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Nuclear Instruments and Methods in Physics Research A 520 (2004) 427–430

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

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# SCUBA-2 arrays to system interfaces

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## Abstract

Submillimeter common user bolometer array (SCUBA)-2 is a wide field sub-mm bolometer camera designed to replace the existing SCUBA instrument on the JCMT in Hawaii. It will be many hundreds of times faster in large area mapping than SCUBA and will also go deeper in a single frame. It will enable the many discoveries of SCUBA to be followed up with deep systematic surveys and help act as a pathfinder for the ALMA interferometer. The key technologies for making the arrays have been demonstrated and will be put together to fabricate the first prototype later this year (2003). The wide field nature of the SCUBA-2 bolometer camera, combined with the diffraction limit at sub-mm wavelengths, leads to physically large focal planes where the issues of stray light control, magnetic shielding, and electrical, thermal and mechanical connection must be carefully addressed in order to realise a successful instrument. We describe the solutions we have adopted for these problem areas.

*Keywords:* SCUBA-2; Niobium flex; Array interfaces; SQUID multiplexer

## 1. Introduction

All low-temperature detector arrays have complex interfaces to the rest of the instrument. As our ability to produce larger format arrays increases providing solutions to these complex interfaces

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doi:10.1016/j.nima.2003.11.355

becomes more difficult and expensive. Solutions to the few by few pixel arrays will not scale to larger format arrays where pixel counts are in the 10's of thousands. submillimeter common user bolometer array (SCUBA)-2 is close to the current forefront in terms of pixel count and physical size of LTD arrays. In this paper we describe some of the major interfaces and how we have met their challenges in the SCUBA-2 instrument.

## 2. Array interfaces and requirements

### 2.1. Magnetic shielding

TES devices and SQUID's require shielding to fields lower than the Earth's field for proper and consist operation. In SCUBA-2 this will be implemented using nested high permeability materials in the cryostat walls and at 4 K. Additional shielding is added using Pb plating of the 1 K box. Finally the array multiplexer chip has a superconducting metalization layer (Nb) on its lower surface.

### 2.2. Optical

We require arrays with a high QE which can drive the physical construction and size of the pixels and hence the focal plane size. Baffles and a low-temperature environment are needed to control stray light and the background. A mechanical interface to bandpass defining filters and method of alignment of arrays to the optical systems are also essential. Although one of the key interfaces to the SCUBA-2 arrays, we will not discuss this interface further.

### 2.3. Thermal

The arrays need to be attached via a thermal link to the refrigeration system. The thermal link must be of low enough impedance to allow the power dissipated in the focal plane to flow away without developing a large temperature gradient which may prevent the array reaching the required operating temperature. Power typical arises from the optical system and background, bias and multiplexer, the electrical connections and mechanical support.

Problems arise in this area, especially with large focal planes that tend to have greater mass and high-power dissipation.

Necessarily the detectors and multiplexer are fabricated on an electrically non-conducting medium (e.g. silicon) and the thermal link will typically be highly electrically conducting (e.g. copper). In these situations and at mK operating temperatures, phonon scattering between dissimilar materials and phonon to electron coupling may lead to large temperature gradients in the boundary region between the thermal link and detector and cannot be ignored. Overcoming this problem generally requires high contact area. This will tend to introduce high mechanical stresses when materials with high differential thermal contraction rates are fixed together (e.g. silicon and copper). These stresses can be considerable and lead to fracture of the array.

In the event of needing high contact area, the thermal link may also form part of the mechanical support system and have to be engineered to hold the array flat and avoid significant bending as well as fracture stresses in the arrays. This requirement may by quite difficult to meet when arrays with detectors and multiplexers hybridized together by bump bonding are employed. Bending of the middle of the array relative to the edge by more than $\sim 10\,\mu\mathrm{m}$ may cause bonds to fail and partial delaminating of the two devices.

SCUBA-2 power dissipation is 2–3.5 $\mu$W, depending on the SQUID multiplexer [1] bias conditions. We will use a wire machined BeCu 'hair brush' to support the array (Fig. 1). This consists of 20 mm long pins with a flat top machined out of a solid block of metal. The pins are on a ~1 mm pitch. The heads of pins are epoxied to the underside of the sub-array. This is actually the multiplexer chip to which the detector chip is hybridized.

The hairbrush is designed to maximize contact area and minimize stress and bending in the silicon by allowing the pins to bend instead. The shear stress at the epoxy joint is proportional to the length of the pins cubed so lengthening the tines is any easy way to control stress. The thermal

Fig. 1. Bc Cu hair brush – 40 by 40 mn sq. Tines are 21 mm long.

impedance of this joint has been measured and a temperature drop of 7 mK is predicted for the power expected.

The base of the hair brush contains a passive thermal joint (makes on cooling) which connects it to the thermal link. The thermal link is the main mechanical support for the sub-arrays and any number up to four may fitted.

### 2.4. Cryogenics

The thermal link interfaces to the chosen refrigerator system, but the array size, mass, power dissipation and operating temperature and stability will determine the nature and cost of the refrigeration system.

SCUBA-2 will use a commercially sourced high cooling power dilution refrigerator that is designed to be cryo-free. Cooling power at 25 mk is ~20 μW.

### 2.5. Mechanical

The mechanical support must hold the arrays in position relative to the optical system with sufficient stiffness. Large-area focal planes may require arrays to be butted together. The mass will increase with large focal planes and hence support stiffness and heat leak will increase. Generally the delicate arrays should be made simple and easy to mount and dismount and the focal plane may not be operated fully populated. The mechanical support system will also have to cope with these requirements.

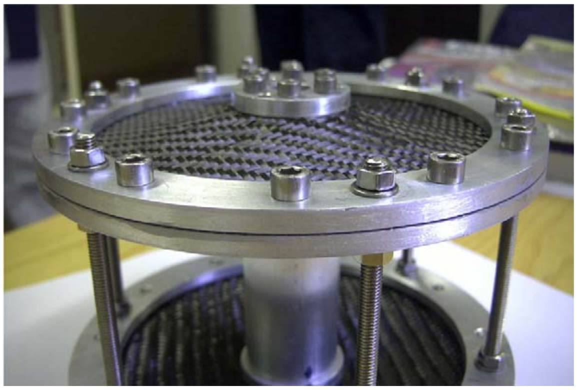

Fig. 2. Carbon cloth support. OD is ~135 nm. ID ~40 nm.

SCUBA-2 will adopt the principle of mechanically supporting the thermal link to the dilution refrigerator rather than the arrays directly. This allows heat leaks from the support to flow directly to the mixing chamber rather than through the array heat sink. The thermal link, together with a fully populated focal plane (four sub-arrays installed) will have a mass of ~7 kg. The thermal link will use two fabric disks of kevlar or carbon cloth with the thermal link passing through the center (Fig. 2). The outer ring is held at ~1 K by being linked to the still of the dilution refrigerator. This system is very stiff and has a heat leak of ~2 μW. The fibers of the fabric will ~100 μm in thickness.

### 2.6. Electrical

Large arrays will require multiplexing to avoid a physically and thermally impossible wiring solution. The wiring carries signals, bias currents and voltages and multiplexer clocking signals as well as housekeeping signals such as connection to thermometers.

It should be noted that the connection count may still be high if the multiplexer is complex, as in the case of time division SQUID based multiplexers. The connection density at the edge of

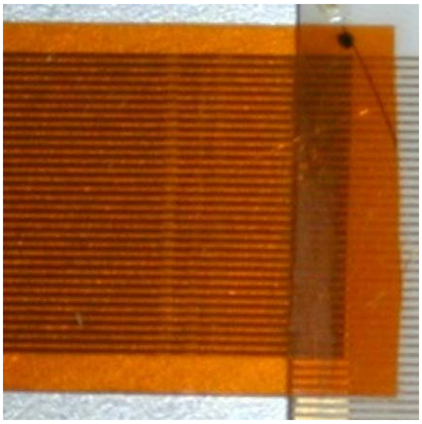

Fig. 3. Niobium flex (RHS) bonded to ceramic pcb (LHS).

array may therefore be, too high for direct attachment to wiring harnesses or ribbon cable.

SCUBA-2 needs 300 connections per sub-array, 1200 per focal plane. The solution is to use a fanout ceramic circuit board (the 'batwing' in project parlance) which is wire-bonded to two edges of the sub-array and fans out the connections to a diagonal edge where connection may be made to the wiring from 1 K. The batwing will be at 40 mK. The 1 K wiring uses niobium deposited onto 50 μm kapton. The flex are 55 mm long. The intention is to $z$-axis adhesive bond[1] the flex to the pcb (Fig. 3). Trials at 77 K show good isolation between tracks and no loss of contacts on repeated cycling. The contact resistance at 4 K has to be measured to confirm its suitability—we require $<0.1\,\Omega$. Should the contact resistance be too high, we will have to employ a solution using 50 μm NbTi wire (coated with CuNi) looms[2] soldered to the pcb's.

The heat flow down the all the flex is ~1.6 μW. This flows into the batwing pcb's and then into a support shelves for the pcb which is attached to the solid metal part of the hair brush. The power flow then avoids the hair brush to array interface.

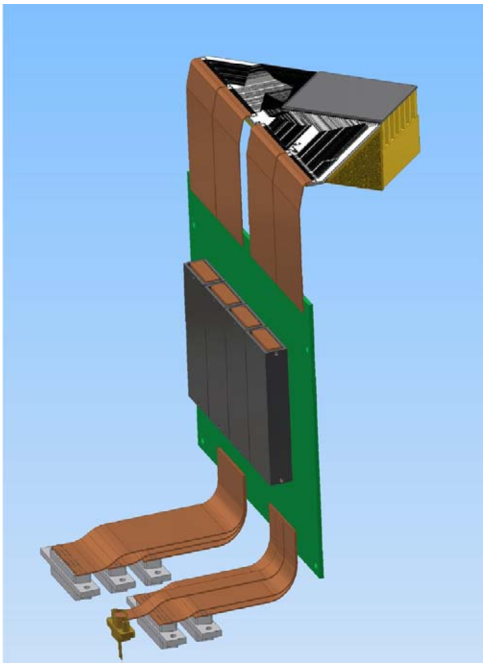

Fig. 4. One quadrant of a SCUBA-2 focal plane showing, from top to bottom, sub-array on hairbrush, fanout ceramic pcb. flex, 1 K pcb with SQUID series array cans, and copper flex with MDM connectors.

## 3. SCUBA-2 focal plane–one quadrant

The diagram in Fig. 4 shows the a complete quadrant of the SCUBA-2 focal plane. These quadrants are two side buttable to allow a focal plane of four sub-arrays to be built up.

## References

[1] Kent Irwin, et al., In-focal-plane SQUID multiplexer, Nucl. Instr. and Meth. A, (2004) these proceedings.

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[1] Anisotropic conducting tape. Contact Hitachi Europe tondeur@hitachi-chemical.de for details of the tapes.

[2] Tekdata Ltd. See http://www.tekdata-interconnect.co.uk/cryoconnect1.htm.