TT 11: Poster Session: Matter at Low Temperature

Time: Monday 14:00–18:00 Location: P4

TT 11.1 Mon 14:00 P4

Development of a large-area detector for position and energy resolving detection of molecular fragments — •Alexandra Kampkötter, Andreas Fleischmann, Loredana Gastaldo, Sebastian Heuser, Sebastian Kempf, Christian Pies, Jan-Patrick Porst, Philipp Ranitzsch, Sönke Schäfer, Sarah Vick, Thomas Wolf, and Christian Enss — Kirchhoff Institute for Physics, Heidelberg University

The recombination of a molecular cation with a low-energy electron, followed by fragmentation, is a fundamental reaction process in cold and dilute plasmas. For polyatomic ions, it can yield molecular fragments in excited states. The construction of a cryogenic ($\sim 2\,$K) storage ring to store molecular ions in their groundstate is in progress to be built at the Max-Planck Institute for Nuclear Physics in Heidelberg. For measurements in the ring the usage of a metallic magnetic calorimeter (MMC) is planned. A MMC consists of a particle absorber and a paramagnetic temperature sensor, placed in a weak magnetic field. According to the calorimetric detection principle, the deposition of energy in the absorber causes a rise in temperature of the detector. The resulting magnetization change of the sensor can be read out as a change in magnetic flux by a low-noise dc-SQUID-magnetometer. Additionally to an energy-resolution the detector for the application in the CSR shall give information about the position of a detected particle. Due to the diffusive expansion of heat in a large-area absorber, the impact location can be associated to the rise-time of the detector-signal for particles with energy of a few keV upwards.

TT 11.2 Mon 14:00 P4

Noise Contributions in Metallic Magnetic Calorimeters — •S. Heuser, S. Kempf, A. Fleischmann, L. Gastaldo, A. Kampkötter, C. Pies, J.-P. Porst, P. Ranitzsch, S. Schäfer, S. Vick, T. Wolf, and C. Enss — Uni Heidelberg, Heidelberg

Metallic magnetic calorimeters (MMCs) are particle detectors operated at a temperature below 100 mK. The energy deposited by an absorbed particle produces an increase of the detector temperature which induces a change of magnetization of the paramagnetic Au:Er temperature sensor sitting in a small magnetic field. Low-noise high-bandwidth dc-SQUIDs are used to detect the change of flux in a pick-up coil. In the last years MMCs showed a rapid progress both in the achieved energy resolution and in the reproducibility of the performance. Presently the energy resolution for x-rays is 2.8 eV (FWHM) at 6 keV. Detector modeling predicts sub-eV sensitivity for the next generation of devices. To achieve this goal, each noise source needs to be under control. The thermal fluctuation noise (TFN), dependent on the thermodynamical properties of the detector, is only finite intrinsic resolution limit. The read-out noise mainly depends on the properties of the SQUID and its coupling to the sensor. Magnetic Johnson noise is due to fluctuating current in normal metal in the vicinity of the pick-up coil. Finally we have observed a 1/f noise contribution caused by the sensor material, which can presently only be described empirically. In order to achieve optimal performance of MMCs, the last three noise contribution should be negligible in respect to the TFN. We discuss all these noise sources in detail and how they affect the detector performance.

TT 11.3 Mon 14:00 P4

Millikelvin-System for the investigation of solid state/cold atom hybrid devices — •Martin Knufinke, Petra Vergien, Helge Hattermann, Florian Jessen, Florian Karlewski, Daniel Bothner, Daniel Cano, Kai Buckenmaier, Tobias Gaber, Matthias Kemmler, Dieter Koelle, József Fortágh, and Reinhold Kleiner — Center for Collective Quantum Phenomena and their Applications, Eberhard Karls Universität Tübingen

The investigation of hybrid systems consisting of solid state devices coupled to ultracold atoms has a strong perspective towards fundamental physics. For example, in the context of cavity QED, strong coupling of cold atoms via a superconducting resonator or coupling between atoms and superconducting qubits should be feasible.

An appropriate setup has to meet the combined requirements of both the operation of superconducting devices and the ultracold atomic clouds. This demands for stable temperatures in the millikelvin regime even with thermal load from the magneto-optical trap used for the preparation of the atomic cloud, the radiation from the optical ports and the lasers. At the same time, excellent vacuum conditions and high quality optical access to the sample have to be provided. We report on the design, installation and testing of our dry dilution refrigerator. We show first measurements for the characterization of the system.

TT 11.4 Mon 14:00 P4

Mechanical dissipation in bulk silicon for precision measurements — •Gerd Hofmann[1], Christian Schwarz[1], Julius Komma[1], Daniel Heinert[1], Ronny Nawrodt[1], Giles Hammond[2], Alexander Grib[3], and Paul Seidel[1] — [1]Friedrich-Schiller-Universität Jena, Institute for Solid State Physics, Helmholtzweg 5, D-07743 Jena, Germany — [2]University of Glasgow, Institute for Gravitational Research, Kelvinbuilding, University Avenue, G12 8QQ Glasgow, Scotland — [3]Kharkov National University, Physics Department, 61077 Kharkov, Ukraine

Low mechanical loss materials are of great interest in high precision lengths measurements like interferometric gravitational wave detectors or cavities for laser stabilisation. The Brownian thermal noise of a test mass is directly linked to its mechanical loss by means of the fluctuation dissipation theorem.

We present systematic loss measurements of silicon bulk materials in a temperature range from 5 to 300 K and a frequency range from 10 to 100 kHz. The mechanical loss is obtained at the resonance frequencies by a Q-factor measurement. Dissipation processes that cause the mechanical loss like thermo-elastic damping or impurity based damping in the silicon samples are discussed in detail. Especially, the influence of oxygen impurities introduced during crystal growth on the mechanical loss is discussed. A strong dissipation peak at around 113 K is linked directly to transitions within a siloxane complexe (Si-O-Si). Mechanical losses as low as 2×10^{-9} have been obtained around 5.6 K.

This work is supported by the DFG under contract SFB TR7.

TT 11.5 Mon 14:00 P4

Development of a CuBe cell for magnetostriction and thermal expansion measurements in the PPMS — •Thomas Bauer, Robert Küchler, Manuel Brando, and Frank Steglich — Max-Planck-Institut für Chemische Physik fester Stoffe, Nöthnitzer Str. 40, 01187 Dresden, Germany

Thermal expansion and magnetostriction of solids give important information about the temperature and magnetic-field dependence of sample properties. Here, we report on the development of a cell designed to perform such kinds of measurements in the Physical Property Measurement System (PPMS) by Quantum Design. Due to limited sample space the biggest challenge to face was the miniaturisation of the cell. An entirely new concept of fabrication has been used to assure maximum resolution, easy and fast applicability and simple accessibility. We could achieve sensitivities equal to those of presently established thermal expansion measurement cells, i.e., within the range of $\Delta L = 10^{-1}$ to 10^{-2} Å[1]. For better thermal coupling and less influence of induced currents by the magnetic field, CuBe has been chosen as the adequate material. First test measurements of thermal expansion as well as magnetostriction have been performed from room temperature to 5 K on single crystals of selected systems which show 1^{st} and 2^{nd} order phase transitions.

[1] R Pott and R Schefzyk 1983 *J. Phys. E: Sci. Instrum.* **16** 444

TT 11.6 Mon 14:00 P4

Cantilever-based ESR detection at frequencies up to 400 GHz — •D. Kamenskyi, A. Dankert, O. Ignatchik, J. Wosnitza, and S. Zvyagin — Dresden High Magnetic Field Laboratory (HLD), FZ Dresden-Rossendorf, D-01314 Dresden, Germany

We present our recent developments of a new technique to measure electron spin resonance (ESR) spectra by means of cantilever-torque magnetometry. By combining a modulation technique with the use of a capacitive cantilever, we successfully observed ESR spectra in Cu-based weekly anisotropic materials (including $CuSO_4{\cdot}5H_2O$ and $CuCl_2{\cdot}2H_2O$) at frequencies up to 400 GHz and magnetic fields up to 16 T. The experimental details, performance, and limitations of the used ESR setup will be described.

Part of this work has been supported by Deutsche Forschungsgemeinschaft and EuroMagNET (EU contract No. 228043).

TT 11.7 Mon 14:00 P4

Coherent broadband continuous-wave THz spectrometry at low temperatures — Jennifer Marx[1], •Ernesto Uldarico Vidal[1], Komalavalli Thirunavukkuarasu[1], Holger Schmitz[1], Axel Roggenbuck[2], Anselm Deninger[2], Iván Cámara Mayorga[3], Rolf Güsten[3], Joachim Hemberger[1], and Markus Grüninger[1] — [1]II. Physikalisches Institut, Universität zu Köln, Zülpicher Str. 77, D-50937 Köln, Germany — [2]TOPTICA Photonics AG, Lochhamer Schlag 19, D-82166 Gräfelfing, Germany — [3]Max-Planck-Institute for Radio Astronomy, Auf dem Hügel 69, D-53121 Bonn, Germany

We report on the implementation of a cryostat into a continuous-wave THz spectrometer which uses the principle of mixing the light of two NIR DFB diode lasers at a photomixer for generating THz radiation over a broad range from 60 GHz to 1.3 THz. The THz radiation is detected coherently by a second photomixer. In combination with a fiber stretcher, our compact fiber-based setup allows very reliable determination of both real and imaginary parts of the complex optical functions, eliminating the need for Kramers-Kronig transformation. Furthermore, photocurrent correction can be used to correct for instabilities such as thermal drifts. Here, we present some results on different solid-state samples as an illustration of the capability of the spectrometer in the temperature range from room temperature to 1.5 K.

TT 11.8 Mon 14:00 P4

Coherent broadband continuous-wave THz spectrometer: Implementation at low temperature and high magnetic field — •Malte Langenbach[1], Komalavalli Thirunavukkuarasu[1], Andreas Janssen[1], Holger Schmitz[1], Iván Cámara Mayorga[2], Rolf Güsten[2], Axel Roggenbuck[3], Anselm Deninger[3], Markus Grüninger[1], and Joachim Hemberger[1] — [1]II. Physikalisches Institut, Universität zu Köln, Zülpicher Str. 77, D-50937 Köln, Germany — [2]Max-Planck-Institute for Radio Astronomy, Auf dem Hügel 69, D-53121 Bonn, Germany — [3]TOPTICA Photonics AG, Lochhamer Schlag 19,D-82166 Gräfelfing, Germany

Our high-resolution THz spectrometer employs photomixing of two NIR-DFB diode lasers for generation and phase sensitive detection of THz radiation of frequency from 60 GHz to 1.8 THz. A fiber-based phase modulation allows simultaneous determination of THz amplitude and phase. The two photomixers (the source and the detector) offer a compact face-to-face spectrometer assembly. Recently, this assembly was successfully integrated in the commercial magnetic cryostats. The initial problem of a low temperature resistant coupling between laser fibers and photomixers was overcome with a better design. We will present some first results to illustrate the properties of our setup and the response of the antennas for different temperatures down to 3 K and magnetic fields up to 8 T. The integrated setup enables phase sensitive broadband transmission spectroscopy in the subphonon regime at low temperatures and in high magnetic fields facilitating the study of low energy excitations in complex materials.

TT 11.9 Mon 14:00 P4

Design and first results of a ultra low temperature scanning tunnelling microscope — •Danny Baumann[1], Martha Scheffler[1], Ronny Schlegel[1], Torben Haenke[1], Christian Hess[1], Marko Kaiser[2], Ralph Voigtländer[2], Dirk Lindackers[2], and Bernd Büchner[1] — [1]Institut für Festkörperforschung, IFW Dresden — [2]Bereich Forschungstechnik, IFW Dresden

We present the design of a home build 300 mK, ultra high vacuum (UHV) scanning tunneling microscope (STM). The STM is equipped with a 9 T superconducting magnet, a home build xy-sample positioning system, in situ tip and sample exchange, radio frequency filter for all relevant signals as well as a three chamber UHV system to prepare, analyze and store tips and samples.

Furthermore, we show the results of energy calibration measurements with different tip-sample configurations using a Niobium BCS superconductor.

TT 11.10 Mon 14:00 P4

Setup of a STM Operating at milliKelvin Temperature — •Udai Raj Singh, Mostafa Enayat, Seth Cullen White, and Peter Wahl — Max-Planck-Institute for Solid State Research, Stuttgart, Germany

We present the set-up of a dilution-refrigerator based spectroscopic imaging scanning tunneling microscope. The STM can operate at temperatures down to below 10mK and in magnetic fields up to 14T to allow for studies of unconventional superconductors and heavy fermion materials. The system provides a continuous measurement time on the order of 150 hours and allows for sample transfer and in-situ sample cleavage. We present first results obtained at $T_{MXC} \approx 9$ mK on a $NbSe_2$ sample. To determine the energy resolution we have measured the superconducting gap of Aluminum. By fitting a BCS gap function to the spectra we have found the electronic resolution of our STM to be around 150 mK.

TT 11.11 Mon 14:00 P4

Broadband magnetodielectric spectroscopy on quantum paraelectric materials in the millikelvin-regime — •Christoph Grams, Max Schalenbach, Daniel Niermann, Harald Kierspel, and Joachim Hemberger — 2. Physikalisches Institut, Universität zu Köln, Deutschland

Quantum paraelectric materials are characterized by an extended dielectric permittivity due to the vicinity to a ferroelectric transition which, however, is suppressed by quantum fluctuations down to lowest temperatures.

Using broadband dielectric spectroscopy from 10^{-2} Hz to 1 MHz we examine the polarization dynamics in quantum paraelectric materials by measuring the complex permittivity as a function of temperature and magnetic field.

We present our results on (Fe-doped) $SrTiO_3$ and $Dy_2Ti_2O_7$. For the latter compound special weight has been put on the investigation of the magneto-dielectric response within the spin-ice regime which previously has been discussed in connection with the formation of magnetic monopoles [1]. *This work was supported by the DFG through SFB 608.*

[1] C. Castelnovo, R. Mössner, S. L. Sondhi, *Nature*, **451**, 06433 (2008)

TT 11.12 Mon 14:00 P4

Spectral Functions for Strongly Correlated Multi-Orbital Systems with full Coulomb Vertex — •German Ulm[1] and Alexander I. Lichtenstein[2] — [1]German Research School for Simulation Sciences and RWTH Aachen University, 52425 Jülich — [2]1. Institut für Theoretische Physik, Universität Hamburg

We present an efficient approach for calculating dynamical properties of solids with strong electron correlations. The fast cluster method, a finite temperature Lanczos method, is combined with Dynamical Mean-Field Theory (DMFT) in order to study orbital degenerate systems as function of temperature. The full local Coulomb interaction is taken into account in all calculations. We analyze different double-counting correction schemes for systems with strong electron correlations. We show results of an extensive study of the charge transfer system NiO in the LDA+DMFT framework using quantum Monte Carlo and finite-temperature Lanczos impurity solvers.

TT 11.13 Mon 14:00 P4

Channel-decomposed renormalization group equations for the vertex in a superconductor — •Andreas Eberlein and Walter Metzner — Max Planck Institute for Solid State Research, Heisenbergstr. 1, D-70569 Stuttgart

The investigation of superconductivity in repulsively interacting electron-systems is complicated by the interplay between different interaction channels, which have to be treated on equal footing. We use the functional renormalization group (fRG) to investigate the low-energy properties of such systems with the aim of finding an efficient parametrization of the effective Nambu two-particle vertex in a singlet superconductor. We analyse general properties of the vertex and the renormalization group flow for a reduced model with pairing and forward scattering with the aim of investigating superconductivity in the Hubbard model. Using a decomposition of the vertex in various interaction channels, we manage to isolate singular momentum and frequency dependences in a way suitable for an efficient parametrization.

TT 11.14 Mon 14:00 P4

Strong-coupling expansion in the Hubbard model by a diagrammatic-combinatorial computer algorithm — •Martin Paech[1,2], Eva Kalinowski[2,3], Walter Apel[4,1], and Eric Jeckelmann[1] — [1]Leibniz Universität, Hannover, Germany — [2]Academy of Computer Science and Management, Bielsko-Biała, Poland — [3]Union IT Services GmbH, Frankfurt am Main, Germany — [4]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Motivated by the efficient diagrammatic approach for the evaluation of high-order terms in the strong-coupling limit for the Hubbard model on the half-filled Bethe lattice with infinite coordination number we present an optimized and parallelized implementation of the underlying 'divide-and-conquer' algorithm. This new implementation is accompanied by a functional analysis of its recursive kernel and extended to systems away from half filling and finite-dimensional systems. As a first application, we study the ground-state energy and determine the critical coupling of the Mott-Hubbard transition from the radius of convergence of the series.

TT 11.15 Mon 14:00 P4

Abelian Z(N) topological order and its breakdown — •Marc Daniel Schulz[1], Julien Vidal[2], Sébastien Dusuel[3], and Kai Phillip Schmidt[1] — [1]Lehrstuhl für Theoretische Physik I, TU Dortmund, Otto-Hahn-Straße 4, D-44221 Dortmund, Germany — [2]Laboratoire de Physique Théorique de la Matière Condensée, CNRS UMR 7600, Université Pierre et Marie Curie, 4 Place Jussieu, 75252 Paris Cedex 05, France — [3]Lycée Saint-Louis, 44 Boulevard Saint-Michel, 75006 Paris, France

In the last years, topologically ordered systems gained much interest. Typical phenomenology uses models like Wen's plaquette model or the Toric Code proposed by Kitaev, which are exactly solvable models exhibiting topologically ordered ground states. Excitations in these models are Z(2) Abelian anyons which are completely local because they are protected by conservation laws. Here we present a generic extension of these type of models to the Z(N) case which possess a richer ground state degeneracy and a richer excitation spectrum. The major aim is to understand the robustness of the highly-entangled topologically ordered states against local perturbations. To this end we study for the cases $N = 3, 4$ the effect of external magnetic fields which results in mobile and interacting anyonic excitations.

TT 11.16 Mon 14:00 P4

Optimization of evaporation trajectories in weightlessness — •Roman Nolte — TU Darmstadt

Evaporative cooling is the essential method for attaining quantum degeneracy. Nowadays, optimization of evaporative cooling is done in the laboratory as an iterative process. Speed and yield are important aspects but usually not system critical. Not so, in the QUANTUS experiment [1], which explores quantum gases in microgravity. There evaporation time as limited resource and should be as short as possible.

In this contribution, we examine in detail the nonequilibrium process of evaporation in time-dependent traps for a classical gas [2]. We compare solutions of the ergodic Boltzmann equation with N-particle molecular dynamics codes performed on graphic cards. Results of various numerical simulations of particular evaporation processes are compared for the purpose of optimizing yield and duration.

[1] T. van Zoest et al., Science 328, 1540 (2010).
[2] O. J. Luiten et al., Phys. Rev. A 53, 381-389 (1996)

TT 11.17 Mon 14:00 P4

Condensation of bound states and pairs in interacting Fermi gases — •Michael Maennel[1,2], Klaus Morawetz[1,3], Pavel Lipavsky[4,5], and Michael Schreiber[2] — [1]Department Physical Engineering, Münster University of Applied Science, 48565 Steinfurt, Germany — [2]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [3]International Institute of Physics, Universidade Federal do Rio grande do Norte, 59.072-970 Natal-RN, Brazil — [4]Institute of Physics, Academy of Sciences, 16253 Prague 6, Czech Republic — [5]Faculty of Mathematics and Physics, Charles University, 12116 Prague 2, Czech Republic

We investigate a Fermi gas with finite-range interaction using a scheme to eliminate self interaction in the T-matrix approximation. In this way the corrected T-matrix becomes suitable to calculate properties below the critical temperature, without the use of anomalous functions. We calculate the phase diagram, excitation spectrum and equation of state. While in the low-density limit we find a condensation of bound states, for high density there is pairing. In between there is the BCS-BEC crossover.

TT 11.18 Mon 14:00 P4

Non-Equilibrium Dynamics of two coupled 1D condensates of interacting atoms — •Clemens Neuenhahn[1,3], Florian Marquardt[1,2], and Anatoli Polkovnikov[3] — [1]Institut für Theoretische Physik, Universität Erlangen-Nürnberg, Staudtstr. 7, D-91058 Erlangen, Germany — [2]Max Planck Institut for the Science of Light, Günter-Scharoswky- Strasse 1/Bau 24,D-91058 Erlangen, Germany — [3]Boston University, 590 Commonwealth Avenue Boston, MA 02215, USA

Motivated by recent experiments, we investigate the non-equilibrium dynamics of two interacting one-dimensional condensates following a quench of the tunnel-coupling to finite values. These coupled condensates provide a realization of the quantum sine-Gordon model, whose non-linear time-evolution after turning-on the coupling is studied using the semiclassical truncated Wigner approximation. We analyze the amplification of initial quantum fluctuations of the relative phase and the emergence of localized phase structures.

TT 11.19 Mon 14:00 P4

Relaxation phenomena in ultracold atomic systems after quenching the external potential — •Akos Rapp, Stephan Mandt, and Achim Rosch — Institute f. Theoretical Physics, Uni Cologne, Cologne, Germany

In contrast to the subjects of traditional solid state physics, ultracold atoms offer ways to realize and study states of matter without the influence of background degrees of freedom, impurities, etc. Furthermore, one can change the shapes and strengths of external potentials relatively easy, to investigate dynamics out of equilibrium. We study how a cloud of ultracold atoms in equilibrium in a harmonic trap evolves after the potential is changed suddenly. Without an optical lattice, the physics is usually relatively simple. However, in a deep optical lattice the kinetic energy is bounded, leading to unexpected relaxation phenomena. Even by simply turning the confining potential off, the system evolves through a nontrivial interplay of diffusive and ballistic motion of the atoms [arXiv:1005.3545], while reversing the sign of the harmonic potential allows equilibration to negative absolute temperatures, T<0 [PRL 105, 220405 (2010)]. We discuss direct experimental consequences of different external potential quenches and the common aspects of these out of equilibrium processes.

TT 11.20 Mon 14:00 P4

Radiofrequency spectroscopy of a strongly interacting twodimensional Fermi gas — •Enrico Vogt, Bernd Fröhlich, Michael Feld, Marco Koschorreck und Michael Köhl — Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, Cambridge CB3 0HE, United Kingdom

We have realized and studied a strongly interacting two-component atomic Fermi gas confined to two spatial dimensions using an optical lattice. Using radio-frequency spectroscopy we measure the interaction energy of the gas. We find that the strong confinement to two dimensions induces scattering resonances and leads to the existence of confinement-induced molecules which have no counterpart in three dimensions.

TT 11.21 Mon 14:00 P4

Strongly correlated fermions in disordered optical lattices — •Denis Semmler[1], Krzysztof Byczuk[2,3], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, 60438 Frankfurt am Main, Germany — [2]Institute of Theoretical Physics, Warsaw University, ul. Hoża 69, 00-681 Warszawa, Poland — [3]Theoretical Physics III, Center for Electronic Correlations and Magnetism, Institute for Physics, University of Augsburg, 86135 Augsburg, Germany

Strongly correlated fermions in binary and speckle disordered optical lattices are investigated. We numerically solve the Anderson-Hubbard model within the statistical dynamical mean-field theory, which incorporates fluctuations due to disorder as well as local correlations. Localization due to disorder is studied by means of the probability distribution function of the local density of states. In both cases, the paramagnetic ground state phase diagram is determined. Binary disordered fermions exhibit a Mott metal-insulator transition at non-integer filling. In contrast to box disordered fermions, the Anderson-Mott insulator and the Mott insulator are not continuously connected in the presence of speckle disorder.

TT 11.22 Mon 14:00 P4

Magnetorotons versus transverse magnetophonons of quasi twodimensional electrons in high magnetic fields — •Guenther Meissner and Uwe Schmitt — Theoretische Physik, Universitaet des Saarlandes, Postfach 151150, D-60041 Saarbruecken

The nature of two condensed phases: an incompressible quantum liquid of Bose-condensed charge-vortex composites and a 2D quantum solid with a lattice-periodic structure of the guiding centers of the Coulomb-interacting electrons, is investigated. Applying sum-rule techniques in a unified many-body approach, a finite gap (magnetorotons) due to correlations in the density fluctuations of the cyclotron orbits or no gap (magentophonons), because of broken magnetic translational invariance, are shown to exist rigorously in the long-wavelength limit of the low-lying collective modes. Effects of random disorder on the dispersion of the collective excitations of the two phases are investigated for a comparison with experimental results of systems exhibiting the fractional quantum Hall effect.