Consultation on possible topics for future activities
for integrating and opening existing national research infrastructures

Title

Title of the proposal

Microkelvin – a collaboration of European laboratories to foster education, technology development, and research at ultra-low temperatures as a joint "laboratory without walls".

Contact person

Family name

Krusius

First name(s)

Matti

Organisation

Microkelvin Programme – grant 228464 under FP7

Position in the organisation

Coordinator

Postal address

O.V. Lounasmaa Laboratory - Low Temperature Section, School of Science, Aalto University

Country

Finland

e-mail address

mkrusius@neuro.hut.fi or matti.krusius@aalto.fi

Is your proposal representing your own personal view or are you	Organisation

responding on behalf of your organisation as a whole?	view

Description of the research infrastructures covered and the trans-national access and /or services provided

Indicate the type of research infrastructures to be covered by the proposed topic, and list the research infrastructures in Member States, Associated Countries and Third Countries, that would provide transnational access and/or services to researchers, with brief descriptions of the state-of-the-art equipment and services offered to users that make them rare or unique in Europe. Outline the specific areas of research and scientific communities normally served by the infrastructures, as well as new areas opening to users, if any. Indicate what would be the overall access modalities necessary to be developed. Text of maximum 4000 characters including spaces.
Type of infrastructure: We promote European integration in the field of ultralow-temperature (ULT) physics, with the goal of submitting a proposal for a European infrastructure, the "European Ultralow Temperature Laboratory", a distributed research infrastructure without walls. This proposal builds on the successful concept of the European Microkelvin Collaboration under FP-7. **Microkelvin:** The current EU grant for ULT collaboration, which continues until September 2013, has encouraged and supported new research initiatives at ultralow temperatures, by providing access to refrigeration and measuring instrumentation which is not widely available in national institutions. It also provides education and training in low temperature physics and techniques for graduate students and has established a new forum for European cryogenic business to meet and discuss. The appearance of these new opportunities and the lively activity around them has gained Microkelvin great popularity in the European low temperature community. There is an urgent popular demand for a continuation of this effort. **Structure of collaboration:** Within Microkelvin, trans-national access to research infrastructure is provided by three centralized laboratories located in different Member States. These have been selected to have the capability of reaching temperatures down to the microkelvin range, with a large assortment of different types of refrigeration installations. The second requirement is to provide the measuring equipment and expertise for covering a wide range of different important experimental techniques. This is achieved by including in the current Microkelvin programme altogether 12 Partners from 8 Member States. In a new plan we propose to widen our constituency of partners and access sites. **Services & clientele:** The users of the ULT infrastructure are traditionally research groups in materials science and more recently in nanoscience. Microkelvin emphasizes the need to advance the range of accessible temperatures well below 10 millikelvin in nanosciences. Novel approaches are developed for cooling conduction electron systems to low millikelvin temperatures. For materials science research we plan to provide further

possibilities by including higher magnetic fields and elevated pressures in our assortment of opportunities. A further goal is to develop more sensitive measuring systems – often making use of SQUID-based sensors – for measurements approaching the quantum limit. The turn-around time of our equipment is improved by promoting automatic computer-controlled routines, especially for the operation of refrigerators. Much of the current refrigeration technology is based on the use of liquid helium; its market price is now unstable and rapidly rising. To reduce the dependence on liquid helium, we invest in cryogen-free "dry" refrigeration technology. The development of these capabilities has improved the quality and service offered at our infrastuctures and has reduced the time needed for a typical experiment.

Trans-national access modalities: ULT measurements are complicated by the demands on vacuum tightness, low heat loading, and reduced signal levels. Thus typical visiting times at the access site tend to be 1 – 3 months in duration. Secondly, the large assortment of different equipment and working routines require that the visitor and the host team work closely together during the visit. To put this in perspective, the Microkelvin 36 month periodic review report lists 40 months of total visitor time spent at the three access sites which is divided among 23 user groups and their 38 individual visiting researchers. Most visits lead to joint publications between the user group and the host team. The 36-month report lists 22 joint published reports with many more in the pipe line (see web page http://www.microkelvin.eu/project-activities-transnational.php).

Scientific domains served by the research infrastructures

Select the scientific domain(s) served by the research infrastructures	Engineering, Material Sciences and Analytical Facilities Physical Sciences
Indicate the main scientific domain served	Physical Sciences

Key potential partners

Indicate a list of key potential partners. Text of maximum 3000 characters including spaces, with 1 line per potential partner (participant organisation name, country and contact person)

The current Microkelvin collaboration has 12 partners which are listed below:

1) **O.V. Lounasmaa Laboratory**, **Aalto University**, Finland, National Centre of Excellence, selected and supported by the Academy of Finland for 2012-16. Its research concentrates on nanoelectronics and ultra-low temperatures. The Laboratory has two record low-heat-leak ULT refrigerators, of which one is a rotating machine. A new “dry” sub-millikelvin refrigerator is in construction, prof. Matti Krusius

2) **Institut Néel**, **Centre National de la Recherche Scientifique**, Grenoble, France. The largest centre in Europe dedicated to low-temperature research, with three sub-millikelvin refrgerators, prof. Henri Godfrin

3) **Ultralow Temperature Group**, **Department of Physics, Lancaster University**, UK. Lancaster physics was rated top in the UK (in the most recent UK research assessment exercise, RAE2008). Its Microkelvin Group has the largest cluster of advanced nuclear cooling refrigerators in Europe for studies on materials and devices down to 100 microkelvin. A new refrigerator built during Microkelvin is dedicated to nanoscience studies. The group holds the world record for dilution refrigerators (1.75 mK), also for the nuclear cooling of metals (copper and platinum), as measured by an in-situ thermometer (6 microK), and for cooling liquid helium-3 (~80 microK), prof. George Pickett

4) **Ruprecht-Karls-Universitaet** Heidelberg, Germany, prof. Christian Enss

5) **Royal Holloway and Bedford New College**, University of London, UK, prof. John Saunders

6) **Scuola Normale Superiore di Pisa**, Italy, prof. Francesco Giazotto

7) **Institute of Experimental Physics, SAS, Kosice**, Centre of Low Temperature Physics, Centre of Excellence of the Slovak Academy of Sciences, Slovakia, Dr. Peter Skyba

8) **Universitaet Basel**, Switzerland, prof. Dominik Zumbuehl

9) **Technische Universiteit Delft**, The Netherlands, Prof. Teun Klapwijk

10) **BlueFors Cryogenics**, Helsinki, Finland, Dr. Rob Blaauwgeers

11) **Universiteit Leiden**, The Netherlands, prof. Tjerk Oosterkamp

12) **Physikalisch-Technische Bundesanstalt**, Berlin, Germany, Dr. Thomas Schurig

The present members will constitute the core of a new application in the next call for EU research infrastructures. Negotiations about partners and structure of the successor programme are ongoing. Access sites will be chosen to possess both the capability of achieving sub-millikelvin temperatures and of making available different physical measurement techniques so that these laboratories together carry expertise and equipment to serve as wide a range as possible of customer groups with different interests.

Scope and activities

Describe the overall objectives of the activity. Describe the benefit that the proposal would bring about in terms of integrated provision of infrastructure related services. When appropriate, describe how the network would integrate with the relevant e-Infrastructures. Text of maximum 2000 characters including spaces.
Outreach: Historically research in materials sciences has been driving the quest for lower temperatures. In Microkelvin, one of the principal objectives has been to reach out also to nanosciences. The ever-increasing complexity of electronics is rapidly bringing us to the limit when typical component sizes reach atomic dimensions and no further miniaturization is possible. At that point we need something new. Electronics based on coherent electron behaviour promises to provide a new way forward. In nanocircuits, the electrons can behave coherently over the circuit dimensions and thus follow the quantum rules of wave motion rather than Ohm's law. This will open up a whole range of new devices based on quantum electronics and this is where lower temperatures can help. For coherent transport, the electrons must be able to move through the circuit without scattering. To achieve scattering lengths larger than the sample size, we need to minimize both impurity scattering and thermal scattering. The former demands high purity materials. The latter, requires low temperatures. For this, even at the more easily accessible millikelvin temperatures, the circuits need to be of nanoscale. This size restriction provides the motivation for exploiting the advantages to be gained by working at much lower microkelvin temperatures. Despite this need, nanoscience is inhibited from advancing below the millikelvin temperature regime by a lack of expertise and facilities. In Europe we already have the greatest concentration of microkelvin infrastructure and expertise in the world, developed by our quantum-fluids community. Microkelvin has been putting this existing infrastructure at the disposal of the nanoscience community, developing together new techniques to bring coherent structures into a new temperature regime. This is leading to the creation of a European microkelvin "laboratory without walls" and is encouraging new European commercial interests.

Indicate the Networking Activities that could be foreseen to foster a culture of co-operation between the research infrastructures and scientific communities. Indicate the Joint Research Activities that could be foreseen to improve, in quality and/or quantity, the services provided by the infrastructures. Text of maximum 4000 characters including spaces.
The mix of different activities in the current Microkelvin grant, consisting of networking, trans-national access, and joint research tasks, has proven both practical and efficient: Networking activities have provided an incentive to start new services for the low-temperature community, while trans-national access services have invigorated the research field, by creating new initiatives and by bringing more researchers in the centre

of the action. Among these is our effort to bring both leading experts from high-level laboratories and researchers from developing countries to our Microkelvin and Microkelvin-related meetings. The four packages of Joint Research Activities have been instrumental in developing refrigeration and measuring techniques. In the absence of Microkelvin, they would not necessarily have been worked on, unless they happened to be essential stepping stones for progress within the agenda of some single research group. This is because physics at ultralow temperatures requires elaborate large-scale infrastructure in refrigeration and measuring instrumentation that is difficult to build and maintain in sufficient extent by individual academic research units.

Joint Research Activities: Two of the four Joint Research Activity packages develop cooling techniques, both with conventional approaches (JRA1) as well as by applying new "on-chip" nano-electronics methods (JRA2). High- sensitivity low-noise measurement, in some cases at the quantum limit, is a further important field of development (JRA4). Some results from these efforts are tested within the Collaboration in studies of fundamental physics questions in experiments at microkelvin temperatures (JRA3). These are condensed matter simulations of problems in the physics of atomic condensates, in cosmology, gravitation, or particle physics. All tasks in the different JRA packages are from the very frontier of ULT research and have been planned to provide input to other physics communities for their research. The 70 Microkelvin research publications listed in the 36-month Periodic Review Report characterize the extent of this work (see web page http://www.microkelvin.eu/documentation.php).

In nanoelectronics a major present obstacle is the cooling of conduction electrons to 10 mK and below. In JRA1 conduction electrons have now been cooled to lower temperatures than before, by improving thermal contact to the refrigerator, by reducing heat leaks from external sources, and by including active direct cooling of the electrons. Faster and more accessible refrigeration has been achieved with new "dry" pulse-tube-cooler operated 3He-4He dilution refrigerators which have been developed by our SME partner BlueFors and which then have been tested by our various partners. In Lancaster an advanced large-size low-heat-leak refrigeration installation has been constructed which is specifically designed to increase access for nanoscience and quantum coherence measurements in nanomechanics at microkelvin temperatures.

In JRA2 different novel approaches are developed to cool nanodevices with both ex-chip techniques, by improving thermal contact and electric filtering, and directly with on-chip nanocoolers. The goal is to generate for various types of thin-film sensors a platform which would cool from 0.3 K to 50 – 10 mK temperatures. Obviously success here would be of great value for instance in satellite-borne infrared astronomy. At present the goal is to demonstrate improved cooling with a thermometer integrated on the same chip or platform. Coulomb-blockade or GaAs quantum dot thermometers for this task are developed in JRA4, along with other thermometry down to the microkelvin regime. High-sensitivity SQUID amplifiers operating at different frequency regimes is a further frontier in the JRA4 development work.

Need for European integration

Explain why this proposed topic would require a European (rather than a national or local) approach. Describe how resources provided by EU would be mobilised. Indicate how account is taken of other national or international activities, and any resources that would complement an EU contribution. Text of maximum 3000 characters including spaces.

The need for integration: Traditionally, the development of refrigeration and measurement techniques at ultra-low temperatures has been the responsibility of small academic research groups. Their limited resources of manpower and funding have enforced narrow specialization of the research agenda. No single European country has been able to create a laboratory strong enough to cover all the demands on development and services which are now needed on the European scale. The same considerations apply to present needs of advancing research and education. Currently it is the Microkelvin Collaboration which provides a forum for discussing and funding coordination of research efforts, training, and access services on the inter-European arena. Now after three years of operation, we realize how this has created new opportunities, revitalized the field, and accelerated progress. This should be continued.

Workshops: To advance its inter-disciplinary goals, Microkelvin has organized annually its own one-week workshop of 50 – 80 participants. The programme is constructed around different topics of great current interest, with the aim to bring together both the ULT community and research groups in materials and nano-sciences which are particularly interested in pushing their efforts to lower temperatures. In addition, in special sessions Access Users have an opportunity to present their results to the workshop audience, to receive feedback and to discuss further new ideas. The workshop programme also includes training sessions for graduate students in various different aspects of ULT techniques.

Education: The ULT community has organized every second year a two-week lecture and training course in low-temperature physics and techniques for 30 – 50 European graduate students. It consists of series of lectures on different topics which have been delivered by professors and senior researchers, with the goal to familiarize senior students from different fields with low-temperature refrigeration and measurement. In the intervening years a cryo-conference has been taking place where graduate students lecture about their own research and discuss its results. Both types of training programmes have been extremely popular among the graduate students who have learnt to know both physics and their fellow students from all around Europe. These activities have been supported by the Marie Curie Training programme and now by the Microkelvin Collaboration.

Popularization: A popular effort within Microkelvin has been the popularization of physics in general as well as in the ultralow temperature regime. This has been carried out usually locally and annually by the individual Partners in the form of public lectures, exhibitions, and happenings.

Expected impact

Describe the expected impact of the proposed activities on the scientific communities, on the functioning of the research infrastructures, and on the development of the European Research Area (including balanced territorial development). Highlight the contribution to socio-economic impacts, including for promoting innovation and developing appropriate skills in Europe. Text of maximum 3000 characters including spaces.

Research at the frontier near absolute zero has long been a powerhouse for generating new ideas in physics and beyond, from concepts in particle physics to practical ultra-sensitive devices for application in technology and medicine. One in four Nobel prizes over the last century has gone to a low-temperature physicist. In the same period the lowest accessible temperatures have fallen by 10 orders of magnitude (from 4 K to 100 pK), far exceeding the rate of miniaturization of microcircuits (Moore's law) over recent decades. Today some 250 (1000) low temperature research groups (researchers) in Europe work at sub-Kelvin temperatures. Ten major companies and 15 SME's have cryoengineering groups. Their total annual turn¬over is about 1 000 000 000 € and 50 000 000 €, respectively. More than two thirds of the annual world production of refrigerators for reaching temperatures down to the 10 millikelvin range is produced in Europe (by BlueFors in Finland and Oxford Instruments in UK). There is a European need for around 100 low temperature scientist and cryo-engineers per year.

While Europe is the current world leader in microkelvin physics, in terms of research workers, records held and research output, the effort is fragmented between universities and government laboratories and often lacks the critical mass for high quality research and training programmes. No commercially available refrigerators exist which are able to reach the sub-millikelvin regime. Less than 20 laboratories worldwide can build their own microkelvin refrigerators, most of these are in Europe and are involved in the current Microkelvin Collaboration.

The interest in lower (sub 10 mK) temperatures has recently been boosted by the need to increase coherence in nanocircuits. This requires better purity of the materials, improved architecture of nanocircuits, but also a large reduction in the influence of the surrounding thermal 'outside world'. Thus more efficient research in the microkelvin regime, accomplished by means of networking and integration of the European low-temperature community, will help to respond to similar new needs and to open the microkelvin temperature regime to a wider range of scientists. Here the current Microkelvin trans-national access programme, which encourages visiting scientists to make use of existing ULT infrastructures and expertise, has greatly widened the circle of researchers who are familiar with experimental possibilities and techniques at ULT conditions. As a result, more measurements have been performed on fundamental physics problems, nanosciences are being introduced into the microkelvin arena, and new industrial entries into the field are going to be emerging.

Projects previously funded under FP7 and FP6

Only for those proposed topics that correspond to the follow-up of FP7 or FP6 funded Integrating Activities, please provide specific additional information on: the project(s) previously or currently funded and the level of funding; the main results and expected achievements of the funded project(s); the progress foreseen in the activities proposed beyond FP7. Text of maximum 4000 characters including spaces.

The total EU contribution to the Microkelvin grant (# 228464) is 4.2 M Euros. For the European ULT community this investment has proven its worth: There exists common agreement that an increased level of achievement has resulted from better inter-European planning and coordination of the research effort. We expect to continue the collaboration in any way possible. Since funding is necessary, the only route viable is through an EU- supported programme for research infrastructures.

The ULT community supports unanimously the existence of grants for infrastructures in the upcoming Horizons 2020 framework, with bottom-up possibilities for different communities to submit an application.

To develop a coherent approach which takes us beyond the current Microkelvin grant, which finishes in September 2013, the Microkelvin partners have agreed to establish a unified European Ultralow Temperature Laboratory (EUTL). As a first step towards such a laboratory with¬out walls, we have formed a close coalition among the leading European ultra-low temperature groups, with the purpose to develop together a common distributed infrastructure with complementary instrumentation. We expect important advances from our work, which will make the ULT regime more practical and attractive with our many new technical solutions. Lower temperatures introduce clear advantages in many types of measurements. This fact can be exploited by familiarizing a growing circle of Users at our Access Sites to simpler and more proficient ULT solutions. This is in stark contrast to the situation before Microkelvin. We hope that the new EU grant programme for supporting research infrastructures will make it possible to continue this development, to further extend our knowledge and use of the very lowest temperatures.

Meta Informations

Creation date

22-10-2012

Last update date

User name	
Case Number	887389137111129612
Invitation Ref.	
Status	N
Language	en