SUPERCONDUCTING AND FLEXIBLE MULTILAYER HIGH DENSITY INTERCONNECT

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Abstract

Space satellite mission and quantum computing put both stringent requirements on connections between different low-temperature stages [1, 2]. In collaboration with CEA Saclay we show the successful fabrication of such a shielded multi-conductor harness whose design can be adapted to both needs. The first measurements on critical temperature, thermal conductance prove applicability and will soon be followed by extensive reliability tests.

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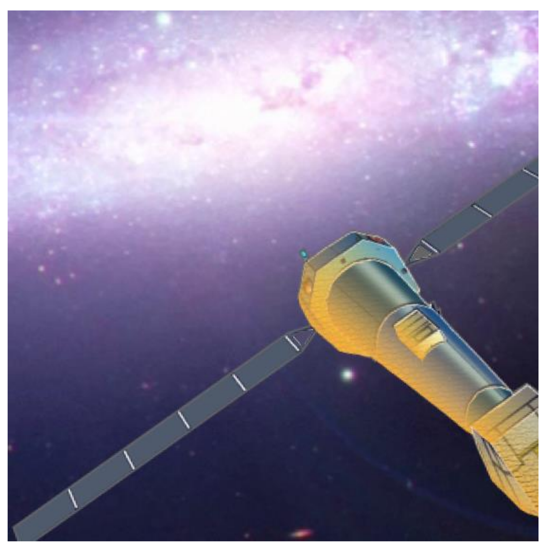
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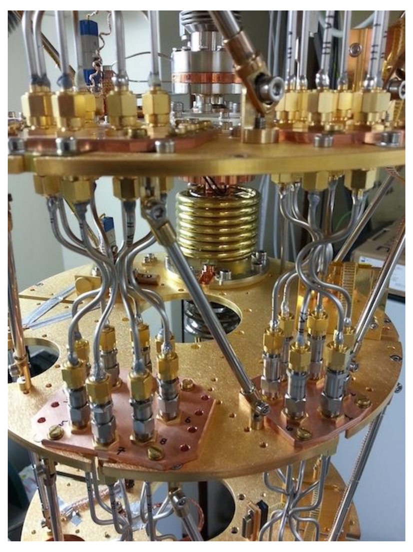

http://www.cfas.ox.ac.uk/facilities

Applications

- Connection to thermally sensitive TES Detector
- RF connection to mK stage
- RF feed line for Quantum Computers
- SQUID Readout
- Space applications
- General superconducting applications at K or mK stage

Our solution

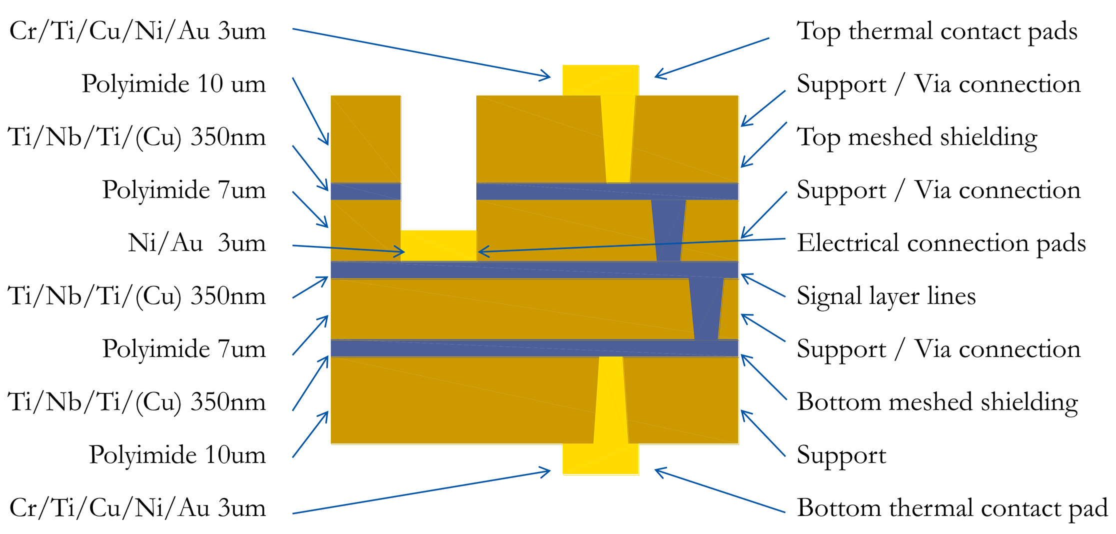
- Thin polyimide support ~34 um total
- Narrow tracks 15um
- Superconducting Ti/Nb/Ti stack [3]
- Multilayer for shielding and RF strip lines
- Layer by layer fabrication
- Laser direct writing assisted photolithography
- Nb structuring by reactive ion etching
- Electroplated Ni/Au contact pads
- Laser shot microvia interlayer connections

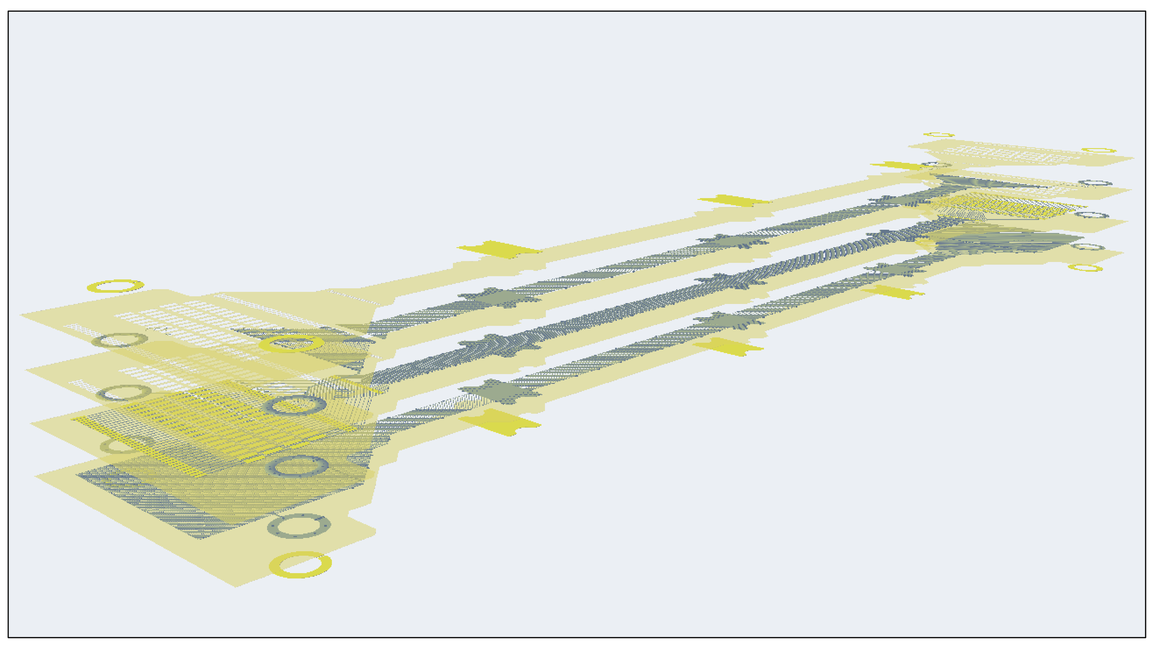
Features

- Wire bonding interconnects
- Standard surface mount technology possible
- Stays flexible down to low temperatures
- Application specific design
- Low loss tangent at low temperature [4] enable performance into the GHz range
- Implementation of planar filters possible
- Very light weight
- Small space requirements
- Low thermal conduction [5]

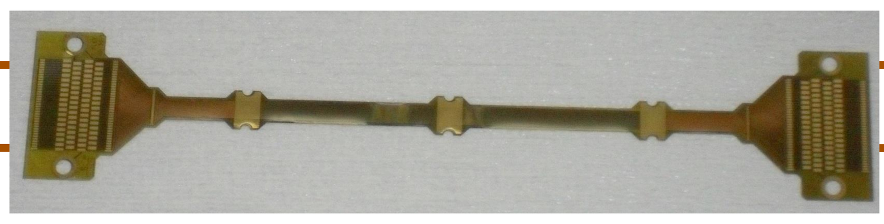
Realization – Design for Athena Satellite Project

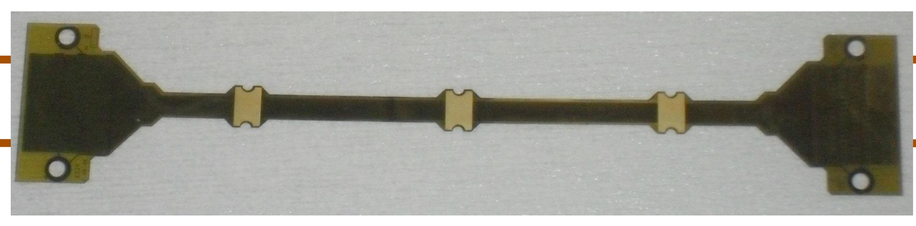
Stack-up

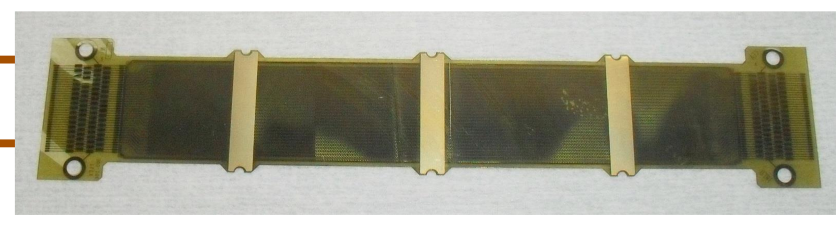




Characteristic	Value
Polyimide width	5.21 mm
Total length	100 mm
Track width	30 µm
Critical current	10.5 mA
Thermal conductance	2.95 W/K
Coefficient of thermal expansion	3 ppm/K
Dissipation factor at 293 K and 1 kHz	0.002
Dielectric constant	2.9


Flexible interconnect as a narrow variant from top side view.


The same narrow interconnect from bottom side view.


A variant with 32 wider lines

Measurements & Performance

Critical Temperature:

- The transition has been improved from 8.3 K in the first batches to 9.21 K in the last.
- Metallization layers with better adhesion have varying transition between 8.3 and 9.0 K

Residual resistance ratio (RRR):

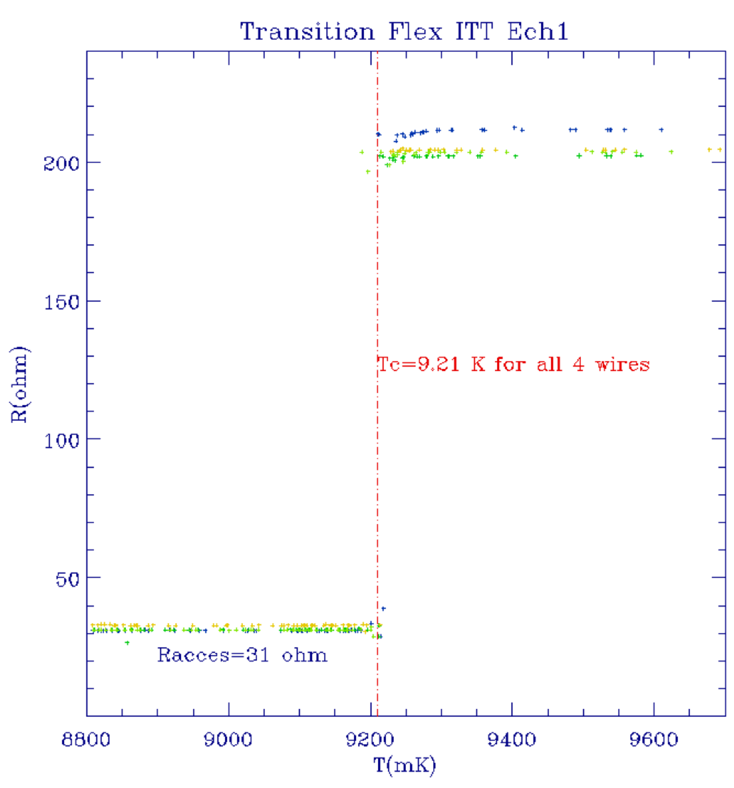
- Values are between 1.6 and 4

Thermal conductance:

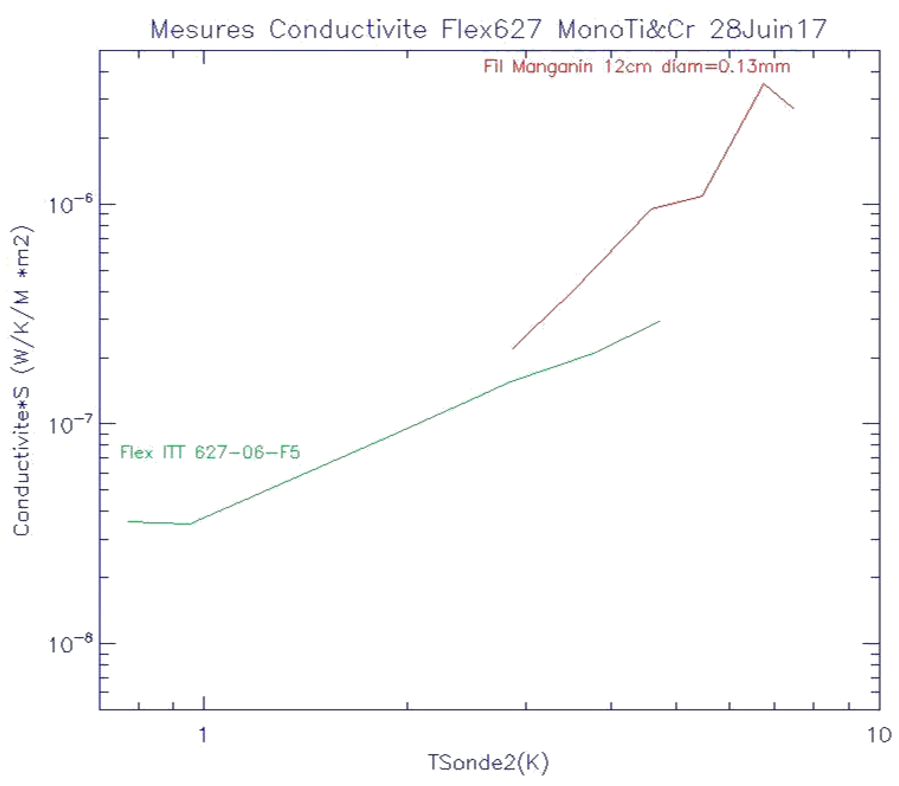
- So far only comparative measurement

Radio frequency:

- Preliminary measurements show minimal attenuation



Transition Temperature measured on 4 lines on cable. The residual resistance is due the access lines in the measurement setup.



Thermal conductivity (arbitrary unit) of a variant with 37 lines and cable width of 5.2mm versus the hottest side temperature. The data is compared to that of a manganin wire (l=120mm, d=0.13mm)

Outlook

- Long-term reliability testing
- Absolute thermal conductance measurements
- Final production run for the satellite project
- Process extension to large substrate to enable **500mm long** stretched cables

References

[1] X. Barcons et al. *Athena: ESA's X-ray observatory for the late 2020s,* Astronomische Nachrichten **338,** (2017) 2-3
[2] D. J. Reilly, npj Quantum Information **1**, (2015) 15011
[3] H. van Weers et al., Cryogenics **55–56**, (2013) 1–4
[4] D. B. Tuckerman et al., Supercond. Sci. Technol. **29** (2016) 084007
[5] M. Barruci et al., *Low temperature thermal conductivity of Kapton and Upilex*, 2000, and L. Risegari, M. Barucci, *Very low temperature thermal conductivity of polymetric supports for massive cryogenic detecors*, 2003.

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