SCUBA-2: A Large-Format TES Array for Submillimetre Astronomy

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The James Clerk Maxwell Telescope (JGMT) on Mauna Kea, Hawaii

http://www.roe.ac.uk/atc/projects/scuba_two/

Introduction
SCUBA-2, which replaces SCUBA on the JCMT in 2006, will be the first CCD-like array for submillimetre astronomy. It will offer imaging of an 8 x 8 arcmin field of view at 850 and 450 μm simultaneously using two dc-coupled, monolithic arrays of ~10,000 bolometers. SCUBA-2 is expected to have a huge impact on the study of galaxy formation and evolution in the early Universe as well as star and planet formation in our own Galaxy. SCUBA-2’s absorber-coupled pixels use superconducting transition edge sensors operating at ~120 mK for photon noise limited performance. The silicon detector arrays are deep-etched for thermal isolation and bump-bonded to a backplane formation and evolution in the early Universe as well as star and planet formation in our own Galaxy. SCUBA-2’s absorber-coupled pixels use superconducting transition edge sensors operating at ~120 mK for photon noise limited performance. The silicon detector arrays are deep-etched for thermal isolation and bump-bonded to a backplane.

Instrument Design
To achieve sky background limited performance the arrays are operated at ~120 mK. The cryostat is designed to operate without liquid cryogens to reduce operational costs. It uses a dilution refrigerator to cool the detector stage to 60 mK and the focal plane unit to 1 K. Pulse tube coolers cool the internal filters and optics at the 60 and 4 K stages.

A dichroic beamsplitter at the 1 K stage splits the beam into components of wavelength 450 and 850 μm and directs them to two focal plane units (FPUs). Each FPU fills the field of view with four subarrays as shown below. The subarrays have been shrunk to 40x32 pixels from the original 40x40 for more reliable patterning of the MUX on a 3” wafer. Niobum flex cables (see Poster 906) bring the multiplexed signals to series array amplifiers. The niobium flexes also provide a thermal break between the 60 mK stage and the 1 K stage. Ribbon cables carry the amplified signals out of the cryostat to a readout card incorporating an FPGA. Output values will be co-added and stored in the FPGA before being sent over a fibre optic link to a data collection PC (one per sub-array) at a rate of 200 frames per second.

Ceramic PCB niobium flex cables 40x32 Subarray

Monolithic Subarrays
One 40x40 subarray test piece diced into shape required for final assembly. Each focal plane will consist of 4 subarrays binned together. Note that the subarray size is now 40x32 pixels.

SCUBA-2 Unit Cell

SCUBA-2 single-pixel test results
The pixels easily meet the noise equivalent power (NEP), speed, and power handling requirements for SCUBA-2. Dark NEPs of ~3 x 10^-11 W/Hz have been measured for devices with transition temperatures of 130 mK.

Current Status
SCUBA-2 is due to be on the telescope in late 2005. Fabrication of the prototype detector subarrays is under way.

Deep-etched trench (10 μm)
Implanted Absorber
Quarter-Wave Si Brick
SCUBA-2 absorbers are essentially quarter-wave antireflection coatings. A pixel consists of a quarter-wave brick of silicon with a backshort and an implanted resistive layer on the top.

Pixel Modelling
To verify the performance of the pixel design, we have carried out an extensive programme of finite-element electromagnetic modelling with the Ansoft HFSS software package. The results led us to alter the pixel design to maximize the efficiency. Our original design had high silicon walls between pixels for mechanical strength. These have now been removed.

Calibration
A cold shutter will take dark frames to compensate for any drifts in the detectors and read out electronics. We intend to monitor the response of the pixels by injecting signals based on maximum-likelihood models of the background. The results will be used to determine the detector efficiency and sensitivity.

Arrays:

- 400 75 90 32
- 10 1 12

Parameters

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<tr>
<th>Parameter</th>
<th>SCUBA-1</th>
<th>SCUBA-2</th>
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The instrument challenge: Incorporate new developments in detector technology to build the submillimetre “CCD” camera.

Maximize the survey potential

- map large areas of sky >10^16 times faster than SCUBA

Deep Imaging

- to the confusion limit in only a few hours

Imaging at two colours simultaneously

- study physical properties of dust emission

Improve the image fidelity and map dynamic range

- have fully-sampled image planes, no sky chopping

Instrument Design

- SCUBA-2's absorbers are essentially quarter-wave antireflection coatings. A pixel consists of a quarter-wave brick of silicon with a backshort and an implanted resistive layer on the top.

Absorber-coupled Pixels

I incident radiation passes through the quarter-wave brick and is reflected by the backshort (the TES). There is constructive interference between the incident and emergent waves at the top of the slab. The energy of the radiation is dissipated in the resistive layer.

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A cold shutter will take dark frames to compensate for any drifts in the detectors and read out electronics. We intend to monitor the response of the pixels by injecting signals based on maximum-length sequences (MLs) into the bias or heater lines. A ML is a pseudorandom binary sequence of length 2^n-1 bits which has the property that any k-bit subsequence within it is unique. This means that its circular auto-correlation is zero. The SCUBA-2 software will apply a ML to a pixel and cross-correlate the resulting signal with the applied signal, yielding the pixel’s impulse response.

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