TES III : Third International Workshop on Transition Edge Sensors

Audley, Damian

University of Cambridge

Title : Performance of prototype finline-coupled TES bolometers for CLOVER

CLOVER's three telescopes will map the linear polarization of the CMB at frequencies of 97, 150, and 220 GHz. The telescopes have 512 (320 at 97 GHz) TES detectors operating with a base temperature of 100 mK. To ensure fully-functioning focal planes we use individual detector chips rather than monolithic arrays. Radiation is coupled to the TES bolometers by finline transitions. The first prototype detectors for CLOVER operate at 230 mK and are used to validate the detector design and the polarimeter technology. We describe the design and packaging of CLOVER's detectors and present measurements of the prototype detectors' performance.

Bailey, Catherine

Case Western Reserve University

Title : Detector Development for the Next Phases of the Cryogenic Dark Matter Search

Recent experimental results indicate that nearly 23% of the universe is made up of dark matter, possibly in the form of Weakly-Interacting Massive Particles detectable via recoils of atomic nuclei in terrestrial detectors. The Cryogenic Dark Matter Search (CDMS) is searching for these particles using TES-based phonon sensors. CDMS is able to discriminate between candidate (nuclear recoil) and background (electron recoil) events by collecting both phonon and ionization energy from recoils in the detector crystals. Looking toward the future, it is necessary to increase the detector mass, collection efficiency, and discrimination capability. New detector designs have recently been fabricated and initial testing shows promise of accomplishing these objectives.

Bandler, Simon

Goddard Space Flight Center

Title : High-density arrays of x-ray microcalorimeters for Constellation-X

We have been fabricating arrays of x-ray microcalorimeters with the fill-factor, speed, and quantum efficiency required for the Constellation-X microcalorimeter spectrometer. These 8x8 arrays of 0.25-mm pixels arranged with 92% fill factor consist of Mo/Au superconducting transition-edge sensors (TES) with either Bi/Cu or Bi/Au absorbers. We have achieved a resolution of 4.0 eV FWHM at 6 keV in such devices. In order to reproducibly construct absorbers above TESs in a way that does not allow diffusion to affect the transition temperature and shape, we have been investigating a new design for the contact between the TES and the absorber where there is no direct interface between these two components. We will present the results of our studies of thermalization in our different absorber designs.

Bay, T. J.

Stanford University

Title : Optical TES Imaging: Some stuff you never think about

Practical imaging of a room temperature source onto a cryogenic detector housed in an ADR presents difficulties both in maintaining alignment and proper filtering of incident radiation. One such difficulty comes from the need to sufficiently filter out-of-band radiation while maintaining an acceptable on-the-sky efficiency. For instance, many common filtering materials (e.g. glasses) have a relatively larger transmission window around 2.5 micrometers, potentially giving a large IR leak. Our multi-pronged approach to filtering and alignment is presented.

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Benford, Dominic

Goddard Space Flight Center

Upcoming TES Bolometer Arrays in Cameras For Millimeter Wavelength Astronomy

Bock, Daniel

Carnegie Mellon University

Title : Superconducting Nanowire Bolometers

Tests of superconducting antenna-coupled nanowire bolometers, fabricated from molybdenum, and operated at 0.4 K are presented. These devices have been shown to detect optical radiation, and are expected to be very sensitive across a five-decade range of frequencies. The measured thermal conductance is ~ 10-11 W/K. Responsivity, measured electrically, is 109 V/W, and the calculated thermal time constant is ~1 ns. The measured noise of these devices is less than 5 ×10-18 W/sqrt(Hz).

Bogorin, Daniela

University of Miami

Title : Developing Fully Integrated TES Microcalorimeters using Ir TES and Sn Absorbers

Cryogenic Microcalorimeters are the future detectors for X-ray astrophysics. Our group is focusing on developing transition edge sensor (TES) using single layer Ir as detector and deposited Sn as absorber. We obtained good unsuspended devices with reproducible transition temperature around 120mK and transition width of 1-2 mK. Ir films are deposited using RF magnetron sputtering and photolithography lift-off techniques. Al is used for electrical traces and is deposited via RF magnetron sputtering and wet etching. We also successfully deposited Sn mushroom like structure with high filling factor using photolithography techniques on a Si substrate. For future work we will bring the two processes together in order to obtain fully integrated devices.

Brandt, Daniel

University of Leicester

Title : Excess Noise in TESs: A Comparison of Current Theories

Microcalorimeters based on transition edge sensors have been found to be subject to a level of excess noise which cannot be explained from conventional noise sources such as Johnson noise and thermal fluctuation noise. Different theories exist concerning the source of this noise. The aim of this talk is to create a direct comparison between the existing theories of percolation noise and phase slip shot noise. It will be discussing the predicted dependencies on parameters such as magnetic field and temperature as well as contrasting differences in prediction and analyzing agreement with the experimental data available to date.

Brown, Ari

Goddard Space Flight Center

Title : Cantilevered X-ray Absorbers for Close-Packed TES Detector Arrays

We present fabrication techniques and characterization of cantilevered x-ray absorbers for close-packed microcalorimeter detector arrays. We have demonstrated a generic fabrication process for absorber structures that is compatible with both physical vapor deposition and electrodeposition, for Bi, Au, Au/Bi, and Cu/Bi absorbers. We report electrical and morphological characteristics of candidate absorber films deposited by the various techniques in single layer and bilayer systems. Absorber arrays possessing a filling fraction of 95-97% were fabricated for several of the candidate materials systems and successfully integrated with arrays of superconducting transition edge sensors. We describe techniques for improved thermalization and mechanical robustness of cantilevered structures and show micrographs of our latest devices.

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Burney, Jennifer

Stanford University

Title: TESs Take Pretty Pictures

No color enhancement necessary! In tag-team fashion, we will take you through the life story of the first imaging instrument of optical Transition-Edge Sensors. We discuss both highlights (first light on an operating array, fun applications) and hurdles (the difficulty of direct imaging, filtering subtleties, and noise). Finally we shed light (hah!) on some fundamental detector questions (position dependence, noise components, efficiency) and the ways in which our direct imaging system has begun to offer some long-awaited answers.

Ferrari, Lorenza

National Institute of Nuclear Physics (INFN)

Title : Low temperature transformer readout electronics for microcalorimeters

The MANU2 experiment is implementing an alternative transformer readout electronics, with respect to the conventional SQUID-TES coupling. The results, on the trans-resistance amplifier coupled to the TES using a transformer electronic chain, will be presented. A trans-resistance amplifier is coupled to the TES using a transformer. The tests performed on various transformers with different core materials, indicated the spin glasses as the best choice. The low noise room temperature JFET amplifier tested showed a noise level of 0.9 nV/rtHz, in a simplified experimental setup. The implementation of a integrating stage is further used in order to flat the transfer function. The 4 K measured input current noise is 14 pA/rtHz @ 1 kHz, < 20 pA/rtHz @ 0.5-5 kHz. The expected equivalent input current noise is on the order of 2 pA between 0.2-6 kHz. Further improvements will be discussed such as the use of new JFET, with 0.3 nV/rtHz and 10 fA/rtHz, slight higher mutual inductance transformers, or optimization of the TES resistance, moving the current equivalent thermal noise to the same range of the current equivalent input noise of the electronics.

Figueroa-Feliciano, Enectali

Massachusetts Institute of Technilogy

Title : Position Sensitive Transition-Edge Sensors: Recent Progress and Current Issues

We have been developing Position-Sensitive Detectors for applications in future X-ray missions. These devices function by reading out two transition edge-sensors placed at the ends of a long X-ray absorber. The position and energy of the X-ray are determined from the difference and sum of the two signals. The technology has progressed significantly from the first 32 eV FWHM @ 6 keV result, to our best resolution today at 8 eV FWHM @ 6 keV. There are still many challenges to bring this technology to flight qualified status. Tc variations in the two TESs cause problems in biasing these devices, and electrical crosstalk issues become important as the resolution of the device gets better. We will discuss our latest results, and talk about some of the challenges and solutions on the next generation of devices.

Galeazzi, Massimiliano

University of Miami

Title : Multiplexed Transformers to Read Out Arrays of Microcalorimeters

Transition Edge Sensors are usually coupled to the input coil of a SQUID working as current transducer. Such readout scheme has proved reliable and efficient in single pixel experiments, however its extension to arrays of hundreds of detectors is not straightforward due to issues related to power dissipation and wiring. Multiplexing schemes are therefore being developed. We investigated the possibility of using transformers to replace SQUIDs. This simple scheme has already been used in the past, however it was discarded for the use with TES microcalorimeters for the inadequate performance. Our work shows that, with a few changes, the performance of transformers as current transducers, while still not comparable to that of SQUIDs, is sufficient to read out the signal from TES microcalorimeters without any degradation in speed or energy resolution. Compared to

SQUIDs, transformers do not dissipate any power and their working principle makes them natural candidates for frequency multiplexing. Their extension to several channels is therefore straightforward. In this talk we will present our scheme to frequency multiplex transformers and we will discuss the results obtained with a first prototype.

Galeazzi, Massimiliano

University of Miami

Title : Flux Flow noise in Transition Edge Sensors

While microcalorimeters using TESs have achieved impressive results, their performance is still limited by excess noise of unknown origin. We believe that such noise originates from the fluctuation in the number of magnetic vortices penetrating the TES. We will present a few simple, back of the envelope, theoretical calculations on the characteristics of such noise. We have also applied our calculations to real data acquired at the NASA/GSFC, showing good agreement between our calculations and real data.

Hilton, Gene

National Institute of Standards and Technology

Title : Time-division SQUID multiplexer for 128 TES X-ray microcalorimeters

We discuss testing of a focal-plane architecture to read out an array of 128 TES X-ray microcalorimeters using four NIST 1x32 SQUID time-division-multiplexer chips. Preliminary measurements show an open-loop bandwidth of 2 MHz, which dictates a dwell time of roughly 600 ns per row. We present preliminary test results of 128-pixel arrays of two types of detectors: (1) Constellation-X-style detectors, with ~400 usec response times and on a 250 um pitch and (2) a Micro-X / NeXT-style detectors, with ~1.2 ms response times and on an 800 um pitch. Both types of detectors have 6-8 um-thick Bi absorbers, giving high quantum efficiency for X-ray energies up to 6 keV. We discuss the various sources of multiplexer noise and the predicted limits of multiplexer performance.

Hoshino, Akio

Tokyo Metropolitan University

Title : First result of EDXRD experiment using a gamma-ray TES calorimeter with Sn absorber

We report the first result of energy dispersive X-ray diffraction (EDXRD) experiment at a synchrotron facility using a gamma-ray TES calorimeter with Sn absorber. Details of the calorimeter is presented by T.Oshima's talk. We successfully detected a diffraction pattern of a NaCl crystal at 2-theta = 8 degree, however the energy resolution was significantly degraded to 600 eV at 32 keV due to a malfunction of the TES bias line inside the adiabatic demagnetization refrigerator. Our primary goal is to analyze a phase diagram of complex crystal structures like Bi under the extreme high pressure situation.

Irwin, Kent

National Institute of Standards and Technology

Title : Near-equilibrium thermodynamics of nonlinear resistive bolometers

The conventional theory for the noise in a resistive bolometer or calorimeter is partially based on equilibrium thermodynamics, including Nyquist's formula for the noise in a resistor. This theory cannot be rigorously applied to a bolometer whose temperature is different from the bath temperature. The term excess noise in a transition-edge sensor is misleading, as it is measured relative to a theory that is not thermodynamically correct. In order to better understand the baseline thermodynamic noise, we have used Stratonovich's formalism for non-equilibrium thermodynamics to extend the conventional equilibrium bolometer theory of Mather to first order perturbations away from equilibrium.

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Iyomoto, Naoko

Goddard Space Flight Center

Title : Characterization of x-ray microcalorimeters for Constellation-X

As we construct arrays of x-ray microcalorimeters with the fill-factor, speed, and quantum efficiency required for the Constellation-X microcalorimeter spectrometer, we continue to characterize our devices thoroughly. These measurements include measuring the transition shapes with and without bias and studying the effect of current and magnetic field on the transition shapes. We have studied the uniformity of the transition shapes, and how the uniformity is affected by a substrate and the design of noise-reducing normal metal bars. We have investigated the noise of our devices, and how the noise varies throughout the transition, and how the pulse-shape and noise compares with that which is expected from modeling. We have continued to study the thermal conductance of our microcalorimeter designs, and looked at how this conductance is affected by detector components that extend onto islands within the outer membrane. And we have been investigating the linearity of the microcalorimeters as a function of energy, and whether the linearity agrees with the expected linearity from modeling. The results and conclusions from these studies are presented.

Karasik, Boris

Jet Propulsion Laboratory

Title : A Hot-Electron Direct Detector for Low-Background Sub-millimeter Applications

We have developed a hot-electron superconducting transition-edge sensor (TES) with extremely high sensitivity for low-background sub-millimeter space applications. We fabricated superconducting Ti nanosensors with a volume of ~ 3×10^{-3} ?m^3 on planar Si substrate and have measured the thermal conductance due to the weak electron-phonon coupling in the material and the Andreev reflection in Nb contacts G = 40 fW/K at 0.3 K and G=1 fW/K at 60 mK. The corresponding NEP = 0.3 aW/Hz^1/2 at 0.3 K and 0.01 aW/Hz^1/2 at 60 mK. This Hot-Electron Direct Detector (HEDD) is expected to have a sufficient energy resolution for detecting individual photons with f > 1 THz .

Kozorezov, Alexander

Lancaster University

Title : Thermalization and phonon down-conversion noise in TES microcalorimeters

We have identified and analyzed a new source of noise and line broadening in transition-edge sensors. The additional noise arises from the fact that the initial energy down-conversion evolves over a short, but finite, transient period during which a significant fraction of the original photon energy exists in the form of high frequency, non-equilibrium phonons. Depending on the position of the absorption site relative to interfaces, some of these phonons may be lost before their energy is transferred finally to the electron system. Their loss is also subjected to statistical fluctuations arising from the details of phonon energy exchange across the interface. We show that this additional source may be responsible for limiting significantly the resolving power of current transition-edge detectors for the optical range.

Leman, Steve

Stanford University

Title : Doped Silicon Phonon-Mediated, Distributed, TES Detector With Deep Trenches For Use In Astronomy

Development of a phonon-mediated, distributed, TES detector continues. In this latest round we significantly deepen trenches to 90% of the substrate thickness. Also, to reduce the likelihood of phase separation, we `split' each of the four TESs such that the bias lines run down the sides of the TES and the ground line runs down the center.

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Lindeman, Mark

University of Wisconsin-Madison

Title : Equivalent circuit measurement and complex impedance of calorimeters and bolometers

We present a new method for measuring the complex impedance of transition-edge sensors, bolometers, and calorimeters. Impedance measurements provide a useful probe of the physics of these devices. In previous work, stray impedances and other characteristics of the measurement apparatus have resulted in artifacts in the impedance data. The new technique allows experimenters to find a mathematical transformation representing a Thevenin / Norton equivalent circuit for the bias electronics. This new method allows experimenters to easily isolate the impedance data and remove unwanted components from the data such as parasitic impedances and frequency dependent gains in amplifiers.

Ohno, Masashi

University of Tokyo

Title : Analysis of saturated pulses for the waveform domain multiplexing readout of Ir-TES

Multiplexing methods for large-format TES array are challenging area and we are studying a waveform domain multiplexing method, which controls and utilizes a small variation in the waveform among individual pixels. In this study, we have analyzed the response function of the TES waveform pulse in the saturated region in detail. We observed two distinct decay times in the saturated region for our small-heat capacity Ir/Au TES. A slow decay component followed by a fast decay component was clearly observed at a lower bias point, which indicates the two components do not come from parallel sources but from dynamic response of the TES itself. It is thought to be due to the change in the current flow mode inside the TES film. By the proximity effect, resulted Tc of the edges may be higher than the central part and therefore the edges of the TES become the superconducting transition first, while the center part is still in normal conduction. We think that the broadening of the transition curve which results in the slow components at a small excitation current is due to the current increasing around the edges of the TES.

Oshima, Tai

Tokyo Metropolitan University

Title : A high energy resolution gamma-ray TES calorimeter with 0.5ms response time

We report on the development of the fast response gamma-ray TES calorimeter composed of a bulk Sn absorber coupled to a Ti/Au TES. We performed a SPICE simulation to optimize the heat capacity of the absorber and the thermal conductance between the absorber and the TES considering the energy resolution, saturation, and linearity. By fabricating the device based on this optimization and irradiating the device with Am241 source, we have demonstrated an energy resolution of 38eV at 60 keV with a time constant of 0.5ms. Results of applying this device to EDXRD experiment will be presented by A.Hoshino's poster.

Pantic, Emilija

Max-Planck Institute for Physics

Title : Light detector development for CRESST Dark Matter Search

In the CRESST-II experiment, scintillating CaWO4 crystals are used as absorbers for direct WIMP detection. Both the absorber crystal and the light detector used for the detection of the scintillation light are operated as cryogenic detectors and read out by tungsten superconducting phase transition thermometers. The development and performance of extremely sensitive large area (12 cm2) light detectors measuring typically less than 1% of the energy deposited in CaWO4 crystal will be discussed. Results on different materials to be used as light detector absorbers together with the improvement of the light detector thermometer geometry will be presented.

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Razeti, Marco

National Institute of Nuclear Physics (INFN)

Title : How the electrothermal feedback affects current response and linearity in transition edge sensors

It has been recently shown how the thermal decay time is actually time dependent, in presence of electrothermal feedback and when the small signal approximation does not hold anymore. In these conditions, a new form for the transition edge sensors current response has been found in order to assure the expected linearity and energy conservation when the extreme electrothermal feedback operation mode is exploited.

Ribeiro Gomes, Maria

National Institute of Nuclear Physics (INFN)

Title : Status report on the development of TES for MANU2

MANU2 is the second generation microcalorimetric experiment on the beta-decay of 187Re for direct measure of the neutrino mass, making use of the full absorption method, in which all the energy released on the 187Re75 beta-decay is expected to be detected. The experiment will be executed with ~300 detection channels, a total rhenium mass of 250 mg with an expected count-rate ~1010 for one year of measurement, providing an expected neutrino mass sensitivity of ~1.5 eV/c2 (90% C.L.). Each channel is composed of a Re single crystal absorber, a IrAu TES and a non-conventional voltage amplifier readout using a transformer. The experimental results on the coupling optimization between all parts will be presented in terms of the physics underlying the superconducting sensor thermal&time response, transformer characteristics and expected detector performance.

Saab, Tarek

University of Florida

Title : Excess Broadening Due to Diffusion in the Absorber

Non instantaneous thermalization in a microcalorimeter absorber will lead to a degraded energy resolution due to varying detector response as a function of event position. We will show how position dependent pulse shapes, due to finite diffusion times in the absorber can lead to a line response with a high energy tail and significant excess broadening when pulse heights are estimated with an optimal filter. We will also show a pulse height calculation technique that can significantly reduce the effect of pulse shape variation, with a minimal increase in baseline resolution.

Ullom, Joel

National Institute of Standards and Technology

Title : Gamma-ray microcalorimeter arrays for nuclear materials analysis

Gamma-ray microcalorimeters based on bulk superconducting absorbers and thin-film TES thermometers have an order of magnitude better resolution than conventional germanium sensors and thus are potentially powerful tools for nuclear materials analysis. We present data from a multiplexed thirteen pixel gamma-ray array with a coadded resolution of 51 eV at 103 keV. In addition, we present data from a single pixel with 27 eV resolution at 103 keV. We present recent measurements of a mixture of plutonium isotopes and discuss ongoing efforts to build a large-area, multiplexed, cryogen-free spectrometer.

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van der Kuur, Jan

Space Research Organization Netherlands

Title : Study of transition steepness for wiring and absorber coupling geometries

We present a study of the transition steepness alpha for different wiring materials, wiring geometries, substrate and aspect ratio of a TiAu TES. With a bare TES we reach alpha's up to 1000. This can be strongly reduced by stress via the wiring. The upper part of the transition is flattened by a lateral proximity effect. We also study different coupling geometries between TES and Cu absorber. With normal metal dots on the TES surface we tune alpha. For a TES/insulator/absorber geometry, with thermal contact via holes in the insulator, we present noise measurements. We discuss work on array fabrication.

van der Kuur, Jan

Space Research Organization Netherlands

Title : Recent developments in frequency domain multiplexing

Frequency domain multiplexing (FDM) is being developed at SRON for the readout of imaging arrays of microcalorimeters for XEUS and SPICA. We will show recent results of this ongoing development work, in the field of single pixel performance under AC bias at 250 kHz and cryogenic high-Q bandpass filter using aluminum oxide as the dielectric. Furthermore, we will show how the dissipative bias resistor can be omitted in a FDM readout scheme. Finally, we will propose a SQUID amplifier scheme which widens the bandwidth of the SQUID amplifier to approximately 10 MHz, while conserving the dynamic range.

Vystavkin, Alexander

Institute of Radio-engineering and Electronics of RAS (CPLIRE)

Title : TES bolometer with non-Andreev contacts

The electron energy balance equation was modified to take into account the effect of transfer of hot electron power from TES bolometer absorber combined with the sensor to the biasing circuit with the electron current for the case of non-Andreev contacts. Estimation calculations have shown that the power flow connected with said transfer is negligibly small in comparison with the hot electron power transfer to the thin metal film structure and substrate through electron-phonon interactions for studied earlier molybdenum-copper bilayer thin film structures in 0.08 0.4 K temperature range [1]. The obtained equation was used to estimate a ratio of current decrement to incident radiation power (current sensitivity) of the TES bolometers as well. There were no significant changes in the TES bolometers current sensitivity found at fixed bias voltage across the absorber for the studied structures except the case at absorber lengths 1 μ and less when the current sensitivity gain of order of several tens have been calculated.

Yoshino, Tomotaka

Institute of Space and Anstronautical Science

Title : Understanding thermal process in TES X-ray microcalorimeters using a FEM thermal model

Our microcalorimeter with a Ti/Au bilayer TES and a vacuum-evaporated Bi absorber showed an energy resolution (20eV@5.9keV) degraded from the baseline resolution (8eV). We constructed a thermal model of the calorimeter using the finite element method (FEM). The thermal conductivity and the specific heat of the absorber and the TES are estimated from experiments. By adjusting the unknown parameter of thermal conductivity at the Bi-TES boundary, we successfully reproduced the fluctuation of the observed pulse shape. The model shows that, in our case, the thermal diffusion mainly occurs in the TES , which causes the position dependence of pulse shape.

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Zhang, Hengsheng

University of Miami

Title : Noise studies in Tin

We will report noise studies in the transition region of conventional superconductor Tin film. While noises in the transition region have been reported in the past, we are focusing the current dependence of the noises and the I-V characteristics to understand the origin of these noises.