Low Temperature Detectors Workshop

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October 17, 2011 (HE61). The Low Temperature Detectors (LTD) Workshop is held each two years and gathers scientists developing, using and planning to use high precision particle and radiation detectors which are operated at very low temperatures. New achievement in the development and application of low-temperature detectors plus the description of large experiments enabled by them are discussed in this meeting series.

The LTD14 was held at the Kirchhoff Institute for Physics (KIP), Heidelberg University, Germany, from the 1st to the 5th of August 2011. It hosted about 300 scientists from all over the world.

The conference was kicked-off on Monday morning (August 1st) by the conference chair Christian Enss and the Dean of the physics faculty Manfred Salmhofer, followed by a tutorial session for students and researchers new to this field. Blas Cabrera introduced the different types of low temperature detectors developed so far, outlining the characteristic properties of the different detection techniques. In the second tutorial, Alex Burin described the physics of two-level systems (TLS) in amorphous materials (Fig. 1)[1]. This topic became of large interest in the LTD community due to the TLS effect on the performance of Kinetic Inductance Detectors (KIDs), and more generally on excess 1/*f* noise in micro-fabricated superconducting devices close to quantum limit.

Fig. 1. The lecture hall during the tutorial of Alex Burin.

The tutorials were followed by two very interesting sessions on Transition Edge Sensors (TES), the first of which discussed new insights into the physics of TES. Even though TES sensors have lateral dimensions of tens to hundreds of micro-meters, the physics of weak links and the quantum interference effects that go along with it seem to be of great importance for understanding of TES $R(I,T)$ characteristics and the noise when biased within the transition. In the second session, experiments where TES arrays are used or planned to be used were presented. Among the major applications were astrophysical experiments such as large sub-millimeter cameras or detectors able

[1] Electronic preprint of his corresponding paper submitted to JLTP is included in the October 2011 Issue of ESNF (No. 18).

to study solar physics. Upcoming experiments measuring the Cosmic Microwave Background polarization will as well widely use the TES technology.

The second day (Tuesday) was started by a session on the micro-fabrication of low temperature detectors and on cryogenics. Besides the comprehensive discussion of the specifically developed techniques, it was pointed out that low temperature detector arrays will be hardly produced by commercial companies. This is not due to the complexity of the involved fabrication processes, but rather to the flexibility needed in the selection of materials and geometries required for low temperature detectors. A very interesting and inspiring session on novel detection techniques followed, where calorimetric detectors using magnetic penetration thermometers (MPT) were drawing lots of attention. This renewed development of thermometers based on the temperature-dependent magnetic flux penetration of a superconducting sensor enabled to produce first x-ray detector prototypes with energy resolutions already approaching the performance of state-of-the art TES and MMC (metallic magnetic calorimeter) detectors. Diverse and fruitful future developments may be expected in this field, as this new detection concept is related to many of the presently leading technologies. This is illustrated by discussion comments such as: “It’s an MMC, replacing the paramagnet by a superconductor”, “it’s an inductive read-out TES” or “it’s an MKID (microwave kinetic inductance detector) operated in the thermal regime”.

The 2nd day afternoon session ranged from cutting-edge low-noise high-bandwidth readout of single channel devices to recent developments and future plans for the readout of future kilo- and mega-pixel devices, based on mixed time- and frequency-multiplexing schemes with low power dissipation at low temperatures. A new light was also shed on the time-domain pulse analysis as a promising approach for data reduction.

Fig. 2. LTD-14 participants enjoying the barbeque, drinks and discussions, before coming back to the public evening talk.

The Tuesday evening program included a public talk held by Christof Wetterich about “neutrinos as trigger for dark energy”. The time between the closing of the poster session and the evening talk was bridged by a barbeque, where everybody enjoyed food, drinks and certainly lot’s of scientific discussions in a perfect summer sunset atmosphere.

The two sessions on Wednesday morning were dedicated to MMCs and to the physics of particle absorbers and antennas. MMCs with improved flux coupling scheme, the paramagnetic sensor being sandwiched between the two superconducting layers of the pickup-coil, were presented. For soft x-rays, the energy resolution (integrated NEP) of 1.8 eV (FWHM) approaches already that achieved with TES sensors (1.6 eV @ 6keV) and no show-stopper is seen for resolutions below 1 eV. Besides single pixel achievements, realistic multiplexing schemes for MMCs where discussed opening the way to the use of those detectors in large-scale experiments. The importance to understand the physics behind the thermalization of energy in x-ray and particle absorbers was discussed in the second session. Even though superconductors have been considered for decades

to be very promising materials for large particle absorbers due to their small specific heat far below T_c, the down-conversion of energy to thermal excitation still remains a puzzling problem.

On Wednesday afternoon the LTD14 participants could continue their discussions on low temperature detectors in different sceneries during the excursions to Speyer, Burg Guttenberg, Neckarsteinach or Kloster Neuburg.

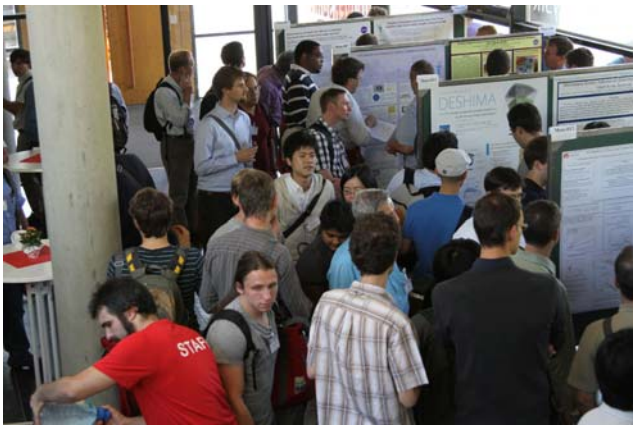

Fig. 3. A snapshot from one of the poster sessions. Important aspects of the physics of low-temperature detectors and results obtained in a wide range of experiments were discussed during the three poster sessions. LTD14 participants could learn from more than 200 posters which were hanging during the entire conference time.

The science program continued on Thursday morning with a session on neutrino physics studied by means of low-temperature detectors. The results achieved by already running experiments searching a neutrino-less double beta decay were presented and new promising results were discussed which show that low temperature detectors are getting ready for a direct neutrino mass determination by measuring the endpoint of calorimetric β^- and EC spectra. The second session was dedicated to kinetic inductance detectors. New geometries, resonators based on lumped elements, refined micro-fabrication techniques and new superconducting materials were discussed to allow for suppression of two-level system noise and to reach the intrinsic quasi-particle recombination noise level. The very good results obtained in the detection of microwave radiation combined with their intrinsic multiplexing capability makes MKIDs one of the most attractive techniques for large bolometer arrays in the next years. The Thursday afternoon session was dedicated to x-ray detectors. Due to the great performance of low- temperature detectors discussed in the previous days, it was not a surprise but still very impressive to see the test results obtained with the TES-based detector arrays having sub-2eV resolution for imaging x-ray spectroscopy in astrophysical experiments, the achievements of STJ (superconducting tunnel junction) detectors optimized for measurements at synchrotron facilities and the outstanding results obtained by TES based detectors used for nuclear safeguard gamma spectroscopy.

After Thursday's scientific program, the LTD14 participants gathered on the terrace of Heidelberg Castle for an aperitif watching the sunset over Heidelberg. The subsequent conference dinner in the prestigious Königssaal of the castle offered an almost fairy tale atmosphere.

Fig. 4. Two snapshots of the conference dinner. The welcome aperitif on the Heidelberger Schloss Terrasse, from which the LTD14 participants could enjoy a wonderful sunset (left). The Royal Hall (Königsaal) during the dinner (right).

The last day of LTD-14 started with the latest news in infrared astronomy and the importance of even more sensitive instruments to gain ever more information on the properties of interstellar media. Low-temperature detectors will in next future allow one to measure the polarization of the Cosmic Microwave Background. Instruments based on large arrays of antenna-coupled TES bolometers already show promising results, and the size of detector arrays deployed in ground-based telescopes is presently rising by kilo-pixels per year. KID arrays have been catching up very fast and have been successfully used also in the detection of mm-wave radiation, demonstrating that KIDs are a viable technology for astronomical investigations. A totally different but perhaps important application of LTDs optimized for terahertz radiation is a passive infrared camera for security applications. A first prototype of such a TES based device was presented and the achieved results suggest a considerable potential in this field.

Presentation of the session on IR to UV frequency range single photon detection showed that the use of low temperature detectors will allow for large improvements in quantum information permitting one to establish large bandwidth communication capacity or to obtain the lowest bit error rate. This is not the only field where single photon detectors will be used. Other examples are biological measurements and metrology in which the aim is to redefine the SI unit "candela". Different technologies can be applied for the development of single photon detectors: TES have already well established performance and many physics results have already been achieved; very interesting investigations have also been done for SNSPDs (Superconducting Nanowire Single Photon Detector).

Low-temperature detectors will also have a key role in promoting the understanding of the composition of the Universe. This topic was discussed in the session about Dark Matter detection experiments. A complete overview on the presently running and planned experiment and the exclusion plots combining all the present results were presented. The status and perspective of the main experiments for Dark Matter detection using low-temperature detectors, CDMS, EDELWEIS and CRESST, were discussed. In particular new and very promising technical approaches were presented and better understanding of the detector physics for active background rejection in different experiments demonstrated.

The last scientific session of the LTD14 conference was dedicated to the detection of massive particles and radiation. Applications of low-temperature detectors were discussed for: (a) mass spectrometry by means of STJ or SSLD (Superconducting Strip Line Detector) which allow the

precise determination of the mass of even neutral molecules, (b) stopping power measurement of ions in matter and (c) the possibility of an isotopic analysis of radioactive material such as nuclear waste by means of TES-based detectors able to measure with very high energy resolution the energy spectra of alpha particles. The Workshop was concluded with a wrap-up summary talk brilliantly presented by Kent Irwin of NIST in Boulder, CO, USA.

This 14th workshop on low-temperature detectors attracted scientist from all the leading groups in this field, which develop detectors for massive particles and photons based on very different physical properties of solids. The particles to be detected, ranging from THz photons to accelerated heavy ions, span more than 12 orders of magnitude in energy. The sensor concepts range from those exploiting fully athermal effects like in STJs or KIDs, over mixed types as in kilogram scale dark matter detectors, to fully thermalized schemes such as used in calorimetric high resolution x-ray detectors.

Like all previous conferences of this series, the scientific program of LTD-14 was inspiring to the participants by bridging the enormous diversity of sensor concepts and applications of low-temperature detectors with the involved solid state physics, micro-fabrication techniques, low-noise low temperature amplifiers, data processing and cooling techniques. Since the first workshops, over 20 years ago, where low-temperature detectors have mostly been discussed for, at that time, exotic experiments, many new applications have started to benefit from the unique properties of these detectors. New sensor concepts have been developed since then and a few of them are meanwhile mature enough to allow for experiments based on arrays of thousands of detectors or even more in the near future. The necessary low temperature multiplexing schemes are on their way. First prototypes show convincing performance for kilo-pixel arrays and some multiplexing ideas already aim for arrays much larger than these. Besides the improvements in the channel count of arrays, the scientific contributions and discussions at LTD-14 also made clear that there is still enormous room for improvement of the performance of each detector pixel. The phase space of interesting absorber materials has by far not been explored sufficiently and, for some classes of materials, the down conversion of the absorbed energy to thermal excitations has not been fully understood as yet. Looking at the great improvements and new ideas discussed at LTD-14 as well as the large phase space still open to be explored, we are looking forward to the next workshop, LTD-15, which will be held at the California Institute of Technology (CalTech) in 2013.

Fig. 5. Group photo of LTD-14 participants. In red shirts the organizers' team.

The full abstract book of LTD-14 is available here. The Proceedings of the Workshop will appear in an issue of Journal of Low Temperature Physics (JLTP). Electronic preprints of some selected manuscripts are pre-published in Issue 18 of ESNF. Additional preprints might appear in the Issue 19.