Meeting to discuss use of Kevlar at low temperatures
B. Swinyard

A meeting was held at Estec on the 19th March 2003 to discuss the use of Kevlar cord for the suspension of sub-kelvin systems within the SPIRE and PACS instrument on the Herschel mission.

Present:
Gary Parks (JPL)
Henry Abakians (JPL)
Graham Coe (Estec)
Astrid Heske (Estec)
Sam Heys (RAL)
Carsten Scharmberg (Estec)
Jan Rautakoski (Estec)
Lionel Duband (CEA-SBT)
Peter Hargrave (Cardiff University)
Doug Griffin (RAL)
Bruce Swinyard (RAL – Chair)
Louis Rodriguez (CEA – SAp)
Jerome Martignac (CEA –SAp)

Objectives:
(A_Intro_Kevler_moot.ppt)
Bruce Swinyard
The objectives of this meeting were set out before the meeting as:

- Assess all the testing on Kevlar and Kevlar suspended units in SPIRE and PACS
- Come to a common understanding about the mechanisms leading to the changes found in the performance of Kevlar from warm to cold
- Assess the qualification status of the SPIRE and PACS coolers
- Agree on 0.29/0.5 mm Kevlar for evaporator or a process to decide
- Assess the qualification status of the SPIRE (and PACS?) detector suspension
- Assess the qualification status of the SPIRE (and PACS?) 300 mK strap support units

It was initially thought that this meeting would be a formal Material Review Board (MRB) on the change in performance of the STM coolers from warm to cold under vibration. However, since the test that was carried is seen only as a characterisation (see below), no NCR was raised and therefore no formal MRB need be convened. The meeting should be seen rather as a technical discussion meeting to assess best practice and to map a way forward for the use of Kevlar in the context of the Herschel project.

The notes taken at the meeting and reported here are intended to highlight issues raised in discussion of the presentations.

SPIRE Systems Considerations
(*B_SPIRE_Kevlar_moot.ppt)*
Doug Griffin
SPIRE needs to meet a 48 hour cooler hold time specification for scientific and programmatic reasons. At present the thermal model predicts 30-34 hours. Design changes are required to allow SPIRE to meet the 48 hour specification.
In order to meet this SPIRE will “Spread Pain” between subsystems to reduce the thermal load into 300 mK stage.

In particular the thermal difference between ∅0.29mm and ∅0.5mm Kevlar roughly corresponds to 4 hours in hold time. Therefore the use of 0.29 mm Kevlar to support the evaporator is highly desirable to get loads down.

Comment from Lionel Duband – the cold vibration test was not considered a full qualification test but just "a characterisation test". The STM cooler was not configured for thermal

SPIRE/PACS Coolers
(*C_Cooler_Kevlar_moot.ppt)*
Lionel Duband
Note that the latest version of the test report from SBT is HSO-SBT-TN 046 Issue 1.4
"Experimental Characterisation of Kevlar 29 Cords"

New method of measuring young's modulus with Invar struture.
There is a Hysteris in the measurement at room temperature but not at LN2 temp.
Loss of tension with thermal cycling – repeats after bake out even after re-tensioning.
Looks like it could be associated with moisture.

Experiment set up to measure resonant frequency as function of tension – there is an effect. SBT are now trying to model this and look at what happens at low temperature. Just this effect does not fully explain why there was such a large shift in resonant frequency warm to cold.

(Note in proof: In fact Lionel has now realised that the cooler "heart" in the STM was made of Aluminium – therefore there was a large change in tension in the cords associated with the differential CTE between the Ti structure and the Al heart)

Astrid Heske asked is it the same type of cord in all tests –
Yes it is Cousin Filterie twisted rope with resin to hold it. There is no specification on the resin from the manufacturer.

Jerome Martingac asked if there is any slipping –
No the signatures are the classic resonant response.

Doug Griffin asked can you increase the pre-load to prevent the slipping in the 0.29 mm case –
Yes but Lionel prefers not to exceed 50% of the breaking strength.

Graham Coe asked whether thermal conductivity measurements have been done on this cord –
The Performance of the EM model is in line with Lionel's home measured data. PACS cooler is being prepared for tests that should start in April.

JPL Kevlar Programme Overview
(*D_JPL_over_Kevlar_moot.ppt)*
Gary Parks

- Found that frequencies dropped from warm to cold and that resonances were lower amplitude
- Bolometer Detector Assembly (BDA) movement was > 100μm and therefore out of specification – there was no major mechanical failure.
- The BDA was designed to behave identically warm and cold
- CTE of Kevlar was three times higher than theory
- Increased the tension from 33lbs to 50lbs in parallel
- At 50lbs BDA did not move
- Simulated all steps of the Kevlar assembly procedure in individual lab tests
- Bake-out caused a 50% loss in pretension
- These calculations indicated that the pre-load when the BDA was cold was only a few lbs
- It is important that the Kevlar be preconditioned in-situ and that it removes all the effects of preload loss

- Planning on carrying out a vibration test at 2K in order to confirm that there are no differences between 77K and 2K
- JPL Pre-load is approximately 50%
- Kevlar pre-load increases by approximately 10% due to humidity

JPL Kevlar Programme Technical Details
(E_JPL_tech_Kevlar_moot.ppt)
Henry Abakians
Note that the Kevlar JPL use is not the same as used by Lionel – it is the same Dupont material but woven rather than twisted and has no resin in it.

- Thermal expert, not Kevlar expert
- Kevlar 29, type 964 (may not ultimately be the best choice of Kevlar type)
- Braided 400
- Average area 0.0006in^2
- In the Force/Displacement tests, the small relaxations are more pronounced cold
- The Stress Strain curve indicates a much lower E compared to the theoretical 69Gpa
- Compared capstan grips vs. Flat grips
- In 20 hours, the Kevlar relaxed from 33lbs to 27lbs
- A combination of bake-out and re-tensioning eventually yields a stable system (at 0% relative humidity)
- The CTE goes from -11.9-14x10^{-6}/°C unconditioned to –12.0-12.3x10^{-6}/°C after conditioning
- There are some issues involved with the termination of the Kevlar – these would be solved if there were space enough to have four turns around the capstan.
- Low level sine sweep cold will be used to screen for workmanship on delivered BDAs.

SPIRE 300 mK strap supports
(No presentation available?)
Peter Hargrave

- The Kevlar preload is calculated to be around 10% c.f. Lionel and JPL have a preload of 50%
- The failure during integration was only on the light trap type support
- The thermal difference between 0.5 and 0.29 mm Kevlar is 66%
- You would earn approximately 1μW if you went to 0.29 Kevlar on the in line supports and another 1μW if you went to 0.29 mm on the light trap type support
- It is desirable that the Kevlar used for the in-line supports is also reduced from the present 0.5 mm to 0.29 mm
- Cardiff will be carrying out tests on the thermal conductivity of Kevlar down to 100 mK

PACS Detector structure
(G_CEA_Kevlar_moot.ppt)
Jerome Martignac

- Bolometer Focal Plane (BFP) Structure static stiffness tests and warm vibration tests have been carried out
- The pulleys on the system are free to rotate at present – the Kevlar is taken one turn and then glued
- Stabilisation procedure is used before gluing wires
- 70N preload used on Kevlar cf. 120N UTS
- ∅0.29 mm Cousin Filterie Kevlar is used

- Only made measurements of the Force-Displacement curve during loading – none made during unloading
- Test on stiffness is compromised by have a warm finger touching the suspended part.
- Had problems of the BFP moving after release of the assembly tool. Tried to mitigate this problem with thermal and mechanical shocks
- Transverse Eigen frequency is 180Hz and axial is around 560Hz
- Levels seen at the focal plane are 6.7g-rms instead of 78g-rms seen on unit tests against stiff interface
- PACS instrument level Cold Vibration at CSL in May/June

Conclusions

General conclusions from the meeting

1. Although it is difficult to directly compare the JPL and SBT experience due to the different material type used it is clear that there is a difference between the performance of these systems warm and cold associated with loss of tension in the Kevlar strings
2. In systems where the tension is maintained warm to cold (Cardiff 300 mK supports) thre is little or no change in characteristic warm to cold
3. Kevlar pre-conditioning is extremely important in maintaining the mechanical characteristics of the Kevlar
4. The pre-conditioning of the Kevlar i.e. bakeout and re-tensioning needs to be done in situ. Baking the Kevlar un-tensioned and then using it does not maintain the characteristics of the material.
5. Cold vibration testing is essential to understanding the Kevlar supported systems and screening for problems associated with loss of tension in the Kevlar.

Conclusions on the 300 mK cooler

1. The Cooler went through a warm vibration test at CSL (with 0.5 mm Kevlar) at levels higher than now predicted for the SPIRE instrument
2. Failed with 0.29 mm Kevlar installed, however the general conclusion is that these systems fail due to slip and abrasion not related to the UTS of the material; thicker Kevlar allows higher preload and therefore higher friction forces.
3. The SPIRE STM cooler went through cold vibration at RAL with 0.29 mm Kevlar, albeit with lower input levels than were seen at CSL
4. Large frequency shift with 0.5 mm cord compared with 0.29 mm cord probably explained by the fact that the cooler heart was fabricated from Aluminium rather than Titanium (CQM and PFM).
5. SPIRE vibration levels will be revisited after Warm instrument STM tests (end of April)
6. Lionel needs to assemble the SPIRE cooler with either 0.29mm or 0.5mm Kevlar to carry out the thermal characterisation in the next week or so
7. The recommendation is that 0.29 mm cord should be used for the SPIRE CQM cooler dependent on the results of the instrument level vibration tests.

Conclusions on the SPIRE BDA programme

1. After much pain JPL now understand how to treat there Kevlar support structure
2. The only outstanding issue for JPL is the termination of the Kevlar at the capstans. They would be home clear if they could have 4 turns round their capstan. JPL will investigate the issues surrounding the use of larger capstans in the BDAs
3. JPL will take SBT provided Cousin Filterie Kevlar and carry out the same characterisation tests

Conclusions for the SPIRE 300 mK supports

1. The units have been through a qualification programme with 0.5 mm Kevlar and have shown no change in characteristics from warm to cold.

2. The design of the system is such that it should be independent of the changes in the Kevlar from warm to cold or due to any other reason.
3. It is however recommended that the supports are baked with the Kevlar under tension to stabilise the tension within the cords
4. It is desirable that the cord used on the inline supports is changed from 0.5 mm to 0.29 mm. A further test will be required on the supports with 0.29 mm Kevlar to confirm the qualification of the units.