrow bandwidth need to be increased to get >1000 pixels/channel \rightarrow GHz HEMTs and dissipation-less SQUIDs are needed ... and under development !

Read-out electronics for time-domain multiplexed bolometers for millimetric and sub-millimetric astronomy. E.S.Battistelli (University of British Columbia). Talk T03.

Multi-channel electronics (MCE) controlling SQUIDs amplifiers and NIST multiplexer were developed. One MCE box reads the signals of 32×41 TES pixels sub-array. A MCE consists of hybrid analog/digital hardware and firmware developed for Altera FPGAs. The signals are read through 14-bit, 50MHz ADCs. A running PID-calculation determines the SQUID feedback necessary keep the amplification chain linear at optimal gain. Initially developed for SCUBA 2 10000 pixels, it is used in other instruments such as ACT, CIOVER, SPIDER, BICEP, SPUD.

Noise analysis of microwave frequency division multiplexers. K.W.Lehnert (JILA University of Colorado, NIST). Talk T04.

A series of many SQUIDs per HEMT amplifier convert the current at the output of a LTD into a shift in the resonance frequency of a high-Q superconducting resonant circuit. HEMT dynamic range ≈ 170 dB/Hz, $Q \approx 4000 - 20000$, low dissipation power (~ 2.4 pW) and low flux noise ($0.17 \mu\Phi/\sqrt{\text{Hz}}$ @ 100 kHz) per SQUID $\rightarrow 400 - 1000$ pixels can be multiplexed. This technology is well suited for TESs and MMC. A 32 resonators multiplexer prototype is being build.

A TDMA SQUID multiplexer for the read-out of high-speed large format detector arrays. C. Reintsema (NIST). Poster T08.

A multiplexed read-out for TESs based on hybrid time and frequency domain basis, similar to that used in time-division multiple-access (TDMA) mobile phones.

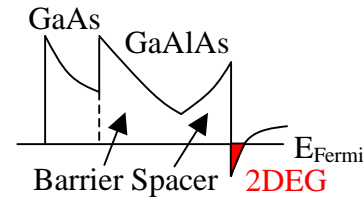
A time domain multiplexer for large arrays of high impedance low temperature bolometers. C.Hoffmann (CRNS Institut Neel). Poster T12.

A time domain multiplexer for high impedance bolometer arrays was built, using quantum-point-contact high-electron-mobility-transistors (QPC-HEMT) as low temperature switches and a cold FET amplifier with programmable auto-zero-circuit. This system will be used for the mm-wave bolometric camera developed for the 30m IRAM telescope.

Session U, Signal readout:

Development of ultra-low noise HEMTs for cryoelectronics at 4.2 K. Y.Jin (CNRS LPN). Talk U02.

In high electron mobility transistors (HEMTs) electrons of a two-dimensional electron gas (2DEG) reside in a very pure crystal and are isolated from donors by a spacer layer. Electron-donor collisions and electron frozen at ionized donors can be avoided at low temperature, thus improving noise performances. LPN built high performance low-power and low frequency HEMTs working at low temperature for the readout of LTDs. The electron mobility of their HEMT 2DEG is $\sim 8000 \text{ cm}^2/\text{Vs}$ @ 300 K and reach $\sim 800000 \text{ cm}^2/\text{Vs}$ @ 4 K. Very low input voltage noises were achieved: 1.2, 0.3 and 0.1 nV/ $\sqrt{\text{Hz}}$ at 1, 10 and 100 kHz respectively.



Software framework concepts to support high rate detector system. S.Maher (NASA GSFC). Poster U08.

A generic Java framework provides a mechanism to “plug-in” various modules (algorithms, visualizations, archivers) for real-time analysis and data reduction of various types of LTDs. I think they use this system for GISMO...

Norton-corrected measurement of complex impedances of a large format bolometer array. D.Benford (NASA GSFC). Poster U13.

Application to GISMO of a method based on Norton equivalent circuit to measure with precision complex impedances of bolometers in a time domain multiplexed array.