Session 25EP

The Influence of Small Impurities of ^{4}He on the ^{3}He Melting Curve Thermometer Behavior **25EP1**

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The melting curve of ^{3}He containing a small ^{4}He impurity was measured in the temperature range $20 - 600$ mK. It is found that the coordinates of the minimum of the melting curve are shifted and the slope of the melting curve at low temperatures is changed. The hysteresis between melting and crystallization curves appears. The data obtained agree with a calculation that takes into account the change in the coordinates of the minimum due to the entropy of mixing of the ^{3}He - ^{4}He solution. The results of the experiment are used to estimate the error of the melting curve thermometry using ^{3}He with ^{4}He impurity up to 2 %.

A computer-based pulsed NMR thermometer **25EP2**

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A mK or sub-mK pulsed Pt-NMR thermometer with a novel, easily implemented, computer-based control system has been developed. Timing, excitation, and signal acquisition are accomplished with a single standard National Instruments Data Acquisition (DAQ) board in a PC computer and a minimum of external analog circuitry. User interface, control of the DAQ board, signal processing, and a graphical display is implemented in the LABVIEW software system. The result is a flexible and robust alternative to NMR thermometer control. This work is supported by NSF and NASA.

25EP3 SRD1000: A superconductive reference device for thermometry below 1 K

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A Superconductive Reference Device (SRD1000), providing 10 reference points in the temperature range 10 mK - 1 K with dedicated measurement electronics, has been developed to provide direct traceability to the new Provisional Low Temperature Scale (PLTS-2000). We report on the reproducibility and the accuracy of the transition temperatures of samples of IrxRh100-x alloys (with transition temperatures between 20 and 100 mK) and some single crystals (Cd, Zn, $AuIn_2$, $AuAl_2$ and W).

25EP4 EU Dissemination of the Provisional Ultra-low Temperature Scale, PLTS-2000

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PLTS-2000 covers the temperature range from 1 K to 0.9 mK, and is defined by an equation for the melting pressure of ^{3}He (JLTP 126, 633-642, 2002). We report on the development, within the EU project 'ULT Dissemination', of several primary and secondary thermometers and fixed points with associated instrumentation, to disseminate the scale to users. Principal are a current-sensing noise thermometer (CSNT), a Coulomb blockade thermometer, an industrial-type CMN and a second-sound acoustic thermometer and a superconductive reference device SRD-1000. Several partners have set up ^{3}He melting-pressure thermometers to realise the scale, and will check this using PtNMR, CMN and noise thermometers. Other devices in the project are RuO_2 sensors and a self-contained ^{3}He melting pressure thermometer.

25EP5 Coulomb blockade thermometry in the milli-Kelvin temperature range in high magnetic fields

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We have investigated the usability of a Coulomb blockade thermometer (CBT) in high magnetic fields up to 27 T at temperatures around 50 mK. The experiments performed extend previous investigation both to lower temperatures and to higher magnetic fields. We show that CBTs provide an easy way of magnetic field independent thermometry in an up to now problematic temperature range.

High resolution Coulomb blockade primary thermometry in the mK temperature range 25EP6

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We present high resolution measurements using Coulomb blockade thermometers (CBT) in a temperature range from 4 K down to 20 mK. The purpose of the described experimental series is to extend the accessible temperature range of the CBT sensors for low temperatures, where the electron-phonon coupling gets weaker and affects the performance of the CBT. The results allow us to determine the absolute accuracy of the device and generate a valuable input for the design of further improved sensors.

Construction of an Ultra-Low Temperature STM with a Bottom Loading Mechanism 25EP7

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An STM that works with an atomic resolution at ultra-low temperatures (T $>$ 50 mK) in high magnetic fields (B $\leq$ 6 T) has been constructed and tested. An STM head is made of non-magnetic silver based alloys, and is attached to the mixing chamber of a dilution refrigerator (DR). Clean sample surfaces are prepared either by cleavage or by repeated cycles of Ar ion sputtering and annealing in an ultra-high vacuum chamber. The resultant surfaces can be evaluated by low energy electron diffraction in the same chamber. A bottom loading mechanism enables us to change the samples and STM tips quickly without warming the DR above 2 K and to cool it back to the base temperature within 3 hours. We demonstrate atomically resolved imaging and tunneling spectroscopy capabilities of this new instrument.

Improved laser scanning microscope for low-temperature probing of local resistive and microwave properties in superconducting structures 25EP8

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We present a new design of Low-Temperature Laser Scanning Microscope (LTLSM) for probing the spatial inhomogeneities of dc and ac current flow in superconducting structures. This far-field LTLSM apparatus is a substantial improvement over similar microscopes utilized by other groups and us earlier. The performance of the LTLSM is evaluated and sample results on imaging the distribution of optical, resistive and microwave 2-D patterns in real superconducting devices are presented.

25EP9 Development of Interdigital Capacitor as Solid ^{4}He Height Detector

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A compact interdigital capacitor is developed as a level detector of solid ^{4}He. The capacitor consists of 38 interlaced 50 μm wide and 3.8 mm long gold films separated by 50 μm and deposited onto a flat 5×5 mm^2 sapphire substrate. The background capacitance is 6.5 pF. The capacitance change is 1.3×10^{-3} pF/mm of solid ^{4}He height change. A height change of 20 μm is detectable. Observations at 1.2 K in a 6.7×8.7×9.1 mm^3 cell show over pressures (measured with a low temperature strain gauge) up to 25 mbar prior to nucleation of solid. The solid height may be controlled by varying heat applied to a pressure bomb cooled to 77 K.

25EP10 He-3 cryostats for SPM application near 300 mK

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Various types of He-3 cryostats have been developed for Scanning Probe Microscopy application in UHV environment. These systems provide base temperatures between 280 mK to 340 mK with holding time of 24 to 60 hours. Different application features are available for different systems, such as that samples can be top-loaded in a UHV sample tube by a sample probe with the He-3 insert be fixed; the He-3 insert can be moved up and down by a linear motion manipulator and the samples can be ”bottom” loaded directly onto the sample holder located in UHV space; with the high field superconducting magnet installed, the sample may either share the UHV space with the dewar, or has its own UHV space; ESR modulation coils installed for versatile application of the system, etc. Design and performance details will be discussed.

25EP11 Distributed τ_2 Effect in Relaxation Calorimetry

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In relaxation calorimetry at low temperatures, the so-called “distributed τ_2 effect” influences the time evolution of temperature, if the thermal conductance of the sample is small. This effect appears as a fast initial relaxation of the temperature that cannot be described by an exponential. If calorimetry data displaying such a feature are analyzed by conventional methods, systematic errors are introduced in the measured heat capacity. Drawing examples from our experimental data of a magnetic insulator sample in high magnetic fields, we show how these errors can be eliminated by a data-analysis method recently proposed by Takano and Muttalib.

High-Q Vibrating Wire for the Study of Quantum Vortex in Superfluid ^{3}He 25EP12

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To investigate quantum vortices in superfluid ^{3}He we have fabricated a vibrating wire from single crystal silicon with impurities less than 10^{-6}. The wire of 100 μm wide and 60 μm thick is controlled in a goal post shape of 2 mm square which is similar to a silicon vibrating wire studied by Grenoble group. We have investigated the characteristics of the vibrating wire in vacuum at 4.2 K in a magnetic field of 50 mT. The obtained quality factor (Q) is 1.2×10^5 at the resonant frequency of 8.7 kHz. This Q value is much higher than conventional Nb-Ti vibrating wires and four times higher than the previous silicon vibrating wire. The high-Q and shape-controllable vibrating wire of a single crystal silicon has the advantage for the creation and detection of the quantum vortex in superfluid helium.

X-ray diffraction measurement at 0.20K 25EP13

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We have developed an x-ray diffraction measurement system for powder samples below 1K. We use a dilution refrigerator of Oxford Instr. Kelvinox VT, which was modified for the x-ray measurement, mounted on a specially designed goniometer, provided by Rigaku Co. The x-ray beam was reduced approximately 1/15, after passing through the windows of the dilution refrigerator. The windows are consist of 4 walls of Be 2mm thick, 2 Al film 10μm thick and 2 aluminized mylar walls. The lowest temperature of the x-ray measurement was about 0.20K. For checking the temperature difference between the specimen and the thermometer (RuO_2) which attached to the mixing chamber of our measurement system, we have studied the temperature dependence of the Jahn-Teller distortion of $TmVO_4$ with T_c=2.15K.

High field ESR measurements of quantum spin system under high pressure 25EP14

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We developed a new high field ESR system under pressure and at low temperature. A clamped-type pressure cell with sapphire pistons is used to transmit the electromagnetic wave. We have also studied different quantum spin systems by ESR measurements using the pressure cell. We would like to make a presentation about the calibration of pressure by ruby and the result of the measurements of quantum spin systems under pressure.

25EP15 A Self-contained ^{3}He Melting Curve Thermometer for Dissemination of the New Provisional Low Temperature Scale

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We report progress in the development of a self-contained ^{3}He Melting Curve Thermometer, designed to be both easy to construct and simple to operate. It is based on a cylindrical pressure gauge, with good linearity of pressure versus inverse capacitance making calibration straightforward. The gas handling system is compact and in principle automatic. The readout electronics is based on a tunnel diode oscillator circuit, since one of the capacitance plates of the gauge is necessarily grounded. We present preliminary data on the performance of the thermometer, which will allow convenient dissemination the new provisional low temperature scale PLTS-2000.

25EP16 Mesurement of Thermal Properties for Modelling and Optimization of Large Mass Bolometer

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In this paper we describe our mesurements about the main thermal parameters of our bolometric detectors, operated in the underground Gran Sasso Laboratory to search for rare events. We measured (1) the specific heats of the main detector materials (TeO_2 crystal and Neutron Transmutation Doped Ge termistor) down to few tens of mK, (2) the electron-phonon decoupling in the thermistors and (3) the contact parameters (Kapitza resistence). We found that the thermal decoupling of our thermistors can be well described by the hot-electron model. These mesurements allow us to model our detectors. In order to compair the different detector performances we have introduced a parameter (factor of merit) that describes conveniently the signal-to-noise ratio, and that can be reproduced by the model.

25EP17 Optimization of 320g Ionization-Heat Cryogenic Detectors for the Dark Matter Search

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EDELWEISS is a WIMP direct detection experiment using 320g ionization-heat cryogenic Ge detectors operated in the very low-background environment of the Frejus Underground Laboratory (French Alps). EDELWEISS has presently the best sensitivity for all WIMPs with a mass greater than 70 GeV. For these ionization- heat Ge detectors, the rejection of incomplete charge collection events represents the main challenge. Several developments are pursued in order to improve this rejection, both actively and passively. New results on the rejection power of our detectors will be presented. In addition, the energy distribution of WIMP interactions is peaked at low energies. Therefore, the detectors design had been studied to reduce the energy threshold. The improvement of the detectors responses will be described.

Transition Edge X-ray Sensors for Industrial Applications **25EP18**

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We present the performance of Transition Edge Sensors (TES) using Au/ Ti bilayer (operating temperature 103mK) with fast decay time for industrial applications. The energy resolution was 12.6eV at 5.9keV (designed value 6eV) and the decay time 147us, yielding the count rate 1.1kcps (count per sec.). We found that the energy resolution was limited by excess noise and thermalization noise. The relation between these noises and TES parameters will be discussed.

Direct gas density measurements in the collider cryogenic vacuum chambers **25EP19**

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A principle difficulty arises at pressure measurement in the collider cryogenic vacuum chamber, because the usual gauges situated in the warm part of vacuum chamber don't give real value of the gas density in the cold part. It is caused by that mean speed of the molecules desorbed under irradiation by synchrotron radiation (SR) from the vacuum chamber walls is unknown. A new method of direct measurement of residual gas density in cryogenic vacuum chambers in presence of SR is presented. The method bases on using a photomultiplier tube for the detection of the SR-stimulated gas luminescence, which is proportional to the gas density and SR intensity. The design of the experimental setup and results of the measurements of gas densities (H2, CO2, CO, N2, Ar, O2) by this method are submitted.

Technical developments for solid-state NMR quantum computers **25EP20**

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We discuss practical methods to implement an NMR quantum computer in solids. There are two main issues known for the implementation. One is how to initialize qubits effectively. We show that a *qubit initializer* can be utilized for this purpose, where the combination of an optical pumping and a polarization transfer methods is utilized. The scheme is useful because it enables us to separate the initialization scheme from the computation scheme. The other issue is how to provide an practical inter-qubit coupling for a controlled-NOT (CNOT) gate. We propose to use a switchable CNOT gate realized by magnon-mediated inter-nuclear couplings in a quantum electron spin chain placed in a magnetic field gradient and low temperatures. This scheme provides us with a decoupling-free quantum computer.

25EP21 Multiplex readout of high energy resolution γ-ray calorimeters.

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Large arrays of microcalorimeters will be required in the coming decade for materials analysis and astronomy. To realize arrays of over 1000 pixels, it is essential to multiplex signals. We demonstrate the multiplexed readout of γ-ray calorimeters. The devices are Mo-Cu transition edge sensors with bulk Sn absorbers of area 1mm$\times$1mm. To read out multiple sensors with single SQUID, we biased the devices with an AC current instead of a DC current as used previously. We demonstrate that the resolving power of the sensors is over 1000 at 60keV and is undegraded by a two pixel multiplexed measurement.
This work was performed under the auspices of the U. S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

25EP22 Infrared Spectroscopy under Extreme Conditions

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We constructed a magneto-optical spectroscopy apparatus in the infrared region using synchrotron radiation at SPring-8. In the apparatus, an infrared microspectroscopy ($\sim 20\mu$m) is combined with low temperatures ($\geq$ 3.5 K) and high magnetic fields ($\leq$ 14 T). The purpose is to investigate the electronic structure under extreme conditions of tiny materials such as organic conductors and of small region and its spatial imaging. After installation of a high pressure cell, optical measurements under multiple-extreme conditions will be available. The specification and recent results are presented.

25EP23 Passive Magnetic Shielding for the Submillimeter and Far Infrared Experiment

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Goddard Space Flight Center is developing the Submillimeter and Far Infrared Experiment (SAFIRE). SAFIRE will use SQUIDs as amplifiers for detectors, which must be shielded from the magnet cooling system, an Adiabatic Demagnetization Refrigerator (ADR). This requires the field at the detector package to be at or below the 10^{-7} tesla level while the detectors are operating. However, the ADR produces a central field in the magnet while the detectors are operating of 0.1 tesla. In order to meet the requirements, we tested passive magnetic shielding using ferromagnetic and superconducting material. We have taken the paramagnetic salt pill effect into account in the calculation as well as the nonlinear property of ferromagnetic material. We discuss laboratory tests of the passive shielding and simulations.

Electron Spin Resonance Measurements at Ultralow Temperatures

25EP24

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An electron spin resonance (ESR) measurement system for use at ultralow temperatures using a ^{3}He-^{4}He dilution refrigerator has been developed down to 160 mK. As the first experiment, the ESR was measured on a quantum spin chain Cu benzoate, in which a field-induced gap was recently found. The evaluation of a new ESR mode, so called breather mode, was found at the lowest temperatures. In the present work, we observed a smaller gap in $H\|$b by suppressing of the thermal excitation.

Low Temperature Measurement System based on a Closed-Cycle Refrigerator

25EP25

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We have built a new torque magnetometer with a 4-K closed cycle refrigerator. The temperature of a top-loading space can be lowered down to 1.5 K by pumping out liquefied helium. The torque sensor consists of the four piezoresistors on a silicon cantilever. We measure an off-balance signal of the bridge with a resolution of 1 nV. Using a couple of the two coaxial permanent magnet can vary the magnetic field continuously up to 10 kG. We describe a software for the temperature control, the field control, and the motion control by LabVIEW. The temperature control consists of the two-independent PID loops with a typical stability of $\pm$0.01 K. We have demonstrated the torque measurement of a high-T_c superconductor successfully. The present system can be used for the versatile purposes in the low-temperature laboratory.

Conductive oxide cantilever for cryogenic nano-potentiometry

25EP26

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Nanoscale electrical transport properties have been attracted because of new phenomena such as ballistic transport, quantized resistance, and Coulomb blockade. For measurement of nanoscale resistance, we have been developing a cryogenic atomic force microscope that can operate at 1.8 K. To use it as an electrode, we coated the cantilever with conductive oxides of TiO and indium tin oxide (ITO) . We verified that TiO and ITO thin films remain conductive even at 4.2 K. Also we measured I-V characteristic of the tip-sample contact with a standard sample of $NbSe_2$ single crystal, and found that the conductive coats were not lost under large stresses due to the tip-sample contact. Moreover, we succeeded to obtain a room temperature nano-potentiometry of a gold thin film with the ITO coated cantilever. In conclusion, the TiO and ITO coated cantilevers are applicable to cryogenic nano-potentiometry.

25EP27 New Technique for Measuring Thermal Conductivity at Low Temperatures

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The measurement of the thermal conductivity of samples with small thermal conductance has always been an ongoing challenge, as the acceptable value of the parasitic power dissipation during the measurement decreases with decreasing thermal conductance. This problem is particularly important in measurements at very low temperatures, because the thermal conductivity of most systems becomes very low. For example, this fact prevented until now, beside other reasons, the measurement of the thermal conductivity of glasses at temperatures below $10\,\mathrm{mK}$. We present a new technique for thermal conductivity investigations, which allows for a contact-free measurement and makes use of thermometers with very low parasitic power dissipation. We show first results for the thermal conductivity of glasses obtained with this method at very low temperatures.

25EP28 Modeling of Quantum Random Number Generator on Magnetic Flux Qubits

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The qubit is represented as a magnetic flux quantum $n * f0$, (n=0, 1) in small superconducting ring with hole dimension $D = \ lambda$, $\ lambda$-magnetic field penetration depth, f0-magnetic flux quantum. Lattice of 32x32 holes in superconducting film, with thickness $d > \ lambda$ and lattice parameter $r > \ lambda$, is quantum 1024 dimensions space. Full number of quantum vectors is equal to 2^{1024}. Magnetic flux may be generated by picking up coil, $N * f0$ ($N < 1024$-random number). The random flux quantums may be monitored by 1024 SQUID sensors on the ground surface of ground plate.

25EP29 Calorimeter for a Top-Loading Dilution Refrigerator in High Magnetic Fields

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We have developed a calorimeter for a top-loading dilution refrigerator to achieve a fast turnaround time in specific-heat measurements at temperatures down to 60 mK. The special features of this calorimeter are compatibility with high magnetic fields, stability at temperatures above the normal operating range of dilution refrigerators, and the small amount of sample required for measurements. The calorimeter has been successfully used to measure the specific heat of milligram samples at temperatures between 60 mK and 3 K and in magnetic fields up to 18 T. The sample can be cooled from room temperature to the lowest temperature in just five hours. As an example, we will present the results of an experiment on pure copper at temperatures below 1 K in a 18 T field.

A Simple Sample-Inverting Cryostat for Hall Resistance Measurements 25EP30

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A simple sample-inverting cryostat for Hall resistance measurements is introduced to a superconducting magnet system up to 17 T with temperature variable insert from 1.5 to 300 K (Oxford Inst.). Elliptical sample stage surrounding electric wires in 100 turns, which can be rotated to a horizontal axis, is turned upwards or downwards by switching the current to the 100-turn coil under a magnetic field. The direction of the stage, which is monitored by a Hall sensor on the stage, is controlled by the minimum current from 100 mA at 0.1 T to 1 mA at 15 T. By using the cryostat, Hall resistance is easily and precisely measured by alternating current as well as magnetic field with no mechanical gear or motor. Examples of the Hall resistance on intermetallic compounds such as CeSi are present.

Novel Apparatus for Pulsed Field Experiments: Piezoelectrically Driven Rotator and Micro-Cantilever 25EP31

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Pulsed field experiments are inevitably subject to experimental constraint such as limited space or large noise. It has been strongly desired, however, that various types of measurements can be performed in pulsed magnetic fields as in steady magnetic fields. From this point of view, we present here novel apparatus for pulsed field experiments, piezoelectrically driven rotator [1] and micro-cantilever [2]. The former is useful in fine adjustment of sample position in narrow space, while the latter is a high-sensitive torquemeter applicable to samples of 1μg. Performance in pulsed magnetic fields is demonstrated.

[1] E. Ohmichi *et al.* Rev. Sci. Instrum. **72** 1914 (2001).
[2] E. Ohmichi and T. Osada (submitted).

Real-space observation of surface 2DEG under magnetic field by STM 25EP32

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We have investigated various properties of Au(111) and Cu(111) surface states, which is by nature two-dimensional electron gas system, using scanning tunneling microscopy (STM) under ultrahigh vacuum $(< 1\times10^{-8}Pa)$, high magnetic field $(< 11T)$ and low temperature $(> 0.3K)$. Electron standing waves (ESW) are observed on these surfaces along the step edges and around the defects like a ripple spreading over water. We found that monolayer Pd films formed on these surfaces also showed similar ESW pattern with a longer periodicity, indicative of reduced electron density in the surface state. It demonstrates a capability of electron density modification in the surface 2DEG. We also observed that single atom Pd impurities on the Au(111) surface produce ESW which changes its contrast with magnetic field. The contrast change can be explained by a variation of scattering phase shift with magnetic field.

25EP33 A New Type of Zinc Heat Switch by Diffusion Bonding

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A superconducting heat switch is one of the most important elements in the nuclear demagnetization refrigerator. Aluminum and zinc have been used more often especially at ultra low temperatures. A new type of zinc heat switch has been prepared by a diffusion bonding with copper. The details of the fabrication and its performance are described.

25EP34 Fundamental Physics Research aboard the International Space Station

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NASA's research plans aboard the International Space Station (ISS) are discussed. A double instrument 2K low temperature microgravity physics facility is under development. Each instrument is capable of accomplishing multiple investigations. The first launch will take place in the 2005 to 2006 time frame, studying non-equilibrium phenomena near the superfluid 4He transition and measuring scaling parameters near the 3He critical point. The second launch will investigate boundary effects near the superfluid 4He transition and perform a red-shift test of Einstein's theory of general relativity. Follow-on flights will occur at 22-month intervals. A laser cooled atomic fountain clock is also under development for the ISS. It will serve as a pathfinder experiment for future experiments on laser-cooled atoms in space.

25EP35 Bipolar Photogenerated Terahertz Radiation in Biased Photoconductive Switches

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We study the output scales of photogenerated terahertz (THz) radiation in semi-insulating GaAs using free-space electro-optic sampling (FSEOS) technique for the characterization of freely propagating far-field electromagnetic radiation. The spectrally integrated THz output from biased photoconductive switches are measured for several antenna gap spacings, applied bias fields and optical excitation fluences. Nearly symmetrical terahertz waveforms are observed. The waveforms and frequency spectrum(0.1-3THz) of the emitted radiation displayed essentially no dependence on the excitation fluence and strength of biased fields. However, it does slightly depend on the antenna gap spacing. Mechanisms based on the dynamics of these photoexcited carriers are discussed.

Low Frequency Losses and Flux-Creep in HTSC **25EP37**

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We study AC field losses in a BSCCO cylinder at field frequencies from 0.05 to 250 Hz, and temperatures between 65 K and 90 K. we find one local maximum and evidence for at least another peak. This structure of losses at low frequencies is reported here for the first time. Flux creep is found to be at the origin of this behavior. Measurements of flux relaxation present different regimes characterized by corresponding time constants. Our model explains why the maxima of dissipation are centered at angular frequencies proportional to the inverse of each relaxation constant.

A Sample Abstract for the 23rd Low Temperature Physics Conference **25EP60**

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