TT 60: Cryotechnique: Refrigeration and Thermometry

Time: Thursday 15:00–17:45 Location: HSZ 103

TT 60.1 Thu 15:00 HSZ 103

Characterization of mechanical vibrations and temperature oscillations on a low input power small scale 4 K pulse tube cryocooler — •Jack-Andre Schmidt[1,2], Bernd Schmidt[1,2], Jens Falter[1,2], Günter Thummes[1,2], and André Schirmeisen[1,2] — [1]Justus-Liebig-University Giessen — [2]TransMIT GmbH

Closed-cycle cryocoolers have become an important cooling concept tool for scientific research at low temperatures [1]. We here focus on Gifford-McMahon (GM) type pulse tube cryocoolers (PTC), which offer long measurement periods and low maintenance, but they exhibit undesired intrinsic effects due to the working principle.

The presentation will be about the study of these effects on a small scale 4 K PTC [2] driven by a helium compressor with adjustable input power between 0.9 and 2.3 kW [3]. The compressor makes it possible to characterize mechanical vibrations and temperature oscillations as a function of helium pressure level inside the cold head. Furthermore, the adjustment of the compressor has also influence on the cooling performance. On the basis of the attained results it is possible to propose new cooling procedures for future applications with pulse tube cryocoolers.

[1] R. Güsten, et al., Nature 568 (2019) 357-359
[2] B. Schmidt, et al., Cryogenics 88 (2017) 129-131
[3] C. Chialvo, et al., Cryocoolers 18 (2014)

TT 60.2 Thu 15:15 HSZ 103

Uniaxial strain cell for small-bore cryogenic systems — •Joonbum Park — Hochfeld-Magnetlabor Dresden (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

We present the development status of the miniaturized uniaxial strain cell for small-bore cryostats. This cell operates with two 18 mm piezoelectric stack actuators with a mechanical amplifier circuit and is capable of producing 1.0

TT 60.3 Thu 15:30 HSZ 103

Nanocalorimetry of Quantum Materials — •Mari C. Cole[1], Craig V. Topping[1], Andreas Gauss[2], Maximilian Kühn[2], Thomas Reindl[2], Ulrike Waizmann[2], Jürgen Weis[2], and Andreas W. Rost[1] — [1]University of St Andrews, School of Physics and Astronomy, North Haugh, St Andrews, KY16 9SS — [2]Max Planck Institute for Solid State Research, 70569 Stuttgart, Germany

New strongly correlated quantum materials not yet available as large single crystals as well as designer heterostructures grown by thin film techniques are central to many condensed matter research programmes. Thermodynamic measurements can give clear information about excitations and phase transitions but both types of materials have total heat capacities too small to be studied directly by conventional specific heat experiments. The requirement for a thermometer to have low thermal mass, be field independent, and make a primary temperature measurement due to challenges in calibration lead us to develop a SiN membrane supported Coulomb Blockade Thermometer [1] using Nanofabrication techniques to fabricate $Al/Al_2O_3/Al$ tunnel junctions. Current target materials for our studies include micrometre sized crystals of spin liquid candidates as well as thin films of heavy fermion compounds. I will report on commissioning measurements using heavy fermion compounds such as $CeAuSb_2$.

[1] J. P. Kauppinen et al., *Rev. Sci. Instrum.*, **69**, 4166 (1998)

TT 60.4 Thu 15:45 HSZ 103

Cross Correlated Noise Thermometer for Milli-Kelvin Temperatures — •Christian Ständer, Sebastian Kempf, Andreas Reiser, Andreas Fleischmann, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University.

Within our search for easy-to-use and reliable thermometers for milli-Kelvin and micro-Kelvin temperatures we developed a noise thermometer, where the Johnson noise of a massive cylinder of high purity silver is monitored simultaneously by two current sensing dc-SQUIDs. Operating both SQUIDs in voltage biased mode in a 2-stage configurations allows to reduce the power dissipation as well as the noise of the SQUIDs to a minimum. By cross-correlating the two SQUID signals, the noise contribution of the read-out electronics is suppressed to a marginal level even at micro-Kelvin temperatures. To further reduce the correlated amplifier noise we designed and fabricated SQUIDs with minimal coupling of input and feedback coil. We recently assembled a first small series of such thermometers to best reliability, reproducibility and user friendliness at beta-testing sites. In the complete investigated temperature range from 4 K down to 5 mK, the measured noisepower is linear in temperature. Statistical uncertainty below 0.1% is achieved within integration times of 45 s. The thermometers of the series agree within less than 0.1% in the complete temperature range.

TT 60.5 Thu 16:00 HSZ 103

A Microcalorimeter Based on Metallic Paramagnetic Temperature Sensors — •Matthew Herbst, Andreas Reifenberger, Clemens Velte, Sebastian Kempf, Loredana Gastaldo, Andreas Fleischmann, and Christian Enss — Kirchhoff Institute for Physics, Heidelberg, Germany

We present a micro-fabricated platform designed to measure the heat capacity of mg-sized samples at temperatures between 10 mK and 500 mK. The set-up makes use of the relaxation method, where the thermal response following a well defined heat pulse is monitored in order to extract the specific heat. Thermometry is based on a paramagnetic Ag:Er temperature sensor, which is read out by a dc-SQUID via a superconducting flux transformer. This allows us to reach a relative temperature precision better than $30\,\mathrm{nK}/\sqrt{\mathrm{Hz}}$ and an addenda heat capacity of 400 pJ/K (at 50 mK). Besides the performance of the set-up, we also present the results of first measurements of holmium-doped noble metals. In conjunction with data obtained from other calorimetric set-ups, we are able to shed light on the complex dynamics of these materials, and precisely determine their specific heat at different temperatures and chemical compositions. The measurements also have direct application for projects such as the neutrino mass experiment ECHo, where the heat capacity of holmium alloys directly influences the energy resolution of the detector.

TT 60.6 Thu 16:15 HSZ 103

Chip-based calorimeter for micro- and nanostructures — •Julian Litzel, Sebastian Kölsch, Fabrizio Porrati, and Michael Huth — Institute of Physics, Goethe University, Max-von-Laue-Str. 1, Frankfurt am Main 60438, Germany

Recently, direct-write nanofabrication by focused electron or ion beam induced deposition (FEBID/FIBID) has gained significance in various areas of solid state physics and materials science [1]. Single or multi-component ferromagnetic, superconducting and granular electronic micro- and nanostructures can now be fabricated routinely at a lateral resolution that rivals advanced electron beam lithography but also allows the creation of complex three-dimensional nano-architectures. Due to the small size of these structures, standard techniques for heat capacity measurements cannot be applied.

We are developing a turn-chip based platform for heat-pulse calorimetry that uses a thin SiN_x membrane onto which the heater element and thermometer are deposited by applying direct-writing techniques. This membrane then serves as the platform for the material whose heat capacity is measured. We present the chip design and show first results.

[1] M. Huth, F. Porrati, O. V. Dobrovolskiy, Microelectronic Engineering, 185 - 186, 9 (2018)

15 min. break.

Invited Talk TT 60.7 Thu 16:45 HSZ 103

Heat and Work Fluctuations in a Quantum Heat Engine — Timo Kerremans, Peter Samuelsson, and •Patrick P. Potts — Physics Department and Nanolund, Lund University, Sweden

The fluctuations of thermodynamic observables shed insight into the non-classical nature of quantum thermal machines, paving the way for developing novel quantum technologies. I will present a detailed case study of heat and work fluctuations in the heat engine proposed in [Phys. Rev. B **93**, 041418(R)]. As a thermo-electric device, work fluctuations are directly linked to electrical current fluctuations, circumventing any ambiguity in defining work as a fluctuating quantity in the quantum regime. We find that while heat fluctuations can be described classically, the work fluctuations either require a quasi-probabilistic description, or an explicit description of the measurement process. The non-classicality of the work fluctuations implies that the first law of thermodynamics cannot be formulated for a single experimental run. This is in stark contrast to classical fluctuating systems, where only the second law may be violated for single runs.

TT 60.8 Thu 17:15 HSZ 103

Tunable refrigerator for non-linear quantum electric circuits

— •Hao Hsu and Gianluigi Catelani — Forschungszentrum Jülich, Jülich, Germany

The emerging quantum technological devices call for fast and accurate initialization of the functional quantum states to a low-entropy state. To this end, we theoretically study a recently demonstrated quantum-circuit refrigerator [1][2] in the case of non-linear quantum electric circuits such as superconducting qubits. We find that for typical experimental parameters, the refrigerator is suitable for quickly cooling different qubit types close to their ground states. In fact, the maximum refrigeration rate of transmon and flux qubits is roughly an order of magnitude higher than that of usual linear resonators, providing additional flexibility in design criteria. The dynamic on/off ratio of the refrigeration rates assumes values above 10^4 with typical experimental parameters. Thus the refrigerator is a promising tool for quantum technology and for detailed studies of open quantum systems.

[1] K. Y. Tan et.al., Nat. Commun. 8 15189 (2017)
[2] M. Silveri et.al., Phys. Rev. B 96, 094524 (2017)

TT 60.9 Thu 17:30 HSZ 103

Enhanced Grüneisen Parameter in Supercooled Water

— •Mariano de Souza[1], Gabriel Gomes[2], and Harry E. Stanley[3] — [1]São Paulo State University, IGCE - Department of Physics, Rio Claro - SP, 13506-900, Brazil — [2]University of São Paulo, Department of Astronomy, São Paulo, 05508-090, Brazil — [3]Boston University, Department of Physics, Boston, 02215, USA

We use the recently-proposed compressible-cell Ising-like model to estimate the ratio between thermal expansivity and specific heat (the Grüneisen parameter in supercooled water. Near the critical pressure and temperature, the Grüneisen parameter becomes significantly sensitive to thermal fluctuations of the order-parameter, a characteristic behaviour of pressure-induced critical points. Such enhancement of the Grüneisen parameter indicates that two energy scales are governing the system, namely the coexistence of high- and low-density liquids, which become indistinguishable at the critical point in the supercooled phase. The temperature dependence of the compressibility, sound velocity and pseudo-Grüneisen parameter are also reported. Our findings support the proposed liquid-liquid critical point in supercooled water in the No-Man's Land regime and indicates possible applications of this model to other systems [1]. In particular, an application of the model to the qualitative behaviour of the Ising-like nematic phase in Fe-based superconductors is also presented.

[1] G. Gomes, H.E. Stanley, M. de Souza, Scientific Reports 9, 12006 (2019).