ANNUAL REPORT 2009

Aalto University
School of Science and Technology
Low Temperature Laboratory
Brain Research Unit and
Physics Research Unit
http://ltl.tkk.fi

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PREFACE

Year 2009 marked the end of Helsinki University of Technology (TKK). At the beginning of 2010 the new Aalto University was founded by merging TKK with Helsinki School of Economics and School of Art and Design. The LTL had a special place in TKK's organization. Since 1973 it had served as a separate research laboratory directly under the rector of TKK.

LTL's position in the organization of Aalto University has not yet been decided. Aalto inherited from its parents over 10 separate research institutes outside the teaching departments and faculties. The directors of 8 separate institutes and large research infrastructures held in December 2009 a meeting to analyze the merits and future of their unit in Aalto University. The minutes of that meeting can be found in Appendix 1.

LTL moved to new premises at the end of 2007. The move hit hardest our ultra-low temperature research groups μKI and ROTA which have spent over a year in taking apart, moving and reconstructing their large sub-mK refrigerators. μKI refrigerator became operational already in August 2008. In case of ROTA group, the reconstruction took until the fall of 2009, causing nearly a 2-year break in its productive research work.

The full research program of LTL has been evaluated 9 times since 1995! In 2009 LTL was evaluated two more times, first in June 2009 in the connection of the Aalto University Research Assessment Exercise (RAE), and on second time in October, 2009, by the Scientific Advisory Boards of our two Centers of Excellence (CoE). The RAE report can be found in Appendix 2 and the CoE reports in Appendix 3.

LTL has organized in average one international workshop, symposium or conference per year for more than 30 participants. In 2009, Dr. **Tero Heikkilä** served as the chairman of the organizing committee and Prof. **Pertti Hakonen** as the chairman of the program committee of the XXXXIII Finnish Physics Days, a large national conference which was attended by 531 Finnish and 20 foreign physicists.

The European Research Council (ERC), founded in 2007, is the first European funding body set up to support investigator-driven frontier research. Drs. **Tero Heikkilä** and **Mika Sillanpää** from LTL received the 2009 ERC Starting Grant for their studies of "Mesoscopic heattronics: thermal and nonequilibrium effects and fluctuations in nanoelectronics" and "Electromechanical quantum systems", respectively. So far, there are only 3 ERC Starting Grant winners in physics in Finland. Professor **Riitta Hari** was granted a 5-year position of Academy Professor by the Academy of Finland. This is already her 3rd academy professorship.

Five scientists of the LTL received special recognition in 2009. Professor **Riitta Hari** received the Finnish Science Prize 2009. The Science Prize is given every 2nd year for internationally significant scientific work. Professor Hari was the 7th recipient of this very prestigious prize. Dr. **Mika Sillanpää** and **Tuukka Raij** were elected among 16 other young scientists by the Finnish Academy of Science and Letters to the newly founded Academy Club for Young Scientists. Dr. **Jan Kujala** was granted the Novartis Thesis Prize by Suomen Aivotutkimusseura ry and Ms. **Annika Hultén** the Philip M. Remnich Award by the International Neuropsychological Society.

Mikko Paalanen
Director of LTL

SCIENTIFIC ADVISORY BOARD

LTL has a Scientific Advisory Board (SAB), appointed by the Rector of TKK for the years 2006–2011. The members also serve in the SABs of the Centers of Excellence of the Academy of Finland, coordinated by the LTL. Our current SAB has the following 5 members:

For the Center of Excellence on *Low Temperature Quantum Phenomena and Devices*

Prof. Mats Jonson, Gothenburg University, Gothenburg, Sweden
Prof. William Halperin, Northwestern University, Evanston, Illinois, USA

For the Center of Excellence on *Systems Neuroscience and Neuroimaging*

Prof. Chris Frith, Functional Imaging Laboratory, University College London, UK
Prof. Denis Le Bihan, CEA Saclay, France
Prof. Nikos K. Logothetis, MPI for Biological Cybernetics, Tübingen. Germany

The SABs of both CoEs held their evaluation meeting in October, 2009. The CoE reports can be found in Appendix 3.

PERSONNEL

The number of persons working in the LTL fluctuates considerably since scientists are employed for relatively short periods only and students often work on part-time basis.

ADMINISTRATION AND TECHNICAL PERSONNEL

Mikko Paalanen, D.Sc. (Tech.), Professor, Director of the LTL
Alexander Savin, Ph.D., Technical Manager
Miro Hakonen, trainee, from 8.5.2009
Teija Halme, secretary
Antti Huvila, technician, until 19.12.2009
Pasi Häkkinen, civil service, from 1.7.2009
Mia Illman, nurse (clinical neurophysiology)
Arvi Isomäki, technician
Anna-Lydia Kainulainen, trainee, 1.6.–5.7.2009
Helge Kainulainen, technician
Marita Kattelus, radiographer (AMI)
Tuire Koivisto, secretary
Markku Korhonen, technician
Sari Laitila, secretary, from 27.11.2009
Leena Meilahti, secretary, until 30.11.2009
Pirjo Muukkonen, financial secretary
Liisi Pasanen, secretary, until 30.09.2009
Petteri Räisänen, system administrator
Veli-Matti Saarinen, project engineer
Ronny Schreiber, research engineer
Katariina Toivonen, project planning officer, from 1.08.2009

SENIOR RESEARCHERS

Physics Research Unit

Harry Alles, D.Sc. (Tech.), until 28.2.2009
Vladimir Eltsov, Ph.D.
Aurelien Fay, Ph.D.
Pertti Hakonen, D.Sc. (Tech.), Professor
Tero Heikkilä, D.Sc. (Tech.), Docent
Meri Helle, D.Sc. (Tech.)
Risto Hänninen, D.Sc. (Tech.)
Sergey Kafanov, Ph.D. (Tech.)
Nikolai Kopnin, Ph.D., Professor
Matti Krusius, D.Sc. (Tech.), Professor
Matthias Meschke, Ph.D.
Mikko Möttönen, D.Sc. (Tech.)
Gheorghe-Sorin Paraoanu, Ph.D.
Jukka Pekola, D.Sc. (Tech.), Professor
Alexander Sebedash, Ph.D.
Mika Sillanpää, D.Sc. (Tech.)
Xuefeng Song, Ph.D., from 10.12.2009
Igor Todoschenko, Ph.D.
Juha Tuoriniemi, D.Sc. (Tech.), Docent
Janne Viljas, D.Sc. (Tech)
Grigori Volovik, Ph.D., Professor
Fan Wu, Ph.D., until 28.2.2009

Brain Research Unit

Riitta Hari, M.D., Ph.D., Professor, Head of the Brain Research Unit
Akkal, Dalila, Ph.D., Senior Scientist @ aivoAALTO
Toni Auranen, D. Sc. (Tech.)
Paolo Belardinelli, Ph.D., until 18.11.2009
Synnöve Carlson, M.D., Ph.D., Professor
Nina Forss, M.D., Ph.D., Docent, part-time
Marja-Liisa Halko, Ph.D., Postdoc @ aivoAALTO
Päivi Helenius, Ph.D., Docent
Meri Hilve, M.D., from 1.10.2009
Veikko Jousmäki, Ph.D., Docent
Jaakko Järvinen, Ph.D., until 31.3.2009
Erika Kirveskari, M.D., Ph.D., part-time
Miika Koskinen, Ph.D. (Tech.)
Jan Kujala, D.Sc. (Tech.),
Catherine Nangini, Ph.D.
Lauri Nummenmaa, Ph.D., Senior Scientist @ aivoAALTO
Tiina Parviainen, Ph.D.
Elina Pihko, Ph.D., Docent
Hanna Renvall, M.D., Ph.D., from 1.3.2008
Riitta Salmelin, D.Sc. (Tech.), Academy Professor
Mika Seppä, D.Sc. (Tech.)
Juha Silvanto, Ph.D., from 21.9.2009

Päivi Sivonen, Ph.D.
Pia Tikka, Ph.D., Postdoc @ aivoAALTO
Simo Vanni, M.D., Ph.D., Docent
Minna Vihla, M.D., Ph.D., part-time

GRADUATE STUDENTS - (SUPERVISORS)

Physics Research Unit

Khattiya Chalapat, M.Sc. - (Gheorghe-Sorin Paraoanu)
Robert de Graaf, M.Sc. - (Matti Krusius)
Tommy Holmqvist, M.Sc. (Tech.) - (Jukka Pekola)
Jaakko Hosio, M.Sc. (Tech.) - (Matti Krusius)
Heikki Junes, M.Sc. (Tech.), until 3.5.2009 - (Harry Alles)
Antti Kemppinen, M.Sc. (Tech.), until 16.10.2009 - (Jukka Pekola)
Matti Laakso, M.Sc (Tech.) - (Tero Heikkilä)
Lorenz Lechner, M.Sc., until 30.10.2009 - (Pertti Hakonen)
Li Jian, M.Sc. - (Gheorghe-Sorin Paraoanu)
Sarah MacLeod, M.Sc. - (Jukka Pekola)
Ville Maisi, M.Sc. (Tech.) - (Jukka Pekola)
Matti Manninen, M.Sc. (Tech.) - (Juha Tuoriniemi)
Juha Muhonen, M.Sc. (Tech.) - (Jukka Pekola)
Antti Paila, M.Sc. (Tech.), on leave 15.6.2009-30.6.2010 - (Pertti Hakonen)
Joonas Peltonen, M.Sc. (Tech.) - (Jukka Pekola)
Elias Pentti, M.Sc. (Tech.), until 4.10.2009 - (Juha Tuoriniemi)
Juho Rysti, M.Sc. (Tech.) - (Juha Tuoriniemi)
Olli-Pentti Saira, M.Sc. (Tech.), from 1.6.2009 - (Jukka Pekola)
Anssi Salmela, M.Sc. (Tech.) - (Juha Tuoriniemi)
Karthikeyan Sampath Kumar, M.Sc., from 22.9.2009 - (Gheorghe-Sorin Paraoanu)
Jayanta Sarkar, M.Sc. - (Pertti Hakonen)
Roman Solntsev, M.Sc., until 30.9.2009 - (Matti Krusius)
Andrey Timofeev, M.Sc., until 30.4.2009 - (Jukka Pekola)
Pauli Virtanen, M.Sc. (Tech.) - (Tero Heikkilä)
Juha Voutilainen, M.Sc. (Tech.) - (Tero Heikkilä)

Brain Research Unit

Linda Henriksson, M.Sc. (Tech.) - (Simo Vanni)
Jaana Hiltunen, Phil. Lic. - (Riitta Hari)
Lotta Hirvenkari, M.Sc. - (Riitta Hari)
Annika Hultén, M.Sc. (Psych.) - (Riitta Salmelin, Matti Laine)
Antti Jalava, M.Sc. (Tech.), from 1.12.2009 - (Riitta Salmelin)
Leena Karvonen, M.Sc. (Psych.), from 1.5.2009 - (Riitta Salmelin)
Miiamaaria Kujala, M.Sc. - (Riitta Hari)
Hannu Laaksonen, M.Sc. (Tech.) - (Riitta Salmelin)
Satu Lamminmäki, M.D. - (Riitta Hari)
Mia Liljeström, M.Sc. (Tech.) - (Riitta Salmelin)
Sanna Malinen, M.Sc. (Tech.) - (Riitta Hari)
Lauri Nurminen, M.Sc. - (Simo Vanni)
Lauri Parkkonen, M.Sc. (Tech.), until 30.06.2009 - (Riitta Hari)
Pavan Ramkumar, M.Sc. (Tech.), from 1.3.2009 - (Riitta Hari)

Ville Renvall, M.Sc. (Tech.) - (Riitta Hari)
Kristina Roiha, M.D., from 1.2.2009 - (Nina Forss)
Fariba Sharifian, M.Sc. - (Simo Vanni)
Linda Stenbacka, M.D. - (Simo Vanni)
Johanna Vartiainen, M.Sc. (Tech.) - (Riitta Salmelin)
Nuutti Vartiainen, M.D., until 30.11.2009 - (Nina Forss, Riitta Hari)

UNDERGRADUATE STUDENTS

Physics Research Unit

Petri Heikkinen
Jukka-Pekka Kaikkonen
Tuomas Kortelahti, from 18.5.2009
Jonne Koski, from 25.5.2009
Pasi Lähteenmäki
Antti Puska
Sampo Saarinen, from 11.5.2009
Jaakko Sulkko
Matti Tomi

Brain Research Unit

Hanne Antila, until 31.5.2009
Tuukka Hiltunen, 1.6.–31.8.2009
Marika Kaksonen
Juha Karvonen, 16.3.–30.11.2009
Tiina Liiri, from 11.5.2009
Anne Mandel, from 11.5.2009
Siina Pamilo, from 23.3.2009
Oula Puonti, 11.5.–31.8.2009
Henna Roikola, from 16.3.2009
Timo Saarinen
Anne Virtanen, 1.4.–31.10.2009
Elli Vuokko, from 11.5.2009

VISITORS

MICROKELVIN VISITORS

Bunkov, Yury, Prof., 6.12.–31.12., Institute Néel, CNRS, Grenoble, France
L'vov, Viktor, Prof., 6.–29.8., Weizmann Instutute of Science, Rekhovot, Israel
Oosterkamp, Tjerk, Ph.D., 22.7.–11.8., Leiden University, Leiden, The Netherlands
Schmoranzer, David, M.Sc., 7.5.–1.8., Charles University in Prague, Prague, Czech Republic

OTHER VISITORS

Alles, Harry, Ph.D., 16.–31.8., University of Tartu, Tartu, Estonia
Büchel, Christian, Prof., 17.–19.11., Institut für Systemische Neurowissenschaften, Hamburg, Germany
Cho, Sung Ung, Ph.D., 23.–27.11., Seoul National University, Seoul, South Korea
Courtois, Hervé, Prof., 31.3.–9.4., CNRS and UJF, Grenoble, France

Dreyer, Olaf, Ph.D., 11.6.–17.6., Massachusetts Institute of Technology, USA
Duty, Tim, Ph.D., 23.–25.11., The University of Queensland, Brisbane, Australia
Enrico, Emanuele, M.Sc., 25.5.–7.6., National Institute of Metrology Research, Turin, Itali
Ensslin, Klaus, Prof., 29.8.–4.9., ETH, Zurich, Switzerland
Flachbart, Karol, Prof., 21.–22.1., Institute of Experimental Physics, Slovak Academy of Science, Košice, Slovakia
Garcia, Pascual Cesar, Ph.D., 19.4.–14.5., University of Pisa, Pisa, Italy
Garcia-Sanchez, Daniel, M.Sc., 19.4.–14.5., ICN, Barcelona, Spain
Glaum, Konstantin, Ph.D., 30.5.–12.6., 1.–11.9., Institut for Theoretical Physics, Ulm, Germany
Gusikhin, Pavel, 5.1.–20.2., 8.–12.11., Institute of Solid State Physics RAS, Chernogolovka, Russia
Gustafsson, Martin, M.Sc., 26.4.–14.5., 15.–17.10., Chalmers University of Technology, Sweeden
Hida, **Akira**, Ph.D., 24–26.9., Tokyo Institute of Technology, Tokio, Japan
Gasparinetti, Simone, M.Sc., 16.–18.11., Scuola Normale Superiore, Pisa, Itali
Im, Hyunsik, Ph.D., 1.–3.11., Dongguk University, Seoul, Korea
Ioselevich, Alexei, Ph.D., 22.11.–4.12., Landau Institute for Theoretical Physics, Chernogolovka, Russia
Ishibashi, Koji, Ph.D., 24.–26.9., Advanced Device Laboratory, RIKEN, Japan
Lesovik, Gordey, Prof., 5.–9.10., Landau Institute for Theoretical Physics, Chernogolovka, Russia
Makhlin, Yuriy, Ph.D., 3.9.–11.9., Landau Institute for Theoretical Physics, Chernogolovka, Russia
Nazarov, Yuli, Prof., 15.–21.2.2009, Delft University of Technology, The Netherland
Niebler, Gabriel, M.Sc., 2.4.–1.7., Technische Universität Dresden, Dresden, Germany
Nemirovski, Sergei, Ph.D., 22.3–5.4., Institute of Thermophysics SB RAS, Novosibirsk, Russia
Parshin, Alexander, Prof., 5.–16.10., Kapitza Institute, Moscow, Russia
Pashkin, Yuri, Ph.D., 6.5.–10.6, NEC Nano Electronics Research Laboratories, Tsukuba, Japan
Pikker, Siim, M.Sc., 28.7.–30.7., Institute of Physics, Tartu, Estonia
Prest, Martin, Ph.D., 9.3.–20.3, 27.9.–16.10., University of Warwick, Coventry, UK
Ruspantini, Irene, Ph.D., 23.1.–30.6., National Institute of Health, Rome, Italy
Ryazanov, Valery, Prof., 3.–9.9., Institute of Solid State Physics RAS, Chernogolovka, Russia
Shimizu, Maki, M.Sc., 24.–26.9., Advanced Device Laboratory, RIKEN, Japan
Shinya, Kuriki, Prof., 8.–13.6., Research Center for Advanced Technologies, Denki University, Tokyo, Japan
Silaev, Mihail, Ph.D., 15.2.–1.3., Institute of Physics of Microstructures RAS, Russia
Shnirman, Alexander, Prof., 20.–23.6., Karlsruhe Institut für Technologie, Karlsruhe, Germany
Song, Xuefeng, Ph.D., 14.–17.9., 10.–21.12, Beijing University, Beijing, People's Republic of China
Tsepelin, Viktor, Ph.D., 4.–10.10., Lancaster University, Lancaster, UK
Vercruyessen, Nathan, M.Sc., 15.1.–18.3., 13.5.–14.6., Delft University, The Netherlands

Wiesner, Maciej, Ph.D., 3.1.–4.4., 15.3.–15.7., Adam Mickiewicz University, Poland
Yokosawa, Koichi, Prof., 1.5.–30.9., Hokkaido University, Japan
Yoon, **Youngsoo,** Ph.D., 25.–27.10., Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany

GROUP VISITS

Group from Stockholm Brain Institute (30.1.)

Group of summer students (4.2.)

Microkelvin visitors (14.–15.5.)

Professors from Teheran University (15.9.–15.10.)

8 planners (prearranger/suunnittelijaa) and guides from Tiedekeskus Heureka (14.10.)

10 students from Helsinki University physics training course line (Helsingin yliopiston fysiikan tutkijainkoulutuslinjan 2-3 vuoden opiskelijoita) (6.11.)

Group of librarians from interlibrary loan service (24.11.)

15 neurobiology students from Helsinki University (4.12.)

Groups from various high schools in Finland, during all year

INTERNATIONAL COLLABORATIONS

MICROKELVIN - European Microkelvin Collaboration

Coordinator: **Mikko Paalanen**

Funding: EU's FP7, Capacities Specific Program on Infrastructures (EU contract # 228464)

Duration: 1.4. 2009 – 31.3. 2013

Participating groups of the LTL: KVANTTI, NANO, PICO, ROTA, THEORY and μKI

Partners:
Low Temperature Laboratory, TKK, Finland (coordinator)
CNRS, Grenoble, France
Lancaster University, UK
Ruprecht-Karls-Universitaet Heidelberg, Germany
Royal Holloway and Bedford New College, London, UK
Scuola Normale Superiore di Pisa, Italy
Ustav, Experimentalnej Fyziky Slovenskej Akademie Vied, Kocise, Slovakia
Universitaet Basel, Switzerland
BlueFors Cryogenics, Espoo, Finland
Universitaet Leiden, Netherlands
Physikalisch-Technische Bundesanstalt, Berlin, Germany

European Microkelvin Collaboration includes eleven low temperture research laboratories and one SME, LTL serving as the coordinator. MICROKELVIN program con-

tains three activities: Transnational Access Activities, Joint Research Activities and Networking Activities with a total EU-funding of 4.2 M€.

The Cryohall of the LTL continues to serve European scientists within the MICROKELVIN Transnational Access Activity. The access activity of Cryohall is allocated 27 visitor months in 4 years. During 2009 altogether 4 European visitors from 4 different countries used the facility for 4.0 months.

MICROKELVIN web page: http://www.microkelvin.eu

CONFERENCES AND WORKSHOPS

XXXXIII Finnish Physics Days

12.–14.03.2009, Otaniemi, Espoo, Finland

Low Temperature Laboratory and Helsinki University of Technology organized the 43rd annual conference of the Finnish Physical Society 12.–14.3. 2009 in the Dipoli building. The chairman of the program committee was Pertti Hakonen and the chairman of the organizing committee was Tero Heikkilä.

There were 488 registered participants in the meeting. In addition to these some 40 high school students and their teachers from the Helsinki region attended some of the sessions and approximatively ten undegraduate students from the physics guild helped with the organizations. When including the participants of the two sessions that were open to the public, the Physics Days had more than 550 attendants. Detailed statistics about the past meetings does not exist, but this may well be the record attendance in the history of the Finnish Physical Society.

Fig. 1. Lene Hau, Andre Geim and Friedrich Wagner

The meeting had four plenary sessions with nine speakers:

- Wilfried Buchmüller, DESY Hamburg: *Dark matter in the cosmos and at the LHC*
- Paul L. Richards, University of California, Berkeley: *The cosmic microwave background and state of the art detectors*
- Roberto Car, Princeton University: *Ab-initio molecular dynamics: a virtual laboratory for the study of matter*
- Andre Geim, University of Manchester: *Graphene: Magic of flat carbon*

- Timo Vesala, University of Helsinki: *Atmosphere-biosphere interactions: From Karman vortices to soil microbial decomposition*
- Friedrich Wagner, Max-Planck-Institute for Plasmaphysics, Greifswald: *The physics of magnetic confinement*
- Panu Helistö, VTT Technical Research Center of Finland: *Superconducting detectors for the universe, the earth and the airports*
- Anthony Leggett, University of Illinois at Urbana-Champaign: *Testing quantum mechanics towards the level of everyday life: Recent progress and current prospects*
- Lene Vestergaard Hau, Harvard University: *Slow light in Bose-Einstein condensates: a new paradigm for quantum control*

The meeting program also contained a *Studia Generalia* session where Prof. Päivi Törmä talked with the title *Ohjelmoitavat materiaalit – mistä DNA tietää että sen pitää hymyillä?*

In addition to the plenary sessions, there were in total 15 parallel sessions of which one was a special focus session on ”Physics in Industry”, featuring Finnish physicists from different branches of the industry.

Fig. 2 (Left): High school students asking tricky questions from the plenary lecturers. (Right) Poster session.

Physics Days contained for the first time program directed to high-school students. 12 most successful students in the national physics competition and 40 students from the Helsinki region attended part of the meeting, tours to Helsinki University of Technology physics laboratories and a special session where the students were allowed to ask questions from three of the plenary speakers. The high school student program was sponsored by the Wihuri Foundation.

Physics Days program was sponsored by the Väisälä and Magnus Ehrnrooth Foundations and by the city of Espoo, which hosted the city reception in the WeeGee house. We thank the sponsors, lecturers and meeting participants for creating a pleasant but yet very much physics oriented meeting featuring many high-level presentations from both internationally well-known physicists and also students in the beginning of their career.

On behalf of the physics days program and organizing committees,

Tero Heikkilä

MICROKELVIN Kick-off Meeting

The Microkelvin kick-off meeting was held on Friday, April 3, 2009, at the Helsinki University of Technology. Representitives of 12 European Microkelvin Collaboration partners participated in the meeting. The program included both organizational and scientific talks.

Participants of MICROKELVIN KICK-OFF Meeting

EU-Workshop on Management of FP7 Projects

14.–15.05.2009, Otaniemi, Espoo, Finland

EU-Workshop on Management of FP7 Projects was organized by Innovation Center of Helsinki University of Technology. Representatives of three ultra-low temperature laboratories at TKK (Helsinki), CNRS (Grenoble) and Lancaster University, which offer mikrokelvin facilities within Microkelvin collaboration, participated part in the workshop.

Participants: Yvonne Fox and Barbara Colman (University of Lancaster), Assya Achour and Caroline Bartoli (CNRS Grenoble), Leena Meilahti, Pirjo Muukkonen, Mikko Paalanen and Alexander Savin (TKK/LTL), Krisztina Cziner and Elise Kovanen (TKK/OIC), Tiina Raivio (TKK/Financial Office).

Aalto physics colloquium

Coordinator: Tero Heikkilä

Selection committee:

- Matti Kaivola
- Risto Nieminen
- Mikko Paalanen

Aalto physics colloquium is a high-level colloquium series covering all branches of physics in the Aalto University. Its aim is to invite high-level physicists from all around the world to tell about their research. The lectures are targeted to all physicists and those interested in physics. Entrance to the events is free of charge. Colloquia are organized approximatively once a month during the term time and the invitation responsibility circulates between all physics professors on the Aalto campus. The colloquium is funded by the Aalto Department of Applied Physics, Academy of Finland Center of Excellence COMP (Computational Nanoscience) and Low Temperature Laboratory.

First talk within Aalto physics colloquium was given on Thursday 22nd October at 10:00 by **Carlo Beenakker**: "What is special about graphene?"

Marie Curie Advanced Cryogenics Course

7.–18.09.2009, Lammi and Espoo, Finland

The lectures of this 12 day intensive course on cryophysics and cryogenics took place at the Lammi Biological Station, which is seminar facility administered by Helsinki University and located about 120 km from Helsinki. The practical training and the site visits was organised at the Low Temperature Laboratory.

The course was aimed for graduate students and young researchers from European universities, research centres and industry. 41 persons participated in the course. The course consisted of lectures given by proficient physicists, of visits to some Finnish institutions and facilities applying cryogenics in their functions, and of practical exercises on some low temperature protocols.

AivoAALTO Kick-off Symposium

17.–19.09. 2009, Helsinki and Espoo, Finland

BRU coordinated the aivoAALTO Kick-off Symposium held on Sept 17.–19, 2009. The Kick-off Symposium took place in all the three schools participating in aivoAALTO in Helsinki (TaiK and HSE) and Espoo (TKK). Invited talks: Pascal Belin (Glasgow), David Sander (Geneva), Giorgio Coricelli (Lyon), Kathrin Fahlenbrach (Halle), Uri Hasson (Princeton), Klaus Mathiak (Aachen), and Petri Ylikoski (Helsinki).

LOW TEMPERATURE PHYSICS RESEARCH

NANO group

A. Fay, **P. Hakonen**, P. Häkkinen, L. Lechner, P. Lähteenmäki, A. Paila, A. Puska, J. Sarkar, M. Sillanpää, J. Sulkko, M. Tomi, and F. Wu

Visitors: H. Alles, Yu. Makhlin, E. Sonin, and M. Wiesner

Collaborators: J. Aarik, H. Alles, M. Craciun, H. Craighead, R. Danneau, D. Gunnarsson, J. Hassel, E. Kauppinen, J. Kolehmainen (Diarc Ltd.), J. Li, A. Morpurgo, J. Oostinga, S. Paraoanu, J. Parpia, P. Pasanen (Nokia NRC), J. Penttilä (Aivon Ltd.), B. Plaçais, S. Russo, H. Seppä, R. Simmonds, E. Thuneberg, J. Tuorila, CARDEQ, and MIKES partners

The research work of the NANO group is focused on four areas: 1) Mesoscopic quantum amplifiers and qubits, 2) Quantum transport in carbon nanotubes and graphene, 3) Current fluctuations and fast dynamics in quantum circuits, and 4) Nanoelectromechanical systems. In all of these categories, our measurements are centered at microwave frequencies, involving reflection measurements for qubits, transmission mea-

surements for AC-conductance, and two-channel noise recording for cross correlation studies.

International collaborative research projects have become an integral part of the work of NANO group. Two projects have been ongoing: one of them, coordinated by P. Hakonen, is an IST-STREP dealing with carbon nanotubes and the second one is a Materials Research Network project "Nanoelectromechanical properties of graphene" (with Cornell University), funded by the Academy of Finland and by the US National Science Foundation. Most of our samples, especially the Josephson junction devices, are made in our own in-house semi-clean room. As we are not producing any carbon nanotubes ourselves, all our nanotube samples have been obtained on collaborative basis of some sort, either in European projects or within other collaborations. Also, our graphene samples have either been manufactured in our own clean room or they have been obtained via collaboration.

In the field of mesoscopic quantum amplifiers and qubits, we have further developed the dispersive charge detection techniques deviced by our group recently for studies of the quantum measurement. In addition to charge-phase qubits, we have also worked on pure phase qubits that we have received from Ray Simmonds at NIST, Boulder. In carbon nanotubes and graphene, we have continued our collaboration with Nokia, gradually concentrating more and more on graphene. One of the major goals in the TKK-NRC collaboration is to conceive novel graphene devices which differ by principle from ordinary semiconducting devices. During 2009, one patent application was filed on junction amplifiers in collaboration with VTT.

PHASE QUBITS

M. Sillanpää, J. Li, Yu. Makhlin, S. Paraoanu, and P. Hakonen

The collaboration with the National Institute of Standards and Technology has been continued (NIST in Colorado, USA) on Josephson phase qubits. The co-operation combines the strength of NIST having exclusive microfabrication capabilities, and our experience on high-frequency readout of quantum circuit in 1-4 GHz range. Our collaboration has lead to first studies of the Autler-Townes splitting in a superconducting artificial atom made of a phase qubit. The results were published in Phys. Rev. Lett. **103**, 193601 (2009).

STARK EFFECT AND RESONANCE SHIFTS IN AN ARTIFICIAL ATOM

Yu. Makhlin, **M. Sillanpää**, M. Silveri, E. Thuneberg, J. Tuorila, and **P. Hakonen**

The characteristics of matter and light become intertwined upon interaction. The interconnection of the two can be observed in atomic and optical physics by setting atoms inside mirrored cavity resonators, whereby coupling the zero-point vibrations of the field to atomic transitions. These phenomena can be studied in mesoscopic circuits in a regime not accessible with atoms.

We have made experiments where a superconducting charge-phase qubit has been driven extremely strongly. The quasienergies of the dressed artificial atom were probed with a resonant cavity. The strong flux drive couples via the Josephson energy, which produces novel nonlinear effects seen in the absorption spectrum. The observed Stark shifts of the atomic levels are so pronounced that they cannot be understood neither in terms of the regular rotating wave approximation nor its conven-

tional Bloch-Siegert-type corrections. We had to use the Floquet approach in order to explain the measured spectra.

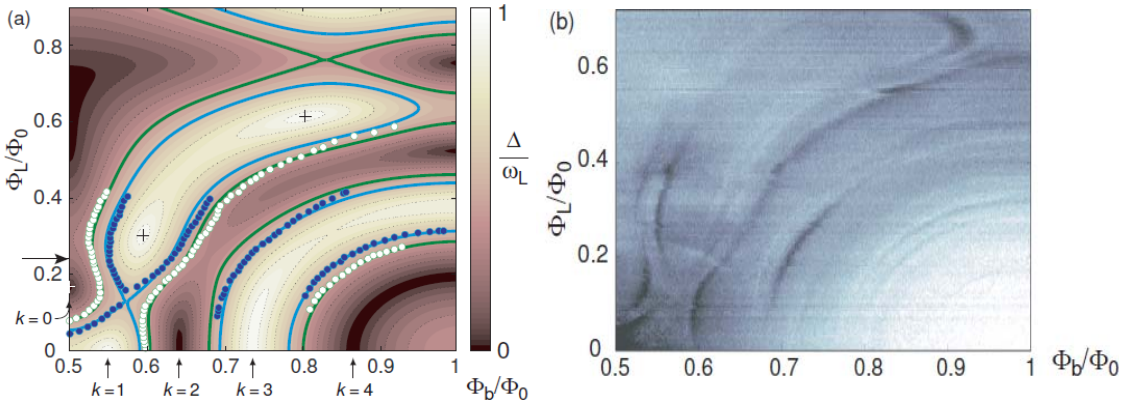

Fig. 1. (a) The landscape of the quasienergy splitting Δ in the bias flux (horizontal) and driving flux (vertical) plane. Solid dots are the experimental resonances picked up from panel (b). (b) The measured phase shift of the probe signal plotted in the bias vs. drive flux plane. Dark corresponds to lower resonance frequency of the system.

BLOCH OSCILLATING TRANSISTORS (BOT)

J. Hassel, L. Korhonen, A. Puska, J. Sarkar, H. Seppä, and **P. Hakonen**

After the analysis of fully superconducting BOT structures, it was concluded that BOTs for the quantum triangle experiment should be done with the old design having a NIS junction on the base. For this purpose, adaptation of a germanium mask process into the fabrication of the BOTs was started. The Ge mask enables good control of the line width and it provides a large undercut that is needed in the BOT manufacture using four angle evaporation. In order to achieve proper amount of undercut, several trial batches were made to optimize the parameters of oxygen plasma etching. Germanium mask also affected other process parameters which had to be adjusted as well. By the end of the year, first BOTs with the Ge mask were obtained. Preparations for a differential current amplifier based on BOTs were initiated.

WIDE-BAND SUPERCONDUCTING CARBON NANOTUBE FET

A. Fay, P. Häkkinen, P. Lähteenmäki, and **P. Hakonen**

Superconducting carbon nanotube devices provide mesoscopic components that are at the same time low-impedance and charge-sensitive. This is exceptional because typically resistance of a nanosample has to be around the quantum resistance $R_Q = h/e^2$ in order to obtain charge quantization effects. The low impedance nature of such devices makes them very attractive for high frequency electrometry as the matching circuits between samples and the 50 Ohm measuring setup can be avoided.

We have investigated the response of nanotube Josephson junctions at 600-900 MHz using microwave powers corresponding to currents 0 … 10 I_C in the junction. We have demonstrated the operation of superconducting FETs as charge detectors at high frequencies *without any matching circuits*. Gate-voltage-induced charge q modifies the critical current, which changes the effective impedance of the junction under

microwave irradiation. This change, dependent on the transfer characteristics dI_C/dq, modifies the reflected signal and it can be used for wide-band electrometry. We obtain a sensitivity of $4 \cdot 10^{-5}$ e/Hz$^{1/2}$ in our samples with maximum switching current of $I_C \sim 2$ nA using this technique.

PROXIMITY EFFECT IN GRAPHENE

A. Fay, M. Tomi, M. Wiesner, and **P. Hakonen**

We have made detailed transport and noise measurements in a superconductor-graphene-superconductor (SGS) junction, at temperatures of 70 - 700 mK. The superconductor leads, which are used to connect the graphene sheet, correspond to a sandwich of 10 nm of titanium (contact layer) and 50 nm of aluminium. The sandwich is a superconductor with a gap energy $\Delta \sim 100$ μeV. The SGS junction can be viewed as a superconductor-normal metal-superconductor (SNS) junction where the density of states in the normal metal can be tuned with an applied gate voltage. Especially, at the Dirac point, the density of states in the graphene vanishes and the transport in graphene takes place by evanescent modes.

In addition to current-voltage characteristics and shot noise of our SGS junctions, we have investigated their current-phase relation. We find clearly non-sinusoidal CPRs as illustrated in Fig. 2 far away from the Dirac point. In these measurements, we also demonstrated the graphene LFET (like an inductively read rf-SQUID) which is a device sensitive both to charge and flux.

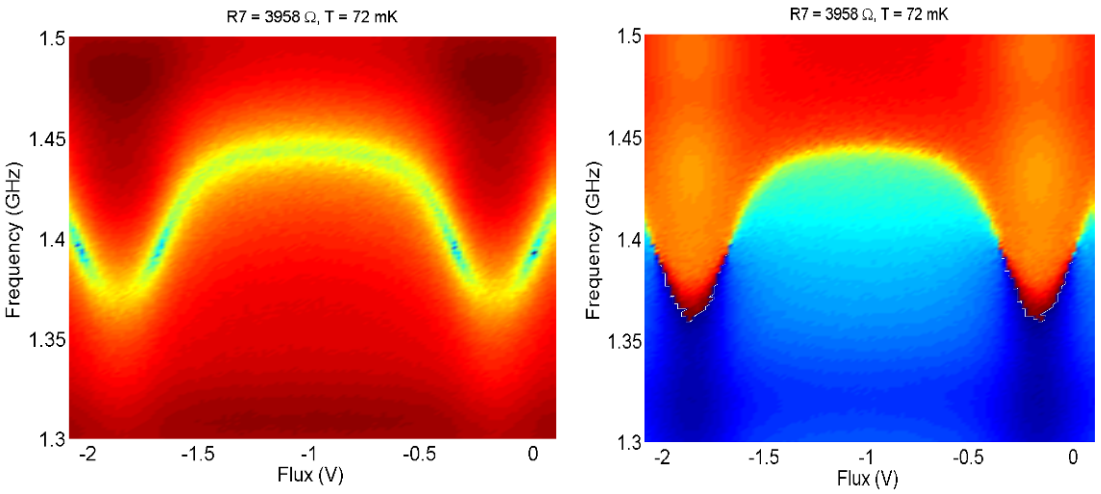

Fig. 2. Measured reflection magnitude (left) and phase (right) vs. flux bias through the superconducting loop containing the graphene junction. One flux quantum corresponds to 1.55 V on the x-axis. Data were measured at $T = 72$ mK using a gate voltage 5 V off from the Dirac point.

GRAPHENE DEVICES

A. Fay, P. Pasanen, A. Savin, M. Tomi, M. Wiesner, and **P. Hakonen**

During the past year, we have taken the first steps towards graphene samples on substrates which are not made of SiO_2 (suspended samples etc.). A central acquisition for this work was the upgrade of our PSIA XE-100 AFM with a Raman spectrometer (HORIBA LabRAM HR UV-NIR). This new setup allows tip enhanced Raman scat-

tering to be explored, making true NanoRaman achievable, with spatial resolution <100 nm. This facilitates, for example, detailed studies of graphene edges and disorder.

NOISE CONDUCTANCE OF CARBON NANOTUBE TRANSISTORS

In collaboration with J. Chaste *et al*. at ENS

We have investigated radio-frequency transmission and noise of high-transconductance carbon nanotube transistors. Gate capacitance C_g, drain conductance g_d, transconductance g_m and current-noise data were analyzed with a ballistic 1-dimensional nano-transistor model where the nanotube channel is described by a quantum capacitance C_q. Current is thermally activated with a transconductance controlled by a bias-dependent electronic temperature. Shot-noise is a thermal noise with a noise conductance g_n different from the drain conductance g_d. Our 1-dimensional model gives a simple formula $g_n - g_d = g_m(C_q/2C_g)$ which is verified in a single walled carbon nanotube transistor.

SQUID AMPLIFIERS

P. Lähteenmäki, M. Sillanpää, and **P. Hakonen**

A prototype microwave amplifier based on negative resistance model for a bandstop shunted single Josephson junction operated as a reflection amplifier was studied with simulation models as well as with direct experimentation. The device was cooled down to 70 mK in a dry dilution cryostat and it was found to perform consistently with the simulation models. A gain of 30 dB at 3 GHz was measured with a bandwidth of 1 MHz. The noise temperature was estimated to be within a factor of two from the quantum limit.

A parametric amplifier based on a cavity made of Josephson metamaterial was designed and fabricated. The measurements indicated that a low loss, highly tunable cavity can be constructed using the existing fabrication process. The cavity, with an unloaded Q-value of 6000, could be tuned from 2.6 GHz to 3.4 GHz using external magnetic field. As an amplifier, the device performance was degraded due to insufficient magnetic shielding of the cryostat which resulted in flux trapping. Improved designs were made to address the problematic issues of both the single junction amplifier and the parametric amplifier.

FIB PATTERNED NEMS RESONATORS

M. Sillanpää, J. Sulkko, and P.J. Hakonen

Mechanical GHz resonators hold great promise for various sensors and detectors, as well as building blocks for quantum information. However, the detection of their vibrations is notoriously difficult, because of a twofold challenge: 1) tiny displacements (down to femtometers) 2) high intrinsic impedance levels considering GHz operation.

We have developed a novel read-out scheme which is based on sideband generation in an LC-circuit in which the mechanical vibration modulates the capacitance C. Easy fabrication, possible room temperature operation, wide bandwidth, and fully electronic readout makes this technique truly promising. We verified experimentally the sideband generation up to mechanical frequencies of 200 MHz, and achieved an ex-

cellent agreement with our theoretical models and previous experiments. In our measurements on a 2-micron-long, doubly-clamped aluminum beam hysteretic behavior, annealing effects, as well as pressure and temperature dependence were observed.

PICO group

Meri Helle, Tommy Holmqvist, Sergey Kafanov, Antti Kemppinen (Mikes), Sarah MacLeod, Ville Maisi (Mikes), Matthias Meschke, Juha Muhonen, **Jukka Pekola**, Joonas Peltonen, Olli-Pentti Saira, and Andrey Timofeev

Collaborator: M. Möttönen (Dept. of Applied Physics, TKK/Aalto)

This year we focused on developing the single-electron turnstile: we studied the subgap current in hybrid junctions and managed to control it, produced high currents by parallel operation of 10 turnstiles, and performed preliminary experiments of counting individual electrons through a turnstile. If all the good features can be combined in a single pumping experiment, the system is perhaps already suitable for redefinition of *ampere*. Another important result of the year was the demonstration of electronic refrigeration by RF-gate voltage drive in a single-electron transistor. A new sensor of small magnetic fields and moments, a SQUIPT was developed in collaboration with SNS Pisa, and preliminary experiments were performed on fast thermometry.

SINGLE-ELECTRON PUMPING

The promising concept of hybrid superconductor-normal metal turnstile [1,2] was the main topic of research in this reporting period. We had found theoretically that the device is capable of reaching the strict requirements of a current source in quantum metrology, i.e. > 100 pA current with < 10^{-7} errors, in a parallel configuration of 10 or more turnstiles [3]. Experiments on large charging energy junctions, needed to fulfill the requirements, were performed in close collaboration with NEC Nanoelectronics Laboratories [4]. The main open questions on the way towards redefinition of ampere using the turnstile have been the issues of realizing sufficiently large currents and, in particular, suppressing the harmful leakage currents of the junctions. Fortunately we have solved, at least partly, both these problems. In an experiment on running parallel turnstiles, we managed to reach currents well above 100 pA in a very simple configuration [5]. If N turnstiles are run in parallel, only N+2 DC control lines are needed. The question of subgap currents (leakage) is more interesting from the physics point of view. We have identified Andreev current and Cooper pair – electron cotunneling as the fundamental sources of error. However, we showed both theoretically and experimentally that the main contribution of the subgap current in experiments is arising from the coupling of the device to the electromagnetic environment: we show that by shunting the junctions with a large enough capacitance, for instance by placing them over a superconducting ground plane, the leakage currents can be suppressed by one to two orders of magnitude [6]. Moreover we show theoretically that the bias dependence due to coupling to the environment can be cast to the widely used phenomenological Dynes form, which introduces lifetime broadening to the density of states of a superconductor. Presently we can state that the flatness of the pumping plateaus is on the level of 10^{-6}, with respect to the normal state conductance, against all the important parameters (bias voltage, gate voltage, drive amplitude), but in order to demonstrate the absolute accuracy, one needs to count the individual pumped electrons and find the error events in real time: an experiment is already in progress.

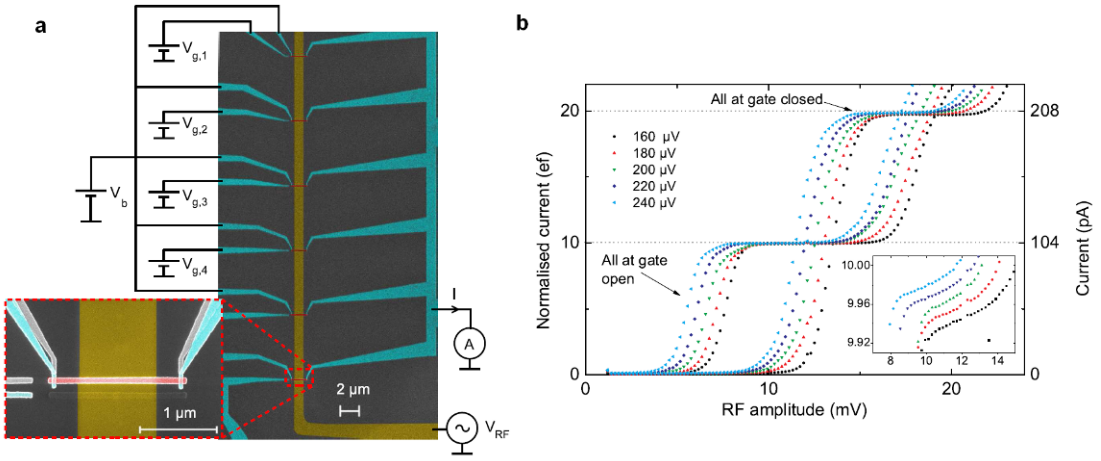

Fig. 1. a, Scanning electron micrograph of parallel turnstiles with common bias voltage and rf-drive. b, Pumping data of ten parallel devices yielding a plateau at a current exceeding 100 pA, the requirement set by the quantum metrological triangle.

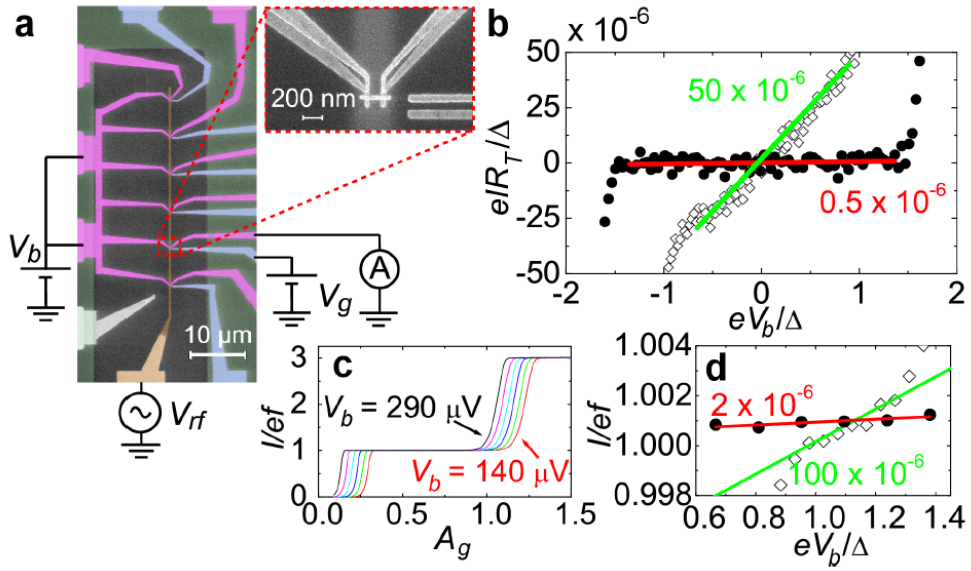

Fig. 2. Performance of the SINIS single-electron turnstile on a ground plane. a, Scanning electron micrographs of the device measured. In this experiment, only one of the six turnstiles is measured at a time. Both sub-gap dc measurements (panel b) and rf pumping measurements (panels c and d) show an order of magnitude improvement with ground plane (red line and solid symbols) compared to the results on reference structures without the ground plane (green line and open symbols).

COOLERS AND THERMOMETRY

During this year we demonstrated experimentally single-electronic radio-frequency refrigeration [7], predicted by us two years earlier [8]. We showed that a small island of a hybrid single-electron transistor can be cooled, at best by almost a factor of two in temperature, merely by applying an AC gate voltage on it. This result is important in cooling nanoelectronic devices, in the first place the island of the turnstile where elevated temperature increases errors in charge transport.

Work on tunnel junction thermometry was active as well. Experiments to compare the basic Coulomb blockade thermometer and the Single Junction Thermometer were

performed at PTB Berlin against the scale-defining 3He melting curve thermometer: the results (still unpublished) show better than 1% agreement over a wide temperature range. Work to develop new fabrication methods of tunnel junctions for thermometry using photolithography are in progress together with VTT.

Electronic cooler platforms are developed for applying them in generic experiments. To assess and improve the performance of micro-coolers, a set of experiments was performed to measure the influence of inverse proximity effect on thermal conductance across a short superconducting line.

NEW ACTIVITIES

The new experiments that were started in 2009 were the measurements of (1) a superconducting quantum interference proximity transistor (SQUIPT) for detection of tiny magnetic fields and moments with very small dissipation, and (2) fast thermometry with > 1 MHz bandwidth to study energy relaxation and fluctuations in time domain in small metallic structures, and (3) influence of dissipation on adiabatic pumping and geometric phases in superconducting circuits.

EQUIPMENT

A new cryostat was launched, a BlueFors cryogen-free dilution refrigerator. During 2009 the fridge has been wired for both DC and RF experiments. The rf-reflectometry measurements of temperature have already started on this fridge.

[1] J.P. Pekola, J.J. Vartiainen, M. Möttönen, O.-P. Saira, M. Meschke, and D.V. Averin, Hybrid single-electron transistor as a source of quantized electric current, *Nature Physics* **4**, 120 (2008).
[2] A. Kemppinen, M. Meschke, M. Möttönen, D. V. Averin, and J. P. Pekola, Quantized current of a hybrid single-electron transistor with superconducting leads and a normal-metal island, *The European Physical Journal - Special Topics* **172**, 311 (2009).
[3] D.V. Averin and J.P. Pekola, Non-adiabatic charge pumping in a hybrid SET transistor, *Physical Review Letters* **101**, 066801 (2008).
[4] A. Kemppinen, S. Kafanov, Yu.A. Pashkin, J.S. Tsai, D.V. Averin, and J.P. Pekola, Experimental investigation of hybrid single-electron turnstiles with high charging energy, arXiv:0903.3482, *Applied Physics Letters* **94**, 172108 (2009).
[5] V.F. Maisi, Yu.A. Pashkin, S.Kafanov, J.S. Tsai, and J.P. Pekola, Parallel pumping of electrons, arXiv:0908.2357, *New J. Phys.* **11**, 113057 (2009). (Presented as a Research Highlight in Nature on Dec. 9, 2009.)
[6] J.P. Pekola, V.F. Maisi, S. Kafanov, N. Chekurov, A. Kemppinen, Yu.A. Pashkin, O.-P. Saira, M. Mottonen, and J. S. Tsai, Photon assisted tunneling as an origin of the Dynes density of states, unpublished.
[7] S. Kafanov, A. Kemppinen, Yu.A. Pashkin, M. Meschke, J.S. Tsai, and J.P. Pekola, Electronic Radio-Frequency Refrigerator, *Physical Review Letters* **103**, 120801 (2009).
[8] J.P. Pekola, F. Giazotto, and O.-P. Saira, Radio-frequency single-electron refrigerator, *Physical Review Letters* **98**, 037201 (2007).

KVANTTI group

Khattiya Chalapat, Jian Li, Karthikeyan Sampath Kumar, and **Sorin Paraoanu**

Our group's main interests are in the field of nanophysics, working at the interface between solid-state physics, quantum optics, and quantum information, and currently focusing on the emerging field of circuit quantum electrodynamics. The research is mostly experimental, but with a significant theoretical component. Additionally, we have developed expertise in the experimental characterization of the interaction between nanostructured materials and microwave electromagnetic fields. The group has had 2 Ph.D. students for the entire 2009; in the fall of 2009, a third student has joined us. Also, during the summer of 2009 the group leader has spent 3 months at the Institute of Quantum Optics and Quantum Information in Vienna, as a Templeton Fellow, in the group of Prof. A. Zeilinger.

ENTANGLEMENT IN COUPLED DRIVEN SYSTEM

We have shown [1] that, for systems of coupled qubits driven externally by a classical field and coupled to two different baths, the system ends up in a stationary state characterized by a finite degree of entanglement. This phenomenon occurs only in a certain region of the parameter space and the structure of the stationary state has a universal form which does not depend on the initial state or on the specific physical realization of the qubits. The concurrence reaches a maximum asymptotic value which is universal and, curiously, is half of the inverse of the golden ratio:

$C_{max} = 1/(1+5^{1/2})$.

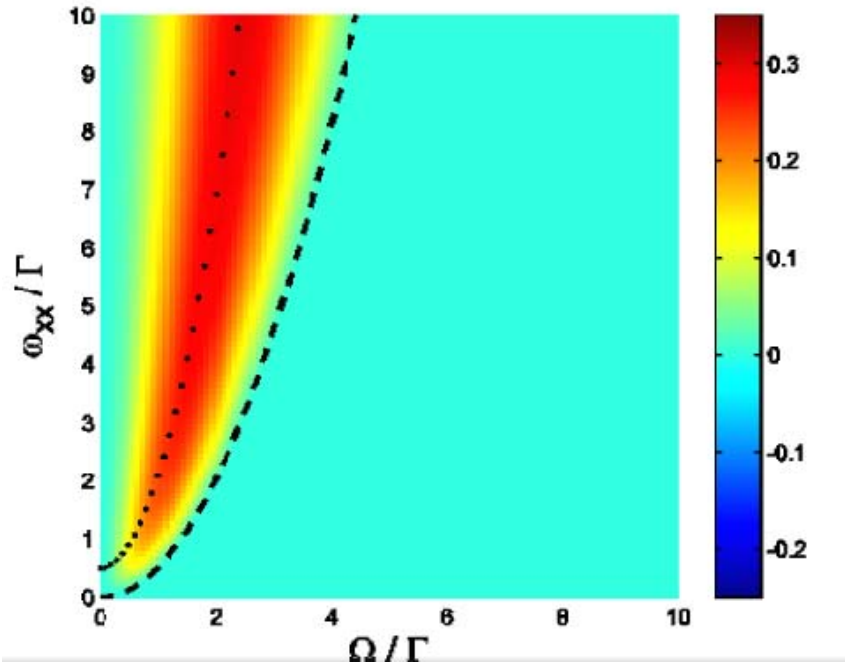

Fig. 1. Asymptotic numerical values for the concurrence as a function of the driving and coupling.

We show that the entanglement thus generated can be propagated within a quantum network using simple local unitary operations. We suggest the use of such systems as "batteries of entanglement" in quantum circuits.

Finally, in a similar quantum circuit we have investigated a scheme for generating entanglement by measuring the state of a cavity to which the qubits are coupled [2].

[1] J. Li and G.S. Paraoanu, Generation and propagation of entanglement in driven coupled-qubit systems, *New J. Phys.* **11**, 113020 (2009)
[2] Jian Li, K. Chalapat, and G. S. Paraoanu, Measurement-induced entanglement of two superconducting qubits, *J. Phys.: Conf. Ser.* **150**, 022051 (2009).

AUTLER-TOWNES SPLITTING IN A SUPERCONDUCTING QUBIT

This work was done in collaboration with the NANO group and NIST. We have seen the splitting of the spectral line of a qubit under a strong driving of another transition, a phenomenon which is indicative for electromagnetic induced transparency. The importance of this lays also in the fact that it opens up the use of the second excited state for quantum information processing. This work is more completely reported by the NANO group.

Reference: M.A. Sillanpää, J.Li, K. Cicak, F. Altomare, J.I. Park, R.W. Simmonds, G.S. Paraoanu, P.J. Hakonen, Autler-Townes effect in a superconducting three-level system, *Phys. Rev. Lett.* **103**, 193601 (2009).

A REFERENCE-PLANE INVARIANT METHOD FOR MICROWAVE MEASUREMENTS

Measuring the electromagnetic properties of materials at high frequencies is a challenging technological problem. We have devised a wideband technique for the simultaneous measurement of the complex permeability and permittivity at microwave frequencies. The method gives in general lower errors than the previously-employed techniques such as the Nicholson-Ross-Weir method.

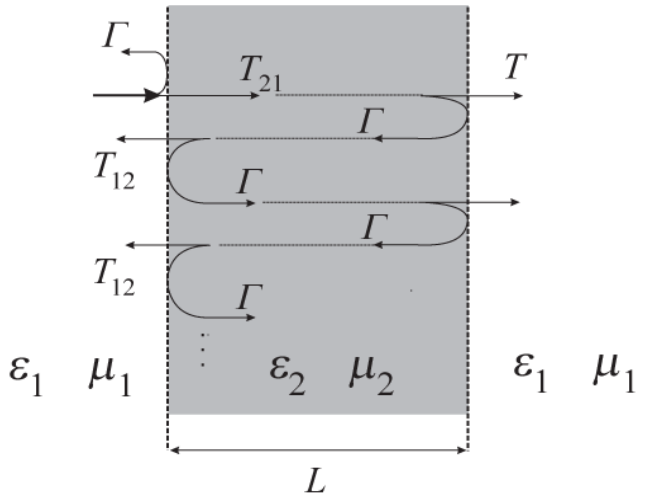

Fig. 2. Multiple partial reflections in a slab of material, resulting in four complex-valued scattering parameters which are measured by a vector network analyzer.

Reference: K. Chalapat, K. Sarvala, J. Li, and G.S. Paraoanu, Wideband Reference-Plane Invariant Method for Measuring Electromagnetic Parameters of Materials, *IEEE Trans. Microw. Theory Tech.* **57**, 2257 (2009).

CARBON-NANOTUBE BASED FAST MEMORY

With the Quantum Dynamics group (Applied Physics Department) we have demonstrated 100 ns write/erase speed using a field-effect single-wall carbon nanotune (SWCNT) transistor with atomic-layer deposited (ALD) hafnium oxide as gate dielectric.

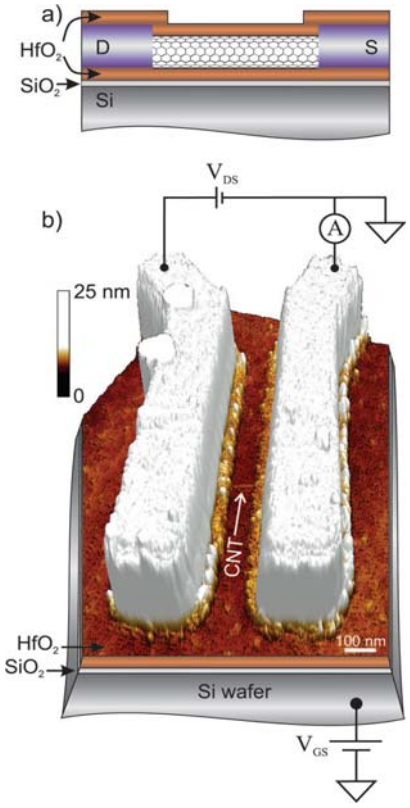

Fig. 3. (a) Side view of a SWCNT-FET having an ALD grown HfO2 gate and passivation layers together with drain (D) and source (S) electrodes. The nominal thicknesses of both HfO2 layers were 20 nm. (b) AFM image of a typical device where a SWCNT is resting on a HfO2 layer and connected with Pd source and drain electrodes having a spacing of 140 nm. The measurement setup is also schematically illustrated. The bias voltage is applied between the drain and source electrodes and the gate voltage to the Si wafer, acting as a backgate, while measuring the current response through the CNT.

Reference: M. Rinkiö, A. Johansson, G.S. Paraoanu, and P. Törmä, High-speed memory from carbon nanotube field-effect transitors with high-k gate dielectric, *Nano Lett.* **9**, 643 (2009).

OTHER WORKS

We have demonstrated a technique for finding the critical temperature of an island [1], we have extended a technique for finding the fragmented many-body state of a cold gas [2], and we wrote a popularization paper which got the third prize in an international essay contest organized by FQXI [3].

[1] J.J. Toppari, T. Kuehn, A.M. Halvari, and G.S. Paraoanu, Method for finding the critical temperature of the island in a SET structure, *J. Phys.: Conf. Ser.* **150**, 022088 (2009)
[2] G.S. Paraoanu, Evolution of fragmented states, *J. Phys.: Conf. Ser.* **150**, 032079 (2009)
[3] http://fqxi.org/community/forum/topic/557.

ROTA group

V.B. Eltsov, R. de Graaf, P.J. Heikkinen, J.J. Hosio, R. Hänninen, and **M. Krusius**

Visitors: Yu.M. Bunkov, V. L'vov, D. Schmoranzer, and M. Silaev

COHERENT QUANTUM MATTER IN T → 0 TEMPERATURE LIMIT

What are the properties of bulk 3-dimensional quantum matter in the zero temperature limit, in the so-called vacuum state, which is characterized by collisionless transport of quasiparticle excitations? Structure, dynamics, and phase transitions of the quantum order parameter field under the reducing coupling to externally applied fields are the features of central interest. In condensed matter physics the quantum vacuum state can be studied in the helium superfluids. These are the only stable bulk superfluids and the best laboratory analogue models of continuous coherent quantum matter. They include the ^{4}He boson superfluid and the A and B phases of the ^{3}He fermion superfluids.

Particularly the ^{3}He superfluids, with a long superfluid coherence length ($\xi \geq 10$ nm) and weak surface interactions with the walls of the container, are well suited for modeling general problems in quantum field theory. Simultaneously much of their basic properties are still unknown and have to be mapped out. One of these unsettled questions is the dynamic response of a superfluid at absolute zero temperature: Is the superfluid a true superfluid at zero temperature, with dissipationless motion of quantized vortices? Or is vortex motion always dissipative, even at the lowest temperatures, and if so, what is that mechanism of dissipation? We now know that the answer depends on the circumstances in which the superfluid dynamics is probed.

Vortices and their dynamics can be examined to some extent in stationary refrigerators, for instance with oscillatory flow using vibrating elements. However, it is clear from past research that in more complicated situations, like the many different vortex structures and their dynamics in the ^{3}He superfluids, vortex studies cannot be carried out comprehensively without uniform rotation. Currently world-wide there exist three rotating cryostats with nuclear cooling. Of these the ROTA installation has the best specifications for work in the $T \rightarrow 0$ limit. The Low Temperature Laboratory moved to a new laboratory building in January 2008. Since then a large part of the experimental effort has been invested in relocating and upgrading the rotating adiabatic nuclear demagnetization cryostat. In August 2009 the machinery was cooled down with a remodeled experiment for measuring the quasiparticle emission associated with a propagating vortex front [1]. The apparatus has now been trimmed to a state where its heat leaks and minimum sample temperatures are lower than before the reconstruction work.

ANDREEV REFLECTION FROM RECTILINEAR VORTICES

The current experimental setup has been designed to measure the heat released during the motion of a turbulent vortex front along a rotating column of superfluid ^{3}He-B. As seen in Fig. 1, the motion is monitored with NMR detector coils at both ends of the column. The density of quasiparticle excitations, which depends exponentially on temperature in the ballistic regime, is measured with quartz tuning fork sensors and calibrated against the temperature readings of a ^{3}He melting pressure gauge. The

smaller lower orifice of 0.3 mm diameter provides the thermal resistance across which the temperature increase is detected.

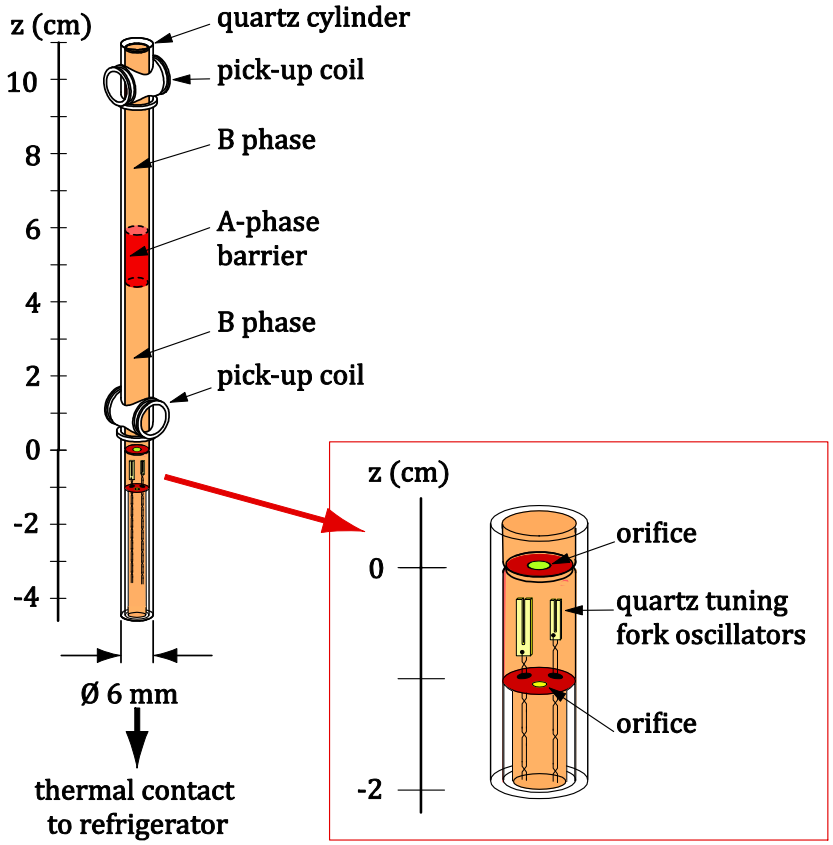

Fig. 1. Measuring setup for investigating the thermal signal from vortex front propagation. The NMR probes for recording the order parameter field are used to monitor the motion of the front in the long upper section of the quartz tube. The quartz tuning fork oscillators are used for measuring the density of quasiparticle excitations in the short lower compartment.

The first measurement with this remodeled setup in the reconstructed cryostat dealt with the thermal properties of the experiment. Using the two quartz tuning fork probes, one as heater and the other as detector, the thermal resistance between the NMR sample and the refrigerator was determined. The measurement was performed starting from a base temperature of ~ 0.20 T_c in the sample volume. It yielded as side product the residual heat leak to the sample volume which proved to be about 10 pW, when the total heat leak to the nuclear cooling stage had been reduced to a level of 2 nW. The heat flow through the small orifice limits the minimum temperature of the sample volume and is therefore of great importance. In rotation the thermal resistance proved to increase linearly with the angular velocity Ω. The linear increase is clear proof that the phenomenon is caused by rectilinear vortex lines which appear in rotation at a density $2\Omega/\kappa$ and block heat transfer through the orifice, owing to the Andreev reflection of quasiparticle excitations from the vortical superfluid flow fields ($\kappa = h/2m_3$ is the superfluid quantum of circulation). This is not the first measurement of Andreev scattering from vortices in superfluid ^{3}He-B, but it is the first time with vor-

tices in a well-defined configuration which can now be analyzed and compared to direct calculations.

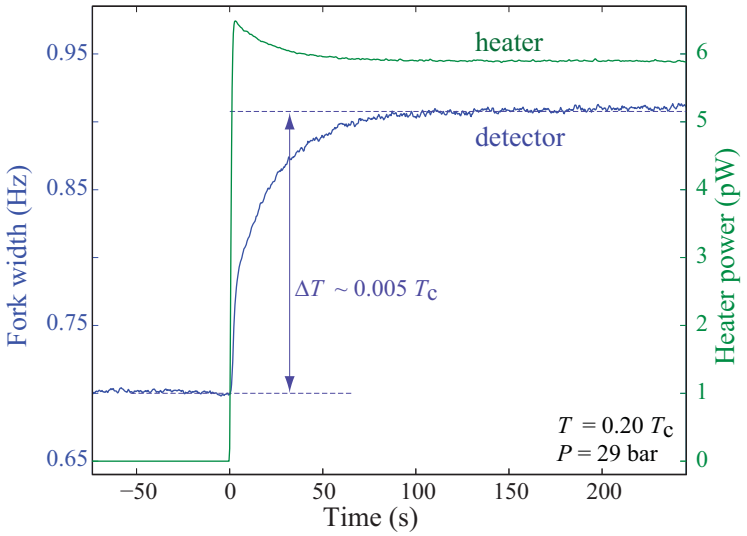

Fig. 2. Thermal signals from quartz tuning fork oscillators in a measurement of thermal resistance. The thermal response of the detector probe is shown when a heating power of ~ 5.7 pW is switched on at the heater fork.

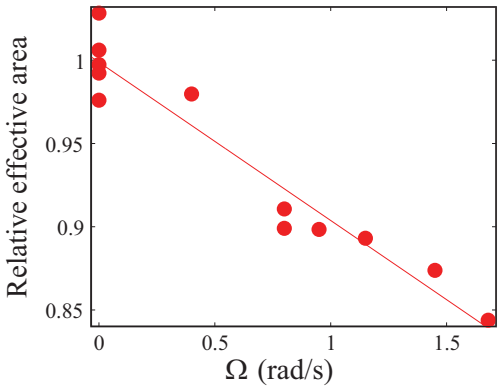

Fig. 3. Results from a measurement of thermal resistance in rotation. The measured data points up to rotation velocities of 1.7 rad/s show that the effective area of the bolometer orifice, which is inversely proportional to the fraction of the retro-reflected quasiparticles, decreases linearly as a function of the vortex density.

The central measurement with the setup in Fig. 1 is to determine whether the dissipation in a propagating turbulent vortex front is transferred to quasiparticle excitations and if so, what fraction of the total dissipation this heat release represents. This measurement has the attractive feature that all measuring signals are recorded while the external conditions are kept constant and thus interference from outside is minimized. All aspects of the experiment are known to work separately from earlier measurements, but the thermal signals to be measured are extremely small, of order 1 pW or less at a rotation velocity of 1 rad/s.

The measurement is based on proven techniques how to maintain the long circular cylinder rotating at constant angular velocity in the so-called vortex-free Landau state. Here the normal excitations are in solid-body rotation with the container walls, while the vortex-free superfluid fraction is at rest with respect to the laboratory. One or more vortices can then be injected at one end of the cylinder. At temperatures below 0.4 T_c these trigger instantaneously a burst of turbulent vortex generation [2] and then start the slow helically winding propagation of the equilibrium number of vortices along the cylinder. A spirally twisted cluster of vortex lines is formed [3] which has a sharp propagating front [1]. The front divides the rotating cylinder in two parts: ahead of the front the superfluid fraction is at rest while behind the front it is close to the

equilibrium vortex state, with the spiral twist slowly relaxing when the vortex line ends slip along the end plate of the cylinder to which they connect. The velocity of the front in stationary-state propagation is then a measure of the rate of dissipation in the vortex motion [1]. At present time, with the current tuning of heat leaks in rotation, this measurement can be performed with a signal-to-noise ratio which is approximately unity. Thus this measurement has become a yard stick for assessing the performance improvements in cryostat operation.

VORTEX FILAMENT CALCULATION OF SUPERLFLUID SPIN DOWN

The idealized model for studying quantum turbulence is the decay of vortex length as a function of time in a homogeneous and isotropic tangle of vortices which is of infinite extent and far from any walls. Few practical models exist for specific flow conditions in the laboratory which would display well-developed turbulence either experimentally or in numerical calculations. One exception is the model developed by Victor L'vov for vortex front propagation in the rotating column [1,4]. Another technique for generating a transient state of tangled vortex motion is spin down of the superfluid component. Spin down is accomplished by stopping rotation abruptly, with the sample initially in the equilibrium vortex state, which then starts the motion of the vortices towards annihilation at the outer container wall. In superfluid ^{4}He measurements spin down has generally been interpreted to occur via the decay of a homogeneous and isotropic turbulent vortex tangle, independently of the shape of the container. We have demonstrated [5] that spin down in ^{3}He-B can either display the characteristics of laminar or turbulent vortex decay, depending on whether the flow geometry has full axial rotation symmetry or is composed of badly obstructed flow paths. Spin down of a cubic container has been studied for superfluid ^{4}He in the University of Manchester by Andrei Golov *et al.* [6]. The resulting vortex tangle was probed with ion transmission measurements and was concluded to be homogeneous and isotropic. Clearly in superfluid ^{4}He strong surface pinning (owing to the small vortex core diameter which is of atomic size ~ 2 Å) is a feature which strongly enhances turbulence and its homogeneity.

To compare the spin down properties in different container geometries a series of vortex filament calculations was performed. The goal here was to find experimentally feasible examples of both laminar and turbulent spin down in the absence of surface pinning. The turbulent states can then be analyzed further, for instance, to which extent they are homogeneous and isotropic. So far calculations have been performed on a sphere, as well as on cylinders and cubes which are tilted from the rotation axis by varying amounts.

Ideally spin down in a cylinder is a purely 2-dimensional laminar process. In practice the cylinder and rotation axes are never perfectly parallel. Thus the vortices in the initial equilibrium vortex state may be slightly misaligned with respect to the cylinder axis and the initial condition for spin down is a state with broken axial rotation symmetry. This was found to affect the overall spin down properties profoundly, so that a cylinder which is inclined by $\leq 30^{\mathrm{o}}$ exhibits laminar flow at least down to 0.22 T_{c}, while at angles $\geq 40^{\mathrm{o}}$ the response is turbulent. Spin down with overall laminar behavior is thus surprisingly robust. Comparing the tilted cylinder to a tilted cube, it is found that in the cube the resulting tangle is a better approximation of homogeneous

and isotropic turbulence, especially when the rotation axis is inclined by a large angle from being perpendicular to two of the cube faces.

In Fig. 4 a comparison is shown of the spin down responses for three container geometries. The three inserts show their vortex configurations at roughly the half-way point in the decay of the total vortex length *L(t)*. The plots in the main panel illustrate two of the important distinctions between laminar and turbulent vortex decay: (1) turbulent decay is faster because of increased dissipation and (2) displays first a sizeable initial overshoot in vortex length immediately after the rotation stop when the turbulent vortex tangle is formed. The transition in Fig. 4 from laminar to turbulent spin down is associated with a sharp increase in the number of reconnections in the bulk volume; it surges up by an order of magnitude. The reconnections are required to form the vortex tangle and to provide the increased dissipation for the faster spin down decay, if compared to pure laminar flow where the vortex length is dissipated only at the cylindrical wall. These are the first numerical calculations which reveal the clear differences between laminar and turbulent vortex flow in an experimentally realistic comparison.

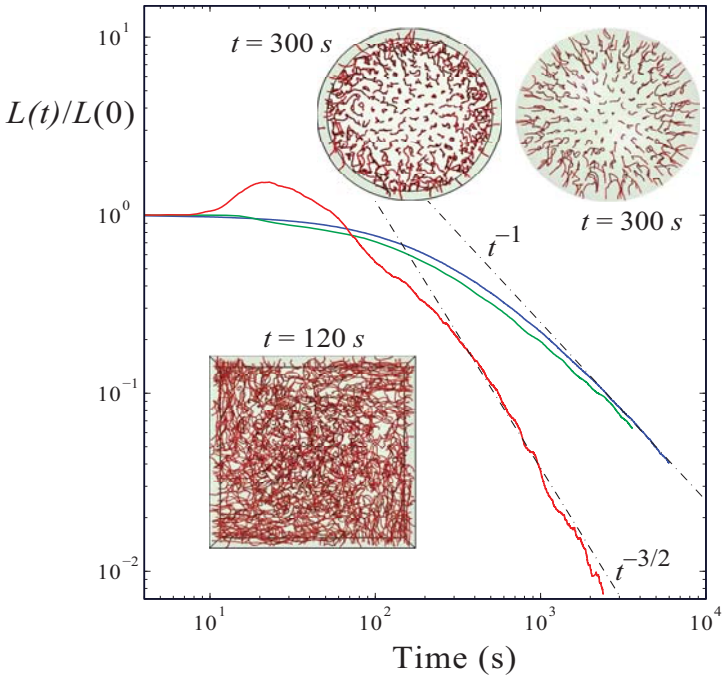

Fig. 4. Laminar and turbulent vortex flow during spin down of the superfluid component after a step-like stop of rotation. (a) blue curve: laminar spin down in a sphere of 6 mm diameter; (b) green curve: laminar spin down in a cylinder of diameter = length = 6 mm, which in the initial equilibrium vortex state is tilted by 2^o from the rotation axis; (c) red curve: turbulent spin down in a cube of 6 mm, which in the initial equilibrium vortex state is tilted by 2^o from the rotation axis. *Inserts:* (Top left) Vortex configuration in a cylinder seen from the top, after 300s of laminar spin down decay, when roughly half of the initial vortex length has annihilated. Note that the vortices in the center are relatively straight while the annihilating outermost vortices have reconnected at the cylindrical wall, to form shorter sections. (Top right) In the sphere the vortices are curved since they have to be perpendicular to the wall at their end points; here there are even less reconnections at the walls or between vortices than in the cylinder. (Bottom left) Turbulent vortex tangle in a cube, seen from the top 120 s after the stop of rotation, when roughly half of the initial vortex length has decayed. (Parameters: $\Omega(0)$ = 0.5 rad/s, $T = 0.22\ T_c$, and P = 29 bar).

In the above numerical examples spin down changes from laminar to turbulent, while varying an externally controllable continuous variable, which is the tilt angle in the initial conditions or the shape of the container walls. These are features which can be experimentally reproduced and checked. They are also so far consistent with the results from our measurements: In the upper NMR section of the sample tube in Fig. 1 spin down is laminar down to below 0.2 T_c [5]. In contrast in the lower section of the sample tube in Fig. 1, where the two quartz tuning forks break axial rotation symmetry, spin down is turbulent [5]. These conclusions will now be utilized to study turbulent dissipation as a function of temperature in the $T \rightarrow 0$ limit where reconnections are giving rise to a new mechanism of damping in vortex motion. Its existence was observed while measuring the velocity of the propagating turbulent vortex front [1].

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THEORY group

Tero Heikkilä, Risto Hänninen, Nikolai Kopnin, Matti Laakso, Janne Viljas, Pauli Virtanen, Grigori Volovik, and Juha Voutilainen

LTL theory group draws many of its projects from the in-house experimental groups and aims to support the on-going experiments. However, the theory group works mostly independently from the other LTL groups and a major part of the projects is targeting problems posed by experiments or theory elsewhere.

The theory work concentrates on three major topics: nanoelectronics (Nikolai Kopnin and the team lead by Tero Heikkilä), ultra-low temperature physics (Grigori Volovik and Risto Hänninen) and cosmology (Grigori Volovik). The μKI group relies in its theory support mostly on the short term visits of Alexander Parshin from the Kapitza Institute.

TEMPERATURE FLUCTUATIONS IN MESOSCOPIC ELECTRON SYSTEMS OUT OF EQUILIBRIUM

Tero Heikkilä and Matti Laakso

In collaboration with Yuli Nazarov, Kavli Institute of Nanotechnology, Delft University of Technology

We have devised a general scheme for calculating the statistics of temperature fluctuations in small islands, connected to two reservoirs. In the absence of a bias (temperature or voltage) between the reservoirs, the system is in equilibrium and the temperature fluctuations are Gaussian. We have analyzed what happens to the fluctuations in the presence of a bias: as the temperature fluctuations are caused by heat current fluctuations through the contacts, the bias-induced changes in the heat current fluctuations influence also the temperature fluctuations. Besides the noninteracting normal-metal systems studied in [1], we have recently also analyzed the effect of heating and temperature fluctuations in single-electron transistors [2]. In small systems the temperature fluctuations have a strong influence also on the current noise through the single electron transistor.

SUPERCONDUCTOR-NORMAL METAL-SUPERCONDUCTOR JUNCTIONS

Pauli Virtanen, **Tero Heikkilä**, Matti Laakso and Juha Voutilainen

In collaboration with PICO, Juan Carlos Cuevas, Universidad Autonoma de Madrid, Spain, F. Sebastián Bergeret, Donostia International Physics Center, San Sebastian, Spain, F. Giazotto, University of Pisa, Italy, the group of Helene Bouchiat, Université Paris Sud, France and the group of V. Chandrasekhar, Northwestern University, the USA.

We have studied the properties of superconductor-normal metal-superconductor (SNS) junctions in the presence of microwave radiation. We have solved the Keldysh-Usadel equations describing these systems in the presence of the microwave field numerically exactly and aimed at qualitative descriptions at different limits [3]. In particular, we have shown that while SNS junctions exhibit the stimulated superconductivity behavior similar to bulk superconductors, which are described by the Eliashberg mechanism, the quantitative details differ from the Eliashberg theory. Our findings offer the first microscopic explanation of the supercurrent enhancement in SNS weak links observed over three decades ago. Moreover, we can quantitatively explain the recent measurements of the current-phase relation in the presence of the microwaves.

Together with the experimental group of Helene Bouchiat, we have also explored the ac impedance of the SNS junction at frequencies close to the inverse diffusion time. Our on-going studies reveal new mechanisms affecting the impedance and are in reasonable agreement with the experimental results.

We have studied the energy relaxation in superconducting proximity structures concentrating on two phenomena: proximity corrections on the electron-phonon coupling [4] and the inverse proximity effect on the heat transport through small superconducting islands in contact with normal metals [5]. The latter study has been done in collaboration with the PICO group, where the effect has been probed experimentally.

Together with the experimental group of Venkat Chandrasekhar, we have studied the properties of SNS superconducting quantum interference devices (SQUIDs) and shown that these can be used as extremely sensitive flux sensors [6].

We have also deepened our earlier studies of the Proximity Josephson Sensor (PJS) for sub-THz radiation [7], investigating the microscopic mechanism of radiation coupling to the sensor and the proximity effect corrections to the energy relaxation and noise properties of PJS.

SPIN HEAT ACCUMULATION AND ITS RELAXATION IN SPIN VALVES

Tero Heikkilä

In collaboration with Gerrit Bauer and Moosa Hatami, Kavli Institute of Nanotechnology, Delft University of Technology

We have studied the concept of spin heat accumulation in excited spin valves [8], more precisely the effective electron temperature that may become spin dependent, both in linear response and far from equilibrium. A temperature or voltage gradient create non-equilibrium energy distributions of the two spin ensembles in the normal metal spacer, which approach Fermi-Dirac functions through energy relaxation mediated by electron-electron and electron-phonon coupling. Both mechanisms also exchange energy between the spin subsystems. This inter-spin energy exchange may strongly affect thermoelectric properties spin valves, leading, e.g., to violations of the Wiedemann-Franz law.

ELECTRON-PHONON ENERGY RELAXATION IN GRAPHENE

Janne Viljas, Tero Heikkilä, and Juha Voutilainen

In collaboration with the NANO group

We have theoretically investigated the role of electron-phonon coupling in monolayer and bilayer graphene on the energy relaxation of electrons. At low temperatures and transport voltages the energy relaxation is dominated by diffusion or by electron coupling to acoustic phonons. We have shown that when the either type of graphene is gated far away from the charge neutrality point, the low-temperature electron-acoustic phonon heat current satisfies a power law, which is symmetrical in the electron and phonon temperatures, while in the neutral regime an asymmetrical law is found [9]. At temperatures above room temperature optical phonon scattering becomes the dominant means of energy relaxation.

At bias voltages exceeding roughly 0.2 V, optical phonon scattering also becomes an important form of momentum relaxation and thus a decisive factor in determining the conductivity and shot noise of graphene. In this regime the optical phonons can also heat much above the lattice temperature. We have modeled experiments carried out in the NANO group, where the current-voltage characteristics and shot noise were measured up to a bias of 1 V, and where the shot noise (Fano factor) was used as an electron thermometer [10]. A good agreement between the model and the experimental results is found assuming that the active optical phonons heat together with the electrons up to temperatures of the order of 1000 K.

MOLECULAR ELECTRONICS

Janne Viljas

In collaboration with F. Pauly, Karlsruhe Institute of Technology, Germany, and Juan Carlos Cuevas, Universidad Autonoma de Madrid, Spain

We have studied theoretically the transport of electrons in metallic atomic-sized contacts and single-molecule junctions. Our calculations are based on ab-initio electronic structure methods and tight-binding models combined with Green-function-based transport techniques. In particular we have studied anisotropic magnetoresistance (AMR) of atomic contacts of 3d ferromagnetic metals [11]. We have shown that the

AMR effect, due to spin-orbit coupling, is strongly enhanced in such point contacts compared to bulk materials. This is in agreement with recent experiments.

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NONEQUILIBRIUM PROPERTIES OF MESOSCOPIC SUPERCONDUCTORS

N.B. Kopnin

Collaborators: J. Pekola and PICO group (LTL), Yu.M. Galperin (University of Oslo, Norway), V.M. Vinokur (Argonne National Laboratory, US), and C.P. García and F. Giazotto (Scuola Normale Superiore, Pisa, Italy)

The electron-electron and electron-phonon interactions and the heat transfer between these subsystems in normal-superconductor nanostructures at very low temperatures have been investigated both experimentally and theoretically in collaboration with the PICO group. The quasiparticle energy relaxation at sub-kelvin temperatures has been investigated by injecting hot electrons into an aluminum island and measuring the energy flux from quasiparticles into phonons both in the superconducting and in the normal state. The data show strong reduction of the flux at low temperatures in the superconducting state, in qualitative agreement with the theory for clean superconductors. However, quantitatively the energy flux exceeds the theoretical predictions both in the superconducting and in the normal state, suggesting an enhanced or additional relaxation process [1].

The correct interpretation of the data obtained in the experiment requires the proper attribution of the specific phenomenon either to a quasi-equilibrium (with a well-defined electronic temperature though possibly different from the bath temperature) or to highly non-equilibrium situation where the notion of electronic temperature cannot be introduced. As a generic example, we investigate electronic distributions in non-equilibrium mesoscopic tunnel junctions subject to a high-voltage injection under competing electron-electron and electron-phonon relaxations. We derive conditions for reaching quasi-equilibrium and show that, though the distribution can still be thermal for low energies where the rate of the electron-electron relaxation exceeds significantly the electron-phonon relaxation rate, it develops a power-law tail at ener-

gies of order of the bias voltage. In a general case of comparable electron-electron and electron-phonon relaxation rates, this tail leads to emission of high-energy phonons which carry away most of the energy pumped in by the injected current implying that interpretation of the experimental data based on the quasi-equilibrium distribution function with some effective temperature does not apply.[2]

Effects of the Coulomb interaction on transport in normal and superconducting quantum conductors have been studied for arbitrary transparency of the contacts. We considered resonant transmission through a gated finite-length quantum wire connected to leads via finite transparency junctions, such that the escape time is much smaller than the energy relaxation time in the wire. The coherent electron transport is strongly modified by the Coulomb interaction. The low-temperature current-voltage curves show step-like dependence on the bias voltage determined by the distance between the quantum levels inside the conductor, the pattern being dependent on the ratio between the charging energy and level spacing. If the system is tuned close to the resonance condition by the gate voltage, the low-voltage IV curve is Ohmic. At large Coulomb energy and low temperatures, the conductance is temperature-independent for any relationship between temperature, level spacing, and coupling between the wire and the leads. [3]

STUDIES OF SUPERCONDUCTIVITY IN GRAPHENE

N.B. Kopnin

Collaborators: E.B. Sonin (Hebrew University of Jerusalem, Israel), A.S. Mel'nikov, I.M. Khaymovich, I.A. Shereshevskii (Institute of Microstructures, Nizhny Novgorod, Russia).

Possible superconductivity of electrons with the Dirac spectrum (Fig. 1) is analyzed using the BCS model. Assuming existence of certain pairing interaction between electrons in graphene we calculate the critical temperature, the superconducting energy gap, and supercurrent as functions of the doping level and of the pairing interaction strength. Zero doping is characterized by existence of the quantum critical point such that the critical temperature vanishes below some finite value of the interaction strength. However, the critical temperature remains finite for any nonzero electron or hole doping level when the Fermi energy is shifted away from the Dirac point (Fig. 2). As distinct from usual superconductors, the supercurrent density is not proportional to the number of electrons but is strongly decreased due to the presence of the Dirac point [4].

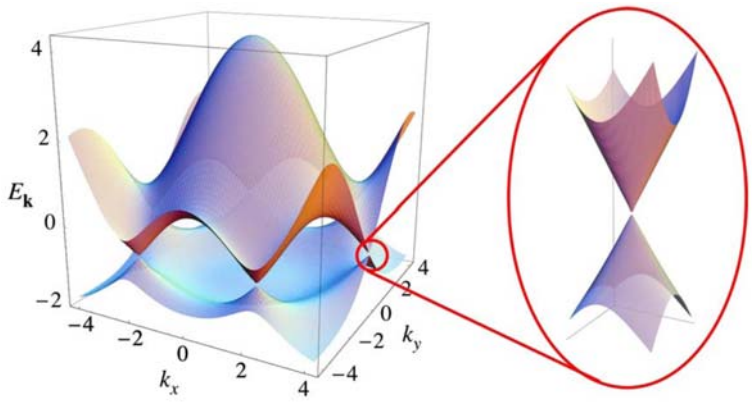

Fig. 1. Electronic spectrum of normal-state graphene [picture from *Castro Neto et al.*, Rev. Mod. Phys. (2009)]

Under the assumption that graphene is in a superconducting state due to either intrinsic or extrinsic mechanisms, we investigate the electronic structure of a multi-quantum vortex in superconducting graphene. The Bogoliubov-de Gennes theory is applied to excitations near the Dirac point. We suggest a scenario describing the sub-gap spectrum transformation which occurs with a change in the doping level. For an arbitrary vorticity and doping level we investigate the problem of existence of zero energy modes. The crossover to a Caroli-deGennes-Matricon type of spectrum is studied. We also present a numerical solution (Fig. 3) describing the transformation of the quasiparticle subgap spectrum with a change in the doping level [5].

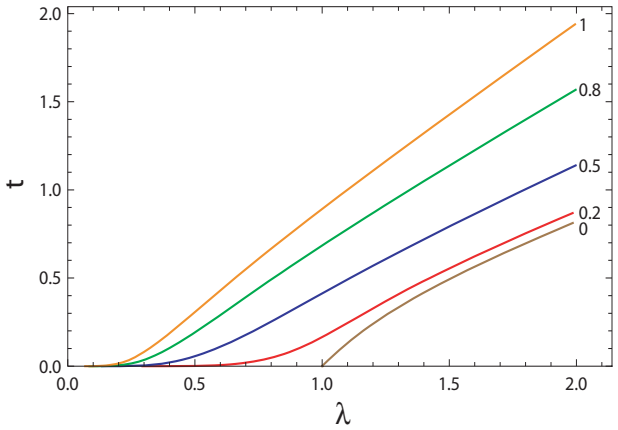

Fig. 2. Superconducting critical temperature of graphene, $t=T_c/\xi_m$, normalized to the interaction cut-off energy ξ_m as a function of the interaction constant λ for various doping levels μ/ξ_m. The quantum critical point corresponds to zero doping. [5]

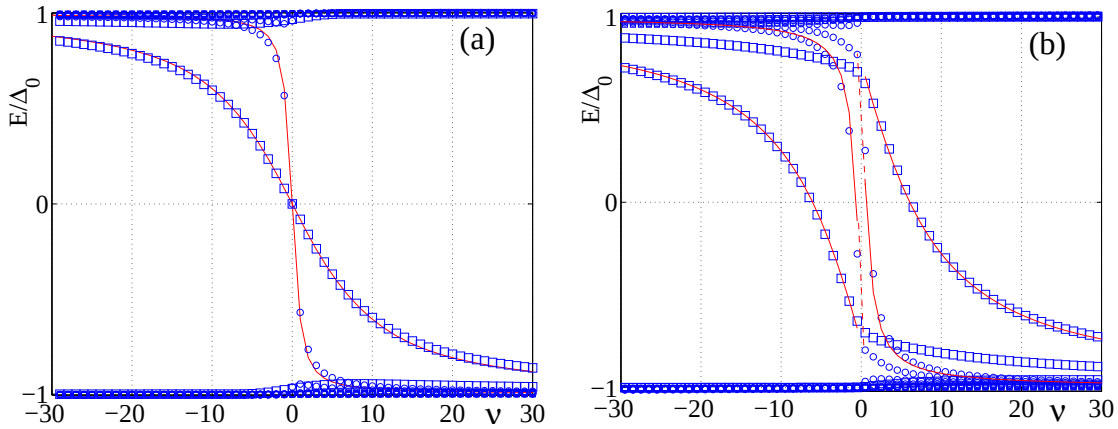

Fig. 3. Spectra of the vortex core states in superconducting graphene as functions of the angular momentum ν at low (circles) and high (squares) doping for singly (a) and doubly (b) quantized vortex. [6]

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SUPERFLUID 3HE AND TOPOLOGICAL QUANTUM MATTER

G. Volovik

Physics of superfluid 3He influences the development of many other areas of physics. There are several reasons for that. One of them is the complicated structure of the order parameter which simultaneously shares the properties of many other condensed matter systems such as magnetic materials, liquid crystals, superfluid 4He, Bose-Einstein condensates (BEC) in ultra-cold gases, high-temperature and chiral superconductors, etc. The other reason is that phases of superfluid 3He share many properties of the topological matter, such as semi-metals, topological insulators, massless and massive phases of the Standard Model of weak, strong and electromagnetic interactions. Different aspects of physics of topological matter include topological stability of gap nodes; classification of fully gapped vacua; edge states; Majorana fermions; influence of disorder and interaction; topological quantum phase transitions; intrinsic Hall and spin-Hall effects; quantization of physical parameters; experimental realization; connections with relativistic quantum fields; chiral anomaly; etc.

According to classification of topological matter, superfluid 3He-A belongs to the same universality class of gapless vacua as the Standard Model in its gapless phase: it is described by the same topology in momentum space. This class is characterized by the existence of topologically stable Fermi points (Dirac points) in the excitation spectrum. Close to the Fermi point all the ingredients of the Standard Model and gravity emerge: left-handed and right-handed fermions, gauge bosons, metric field, relativistic invariance and other physical laws. This supports the new paradigm that the elementary particles (quarks and leptons), weak, strong and electromagnetic fields, as well as the gravitational field and space-time itself, are entities which naturally emerge in the low energy corner of the medium called quantum vacuum.

On the other hand, superfluid 3He-B belongs to the same topological class of gapped vacua as the Standard Model in its massive Higgs phase [1] and topological insulators with time reversal symmetry. They all are described by similar topology in momentum space, and may experience the similar types of the topological quantum phase transitions [2]. The topological superfluid 3He-B provides also many examples of the interplay of symmetry and topology [2,3,4]. In particular, the nontrivial topology of 3He-B in combination with the 3He-B symmetry gives rise to gapless Andreev bound state on the surface of 3He-B; these surface states have the properties of relativistic Majorana fermions [3].

In 3He-B, the symmetry can be manipulated by external magnetic field [4]. Magnetic field violates the time reversal symmetry. As a result, the topological invariant supported by this symmetry ceases to exist, and thus the gapless fermions on the surface of 3He-B are not protected any more by topology: they become fully gapped. If perturbation of symmetry is small, the surface fermions remain relativistic with mass proportional to symmetry violating perturbation -- magnetic field. The 3He-B symmetry gives rise to the Ising variable (with values $I = +1$ and $I = -1$), which emerges in magnetic field and which characterizes the states of the surface of 3He-B. This variable also determines the sign of the mass term of surface fermions and the topological

invariant describing their effective Hamiltonian. The line on the surface, which separates the surface domains with different I, contains 1+1 gapless fermions, which are protected by combined action of symmetry and topology.

SPIN SUPERFLUIDITY AND MAGNON BEC

G. Volovik

Collaborators: Yuriy Bunkov (Institut Neel, France), ROTA group

In addition to fermionic quasiparticle excitations, superfluid 3He has also bosonic quasiparticles, such as magnons. These magnon excitations can form long-lived Bose-Einstein condensates (BEC) [5]. BEC of excitations is presently one of the debated phenomena of condensed matter physics. In thermal equilibrium the chemical potential of excitations vanishes and, as a result, their condensate does not form. The only way to overcome this situation is to create a dynamic steady state with a conserved number of excitations as a non-equilibrium system. Formally BEC requires conservation of charge or particle number. However, condensation can still be extended to systems with weakly violated conservation, such as quasiparticles, i.e. to discrete quanta of energy which can be treated as real particles in condensed matter. The loss of quasiparticles due to their decay is compensated by pumping. For sufficiently long-lived quasiparticles the non-zero chemical potential is well defined and BEC becomes possible. Several examples of Bose condensation of quasiparticles have been observed or suggested, including BEC of phonons, excitons, exciton-polaritons, and magnons or spin waves in ferromagnets and in the superfluid 3He-B [6].

Recently observation of new mode of magnetization precession in superfluid 3He-A in a squeezed aerogel has been reported. It has been identified in [6] as magnon BEC, which emerges in 3He-A due to the appropriate orientation of the order parameter in the deformed aerogel. The type of magnon BEC in 3He-A is essentially different from that which was earlier observed in 3He-B, and is similar to BEC in cold atoms. This identification has been confirmed in further experiments.

At low temperatures the magnon BEC in 3He-B is confined in a magnetic trap, which is formed by the order parameter texture of the superfluid state. It was found that magnon condensation occurs not only in the ground state level in the trap, but also at an excited energy level [7]. Recently the formation of non-ground-state condensates from cold atoms has been proposed, as a dynamic mixture of the ground state and an excited level, by resonant modulation of either the trap potential or the atomic scattering length, e.g. by applying a temporal modulation of the atomic interactions via the Feshbach resonance technique. In contrast to such schemes with atomic condensates in optical traps, the properties of magnon condensates make it possible to populate different excited trap levels by pumping magnons resonantly directly to these levels. Different condensates can be created by choosing among the different excited energy levels [7]. The condensate can then be manipulated by changing the profile of the trap. These magnon condensates can be used to probe the quantum vacuum of 3He-B in the zero-temperature limit, where conventional measuring signals become insensitive. This can serve as a tool for identification of Andreev-Majorana fermions on the surface of 3He-B discussed in [2-4] and inside the vortex cores.

CONNECTION TO PARTICLE PHYSICS AND COSMOLOGY

G. Volovik

Collaborator: Frans Klinkhamer (University of Karlsruhe, Germany)

(a) *Vacuum of Standard Model as a topological medium*. Both known states of the quantum vacuum of SM have non-trivial topology. The insulating state and semi-metal state of quantum vacuum are described by nonzero values of topological invariants supported by symmetry [1]. Momentum space topology suggests a number of possible quantum phase transitions in the quantum vacuum of SM. The transition between the semi-metal gapless state and the fully gapped insulating state of the vacuum is one of them.

(b) *Dynamics of vacuum energy and cosmological constant*. The standard model of elementary particle physics and the theory of general relativity can be extended [8] by the introduction of a vacuum variable which is responsible for the near vanishing of the present cosmological constant (vacuum energy density). The explicit realization of this vacuum variable can be via a three-form gauge field, an aether-type velocity field, or any other field appropriate for the description of the equilibrium state corresponding to the Lorentz-invariant quantum vacuum. The extended theory has, without fine-tuning, a Minkowski-type solution of the field equations with spacetime-independent fields and provides, therefore, a possible solution of the main cosmological constant problem (why the present vacuum energy density is by 120 orders of magnitude smaller that the natural value E_{Planck}^4 estimated from the natural Planck energy scale). This dynamic theory also addresses the next question: why is our present Universe close to the Minkowski vacuum or, in other words, why does Nature prefer flat spacetime? The answer to this question appears to be: because the Minkowski equilibrium state is an attractor and the Universe is moving towards it. We are close to this attractor, simply because our Universe is old.

There remain, however, other problems. Observational cosmology suggests a tiny remnant vacuum energy density and the de Sitter Universe as a final asymptotic state. This, then, leads to the additional cosmic problems: why the present vacuum energy density is frozen, i.e. does not decay to zero in future expansion of the universe; and why the nonzero vacuum energy density is of the same order as the present matter energy density. We propose two scenarios: in the first one the role of the vacuum field is played by the gluon condensate of quantum chromo-dynamics [9] and in the second one the non-zero vacuum energy is triggered by electroweak crossover [10]. In the latter scenario the cosmic coincidence problem is related to quantum-dissipative effects during the cosmological evolution of the vacuum field. It was demonstrated that the electroweak crossover necessarily generates the vacuum energy density comparable with the present value of the cosmological constant. If the freezing mechanism for the vacuum energy suggested in [10] is confirmed, this will support the theories where the dark energy is related to the electroweak physics. In any case, the developed theory transforms the standard cosmological constant problem into the technical problem of search for the proper decay mechanism of the vacuum energy density towards either the final de Sitter Universe or the final Minkowski vacuum.

(c) *Stability of de Sitter Universe*. The de Sitter quantum vacuum is one of the two possible asymptotic states of our universe. Stability of the de Sitter Universe towards the Minkowski vacuum is one of the debated phenomena in particle physics and cos-

mology. Hawking radiation from the de Sitter horizon can be the source of instability. The condensed matter experience allowed us to study this problem. The Hawking radiation from black holes can be formulated as the semi-classical tunnelling process. This quantum tunnelling description is applicable also to de Sitter Universe. It is argued that de Sitter vacuum is stable against the Hawking radiation: though the quantum tunnelling exponent does correspond to the thermal spectrum of radiation, the matrix element is strictly zero due to the special symmetry of the de Sitter vacuum, and the radiation does not occur. On the other hand the detector immersed into the de Sitter background violates the symmetry of the de Sitter vacuum [11,12]. As a result the detector will detect the radiation. Two examples of the radiation caused by the presence of external object in the de Sitter vacuum are considered: ionization of an atom caused by the de Sitter expansion [11], and the decay of the composite particle into two particles in the de Sitter background [12]. The atom (or any other composite or massive particle) plays two roles: it serves as the detector of radiation; and it violates the de Sitter symmetry and provides the nonzero matrix element for the radiation, since as we argue the pure de Sitter vacuum is not radiating due its symmetry. In both examples the radiation looks as thermal, but with the effective temperature twice larger than the Hawking temperature associated with the cosmological de Sitter horizon.

(d) *Physics of Minkowski vacuum*. It is argued that in effective theory, the flat isotropic Minkowski vacuum emerging at low energy is characterized by two parameters: the speed of light and the Planck constant [13]. In such vacuum, the interval s has the dimension of inverse mass: it characterizes the dynamics of particles in the quantum vacuum rather than the geometry of space-time. The action for all quantum fields becomes dimensionless, which reflects equivalence between an action and the phase of a wave function in quantum mechanics. Results are applied to parameters of metrology triangle, which enter the Josepson effect, quantum Hall effect, and quantum pumping.

(e) *Osmotic pressure of matter in Minkowski vacuum* [14]. The walls of the box which contains matter represent a membrane that allows the relativistic quantum vacuum to pass but not matter. That is why the pressure of matter in the box may be considered as the analog of the osmotic pressure. It is demonstrated that the osmotic pressure of matter is modified due to interaction of matter with vacuum. This interaction gives rise to the additional negative contribution to matter pressure inside the box, this pressure is induced by the quantum vacuum. As a result the measured osmotic pressure is smaller than the matter pressure. As distinct from the Casimir effect, the induced vacuum pressure is the bulk effect and does not depend on the size of the box. This effect dominates in the thermodynamic limit of the infinite volume of the box. In the present Universe this effect is extremely small: since the present atomic matter is very dilute compared to the vacuum, the interaction between matter and vacuum produces only small perturbation of the vacuum state. However, inside the neutron stars the modification of matter pressure due to gluon condensate in the quantum vacuum may be considerable. Also such effect was essential in the early Universe, and if the vacuum energy was frozen at later evolution according to freezing mechanism in [10], this could give the reasonable estimate for the present magnitude of the vacuum energy and cosmological constant. Analog of this effect has been observed in the dilute solu-

tion of 3He in liquid 4He, where the superfluid 4He plays the role of the non-relativistic quantum vacuum, and 3He atoms play the role of matter.

(f) *Gravity and condensed matter physics*. Recently, based on Lifshitz point in the theory of phase transitions in condensed matter, Horava proposed a model for gravity. Gravity is described by the Einstein action in the infrared, but lacks the Lorentz invariance in the high-energy region where it experiences the anisotropic scaling. The validity of this proposal is tested in [15] using two condensed matter examples of emergent gravity: acoustic gravity emerging in quantum hydrodynamics and gravity emerging in the topologically nontrivial quantum vacuum with Fermi points. It is suggested that quantum hydrodynamics, which together with the quantum gravity is the non-renormalizable theory, may exhibit the anisotropic scaling in agreement with the Horava proposal. On the other hand, the Fermi point scenario of emergent general relativity demonstrates that under general conditions, the infrared Einstein action may be distorted, i.e. the Horava parameter λ is not necessarily equal 1 even in the low energy limit. The consistent theory requires special hierarchy of the ultra-violet energy scales and the fine-tuning mechanism for the Newton constant.

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μKI group

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The main instrument in our research is a microkelvin refrigerator, the cryostat, which has been constructed by our group based on principles developed largely in our laboratory, and which is one of the most efficient refrigerators in the world-wide scale for macroscopic condensed matter specimens at this low range of temperatures. Our work concentrates on fundamental questions in the field of ultra-low temperature physics, such as the eventual superfluidity of dilute helium mixtures, nuclear magnetism and its relation to superconductivity, quantum crystals, i.e. helium in the solid state, and interfacial phenomena on the surface between superfluid and helium crystals. These are technically challenging long-span projects, upon which not many laboratories in the world have technical capabilities, special skills required or resources to be tied up with.

As reminiscence from earlier experiments on nuclear magnetism, our group still holds the world record of low temperatures – 100 pK produced in the spin system of rhodium nuclei.

ADIABATIC MELTING EXPERIMENT

Elias Pentti, Juho Rysti, Anssi Salmela, Alexander Sebedash, and **Juha Tuoriniemi**

New kind of superfluidity is expected to occur in mixtures of the helium isotopes, if such mixtures can be cooled to even lower temperatures than before. The challenges of this research are to cool the sample in the first place and then to make reliable measurements on the system without intolerable heating. External refrigeration of helium liquids is limited to some 100 microkelvin even under very favorable conditions due to the extremely steeply increasing thermal boundary resistance. To overcome this obstacle we are developing a new cooling technique, adiabatic melting, where the process absorbing heat takes place within the helium mixture itself. This occurs when the lighter isotope of helium (3He, fermion) dissolves into the heavier component (4He, boson). The separation and mixing of the isotopes are controlled by solidification or melting of 4He in the experimental cell by transfer of superfluid 4He in or out of the cell by means of a superfilter capillary. The working principle of the method has been demonstrated successfully below 1 mK in the first experiments by our group.

Several improvements to the experimental cell are needed for operation at record breaking temperatures. These are done for the most parts and the assembly work for the next improved run is on its way.

Besides looking for the extraordinary superfluid state in the mixed system, helium-isotope solutions can also be used for studies of unique phase transition phenomena, such as macroscopic quantum nucleation. From the more technical point of view, the univariant phase equilibrium condition of the saturated mixture with its solid phase may provide the best possible reference standard for the microkelvin scale tempera-

tures. We also have observed acoustic resonance phenomena in the mixtures, which may be useful as means to create a handy secondary thermometer.

INTERFACES IN QUANTUM SYSTEMS

Heikki Junes, Jukka-Pekka Kaikkonen, Matti Manninen, Igor Todoshchenko, and **Juha Tuoriniemi**

Collaborators: Alexander Parshin (Moscow) and Viktor Tsepelin (Lancaster)

Quantum crystals, which are in the phase equilibrium with superfluid, offer the possibility to investigate growth phenomena of crystals under the most ideal conditions. It is possible to study different growth mechanisms, faceting of the crystals, and it is also possible to create unique melting-freezing waves on the surface of the crystal. Such crystallization waves have been observed on 4He, but not so far on 3He, because the required temperature is several orders of magnitude lower. The crystallization waves in 3He also couple to the magnetic degrees of freedom, since 3He has a nuclear spin, unlike 4He. In future the experimental work of our group will concentrate on this problem; the preparations for these experiments are on their way.

The first experimental arrangement under this theme is designed for the generation and detection of predicted crystallization waves on the interface between superfluid and solid 3He in a tubular compressional cell with internal copper nuclear demagnetization plates and heat exchangers. This design is referred to as a Leiden-Lancaster cell, as some features developed in these two famous laboratories have been combined here. The excitation and detection of deflection of the crystal surface will be made by fine interdigital capacitors, which have to endure fair DC voltage needed to adjust the contact angle of the solid surface on the cell wall and which also must deliver reasonable response to the alternating small deviations in permittivity when the helium surface is in motion. Crystallization waves on the surface of solid 3He have specific interest, as unlike anything else they are supposed to have a magnetic component due to the nuclear spin of 3He. In longer term, these experiments are planned to be continued in an even more sophisticated assembly, where optical investigations can be made in presence of a magnetic field strong enough to influence the state of the nuclear spin system in the antiferromagnetically ordered phases of solid 3He at very low temperatures well below one millikelvin.

MICROKELVIN THERMOMETRY

Anssi Salmela, Alexander Sebedash, and **Juha Tuoriniemi**

An issue under constant development in experiments pursuing the lowest temperatures ever reached is thermometry for the experiment at hand. For this purpose we are investing on the most sensitive detection of thermal noise currents in pure metallic specimens by the most refined SQUID amplifiers. In addition, we are developing small secondary probes giving very precise readings of temperature, once calibrated, based on resonances of second sound in helium mixtures coupled to quartz tuning forks. Also, melting curve thermometry on helium mixtures, quasiparticle damping experienced by immersed quartz tuning forks, and NMR on platinum are other tools in development for the studies of quantum fluids at extremely low temperatures.

BRAIN RESEARCH UNIT

The research programs of the Brain Research Unit aim to deepen the understanding of human brain function in health and disease by exploiting, developing, and integrating the most advanced spatiotemporal methods of non-invasive human neuroimaging. The research included design and construction of stimulation and monitoring devices to create versatile but controlled stimulus environments for systems neuroscience experiments.

We study human brain function by measuring weak magnetic fields outside the head. This method, magnetoencephalography (MEG), allows a totally non-invasive view into healthy and diseased human brains during different tasks and conditions. Our 306-channel neuromagnetometer (Elekta Neuromag, Elekta Oy), functional since 1998 and upgraded in 2008, houses 204 gradiometers and 102 magnetometers with a whole-scalp coverage. To combine functional and structural information, we typically integrate MEG data with the subject's magnetic resonance images (MRIs).

We also use functional magnetic resonance imaging (fMRI) at the Advanced Magnetic Imaging (AMI) Centre of TKK; fMRI with its excellent spatial resolution complements the superb temporal resolution of MEG in tracking activation patterns and sequences in the human brain. The AMI Centre operates a 3-tesla MRI/fMRI superconducting magnet (General Electric 3T Signa) for whole-body imaging.

Since the beginning of 2006, we form the core of the Center of Excellence on Systems Neuroscience and Neuromaging, appointed by the Academy of Finland for years 2006–2011. The other partners of the Center of Excellence work at the AMI Centre of TKK, at the Applied Electronics Laboratory of TKK, and at the Neuroscience Unit of the University of Helsinki.

Scientific Advisory Board (SAB) meeting of our CoE was held at Otaniemi November 3rd 2009. SAB members Prof. Chris Frith (University College London, UK) and Prof. Nikos Logothetis (MPI Biological Cybernetics, DE) attended the meeting online. In their evaluation report the SAB unanimously agreed that *"the scientific productivity and activity of the CoE members continue to be outstanding, with an impressive progress in the numbers of papers published or in press in the period of 2008 to 2009. The centre undoubtedly remains an international reference for MEG, with state-of-the-art equipment and leading experts, including the connection to Elekta NeuroMag. Not surprisingly, the CoE continues to be internationally highly visible, and it is attractive for foreign post-docs and visiting scientists"*.

Below we list our achievements from 2009 in the form of published papers.

HUMAN SYSTEMS NEUROSCIENCE

1. **Halko M-L, Hlushchuk Y, Hari R, Schürmann M:** Competing with peers: Mentalizing-related brain activity reflects what is at stake. NeuroImage 2009, 46: 542–548.

Competition imposes constraints for humans who make decisions. Concomitantly, people do not only maximize their personal profit but they also try to punish unfair conspecifics. In bargaining games, subjects typically accept equal-share offers but reject unduly small offers; competition affects this balance. Here we used functional magnetic resonance imaging (fMRI) to study adjustment to competition in a bargain-

ing game where subjects competed against another person for a share of the stake. For medium-sized, but not for minimum offers, competition increased the likelihood of acceptance and thus shifted behavior towards maximizing personal profits, emphasizing the importance of financial incentives. Specifically for mediumsized offers, competition was associated with increased brain activation bilaterally in the temporoparietal junction, a region associated with mentalizing. In the right inferior frontal region, competition-related brain activation was strongest in subjects whose high acceptance rates in the standard ultimatum game hinted at a profit-oriented approach. The results suggest a network of brain areas supporting decision making under competition, with incentive-dependent mentalizing engaged when the competitor's behavior is difficult to predict and when the stake is attractive enough to justify the effort.

2. **Hari R, Kujala MV:** Brain basis of human social interaction: from concepts to brain imaging. Physiological Reviews 2009, 89: 453–479.

Modern neuroimaging provides a common platform for neuroscience and related disciplines to explore the human brain, mind, and behavior. We base our review on the social shaping of the human mind and discuss various aspects of brain function related to social interaction. Despite private mental contents, people can share their understanding of the world using, beyond verbal communication, nonverbal cues such as gestures, facial expressions, and postures. The understanding of nonverbal messages is supported by the brain's mirroring systems that are shaped by individual experience. Within the organismenvironment system, tight links exist between action and perception, both within an individual and between several individuals. Therefore, any comprehensive brain imaging study of the neuronal basis of social cognition requires appreciation of the situated and embodied nature of human cognition, motivating simultaneous monitoring of brain and bodily functions within a socially relevant environment. Because single-person studies alone cannot unravel the dynamic aspects of interpersonal interactions, it seems both necessary and beneficial to move towards "two-person neuroscience"; technological shortcomings and a limited conceptual framework have so far hampered such a leap. We conclude by discussing some major disorders of social interaction.

3. **Koskinen M, Vartiainen N:** Removal of imaging artifacts in EEG during simultaneous EEG/fMRI recording: Reconstruction of a high-precision artifact template. NeuroImage 2009, 46: 160–167.

Functional magnetic resonance imaging (fMRI) induces coarse electromagnetic artifacts into the simultaneously recorded electroencephalogram (EEG). The problem in the signal processing framework is to model the underlying artifact, which is time-continuous, as a discretely sampled waveform. To build up an artifact template, the EEG sampling in relation to the phase of the imaging artifacts should be known. If the MR scanner and EEG sampling are not synchronized, this relation is not constant and a time adjustment of the template with the individual slice artifacts becomes essential. However, lack of synchrony opens up the possibility for approximating a high-precision and continuous artifact template by using the samples acquired from slightly different phases of the induced artifact. In this work, methodology for reconstructing such a template was developed using EEG data recorded simultaneously with fMRI at 3 T. A time-continuous cubic spline approximation was used as the slice artifact model. To overcome the problem of non-synchronized clocks, two methods were proposed to find the starting times of the slice artifacts at sub-sample precision. This ap-

proach yielded efficient imaging artifact reduction: the amplitude at the dominant frequency was attenuated by 55-70 dB (the median values over EEG channels) and the residual signal, at its best, was practically free from sharp transients even with 5000 Hz sampling frequency and without further residual artifact reduction algorithms. The presented methods may reduce the need for post-processing of the residual signal after the template subtraction and may help to preserve the EEG bandwidth.

4. **Kujala MV, Tanskanen T, Parkkonen L, Hari R:** Facial expressions of pain modulate observer's long-latency responses in superior temporal sulcus. Human Brain Mapping 2009, 30: 3910–3923.

The strength of brain responses to others' pain has been shown to depend on the intensity of the observed pain. To investigate the temporal profile of such modulation, we recorded neuromagnetic brain responses of healthy subjects to facial expressions of pain. The subjects observed grayscale photos of the faces of genuine chronic pain patients when the patients were suffering from their ordinary pain (Chronic) and when the patients' pain was transiently intensified (Provoked). The cortical activation sequence during observation of the facial expressions of pain advanced from occipital to temporooccipital areas, and it differed between Provoked and Chronic pain expressions in the right middle superior temporal sulcus (STS) at 300–500 ms: the responses were about a third stronger for Provoked than Chronic pain faces. Furthermore, the responses to Provoked pain faces were about 40% stronger in the right than the left STS, and they decreased from the first to the second measurement session by one-fourth, whereas no similar decrease in responses was found for Chronic pain faces. Thus, the STS responses to the pain expressions were modulated by the intensity of the observed pain and by stimulus repetition; the location and latency of the responses suggest close similarities between processing of pain and other affective facial expressions.

5. **Nahum M, Renvall H, Ahissar M:** Dynamics of cortical responses to tone pairs in relation to task difficulty: A MEG study. Human Brain Mapping 2009, 30: 1592–1604.

We investigated the effect of task difficulty on the dynamics of auditory cortical responses. Whole-scalp magnetoencephalographic (MEG) signals were recorded while subjects performed a same/different frequency discrimination task on equiprobable tone pairs applied in blocks of five, which were separated by a 10 s intertrial interval. Task difficulty was manipulated by the interpair frequency difference. The manipulation of task difficulty affected the amplitude of the N100m response to the first tone and the latency of the N100m response to the second tone in each pair. The N100m responses were smaller and peaked significantly later in the difficult than in the easy condition. The later processing field (PF) responses were longer in duration in the difficult condition. In both conditions, the duration of the PF response was negatively correlated with the subject's performance in the task, and was longer in the less successful subjects. The PF response may thus reflect the subjects' effort to resolve the task. The N100m and the PF responses did not differ between the tone pairs along the five-pair trial as a function of task difficulty, suggesting that changes in response along the five-pair trial are not easily affected by high-level manipulations.

6. **Nangini C, Hlushchuk Y, Hari R:** Predicting stimulus-rate sensitivity of human somatosensory fMRI signals with MEG. Human Brain Mapping 2009, 30: 1824–1832.

With increasing stimulus rate (SR), cortical EEG and MEG responses typically decrease in amplitude whereas BOLD fMRI signals increase. To address this discrepancy, we predicted BOLD responses with squared MEG waveforms using a recently proposed energy-density model. Tactile stimuli were delivered to finger tips at SRs of 1, 4, or 10 Hz in successive 25-s blocks, and brain signals were detected from area 3b of the primary somatosensory cortex of nine healthy adults using a 306- channel whole-scalp neuromagnetometer and a 3-T fMRI magnet. The main MEG deflections decreased in amplitude as a function of SR, whereas the BOLD signals increased from 1- to 4-Hz SR, with no further change at 10 Hz. MEG energy densities, obtained over the whole stimulus train and convolved with different hemodynamic response functions, predicted both the shape and amplitude of the BOLD signals well, and incorporation of nonlinear terms into the model did not offer any further advantage. Thus, squared MEG waveforms obtained over the entire stimulus train provided an appropriate estimate of area 3b neuronal activity associated with the BOLD signal.

7. **Parkkonen L, Fujiki N, Mäkelä J:** Sources of auditory brainstem responses revisited: Contribution by magnetoencephalography. Human Brain Mapping 2009, 30: 1772–1782.

Auditory brainstem responses provide diagnostic value in pathologies involving the early parts of the auditory pathway. Despite that, the neural generators underlying the various components of these responses have remained unclear. Direct electrical recordings in humans are possible only in limited time periods during surgery and from small regions of the diseased brains. The evidence of the generator sites is therefore fragmented and indirect, based strongly on lesion studies and animal models. Source modeling of EEG has been limited to grand averages across multiple subjects. Here, we employed magnetoencephalography (MEG) to shed more light on the neural origins of the auditory brainstem responses (ABR) and to test whether such deep brain structures are accessible by MEG. We show that the magnetic counterparts of the electric ABRs can be measured in 30 min and that they allow localization of some of the underlying neural sources in individual subjects. Many of the electric ABR components were present in our MEG data; however, the morphologies of the magnetic and electric responses were different, indicating that the MEG signals carry information complementary to the EEG data. The locations of the neural sources corresponding to the magnetic ABR deflections ranged from the auditory nerve to the inferior colliculus. The earliest cortical responses were detectable at the latency of 13 ms.

8. **Raij TT, Numminen J, Närvänen S, Hiltunen J, Hari R:** Strength of prefrontal activation predicts intensity of suggestion-induced pain. Human Brain Mapping 2009, 30: 2890–2897.

Suggestion, a powerful factor in everyday social interaction, is most effective during hypnosis. Subjective evaluations and brain-imaging findings converge to propose that hypnotic suggestion strongly modulates sensory processing. To reveal the brain regions that mediate such a modulation, we analyzed data from a functional-magnetic-resonance-imaging study on hypnotic-suggestion-induced pain on 14 suggestible subjects. Activation strengths in the right dorsolateral prefrontal cortex (DLPFC) during initiation of suggestion for pain correlated positively with the subjective intensity of the subsequent suggestion-induced pain, as well as with the strengths of the maximum pain-related activation in the in the secondary somatosensory (SII) cortex. Furthermore, activation of the insula and the anterior cingulate cortex predicted the pain-

related SII activation. The right DLPFC, as an area important for executive functions, likely contributes to functional modulation in the modality-specific target areas of given suggestions.

9. **Raij TT, Valkonen-Korhonen M, Holi M, Therman S, Lehtonen J, Hari R:** The reality of auditory verbal hallucinations. Brain 2009, 132: 2994–3001.

Distortion of the sense of reality, actualized in delusions and hallucinations, is the key feature of psychosis but the underlying neuronal correlates remain largely unknown. We studied 11 highly functioning subjects with schizophrenia or schizoaffective disorder while they rated the reality of auditory verbal hallucinations (AVH) during functional magnetic resonance imaging (fMRI). The subjective reality of AVH correlated strongly and specifically with the hallucination-related activation strength of the inferior frontal gyri (IFG), including the Broca's language region. Furthermore, how real the hallucination that subjects experienced was depended on the hallucination-related coupling between the IFG, the ventral striatum, the auditory cortex, the right posterior temporal lobe, and the cingulate cortex. Our findings suggest that the subjective reality of AVH is related to motor mechanisms of speech comprehension, with contributions from sensory and salience-detection-related brain regions as well as circuitries related to self-monitoring and the experience of agency.

10. **Renvall V:** Functional magnetic resonance imaging reference phantom. Magnetic Resonance Imaging 2009, 27: 701–708.

Functional magnetic resonance imaging (fMRI) is widely used to pinpoint active brain areas. Changes in neuronal activity modulate the local blood oxygenation level, and the associated modulation of the magnetic field homogeneity can be detected with magnetic resonance imaging. Thus, the blood oxygenation level-dependent (BOLD) fMRI indirectly measures neuronal activity. Similar modulation of magnetic field homogeneity was here elicited by other means to generate a BOLD-like change in a new phantom constructed to provide reference activations during fMRI. Magnetic inhomogeneities were produced by applying current to coils located near the phantom containing 1.5 ml of Gd-doped water. The signal-to-noise ratio of the images, produced by gradient-recalled echo-planar imaging, varied between 104 and 107 at a selected voxel when the field was and was not inhomogenized, respectively. The contrast of signals between homogeneous and inhomogeneous conditions was generally stable, except in 3% of time points. During the periods of greatest deviations an observable change would have been detected in a simultaneously measured BOLD signal. Such changes could result from the imaging method or occur through glitches in hardware or alterations in the measurement environment. With identical measurement setups, the phantom could allow comparing intersession or intersubject brain activations.

11. **Renvall V, Hari R:** Transients may occur in functional magnetic resonance imaging without physiological basis. Proceedings of the National Academy of Sciences of the United States of America (PNAS) 2009, 106: 20510–20514.

Functional magnetic resonance imaging (fMRI) has revolutionized the study of human brain activity, in both basic and clinical research. The commonly used blood oxygen level dependent (BOLD) signal in fMRI derives from changes in oxygen saturation of cerebral blood flow as a result of brain activity. Beyond the traditional spatial mapping of stimulus–activation correspondences, the detailed waveforms of

BOLD responses are of high interest. Especially intriguing are the transient overshoots and undershoots, often, although inconclusively, attributed to the interplay between changes in cerebral blood flow and volume after neuronal activation. While physically simulating the BOLD response in fMRI phantoms, we encountered prominent transient deflections, although the magnetic field inside the phantom varied in a square-wave manner. Detailed analysis and modeling indicated that the transients arise from activation-related partial misalignment of the imaging slices and depend heavily on measurement parameters, such as the time between successive excitations. The results suggest that some transients encountered in normal fMRI recordings may be spurious, potentially compromising the physiological interpretation of BOLD signal overshoots and undershoots.

12. **Sorrentino A, Parkkonen L, Pascarella A, Campi C, Piana M:** Dynamical MEG source modeling with multi-target Bayesian tracking. Human Brain Mapping 2009, 30: 1911–1921.

We present a Bayesian filtering approach for automatic estimation of dynamical source models from magnetoencephalographic data. We apply multi-target Bayesian filtering and the theory of Random Finite Sets in an algorithm that recovers the life times, locations and strengths of a set of dipolar sources. The reconstructed dipoles are clustered in time and space to associate them with sources. We applied this new method to synthetic data sets and show here that it is able to automatically estimate the source structure in most cases more accurately than either traditional multi-dipole modeling or minimum current estimation performed by uninformed human operators. We also show that from real somatosensory evoked fields the method reconstructs a source constellation comparable to that obtained by multi-dipole modeling.

13. **Taulu S, Hari R:** Removal of magnetoencephalographic artifacts with temporal signal-space separation: Demonstration with single-trial auditory-evoked responses. Human Brain Mapping 2009, 30: 1524–1534.

Magnetic interference signals often hamper analysis of magnetoencephalographic (MEG) measurements. Artifact sources in the proximity of the sensors cause strong and spatially complex signals that are particularly challenging for the existing interference-suppression methods. Here we demonstrate the performance of the temporally extended signal space separation method (tSSS) in removing strong interference caused by external and nearby sources on auditory-evoked magnetic fields—the sources of which are well established. The MEG signals were contaminated by normal environmental interference, by artificially produced additional external interference, and by nearby artifacts produced by a piece of magnetized wire in the subject's lip. After tSSS processing, even the single-trial auditory responses had a good-enough signal-to-noise ratio for detailed waveform and source analysis. Waveforms and source locations of the tSSS-reconstructed data were in good agreement with the responses from the control condition without extra interference. Our results demonstrate that tSSS is a robust and efficient method for removing a wide range of different types of interference signals in neuromagnetic multichannel measurements.

14. **Vanhatalo S, Jousmäki V, Andersson S, Metsäranta M:** An easy and practical method for routine, bedside testing of somatosensory systems in extremely low birth weight infants. Pediatric Research 2009, 66: 710–713.

This study was set out to develop and describe a novel, simple, and safe method for routine bedside testing of somatosensory system in very early preterm infants. We recorded electroencephalogram (EEG) activity after tactile stimulation of hand (palm) and foot (sole) by a soft hairbrush stimulator in extremely low birth weight infants (n = 10; GA, 24-28, recording at conceptional age 30-32 wk) and compared with the raw EEG responses to those seen by one- or two-channel brain monitors. In every subject, single tactile stimuli produced prominent (100-350 microV) somatosensory evoked responses (SERs) that were readily identified in the ongoing EEG signal. The maximal SER was in the contralateral hemisphere at around the corresponding somatosensory representation areas. Conventional EEG filtering did significantly reduce the SERs, but they could still be identified in the routine brain monitor setting widely available in NICUs. The method described here is directly applicable to assessment of integrity of somatosensory system in the early preterm period. It needs minimal training and requires an EEG system or a brain monitor device that is available in most units. Thus, the technique is likely to open a novel window to neurologic assessment of these babies.

15. **Vartiainen N, Kallio-Laine K, Hlushchuk Y, Kirveskari E, Seppänen M, Autti H, Jousmäki V, Forss N, Kalso E, Hari R:** Changes in brain function and morphology in patients with recurring herpes simplex virus infections and chronic pain. Pain 2009, 144: 200–208.

A recent study described for the first time a patient group that suffered from spontaneous chronic pain and from recurrent herpes simplex virus (HSV) infections. The patients had pain in widespread areas on one side of the body and were—due to subtle immunological abnormalities—susceptible to HSV infections. Although the clinical features of the pain suggested involvement of the central nervous system, supporting evidence for this was lacking. The objective of this study was to search for changes in the central nervous system that could account for the chronic pain in these patients. We monitored the central processing of pain and touch in eight patients and 11 healthy control subjects, who received painful heat and innocuous tactile stimuli to the hands during functional magnetic resonance imaging. Possible changes in the gray matter density of the brain were assessed with voxel-based morphometry. We found functional changes in the patients' central pain circuitry: activation to heat pain was weaker than in control subjects in the insular cortices, anterior cingulate cortex (ACC), and thalamus, while the activations to innocuous tactile stimuli were similar in both groups. Gray matter density was decreased in the patients' frontal and prefrontal cortices and in the ACC. The observed functional and structural changes in the central pain circuitry, together with the clinical features of the chronic pain support the hypothesis for central involvement in the development of chronic pain in these patients.

16. **Vartiainen N, Kirveskari E, Kallio-Laine K, Kalso E, Forss N:** Cortical reorganization in primary somatosensory cortex in patients with unilateral chronic pain. Journal of Pain 2009, 10: 854–859.

Bodily representations of the primary somatosensory (SI) cortex are constantly modified according to sensory input. Increased input due to training as well as loss of input due to deafferentation are reflected as changes in the extent of cortical representations. Recent studies in complex regional pain syndrome (CRPS) patients have indicated that the chronic pain itself is associated with cortical reorganization. However,

it is unclear whether the observed reorganization is specific for CRPS or if it can be detected also in other types of chronic pain. We therefore searched for signs of cortical reorganization in a group of 8 patients who suffered from chronic pain associated with herpes simplex virus infections. The pain was widespread but restricted to unilateral side of the body and included the upper limb. We recorded neuromagnetic responses to tactile stimulation of fingers of both hands in patients and in a group of healthy, matched control subjects. In the patients, the distance between the thumb (D1) and little finger (D5) representations in SI cortex was statistically significantly smaller in the hemisphere contralateral to painful side than in the hemisphere contralateral to healthy side. In the control subjects, the D1-D5 distance was the same in both hemispheres. PERSPECTIVE: The present results indicate that cortical reorganization occurs in chronic neuropathic pain patients even without peripheral nerve damage. It is possible that cortical reorganization is related to chronic pain, regardless of its etiology. Causality between reorganization and chronic pain should be examined further to develop therapeutic approaches for chronic pain.

17. **Ylipaavalniemi J, Savia E, Malinen S, Hari R, Vigário R, Kaski S:** Dependencies between stimuli and spatially independent fMRI sources: Towards brain correlates of natural stimuli. NeuroImage 2009, 48: 176–185.

Natural stimuli are increasingly used in functional magnetic resonance imaging (fMRI) studies to imitate real-life situations. Consequently, challenges are created for novel analysis methods, including new machinelearning tools. With natural stimuli it is no longer feasible to assume single features of the experimental design alone to account for the brain activity. Instead, relevant combinations of rich enough stimulus features could explain the more complex activation patterns. We propose a novel two-step approach, where independent component analysis is first used to identify spatially independent brain processes, which we refer to as functional patterns. As the second step, temporal dependencies between stimuli and functional patterns are detected using canonical correlation analysis. Our proposed method looks for combinations of stimulus features and the corresponding combinations of functional patterns. This two-step approach was used to analyze measurements from an fMRI study during multi-modal stimulation. The detected complex activation patterns were explained as resulting from interactions of multiple brain processes. Our approach seems promising for analysis of data from studies with natural stimuli.

LANGUAGE PERCEPTION AND PRODUCTION

1. **Helenius P, Parviainen T, Paetau R, Salmelin R:** Neural processing of spoken words in specific language impairment and dyslexia. Brain 2009, 132: 1918–1927.

Young adults with a history of specific language impairment (SLI) differ from reading-impaired (dyslexic) individuals in terms of limited vocabulary and poor verbal short-term memory. Phonological short-term memory has been shown to play a significant role in learning new words. We investigated the neural signatures of auditory word recognition and word repetition in young adults with SLI, dyslexia and normal language development using magnetoencephalography. The stimuli were 7-8 letter spoken real words and pseudo-words. They evoked a transient peak at 100 ms (N100m) followed by longer-lasting activation peaking around 400 ms (N400m) in the left and right superior temporal cortex. Both word repetition (first vs. immediately following second presentation) and lexicality (words vs. pseudowords) modulated the

N400m response. An effect of lexicality was detected about 400 ms onwards as activation culminated for words but continued for pseudo-words. This effect was more pronounced in the left than right hemisphere in the control subjects. The left hemisphere lexicality effect was also present in the dyslexic adults, but it was non-significant in the subjects with SLI, possibly reflecting their limited vocabulary. The N400m activation between 200 and 700 ms was attenuated by the immediate repetition of words and pseudo-words in both hemispheres. In SLI adults the repetition effect evaluated at 200-400 ms was abnormally weak. This finding suggests impaired short-term maintenance of linguistic activation that underlies word recognition. Furthermore, the size of the repetition effect decreased from control subjects through dyslexics to SLIs, i.e. when advancing from milder to more severe language impairment. The unusually rapid decay of speech-evoked activation could have a detrimental role on vocabulary growth in children with SLI.

2. **Hultén A, Vihla M, Laine M, Salmelin R:** Accessing newly learned names and meanings in the native language. Human Brain Mapping 2009, 30: 976–989.

Ten healthy adults encountered pictures of unfamiliar archaic tools and successfully learned either their name, verbal definition of their usage, or both. Neural representation of the newly acquired information was probed with magnetoencephalography in an overt picture-naming task before and after learning, and in two categorization tasks after learning. Within 400 ms, activation proceeded from occipital through parietal to left temporal cortex, inferior frontal cortex (naming) and right temporal cortex (categorization). Comparison of naming of newly learned versus familiar pictures indicated that acquisition and maintenance of word forms are supported by the same neural network. Explicit access to newly learned phonology when such information was known strongly enhanced left temporal activation. By contrast, access to newly learned semantics had no comparable, direct neural effects. Both the behavioral learning pattern and neurophysiological results point to fundamentally different implementation of and access to phonological versus semantic features in processing pictured objects.

3. **Liljeström M, Hultén A, Parkkonen L, Salmelin R:** Comparing MEG and fMRI views to naming actions and objects. Human Brain Mapping 2009, 30: 1845–1856.

Most neuroimaging studies are performed using one imaging method only, either functional magnetic resonance imaging (fMRI), electroencephalography (EEG), or magnetoencephalography (MEG). Information on both location and timing has been sought by recording fMRI and EEG, simultaneously, or MEG and fMRI in separate sessions. Such approaches assume similar active areas whether detected via hemodynamic or electrophysiological signatures. Direct comparisons, after independent analysis of data from each imaging modality, have been conducted primarily on low-level sensory processing. Here, we report MEG (timing and location) and fMRI (location) results in 11 subjects when they named pictures that depicted an action or an object. The experimental design was exactly the same for the two imaging modalities. The MEG data were analyzed with two standard approaches: a set of equivalent current dipoles and a distributed minimum norm estimate. The fMRI blood-oxygen-level dependent (BOLD) data were subjected to the usual random-effect contrast analysis. At the group level, MEG and fMRI data showed fairly good convergence, with both overall activation patterns and task effects localizing to comparable cortical regions. There were some systematic discrepancies, however, and the correspondence was less

compelling in the individual subjects. The present analysis should be helpful in reconciling results of fMRI and MEG studies on high-level cognitive functions.

4. **Salmelin R, Baillet S:** Electromagnetic brain imaging. Human Brain Mapping 2009, 30: 1753–1757.

Editorial.

5. **Vartiainen J, Aggujaro S, Lehtonen M, Hultén A, Laine M, Salmelin R:** Neural dynamics of reading morphologically complex words. NeuroImage 2009, 47: 2064–2072.

Despite considerable research interest, it is still an open issue as to how morphologically complex words such as "car+s" are represented and processed in the brain. We studied the neural correlates of the processing of inflected nouns in the morphologically rich Finnish language. Previous behavioral studies in Finnish have yielded a robust inflectional processing cost, i.e., inflected words are harder to recognize than otherwise matched morphologically simple words. Theoretically this effect could stem either from decomposition of inflected words into a stem and a suffix at input level and/or from subsequent recombination at the semantic-syntactic level to arrive at an interpretation of the word. To shed light on this issue, we used magnetoencephalography to reveal the time course and localization of neural effects of morphological structure and frequency of written words. Ten subjects silently read high- and low-frequency Finnish words in inflected and monomorphemic form. Morphological complexity was accompanied by stronger and longer-lasting activation of the left superior temporal cortex from 200 ms onwards. Earlier effects of morphology were not found, supporting the view that the well-established behavioral processing cost for inflected words stems from the semantic-syntactic level rather than from early decomposition. Since the effect of morphology was detected throughout the range of word frequencies employed, the majority of inflected Finnish words appears to be represented in decomposed form and only very high-frequency inflected words may acquire full-form representations.

6. **Vartiainen J, Parviainen T, Salmelin R:** Spatiotemporal convergence of semantic procesing in reading and speech perception. The Journal of Neuroscience 2009, 29: 9271–9280.

Retrieval of word meaning from the semantic system and its integration with context are often assumed to be shared by spoken and written words. How is modality-independent semantic processing manifested in the brain, spatially and temporally? Time-sensitive neuroimaging allows tracking of neural activation sequences. Use of semantically related versus unrelated word pairs or sentences ending with a semantically highly or less plausible word, in separate studies of the auditory and visual modality, has associated lexical-semantic analysis with sustained activation at approximately 200-800 ms. Magnetoencephalography (MEG) studies have further identified the superior temporal cortex as a main locus of the semantic effect. Nevertheless, a direct comparison of the spatiotemporal neural correlates of visual and auditory word comprehension in the same brain is lacking. We used MEG to compare lexical-semantic analysis in the visual and auditory domain in the same individuals, and contrasted it with phonological analysis that, according to models of language perception, should occur at a different time with respect to semantic analysis in reading and speech perception. The stimuli were lists of four words that were either semantically

or phonologically related, or with the final word unrelated to the preceding context. Superior temporal activation reflecting semantic processing occurred similarly in the two modalities, left-lateralized at 300-450 ms and thereafter bilaterally, generated in close-by areas. Effect of phonology preceded the semantic effect in speech perception but not in reading. The present data indicate involvement of the middle superior temporal cortex in semantic processing from approximately 300 ms onwards, regardless of input modality.

VISION SYSTEMS PHYSIOLOGY

1. **Auranen T, Nummenmaa A, Vanni S, Vehtari A, Hämäläinen M, Lampinen J, Jääskeläinen IP:** Automatic fMRI-guided MEG multidipole localization for visual responses. Human Brain Mapping 2009, 30: 1087–1099.

Previously, we introduced the use of individual cortical location and orientation constraints in the spatiotemporal Bayesian dipole analysis setting proposed by Jun et al. ([2005]; Neuroimage 28:84-98). However, the model's performance was limited by slow convergence and multimodality of the numerically estimated posterior distribution. In this paper, we present an intuitive way to exploit functional magnetic resonance imaging (fMRI) data in the Markov chain Monte Carlo sampling -based inverse estimation of magnetoencephalographic (MEG) data. We used simulated MEG and fMRI data to show that the convergence and localization accuracy of the method is significantly improved with the help of fMRI-guided proposal distributions. We further demonstrate, using an identical visual stimulation paradigm in both fMRI and MEG, the usefulness of this type of automated approach when investigating activation patterns with several spatially close and temporally overlapping sources. Theoretically, the MEG inverse estimates are not biased and should yield the same results even without fMRI information, however, in practice the multimodality of the posterior distribution causes problems due to the limited mixing properties of the sampler. On this account, the algorithm acts perhaps more as a stochastic optimizer than enables a full Bayesian posterior analysis.

2. **Henriksson L, Hyvärinen A, Vanni S:** Representation of cross-frequency spatial phase relationships in human visual cortex. The Journal of Neuroscience 2009, 29: 14342–14351.

An image patch can be locally decomposed into sinusoidal waves of different orientations, spatial frequencies, amplitudes, and phases. The local phase information is essential for perception, because important visual features like edges emerge at locations of maximal local phase coherence. Detection of phase coherence requires integration of spatial frequency information across multiple spatial scales. Models of early visual processing suggest that the visual system should implement phase-sensitive pooling of spatial frequency information in the identification of broadband edges. We used functional magnetic resonance imaging (fMRI) adaptation to look for phase-sensitive neural responses in the human visual cortex. We found sensitivity to the phase difference between spatial frequency components in all studied visual areas, including the primary visual cortex (V1). Control experiments demonstrated that these results were not explained by differences in contrast or position. Next, we compared fMRI responses for broadband compound grating stimuli with congruent and random phase structures. All studied visual areas showed stronger responses for the stimuli with congruent phase structure. In addition, selectivity to phase congruency increased

from V1 to higher-level visual areas along both the ventral and dorsal streams. We conclude that human V1 already shows phase-sensitive pooling of spatial frequencies, but only higher-level visual areas might be capable of pooling spatial frequency information across spatial scales typical for broadband natural images.

3. **Nurminen L, Kilpeläinen M, Laurinen P, Vanni S:** Area summation in human visual system: psychophysics, fMRI and modelling. Journal of Neurophysiology 2009, 102: 2900–2909.

Contextual modulation is a fundamental feature of sensory processing, both on perceptual and on single-neuron level. When the diameter of a visual stimulus is increased, the firing rate of a cell typically first increases (summation field) and then decreases (surround field). Such an area summation function draws a comprehensive profile of the receptive field structure of a neuron, including areas outside the classical receptive field. We investigated area summation in human vision with psychophysics and functional magnetic resonance imaging (fMRI). The stimuli were similar to those used drifting sine wave gratings in previous macaque single-cell area summation studies. A model was developed to facilitate comparison of area summation in fMRI to area summation in psychophysics and single cells. The model consisted of units with an antagonistic receptive field structure found in single cells in the primary visual cortex. The receptive field centers of the model neurons were distributed in the region of the visual field covered by a single voxel. The measured area summation functions were qualitatively similar to earlier single-cell data. The model with parameters derived from psychophysics captured the spatial structure of the summation field in the primary visual cortex as measured with fMRI. The model also generalized to a novel situation in which the neural population was displaced from the stimulus center. The current study shows that contextual modulation arises from similar spatially antagonistic and overlapping excitatory and inhibitory mechanisms, both in single cells and in human vision.

4. **von Pföstl V, Stenbacka L, Vanni S, Parkkonen L, Galletti C, Fattori P:** Motion sensitivity of human V6: A magnetoencephalography study. NeuroImage 2009, 45: 1253–1263.

Recent studies suggest the presence of a human homologue of monkey V6 in the dorsal posterior bank of the parieto-occipital sulcus. Monkey V6 comprises a retinotopic representation with relative peripheral visual field emphasis and is sensitive to visual motion. We studied sensitivity to visual motion in human parieto-occipital sulcus. Our upper peripheral visual field stimulus enabled us to distinguish V6 from neighbouring areas, whose upper VF representation is located far from V6. We recorded neuromagnetic signals while the subjects (N=10) fixated and a grating first appeared and then started to drift. The most prominent sustained activation for motion was at the posterior bank of the dorsal parieto-occipital sulcus; that is at the known location of the human V6. This finding suggests that human V6 is a motion-sensitive area. The responses in V6 occurred early, with about the same latency as in V1, in line with known connections in the monkey brain. In addition, on the medial surface of the hemisphere we observed a fast sequence of activations following V6: first precuneus and later an area at the dorsal end of the cingulate sulcus. On the lateral side, both temporo-occipital area and intraparietal sulcus were active, but with delayed onset compared to V6. This rapid flow of visual information along the medial dorsal visual pathway

supports the view that in humans, as in monkeys, the V6 and the connected areas could be involved in online control of visually guided actions.

5. **Simola J, Stenbacka L, Vanni S:** Topography of attention in the primary visual cortex. European Journal of Neuroscience 2009, 29: 188–196.

Previous research suggests that feedback circuits mediate the effect of attention to the primary visual cortex (V1). This inference is mainly based on temporal information of the responses, where late modulation is associated with feedback signals. However, temporal data alone are inconclusive because the anatomical hierarchy between cortical areas differs significantly from the temporal sequence of activation. In the current work, we relied on recent physiological and computational models of V1 network architecture, which have shown that the thalamic feedforward, local horizontal and feedback contribution are reflected in the spatial spread of responses. We used multifocal functional localizer and quantitative analysis in functional magnetic resonance imaging to determine the spatial scales of attention and sensory responses. Representations of 60 visual field regions in V1 were functionally localized and four of these regions were targets in a subsequent attention experiment, where human volunteers fixated centrally and performed a visual discrimination task at the attended location. Attention enhanced the peak amplitudes significantly more in the lower than in the upper visual field. This enhancement by attention spread with a 2.4 times larger radius (approximately 10 mm, assuming an average magnification factor) compared with the unattended response. The corresponding target region of interest was on average 20% stronger than that caused by the afferent sensory stimulation alone. This modulation could not be attributed to eye movements. Given the contemporary view of primate V1 connections, the activation spread along the cortex provides further evidence that the signal enhancement by spatial attention is dependent on feedback circuits.

ATTENTION AND MEMORY

1. **Vuontela V, Steenari M-R, Aronen ET, Korvenoja A, Aronen HJ, Carlson S:** Brain activation and deactivation during location and color working memory tasks in 11-13-year old children. Brain and Cognition 2009, 69: 56–64.

Using functional magnetic resonance imaging (fMRI) and n-back tasks we investigated whether, in 11–13-year-old children, spatial (location) and nonspatial (color) information is differentially processed during visual attention (0-back) and working memory (WM) (2-back) tasks and whether such cognitive task performance, compared to a resting state, results in regional deactivation. The location 0-back task, compared to the color 0-back task, activated segregated areas in the frontal, parietal and occipital cortices whereas no differentially activated voxels were obtained when location and color 2-back tasks were directly contrasted. Several midline cortical areas were less active during 0- and 2-back task performance than resting state. The task-induced deactivation increased with task difficulty as demonstrated by larger deactivation during 2-back than 0-back tasks. The results suggest that, in 11–13-year-old children, the visual attentional network is differently recruited by spatial and nonspatial information processing, but the functional organization of cortical activation in WM in this age group is not based on the type of information processed. Furthermore, 11–13-year-old children exhibited a similar pattern of cortical deactivation that has been reported in adults during cognitive task performance compared to a resting state.

2. Bikmullina R, Kičić D, Carlson S, Nikulin V: Electrophysiological correlates of short latency afferent inhibition: combined EEG and TMS. Experimental Brain Research 2009, 194: 517–26.

Cutaneous stimulation produces short-latency afferent inhibition (SAI) of motor-evoked potentials (MEPs) elicited by transcranial magnetic stimulation (TMS). Since the demonstration of SAI is primarily based on the attenuation of MEPs, its cortical origin is not yet fully understood. In the present study we combined TMS with concurrent electroencephalography (EEG) in order to obtain direct cortical correlates of SAI. TMS-evoked EEG responses and MEPs were analysed with and without preceding electrical stimulation of the index finger cutaneous afferents in ten healthy volunteers. We show that the attenuation of MEPs by cutaneous stimulation has its counterpart in the attenuation of the N100 EEG response. Moreover, the attenuation of the cortical N100 component correlated positively with the strength of SAI, indicating that the transient changes in cortical excitability can be reflected in the amplitude dynamics of MEPs. We hypothesize that the hyperpolarization of the pyramidal cells due to SAI lowers the capacity of TMS to induce the inhibitory current needed to elicit N100, thus leading to its attenuation. We suggest that the observed interaction of two inhibitory processes, SAI and N100, provides further evidence for the cortical origin of SAI.

3. **Artchakov D, Tikhonravov D, Ma Y, Neuvonen T, Linnankoski I, Carlson S:** Distracters impair and create working memory-related neuronal activity in the prefrontal cortex. Cerebral Cortex. 2009, 19: 2680–9.

The prefrontal cortex (PFC) has a central role in working memory (WM). Resistance to distraction is considered a fundamental feature of WM and PFC neuronal activity. However, although unexpected stimuli often disrupt our work, little is known about the underlying neuronal mechanisms involved. In the present study, we investigated whether irregularly presented distracters disrupt WM task performance and underlying neuronal activity. We recorded single neuron activity in the PFC of 2 monkeys performing WM tasks and investigated effects of auditory and visual distracters on WM performance and neuronal activity. Distracters impaired memory task performance and affected PFC neuronal activity. Distraction that was of the same sensory modality as the memorandum was more likely to impair WM performance and interfere with memory-related neuronal activity than information that was of a different sensory modality. The study also shows that neurons not involved in memory processing in less demanding conditions may become engaged in WM processing in more demanding conditions. The study demonstrates that WM performance and underlying neuronal activity are vulnerable to irregular distracters and suggests that the PFC has mechanisms that help to compensate for disruptive effects of external distracters.

4. **Renier LA, Anurova I, DeVolder AG, Carlson S, VanMeter J, Rauschecker JP:** Multisensory integration of sounds and vibrotactile stimuli in processing streams for "what" and "where". The Journal of Neuroscience 2009, 29: 10950–10960.

The segregation between cortical pathways for the identification and localization of objects is thought of as a general organizational principle in the brain. Yet, little is known about the unimodal versus multimodal nature of these processing streams. The

main purpose of the present study was to test whether the auditory and tactile dual pathways converged into specialized multisensory brain areas. We used functional magnetic resonance imaging (fMRI) to compare directly in the same subjects the brain activation related to localization and identification of comparable auditory and vibrotactile stimuli. Results indicate that the right inferior frontal gyrus (IFG) and both left and right insula were more activated during identification conditions than during localization in both touch and audition. The reverse dissociation was found for the left and right inferior parietal lobules (IPL), the left superior parietal lobule (SPL) and the right precuneus-SPL, which were all more activated during localization conditions in the two modalities. We propose that specialized areas in the right IFG and the left and right insula are multisensory operators for the processing of stimulus identity whereas parts of the left and right IPL and SPL are specialized for the processing of spatial attributes independently of sensory modality.

5. **Hannula H, Neuvonen T, Savolainen P, Hiltunen J, Ma YY, Antila H, Salonen O, Carlson S, Pertovaara A:** Increasing top-down suppression from prefrontal cortex facilitates tactile working memory. Neuroimage 2010, 49:1091–8. Epub 2009 Jul 28.

Navigated transcranial magnetic stimulation (TMS) combined with diffusion-weighted magnetic resonance imaging (DW-MRI) and tractography allows investigating functional anatomy of the human brain with high precision. Here we demonstrate that working memory (WM) processing of tactile temporal information is facilitated by delivering a single TMS pulse to the middle frontal gyrus (MFG) during memory maintenance. Facilitation was obtained only with a TMS pulse applied to a location of the MFG with anatomical connectivity to the primary somatosensory cortex (S1). TMS improved tactile WM also when distractive tactile stimuli interfered with memory maintenance. Moreover, TMS to the same MFG site attenuated somatosensory evoked responses (SEPs). The results suggest that the TMS-induced memory improvement is explained by increased top-down suppression of interfering sensory processing in S1 via the MFG–S1 link. These results demonstrate an anatomical and functional network that is involved in maintenance of tactile temporal WM.

6. **Salmi J, Pallesen KJ, Neuvonen T, Brattico E, Korvenoja A, Salonen O, Carlson S:** Cognitive and motor loops of the human cerebro-cerebellar system. Journal of Cognitive Neuroscience 2009, Nov 19 [Epub ahead of print].

Abstract We applied fMRI and diffusion-weighted MRI to study the segregation of cognitive and motor functions in the human cerebro-cerebellar system. Our fMRI results show that a load increase in a nonverbal auditory working memory task is associated with enhanced brain activity in the parietal, dorsal premotor, and lateral prefrontal cortices and in lobules VII-VIII of the posterior cerebellum, whereas a sensory-motor control task activated the motor/somatosensory, medial prefrontal, and posterior cingulate cortices and lobules V/VI of the anterior cerebellum. The load-dependent activity in the crus I/II had a specific relationship with cognitive performance: This activity correlated negatively with load-dependent increase in RTs. This correlation between brain activity and RTs was not observed in the sensory-motor task in the activated cerebellar regions. Furthermore, probabilistic tractography analysis of the diffusion-weighted MRI data suggests that the tracts between the cerebral and the cerebellar areas exhibiting cognitive load-dependent and sensory-motor activity are mainly projected via separated pontine (feed-forward tracts) and thalamic

(feedback tracts) nuclei. The tractography results also indicate that the crus I/II in the posterior cerebellum is linked with the lateral prefrontal areas activated by cognitive load increase, whereas the anterior cerebellar lobe is not. The current results support the view that cognitive and motor functions are segregated in the cerebellum. On the basis of these results and theories of the function of the cerebellum, we suggest that the posterior cerebellar activity during a demanding cognitive task is involved with optimization of the response speed.

OTHER PUBLICATIONS BY BRU PERSONNEL

1. **Kortelainen J, Koskinen M, Mustola S, Seppänen T:** Effects of remifentanil on the spectrum and quantitative parameters of eletroencephalogram in propofol anesthesia. Anesthesiology 2009, 111: 574–583.

Nonlinear electroencephalographic entropy parameters have been proposed for the assessment of depth of anesthesia. The influence of remifentanil, a commonly used intraoperative opioid, on these parameters, namely approximate entropy (ApEn), sample entropy (SampEn), and permutation entropy (PeEn), during induction of propofol anesthesia was studied. Remifentanil was shown to reduce the propofol-induced changes in ApEn and SampEn throughout the transition from awake to burst suppression state. Coadminis-tration of opioids therefore challenges the reliability of these parameters as indicators of depth of anesthesia. No consistent influence on PeEn was observed. However, this may have been due to strong interindividual variation in PeEn values.

2. **Laaksonen H, Hirvonen J, Laaksonen T:** Cellular automata model for swelling-controlled drug release. International Journal of Pharmaceutics 2009, 380: 25–32.

A cellular automata approach for modeling swelling-controlled drug release is presented. In the model, a drug release device is divided into a square grid space. Each cell in the grid contains information about the material, drug, polymer or solvent in that domain. Cells are allowed to change their state according to statistical rules designed to mimic physical phenomena. Diffusion and swelling are modeled by a random walk of mobile cells, and kinetics of chemical or physical processes by probabilities of conversion from one state to another. The model is applied to drug release from a swelling binary polymer/drug device. The effect of simulation parameters on the drug release profiles and the locations of erosion and diffusion fronts are considered. The model was able to produce realistic simulations and is proposed as a new tool for the design of controlled release devices.

3. **Laaksonen T, Laaksonen H, Hirvonen J, Murtomäki L:** Cellular automata model for drug release from binary matrix and reservoir polymeric devices. Biomaterials 2009, 30: 1978–1987.

Kinetics of drug release from polymeric tablets, inserts and implants is an important and widely studied area. Here we present a new and widely applicable cellular automata model for diffusion and erosion processes occurring during drug release from polymeric drug release devices. The model divides a 2D representation of the release device into an array of cells. Each cell contains information about the material, drug, polymer or solvent that the domain contains. Cells are then allowed to rearrange according to statistical rules designed to match realistic drug release. Diffusion is modeled by a random walk of mobile cells and kinetics of chemical or physical processes

by probabilities of conversion from one state to another. This is according to the basis of diffusion coefficients and kinetic rate constants, which are on fundamental level just probabilities for certain occurrences. The model is applied to three kinds of devices with different release mechanisms: erodable matrices, diffusion through channels or pores and membrane controlled release. The dissolution curves obtained are compared to analytical models from literature and the validity of the model is considered. The model is shown to be compatible with all three release devices, highlighting easy adaptability of the model to virtually any release system and geometry. Further extension and applications of the model are envisioned.

4. **Pihko E, Nevalainen P, Stephen J, Okada Y, Lauronen L:** Maturation of somatosensory cortical processing from birth to adulthood revealed by magnetoencephalography. Clinical Neurophysiology 2009, 120: 1552–1561.

OBJECTIVE: To evaluate the maturation of tactile processing by recording somatosensory evoked magnetic fields (SEFs) from healthy human subjects. METHODS: SEFs to tactile stimulation of the left index finger were measured from the contralateral somatosensory cortex with magnetoencephalography (MEG) in five age groups: newborns, 6- and 12-18-month-olds, 1.6-6-year-olds, and adults. The waveforms of the measured signals and equivalent current dipoles (ECDs) were analyzed in awake and sleep states in order to separate the effects of age and vigilance state on SEFs. RESULTS: There was an orderly, systematic change in the measured and ECD source waveforms of the initial cortical responses with age. The broad U-shaped response in newborns (M60) shifted to a W-shaped response with emergence of a notch by 6 months of age. The adult-type response with M30 and M50 components was present by 2 years. The ECDs of M60 and M30 were oriented anteriorly and that of M50 posteriorly. These maturational changes were independent of vigilance state. CONCLUSIONS: The most significant maturation of short latency cortical responses to tactile stimulation takes place during the first 2 years of life. SIGNIFICANCE: The maturational changes of somatosensory processing can noninvasively be evaluated with MEG already in infancy.

5. **Seppänen T, Koskinen M, Seppänen TM, Alho O-P:** Continuous assesment of nasal airflow resistance by adaptive modelling. Physiological Measurement 2009, 30: 1197–1209.

A method to assess nasal airflow resistance is presented that provides a continuous resistance value and applies a novel minimally obtrusive measurement technique. Instead of calculating the resistance once for each breathing cycle conventionally, it is calculated for each signal sample at any sampling frequency. The continuous pressure recording is produced with a nasopharyngeal catheter inserted 8 cm deep along the floor of the other nasal cavity and the flow recording is produced with respiratory effort bands. A least-mean-square (LMS) extension for the resistance model of Broms is developed that dynamically adapts to the time-varying characteristics of the nasal functioning and produces the continuous resistance values. Experimental results are shown that demonstrate the uniqueness and applicability of the new technique in assessing quickly changing resistance in a histamine/xylometatsolin challenges, the differences between normal and symptomatic patients, and the effect of nasal treatment of patients.

6. **Staeren N, Renvall H, De Martino F, Goebel R, Formisano E:** Sound categories are represented as distributed patterns in the human auditory cortex. Current Biology 2009, 19: 498–502.

The ability to recognize sounds allows humans and animals to efficiently detect behaviorally relevant events, even in the absence of visual information. Sound recognition in the human brain has been assumed to proceed through several functionally specialized areas, culminating in cortical modules where category-specific processing is carried out. In the present high-resolution fMRI experiment, we challenged this model by using well-controlled natural auditory stimuli and by employing an advanced analysis strategy based on an iterative machine-learning algorithm that allows modeling of spatially distributed, as well as localized, response patterns. Sounds of cats, female singers, acoustic guitars, and tones were controlled for their time-varying spectral characteristics and presented to subjects at three different pitch levels. Sound category information--not detectable with conventional contrast-based methods analysis--could be detected with multivoxel pattern analyses and attributed to spatially distributed areas over the supratemporal cortices. A more localized pattern was observed for processing of pitch laterally to primary auditory areas. Our findings indicate that distributed neuronal populations within the human auditory cortices, including areas conventionally associated with lower-level auditory processing, entail categorical representations of sounds beyond their physical properties.

TEACHING ACTIVITIES

COURSES

Low Temperature Physics: Nanoelectronics (Tfy-3.4801)
Lectures: Doc. **Tero Heikkilä** 26 hours
Teaching assistant: Dr. **Janne Viljas**

RESEARCH SEMINARS ON LOW TEMPERATURE PHYSICS AND NANOPHYSICS

Coordinators: Vladimir Eltsov, Tero Heikkilä, and Sorin Paraoanu

Janne Viljas, LTL, Finland, *Some topics in "molecular electronics": Modeling elastic and inelastic electron transport in atomic-scale systems*, Jan 20
Karol Flachbart, Institute of Experimental Physics, Kosice, Slovakia, *Magnetism in rare earth borides,* Jan 22
Peter Liljeroth, LTL, Finland, *Why should you bother about scanning tunneling microscopy in nanoscience?*, Jan 27
Juha Muhonen, LTL, Finland, *Nano Journal Club*, Feb 3
Fan Wu, LTL, Finland, *Nano Journal Club*, Feb 10
Yuli Nazarov, Kavli Institute for Nanotechnology, Delft University of Technology, The Netherland, *Multiple nuclear polarization states in a double quantum dot*, Feb 17
Heikki Junes, LTL, Finland, *Experiments on the faceting and supersolidity in helium crystals*, Feb 20
Mika Sillanpää, LTL, Finland, *Nano Journal Club*, Feb 24
Matthias Meschke, LTL, Finland, *News from the single junction thermometer*, Mar 3

Antti Puska, LTL, Finland, *Nano Journal Club*, Mar 10
Anthony Leggett, University of Illinois at Urbana-Champaign, USA, *Some thoughts on the prospects for topological quantum computing*, Mar 16
Pauli Virtanen, LTL, Finland, *Nano Journal Club*, Mar 17
Sergey Kafanov, LTL, Finland, *Turnstile SINIS current pump,* Mar 24
Khattiya Chalapat, LTL, Finland, *Broadband reference-pane invariant method for measuring electromagnetic parameters*, Mar 31
Tero Heikkilä, LTL, Finland, *Nano Journal Club*, Apr 7
Pertti Hakonen, LTL, Finland, *Coherence and noise in graphene samples with superconducting contacts*, Apr 14
Olli-Pentti Saira, LTL, Finland, *Nano Journal Club*, Apr 21
Matti Laakso, LTL, Finland, *Temperature fluctuation statistics under Coulomb blockade*, Apr 28
Jian Li, LTL, Finland, *Dynamics of driven coupled resonators*, May 5
Gabriel Niebler, LTL, Finland, *Nano Journal Club*, May 12
Jukka Pekola, LTL, Finland, *Charge pumping under the influence of noise - work in progress*, May 19
Yuri Pashkin, NEC Nano Electronics Research Laboratories, Japan, *Nonadiabatic Cooper pair pumping*, May 26
Yao Cheng, Department of Engineering Physics, Tsinghua University, Beijing, China, *Phase transition of ^{103m}Rh excited by bremsstrahlung*, Jun 2
Konstantin Glaum, Institut für Theoretische Physik, Universität Ulm, Germany, *Josephson junction as detector for non-gaussian noise – a theoretical approach*, Jun 2
Juha Voutilainen, LTL, Finland, *Nano Journal Club*, Jun 9
Olaf Dreyer, Center for Theoretical Physics, MIT, USA, *Early universe cosmology in internal relativity*, Jun 16
Tommy Holmqvist, LTL, Finland, *Nano Journal Club*, Jun 16
Alexander Shnirman, Universität Karlsruhe, Germany, *Charge solitons*, Jun 23
Alexander A. Balandin, Nano-Device Laboratory Department of Electrical Engineering University of California – Riverside Riverside, USA, *Phonon transport in graphene: Umklapp quenching and heat conduction,* Jul 3
Florian Libisch, Institut fuer Theoretische Physik, Technische Universitaet Wien , Österreich, *Landau-level formation in graphene quantum dots*, Jul 29
Vinay Ambegaokar, Cornell University, USA, *Entropy and time*, Aug 3
Victor L'vov, Weizmann Institute of Science, Israel, *Energy distribution over scales in classical and quantum homogeneous turbulence in superfluids*, Aug 11
Ville Maisi, LTL, Finland, *Parallel pumping of electrons*, Aug 25
Elias Pentti, LTL, Finland, *Dilute helium mixtures at low temperatures: Properties and cooling methods*, Aug 31
Mikko Möttönen, Helsinki University of Technology and University of New South Wales, *Electron transport and spin qubit experiments on single-donor silicon devices*, Sep 1
Andrey V. Timofeev, LTL, Finland, *Tunnel junctions as detectors of noise and energy relaxation in superconducting circuits*, Sep 3
Valery Ryazanov, Institute of Solid State Physics, Russian Academy of Sciences, Russia, *Applications of the SFS pi-junctions in digital and quantum electronics*, Sep 7
Yuriy Makhlin, Landau Institute for Theoretical Physics, Moscow, Russia, *Period-doubling quantum detector*, Sep 8
Xuefeng Song, Department of Physics, Peking University, Beijing, China, *A new way*

to manipulate carbon nanotube and graphene: Towards better research and more applications, Sep 15
Nikolai Kopnin, LTL, Finland, *Vortex core states in superconducting graphene*, Sep 22
Koji Ishibashi, RIKEN, Japan, *1) Transport in carbon nanotube quantum dots and semiconductor nanowires, and 2) Fabrication and characterization of carbon nanotube nanostructures*, Sep 25
Matti Tomi, LTL, Finland, *Raman spectroscopy of graphene and carbon nanotubes*, Sep 29
Gordey Lesovik, Landau Institute, Moscow, Russia, *Quantum divisibility test and its application in mesoscopic physics*, Oct 6
Tero Heikkilä, LTL, Finland, *Spin temperature and thermalization in spin valves*, Oct 13
Per Delsing, Chalmers University of Technology, Sweden, *Sisyphus resistance in a single electron box and photon generation in tunable cavities*, Oct 15
Antti Kemppinen, MIKES/LTL, Finland, *Tunnel junction devices for quantum metrology*, Oct 16
Matthias Meschke, LTL, Finland, *Coulomb blockade and single junction thermometers*, Oct 20
Pauli Virtanen, LTL, Finland, *Nonequilibrium and transport in proximity of superconductors*, Oct 22
Yuri Pashkin, NEC Nano Electronics Research Laboratories, Tsukuba, Japan, *Nanomechanics of a single-electron transistor*, Oct 27
Hyunsik Im, Department of Semiconductor Science, Dongguk University, Seoul, Korea, *Tunneling spectroscopy of inherent interface quasi-particle states in superconducting tunnel junctions*, Nov 2
Janne Viljas, LTL, Finland, *Cooling of electrons by phonons in graphene and in metallic single-walled carbon nanotubes*, Nov 3
Pertti Hakonen, LTL, Finland, *Spins and cross correlations*, Nov 10
William Halperin, Northwestern University, Evanston, Illinois, USA, *Nanoscale NMR imaging of superconductivity at high magnetic field*, Nov 13
Mats Jonson, Gothenburg University, Gothenburg, Sweden and Heriot-Watt University, Edinburgh, Scotland, UK, *Quantum coherent electromechanics of suspended nanowires*, Nov 13
Olli-Pentti Saira, LTL, Finland, *Real-time electron counting for the NIS turnstile and related devices*, Nov 17
Tim Duty, School of Mathematics and Physics, The University of Queensland, Australia, *Phase-flip transitions and amplification in a parametric oscillator based upon a SQUID-tunable microwave resonator*, Nov 24
Sung Un Cho, Department of Physics and Astronomy, Seoul National University, Korea, *Electrical transport properties of nanomechanical shuttles*, Nov 25
Alexey Ioselevich, Landau Institute for Theoretical Physics, Moscow, Russia, *Coulomb effects in a random granular system*, Dec 1
Vincent Bouchiat, Néel Institute, CNRS-Grenoble, France, *Graphene as a platform to study 2D electronic transitions*, Dec 4
Mika Sillanpää, LTL, Finland, *Electromechanical qubits formed by electrostatic nonlinearity*, Dec 8
Jukka Pekola, LTL, Finland, *On the origin of Dynes density of states*, Dec 15

RESEARCH SEMINARS OF THE BRU

Riitta Hari, LTL, Finland, *Ethics and responsible conduct of research*, Mar 2
Lassi Päivärinta, University of Helsinki, Finland, *Inverse problem*, Mar 16
Mikko Tulppo, Toimintakykytutkimusyksikkö, Verve, Finland, *Analysis of autonomic regulation using biosignals: Theory and implications*, Mar 30
Iiro Jääskeläinen, BECS, TKK, Finland, *Neurocinematics*, Apr 20
Tapio Takala, TKK, Finland, *Recent development in virtual and augmented reality*, May 4
Mia Liljeström, LTL, Finland, *Comparing MEG and fMRI views to naming actions and objects*, May 18
Nuutti Vartiainen, LTL, Finland, *Why to image pain?* Jun 1
Annika Hultén, LTL, Finland, *Seize it or lose it! An individual brain signature for success in language learning*, Aug 30
Lauri Nummenmaa, LTL, Finland, *For your eyes only: Neurocognitive mechanisms of gaze perception*, Sep 14
Juha Karvonen, Tiina Liiri, Anne, Mandel, Siina Pamilo and Henna Roikola, *Presentations of summer students*, LTL, Finland, Sep 28
Johanna Vartiainen, LTL, Finland, *Reading isolated words: MEG-fMRI comparison*, Oct 26
Ilkka Nissilä, BECS, TKK, *Near infrared spectroscopy (NIRS)*, Nov 9
Linda Henriksson, LTL, Finland, *Imaging studies on the functional organization of human visual cortex*, Nov 23
Lotus Lin, Institute for Learning and Brain Sciences, University of Washington, USA, *Neural processing of bilingual mental calculation*, Nov 30
Mikko Sams, Iiro Jääskeläinen, Synnöve Carlson, Riitta Salmelin and Riitta Hari, *How to write a (good) grant application,* Dec 14

SPECIAL ASSIGNMENTS

Petri Heikkinen, *High-Q LC Resonance circuit as input to a GaAs MESFET preamplifier at liquid helium temperatures.* Instructor: Prof. **Matti Krusius**.

Jukka-Pekka Kaikkonen, *Kapton compression cell for the studies of 3He crystals*. Instructor: M.Sc. **Matti Manninen**.

Jonne Koski, *Vorteksirenkaan epästabiilisuus ja Kelvin-aallot helium-3 supranesteessä*. Instructor: D.Sc. **Risto Hänninen**.

Matti Tomi, *Characterization of graphene sheets by optical interferometry and Raman spectroscopy.* Instructor: Prof. **Pertti Hakonen**.

ACADEMIC DEGREES

DIPLOMA THESES

Antti Jalava graduated as M.Sc. from the Faculty of Information and Natural Sciences on November 1th. His diploma thesis *Detection of task-related neural networks with imaging of coherent sources* was done in the LTL. Supervisor: Prof. Risto Ilmoniemi. Instructor: Academy Professor **Riitta Salmelin**.

Laura Korhonen graduated as M.Sc. from the Faculty of Information and Natural Sciences on January 6th. His diploma thesis *Development of fully superconducting*

Bloch oscillating transistor was done in the LTL. Supervisor: Prof. Risto Nieminen. Instructor: Prof. **Pertti Hakonen**.

Pavan Ramkumar graduated as M.Sc. from the Faculty of Information and Natural Sciences on February 20th. His diploma thesis *Modeling the dynamics of human neuromagnetic brain rhythms* was done in the LTL. Supervisor: Prof. Samuel Kaski. Instructors: Prof. **Riitta Hari** and M.Sc. **Lauri Parkkonen**.

PH.D. DISSERTATIONS

Heikki Junes defended his Ph.D. thesis *Experiments on the faceting and supersolidity in helium crystals* on 20th February, 2009. His opponent was Dr. Reyer Jochemsen from Leiden University, Leiden, the Netherlands, supervisor Prof. Matti Kaivola, and instructor: Dr. **Harry Alles**.

Antti Kemppinen defended his Ph.D. thesis *Tunnel junction devices for quantum metrology* on 16th October, 2009. His opponent was Prof. Per Delsing from Chalmers University of Technology, Göteborg, Sweden, supervisor Prof. Matti Kaivola, and instructor Prof. **Jukka Pekola**.

Lauri Parkkonen defended his Ph.D. thesis *Expanding the applicability of magnetoencephalography* 12th June, 2009. His opponent was Prof. Shinya Kuriki from Research Center for Advanced Technologies, University of Tokyo, Japan, supervisor Prof. Risto Ilmoniemi, and instructor Prof. **Riitta Hari**.

Elias Pentti defended his Ph.D. thesis *Dilute helium mixtures at low temperatures: Properties and cooling methods* on 31th August, 2009. His opponent was Prof. Brian Cowan from Royal Holloway University of London, UK, supervisor Prof. Matti Kaivola, and instructor Docent **Juha Tuoriniemi**.

Andrey Timofeev defended his Ph.D. thesis *Tunnel junctions as detectors of noise and energy relaxation in superconducting circuits* on 3rd September, 2009. His opponent was Prof. Klaus Ensslin, ETH, Zürich, Switzerland, supervisor Prof. Matti Kaivola, and instructor Prof. **Jukka Pekola**.

Nuutti Vartiainen defended his Ph.D. thesis *Brain imaging of chronic pain* on 18th November, 2009. His opponent was Prof. Christian Büchel from University Medical Center Hamburg-Eppendorf, Hamburg, Germany, supervisors Docent **Nina Forss** and Prof. **Riitta Hari**.

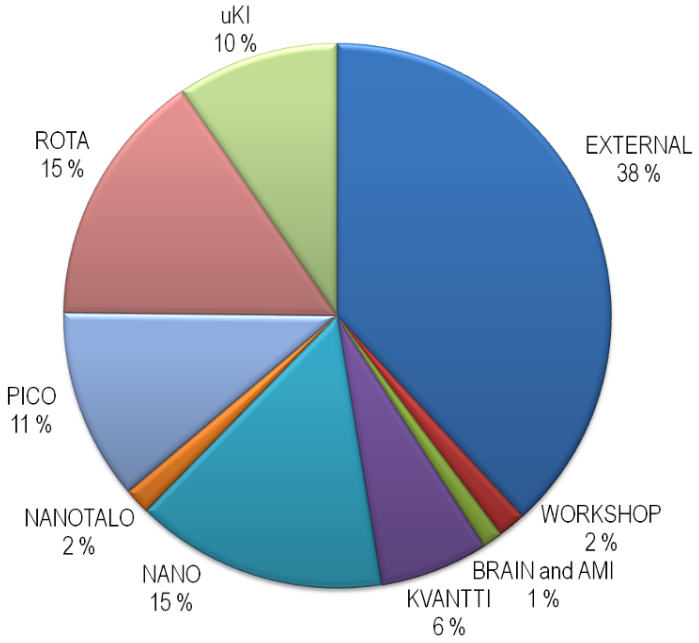
Pauli Virtanen defended his Ph.D. thesis *Nonequilibrium and transport in proximity of superconductors* on 22rd October, 2009. His opponent was Prof. Carlo W.J. Beenakker, Leiden University, Leiden, the Netherlands, and supervisor Prof. Martti Puska, and instructor Docent **Tero. T. Heikkilä**.

TECHNICAL SERVICES

MACHINE SHOP

Kauko Herold, Seppo Hiltunen, Antti Huvila, **Arvi Isomäki,** and Markku Korhonen

Our Machine Shop is a joint unit of Department of Electrical Engineering (Kauko Herold and Seppo Hiltunen), Low Temperature Laboratory (Antti Huvila, Arvi Isomäki, and Markku Korhonen) and Department of Engineering Physics (Hannu Kaukelin).



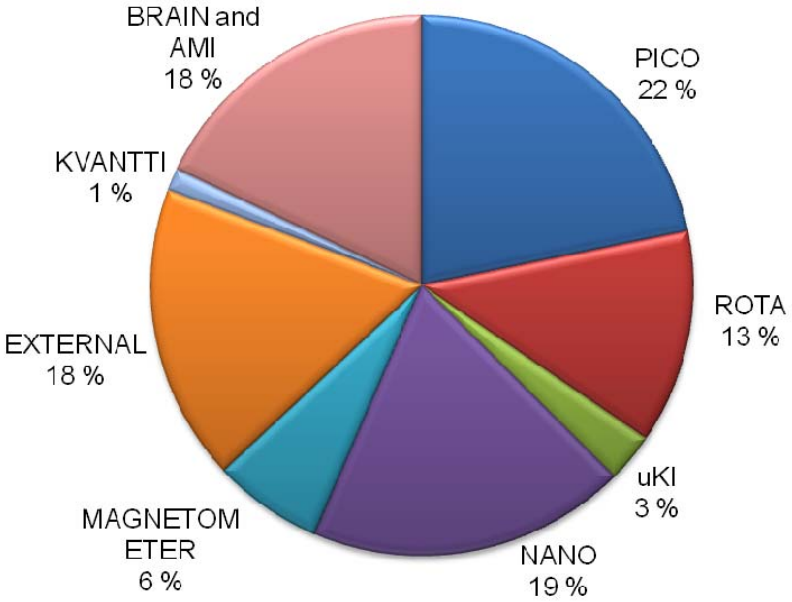
The distribution of workshop usage. Total hours were 3 401 h.

CRYOGENIC LIQUIDS

Arvi Isomäki and Antti Huvila

Liquid helium

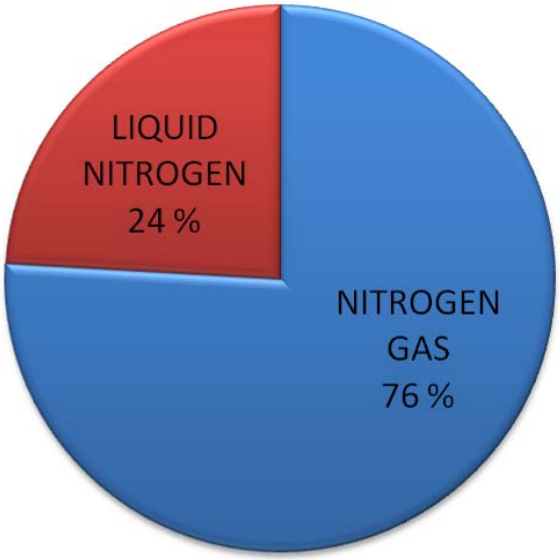
The total amount of liquid helium purchased was 41 057,8 *l* and 27 620 *l* were delivered to the users. The losses of liquid He were 32.7%. The user distribution is depicted below. 18% of the liquid He delivered to the users was sold to external users.



Liquid nitrogen

The main part of liquid nitrogen was used for compressed nitrogen gas system in Nanotalo. Only 24% of nitrogen was used as a cryogenic liquid. Total amount of liq-

uid nitrogen purchased was 69 935 kg. The nitrogen consumption of LTL was about 10% of the total amount of nitrogen.



ACTIVITIES OF THE PERSONNEL

AWARDS AND HONORS

Carlson Synnöve, Lecturer of the year 2009, Medical faculty, University of Helsinki (11.3.)
Hari Riitta, Suomen tiedepalkinto 2009, Finnish Science Prize 2009, Ministry of Education, Helsinki, Finland, 12.5.
Hultén Annika, Phillip M. Rennick Award, International Neuropsychological Society, International Neuropsychological Society, INS 2009 Mid Year Meeting , Helsinki, Finland, 31.7.
Kujala Jan, Novartis väitöskirjapalkinto, Suomen Aivotutkimusseura ry, Suomen Aivotutkimusseura ry, Helsinki, 6.11.
Mika Sillanpää, member of Academy Club for Young Scientists, Finnish Academy of Science and Letters, 1.9. 2009 – 31.5. 2010.

PERSONNEL WORKING ABROAD

Carlson Synnöve

- European Research Network for Investigating Human Sensorimotor Function in Health and Disease (ERNI-HSF) Steering Committee meeting, Amsterdam, The Netherlands, 19.–20.3.

Hakonen Pertti

- Preparation of an EU proposal, University, Gothenburg, Sweden, 21.1.
- ENS, CARDEQ collaboration, University, Paris, France, 3.–28.5.

Hari Riitta

- European Research Council, Brussels, Belgium, 1.–2.4.
- European Research Council, Brussels, Belgium, 29.6–2.7.

- European Research Council: Chair of ERC Advanced Grant Panel LS5, Brussels, Belgium, 6.–8.10.
- European Research Council: Panel Chairs' Meeting, Brussels, Belgium, 10.–11.11.

Heikkilä Tero

- Université Paris-Sud, University, Orsay, France, 25.–27.11.

Hänninen Risto

- University of Lancaster ULT Group, University, Lancaster, UK, 11.–14.12.

Jousmäki Veikko

- Hôpital Erasme de l'université Libre de Bruxelles (ULB), Bruxells, Belgium, 9.–13.3.
- Elekta Neuromag oy, System Integration at Heinrich Heine Universität, Private Company, Düsseldorf, Germany, 23.–27.3.
- Elekta Neuromag oy, System Start at Heinrich Heine Universität, Private Company, Düsseldorf, Germany, 15.–24.4.
- Elekta Neuromag oy, System Start at Universita Di Trento, Italy, Private Company, Trento, Italy, 11.–15.5.
- Hôpital Erasme de l'université Libre de Bruxelles (ULB), Bruxells, Belgium, 28.9.–2.10.
- Hôpital Erasme de l'université Libre de Bruxelles (ULB), Bruxelles, Belgium, 9.–13.11.
- Hôpital Erasme de l'université Libre de Bruxelles (ULB), Bruxelles, Belgium, 9.–11.12.

Kopnin Nikolai

- Argonne National Laboratory, Research Center, Argonne, Illinois, USA, 16.3.–17.4.
- Hebrew University, University, Jerusalem, Israel, 24.10.–20.11.

Laakso Matti

- TU Delft, University, Delft, Netherlands, 16.–29.3.

Lechner Lorenz

- BitBang Study Tour, SF Bay Area, USA, 22.2.–1.3.
- LPA at Ecole Normale Superieure, University, Paris, France, 3.–10.5.

Manninen Matti

- Lancaster University, Lancaster, UK, 1.–14.2.

Meschke Matthias

- PTB Berlin (Physikalisch Technische Bundesanstalt), Berlin, Germany, 29.6.–3.7.

Paraoanu Sorin

- Templeton Foundation Fellowship Programme at IQOQI Vienna University, Vienna, Austria, 6.6.–29.7.

Parviainen Tiina

- Neurodevelopmental MEG Research Centre, Oxford, England, 8.–12.12.

Salmelin Riitta

- Organization for Human Brain Mapping, Programme Committee Meeting, Paris, France, 19.–20.2.

Virtanen Pauli

- Donostia International Physics Center, San Sebastian, Spain, 15.–18.11.
- University of Würzburg, Germany, 30.11.–2.12.

CONFERENCE PARTICIPATION AND LABORATORY VISITS

Carlson

Invited talk, *Influence of distraction on neuronal activity in the primate prefrontal cortex*, Neuro Symposium, RIKEN, Wako, Saitama, Japan (25.–26.5.)
Invited talk, *Distraction and working memory,* Institute for Physiological Sciences, Okazaki, Japan (27.5.)
Invited talk, *Working memory and the prefrontal cortex,* Kyoto University, Kyoto, Japan (28.5.)
Invited talk, *Functional dissociation between memory and attention in prefrontal cortex of people and monkeys: Distraction and working memory,* NEURO Closing Seminar, Helsinki, Finland (25.–26.8.)
Invited lecture, *Miten sokeus muokkaa aivojen toimintaa,* Näkövammaistyön jatkokurssi, Näkövammaisten Keskusliitto, Helsinki, Finland (7.–8.10.)
Invited talk. *Aivot ja tarkkaavaisuus,* Galilei-symposium, BMOL, Helsinki, Finland (13.-15.11.)
Invited talk, *How the brain handles distraction during working memory performance,* Brain and Education Round Table, Moscow, Russia (17.–18.11.)
Invited talk, *Brain and distraction,* Learning Mind and Brain Conference, Helsinki, Finland (3.–4.12.)
Invited lecture, *Aivot ja tarkkaavaisuus*, Kliinisen Neurofysiologian Seminaari, Helsinki University Central Hospital, Helsinki, Finland (24.11)

Chalapat

Poster, *Broadband reference-plane invariant method for measuring the intrinsic properties of materials*, Physics Days 2009, Espoo, Finland (12.–14.3.)
Poster, *Energy-loss mechanisms of magnetic particles at GHz frequencies*, Physics Days 2009, Espoo, Finland (12.–14.3.)

Fay

Invited talk, *Shot noise and transport in graphene: from large strips to nanoribbons*, NORDIC Graphene Workshop, Upsala, Sweden (20.–21.4.)
Invited talk, *Shot noise experiments on graphene*, ICNF, Pisa, Italy (14.–19.6.)
Invited talk, *Conductivity and shot noise in bialayer graphene at high bias voltages*, Conference on Mesocopic Physics, Aussois, France (3.–11.10.)
Oral presentation, *Conductivity and shot-noise in bilayer graphene at high bias voltages*, German Physical Society, Dresden, Germany (23.–27.3.)

Forss

Poster, *Activation of parietal operculum parallels motor recovery in stroke*, 2009 ISACM Conference, 2nd Biannual Conference of the International Society for the Advancement of Clinical Magnetoencephalography, Athens, Greece (3.–5.9.)

Hakonen

Invited talk, *Gate-controlled supercurrents i carbon nanotubes*, International Symposium on Carbon Nanotube Nanoelectronics, Matsushima, Miyagi, Japan (9.–12.6.)
Invited talk, *Shot noise in graphene Josephson junctions*, MESO-09 "Non-equilibrium and Coherent Phenomena at Nanoscale", Chernogolovka, Russia (11.–16.6.)
Oral presentation, *Coherence and noise of graphene samples with superconducting contacts*, Graphene Week 2009, Obergurgl, Austria (2.–7.3.)
Oral presentation, *Progress in nanotube rf-SETs*, CARDEQ Yearly Meeting, Dresden, Germany (24.–26.3.)
Oral presentation, *Introduction to CARDEQ*, CARDEQ Final Review, Copenhagen, Denmark (29.–30.10.)
Oral presentation, *Progress report on WP2*, CARDEQ Final Review, Copenhagen, Denmark (29.–30.10.)
Oral presentation, *Management report on CARDEQ*, CARDEQ Final Review, Copenhagen, Denmark (29.–30.10.)
Lecture, *Shot noise in graphene sheets and in graphene Josephson junctions*, Colloquium of the Physics Department of ENS, Paris, France (7.5.)
Lecture, *Shot noise in graphene sheets and in graphene Josephson junctions*, Seminar of the Nanophysics Group of Orsay University, Paris, France (25.5.)
Lecture, *Shot noise in graphene sheets and in graphene Josephson junctions*, Seminar of the Physics Department of RIKEN, Tokyo, Japan (8.6.)
Participation, DPG March Meeting 2009, Dresden, Germany (23.–27.3.)

Hari

Invited talk, *Muuttuuko mieli, muovautuvatko aivot*, Tieteen Päivät 2009, sessio "Onko ihminen muokattavissa", Helsinki, Finland (11.1.)
Invited talk, *Neurotiede TKK:ssa (Neuroscience at the Helsinki University of Technology)*, Neurotieeen työpaja (Neuorscience Workshop), Espoo, Finland (13.3.)
Invited talk, *Brain, mind, and environment: A neuroscientist's view*, Commemorating Charles Darwin (On the Multidisciplinary Impact of the Theory of Evolution and its Current Status), Les Treilles, France (27.4.–2.5.)
Invited comment, *Veijo Virsu as a scientific collaborator*, Professor Veijo Virsu's Farewell Symposium, Helsinki, Finland (8.5.)
Invited talk, *The role of MEG in cognitive neuroscience*, Symposium on Magnetoencephalography, Inauguration of the CIMeC MEG Laboratory at the University of Trento, Italy, Trento, Italy (26.–27.5.)
Invited talk, *MEG in cognitive neuroscience*, Symposium for the Inauguration of the 306-ch MEG, Heinrich-Heine University, Düsseldorf, Germany (29.5.)
Invited plenary talk, *Brain basis of social interaction*, International Neuropsychology Society Mid-term Meeting 2009, Helsinki, Finland (31.7.)
Invited talk, *Social brains in interaction*, From Neurotrophic Factors to Social Brain, NEURO Final Seminar, Helsinki, Finland (25.–26.8.)

Invited talk, *The brain in time: MEG studies of human brain function*, Distinguished Lecture Series, Berlin School of Brain and Mind, Berlin, Germany (1.10.)
Invited talk, *AivoAALTO*, Multidisciplinary Research of Cognition in Naturalistic Environments, Helsinki, Finland (9.10.)
Invited talk, *Aivojen vuosikymmeneltä mielen vuosituhannelle*, Aaalo-yliopiston Avoin Luentosarja Teknologian, Talouden ja Taiteen Kestävän Kehityksen Näköaloista, Espoo, Otaniemi (15.10.)
Invited talk, *Time scales in human brain function*, The Brain: Function, Imaging and Repair, Goulandris Natural History Museum/GAIA Centre, Athens, Greece (19.–21.10.)
Invited talk, *Keynote: Social brain*, Learning Mind and Brain, Helsinki, Finland (3.12.)
Invited talk, *Multiple time scales in human brain functions*, HIIT Seminar on Interactive Computing, Espoo, Finland (9.12.)
Plenary talk, *Special plenary lecture (Valokeilassa tänään): Aivojen vuosikymmeneltä mielen vuosituhannelle*, Lääkäripäivät 2009, Helsinki, Finland (7.1.)
Invited comment, *Aivotutkijan näkökulma mielen ja aivojen evoluutioon*, Kaikki Evoluutiosta-kirjan Julkistamistilaisuus, Helsinki, Finland (8.1.)
Invited comment, *aivoAALTO*, Eduskunnan Sivistysvaliokunnan Vierailu Aalto-yliopistossa, Espoo, Finland (17.2.)
Oral presentation, *About "aivoAALTO" application*, Meeting of the Aalto University Trasnformation Team A8, Espoo, (29.1.)
Participation, ERC Lunch and ERC Seminar organized by the Academy of Finland, Helsinki, Finland (29.1.)

Heikkilä

Invited talk, *Mesoscopic heattronics*, Workshop on Spin Caloritronics, Leiden, Netherlands (9.–13.2.)
Lecture, *Statistics of temperature fluctuations in an electron system out of equilibrium*, Research seminar, Laboratoire de Physique des Solides, Université Paris Sud, Orsay, France (27.11.)

Helenius

Invited talk, *Lexico-semantic analysis of spoken words: Neuromagnetic studies in normal and language-learning impaired individuals*, Speech and Brain 2009, Helsinki, Finland (19.–20.3.)
Lecture, *Puheen tunnistuksen aivostollinen edustus*, Neuropsykologian Erikoispsykologi Koulutus: Lasten Kielelliset Häiriöt - Diagnostiikka ja Kuntoutus, Helsinki, Finland (2.4.)
Poster, *Neurocognitive correlates of error-induced positivities revealed by MEG*, The 16th Annual Meeting of the Cognitive Neuroscience Society, San Francisco, USA (21.–24.3.)
Poster, *Neural markers of detecting infrequent visual events in ADHD*, Mid-year meeting of the International Neuropsychological Society (INS) 2009, Helsinki, Finland (29.7.–1.8.)
Participation, SNPY:n Juhlaseminaari: Nuoret Kuntoutuksen Haasteena, Helsinki,

Finland (27.11.)
Participation, Learning Mind and Brain, Helsinki, Finland (3.–4.12.)

Henriksson

Oral presentation, *Representation of broadband edges and spatial phase congruency in human visual cortex*, Vision Sciences Society 9th Annual Meeting, Naples, Florida, USA (8.–13.5.)
Participation, Computational Vision Training Workshop, Schloss Rauischholzhausen, Hessia, Germany (17.–21.8.)

Hirvenkari

Oral presentation, *Puheenvuoron vaihtojen seuraaminen kahden henkilön keskustelussa: Silmänliikeanalyysi*, Keskustelututkimuksen Päivät, Turku, Finland (22.–23.1.)
Poster, *Gaze-based MEG averaging during audiovisual speech perception*, Scandinavian Workshop of Applied Eye Tracking 2009, Stavanger, Norway (5.–7.5.)
Participation, RIKEN BSI 2009 Summer Program: Interacting Brains, Tokyo, Japan (14. –24.7.)

Hosio

Oral presentation, *Quantum turbulence in superfluids*, Physics Days, Espoo, Finland (12.–14.3.)

Hultén

Oral presentation, *Neural correlates of word learning and forgetting: An MEG study*, International Neuropsychological Society Mid-Year Meeting 2009, Helsinki & Tallin, Finland & Estonia (29.7.–1.8.)
Participation, Learning Mind and Brain, Helsinki, Finland (3.–4.12.)

Hänninen

Invited talk, *Coupling between different Kelvin waves: Cascade and inverse cascade*, Workshop on Topics in Quantum Turbulence, Trieste, Italy (16.–20.3.)
Invited talk, *Simulations on vibrating sphere and tilted rotating cylinder*, Workshop on Topics in Quantum Turbulence, Trieste, Italy (16.–20.3.)
Invited talk, *Vortex states in an inclined cylinder*, International Symposium on Quantum Fluids and Solids, QFS2009, Evanston, Northwestern University, USA (5.–11.8.)
Invited talk, *Spin-down response of rotating superfluids: laminar or turbulent?*, Condensed Matter and Materials Physics, CMMP09, Warwick, United Kingdom (15.–17.12.)
Oral presentation, *Universal onset of quantum turbulence in oscillating flows and crossover to steady flows*, Quantum Turbulence Workshop of QFS2009, Evanston, Northwestern University, USA (11.8.)
Lecture, *Spin-down response of rotating superfluids: laminar or turbulent?*, Condensed Matter Seminar, Physics Department of Lancaster University, Lancaster, UK (11.12.)

Jalava

Participation, Brain Connectivity Workshop 2009, Maastricht, Netherlands (1.–3.5.)

Jousmäki

Invited talk, *Natural tactile stimulation in MEG*, Neuro symposium, RIKEN, Wako, Saitama, Japan (25.–26.5.)
Participation, Japan Biomag Conference, Kanazawa, Japan (28.–29.5.)

Kafanov

Oral presentation, *SINIS turnstile current pumps*, SCOPE meeting, Karlsruhe, Germany (1.–4.4.)
Poster, *Hybrid turnstile as a current standard for a quantum metrology triangle*, Quantum Measurements and Metrology with Solid State Devices, Bad-Honneff, Germany (1.–5.11.)

Kirveskari

Invited talk, *Intraoperarative monitoring – a necessary part of CN in 2009?*, 25th Nordic Meeting of Clinical Neurophysiology, Trondheim, Norway (14.–16.5.)
Invited talk, *Role of clinical neurophysiology in epileptic focus localization*, 19th Meeting of the European Neurological Society, Milan, Italy (20.–24.6.)
Invited talk, *Herätevasteet neuropaattisessa kivussa*, Valtakunnalliset XIV KNF-päivät, Turku, Finland (10.–11.9.)
Poster, *Motor cortex dysfunction in complex regional pain syndrome*, 2nd Meeting of the International Society for the Advancement of Clinical MEG, Athens, Greece (3.–6.9.)

Kopnin

Invited talk, *Vortex core states in superconducting graphene*, 12th International Workshop on Vortex Matter in Superconductors, Lake Jamanako, Japan (12.–16.9.)
Invited talk, *Non-equilibrium tunnel junctions under high-voltage injection*, Landau days 2009, Moscow, Chernogolovka, Russia (22.–24.6.)

Krusius

Invited talk, *Vortex motion and dissipation at very low temperatures*, Workshop on Topics in Quantum Turbulence, Trieste, Italy (16.–20.3.)
Invited talk, *Vortices and other topological defects in non-equilibrium phase transitions of 3He superfluids*, 6th International Conference in School Format on Vortex Matter in Nanostructured Superconductors, Rhodos, Greece (17.–24.9.)

Kujala

Invited talk, *Data-driven analysis of cortical rhythmic interactions with MEG*, 4th International Summer School in Biomedical Engineering - Brain Connectivity and Information Transfer, Leipzig, Max-Planck-Institute for Human Cognitive and Brain Sciences, Germany (13.–27.8.)

Oral presentation, *Observing intensity of pain from another's face: fMRI and MEG considerations*, Social Cognitive Neuroscience Meeting, Acquafredda di Maratea, Italy (27.2.–4.3.)
Poster, *Brain activation during observation of social interaction between humans or dogs*, The 16th Annual Meeting of the Cognitive Neuroscience Society, San Francisco, USA (21.–24.3.)
Participation, Brain Connectivity Workshop, Maastricht, The Netherlands (1.–3.5.)
Participation, From Neurotrophic Factors to Social Brain, NEURO Final Seminar, Helsinki, Finland (25.8.)

Laakso

Oral presentation, *Charge transport in ballistic multiprobe graphene structures*, Physics Days 2009, Espoo, Finland (12.–14.3.)
Oral presentation, *Statistics of temperature fluctuations in an electron system out of equilibrium*, The Capri Spring School on Transport in Nanostructures 2009, Anacapri, Italy (29.3.–5.4.)
Poster, *Temperature fluctuations and their statistics under Coulomb blockade*, Quantum Transport in Electronic Nanosystems, Karlsruhe, Germany (19.–24.9.)

Lamminmäki

Invited talk, *Frequency tagging in the study of binaural interaction*, NAS (Nordic Audiological Society) Annual General Meeting, Helsinki, Finland (8.9.)
Poster, *Binaural interaction during octave illusion*, The 3rd International Conference on Auditory Cortex, Magdeburg, Germany (29.8.–2.9.)

Lechner

Invited talk, *Focused ion beam for rapid prototyping - The fast road towards graphene electronics*, Special Session SFB569, Ulm, Germany (25.5.)
Oral presentation, *Ultra-sensitive carbon nanotube resonant tunneling transistor*, DPG Spring Meeting 2009, Dresden, Germany (22.–27.3.)
Oral presentation, *Dual beam prototyping of nanocarbon devices*, CARDEQ Meeting 2009, Dresden, Germany (24. - 25.3.)
Poster, *Dual beam prototyping for graphene devices*, FEI International FIB UserClub, Eindhoven, The Netherlands (6.–8.4.)

Liljeström

Poster, *Comparing MEG and fMRI views to naming actions and objects*, Annual Meeting of the Organization for Human Brain Mapping, San Francisco, USA (18.–23.6.)
Poster, *Comparing MEG and fMRI views to naming actions and objects*, Mid-year Meeting of the International Neuropsychological Society, Helsinki, Finland (29.–31.7.)

MacLeod

Oral presentation, *1e/2e periodicity in Aluminium-Titanium SETs*, Physics Days 2009, Otaniemi, Espoo, Finland (12.–14.3.)

Participation, Capri Spring School on Transport in Nanostructures, Capri, Italy, 29.3.–5.4.

Malinen

Poster, *Trying to comprehend audiovisual speech*, Neuroscience 2009, Chicago, USA (17.–21.10.)

Manninen

Participation, Lammi/Espoo, Finland (7.–18.9.)

Meschke

Oral presentation, *Thermometry towards 10 mK*, 4th Meeting of the NanoFridge Project, Delft, Netherland (29.5.)
Oral presentation, *Cooling at the quantum limit and RF-driven refrigeration*, International Conference on Quantum Phenomena at Nanoscale, Hotel Meastral conference center, Pržno, Montenegro (30.8.–4.9.)
Participation, Year 1 Annual Review, Cooltronics, Warwick, UK (21.–22.10.)

Muhonen

Oral presentation, *Electronic cooling of submicron-sized metallic beams*, The XLIII Annual Conference of the Finnish Physical Society (Physics Days 2009), Espoo, Finland (12.–14.3.)
Poster, *Electronic cooling of metallic nanowires*, European School of Nanosciences and Nanotechnologies, Grenoble, France (23.8.–12.9.)
Poster, *Silicon nitride membrane as a cooling platform*, Annual Review Meeting of Cooltronics Project, University of Warvick, Coventry, United Kingdom (21.–23.10.)

Nurminen

Poster, *Neurometric analysis of contrast discimination in single trial fMRI*, Society for Neuroscience conference 2009, Chicago, USA (17.–21.10.)

Paalanen

After dinner talk, Physics Days 2009 (3.3.)
Invited talk, *Future prospect in low temperature quantum electronics and nanorefrigeration*, Jyväskylä, Finland (24.4.)
Invited talk, *Future prospect in low temperature quantum electronics and nanorefrigeration*, Annual Meeting of the Science Teachers of Applied Science Universities, Varkaus, Finland (5.–6.5.)
Invited talk, *Peer review of ERC Starting Grants*, Research Connection, Prague, Czech Republic (7.–8.5.)
Participation, Nobel Symposium on Qu-bits for Quantum Information, Göteborg, Sweden (24.–27.5.)
Invited talk, *New cooling methods at ultra-low temperatures*, Festkolloquium for Prof. Dr. Michael Steiner, Berlin, Hahn-Meitner Institute, Germany (2.–3.6.)

Invited talk, *European Microkelvin Collaboration*, Physics and Metrology at Very Low Temperatures, PTB Berlin, Germany (10.12.)
Invited comment, *Future prospects of SETs in metrology*, EUROMET Expert Meeting on Quantum Electrical Metrology, Paris, LNE, France (3.–5.6.)
Lecture, *Managing European Microkelvin Collaboration*, Lancaster Workshop on Management of FP7 Projects, Lancaster University, Lancaster, UK (30.11.)
Participation, 10th Meeting of the European Association of National Research Facilities, Lund, Sweden (27.10.)
Participation, ERC Starting Grant, Panel Chairs Meeting, Brussels, Belgium (5.11.)
Participation, EUROMET Research Council Meeting, Paris, France (16.12.)

Paraoanu

Invited talk, *Quantum complexity*, Templeton Research Fellows Programme, Vienna, Austria (20.1.)
Invited talk, *Microwave photons and superconducting qubits*, Templeton Research Fellows Programme, Vienna, Austria (20.1.)
Invited talk, *Electromagnetically induced transparency in a superconducting tritit*, group seminar, Technical University Vienna, Vienna, Austria (15.7.)
Invited talk, *Electronic transport in superconducting devices: from single-junction Josephson effects to quantum processing of information with superconducting circuits*, IAEA, IFIN-HH, ICTP: Trends in Nanoscience: Theory, Experiment, Technology, Sibiu, Romania (23.–30.8.)
Oral presentation, *Nanoparticles in microwave fields*, FUNANO Project Meeting, Jyväskylä, Finland (15.1.)
Oral presentation, *Measurement-induced broken gaige symmetry in interacting Bose-Einstein condensates*, Bosonic Josephson Junctions and Tunnel-coupled Systems, Pauli Institute, Vienna, Austria (18.12.)
Lecture, *Superconducting devices for quantum information processing*, Cryocourse 2009 - Marie Curie Advanced Cryogenics Course, Lammi and Espoo, Finland (7.–18.9.)
Poster, *Superconducting coplanar waveguide resonators for quantum information processing*, Physics Days, Espoo, Finland (12.–14.3.)
Poster, *Quantum coherence in a superconducting qubit coupled to a resonator*, Physics Days, Espoo, Finland (12.–14.3.)
Poster, *Entanglement of superconducting qubits via microwave fields*, Physics Days 2009, Espoo, Finland (12.–14.3.)
Poster, *Fragmented States*, 2nd Vienna Symposium on the Foundations of Modern Physics, Vienna, Austria (11.–14.6.)
Poster, *Distinguishable energy-loss mechanisms of magnetic particles at GHz frequencies*, IAEA, IFIN-HH, ICTP: Trends in Nanoscience: Theory, Experiment, Technology, Sibiu, Romania (23.–30.8.)
Participation, Opening of the Turku Center for Quantum Physics, Turku, Finland (15.12.)

Pihko

Invited talk, *MEG in neonatology: Somatosensory cortical processing in healthy and at-risk babies*, 1st International Workshop “Perinatal Biomagnetism 2009: How Can

It Help Sick Ferus/infant", Chieti, Italy (3.–4.4.)
Poster, *Somatosensory evoked magnetic fields in very low birth weight infants*, 1st International Workshop "Perinatal Biomagnetism 2009: How Can It Help Sick Ferus/infant", Chieti, Italy (3.–4.4.)
Poster, *Neonatal auditory and somatosensory evoked magnetic fields*, 1st International Workshop "Perinatal Biomagnetism 2009: How Can It Help Sick Ferus/infant", Chieti, Italy (3.–4.4.)

Ramkumar

Oral presentation, *Characterizing the temporal structure of neuromagnetic rhythms using clustering and self-organizing maps*, 2nd INCF Congress on Neuroinformatics, Pilsen, Czech Republic (6.–8.9.)

Renvall Hanna

Invited talk, *Update on attentional impairments in dyslexia*, Developmental Dyslexia: Searching the Links between Neurocognitive Functions, Rome, Italy (9.–10.10.)

Renvall Ville

Poster, *Transient over- and undershoots in fMRI can occur in absence of physiological over- or undershoots*, Neuroscience 2009, Chicago, United States (17.–21.10.)

Salmela

Poster, *Acoustic resonances in helium liquid probed using quartz tuning forks*, Nordic Meeting 2009, Kopenhagen, DTU, Danmark (16.–18.6.)
Participation, Lammi/Espoo, Finland (7.–18.9.)

Salmelin

Invited talk, *Cortical oscillations as markers of activation and connectivity*, Brain Connectivity Workshop 2009, Maastricht, The Netherlands (1.–3.5.)
Invited talk, *Neurophysiology of language: The MEG Approach*, 25th Nordic Meeting of Clinical Neurophysiology, Trondheim, Norway (14.–16.5.)
Invited talk, *Experimental design for MEG/EEG - theory and practice*, Multi-Modal Short Course, Boston, USA (1.–12.6.)
Invited plenary talk, *Time-resolved brain imaging and the neuroscience of language*, 15th Annual Meeting of the Organization for Human Brain Mapping (HBM2009), San Francisco, USA (18.–23.6.)
Invited talk, *Time-resolved brain imaging of speech perception*, 3rd International Conference on Auditory Cortex, Magdeburg, Germany (29.8.–2.9.)
Invited talk, *Kieli ja aivot*, Suomalaisen Tiedeakatemian Yhteisistunto, Helsinki, Finland (14.9.)
Invited talk, *MEG in the study of language*, New Directions in the Use of MEG for Language Research, Paris, France (8.–9.10.)
Invited talk, *Neural processes of reading*, Max Planck Institute for Psycholinguistics Colloquium Series, Nijmegen, The Netherlands (20.10.)
Invited talk, *Aivot ja kielen tuottaminen (Brain and language production)*, Kehittyvä Kielenopetus -konferenssi, Turku, Finland (20.–21.11.)

Invited talk, *How the brain learns and remembers words*, Learning Mind and Brain, Helsinki, Finland (3.–4.12.)
Invited comment, *Panel discussion*, Speech and Brain 2009, The Second Symposium of the Finnish Speech Research Collegium., Helsinki, Finland (19.–20.3.)
Lecture, *MEG in Cognitive Neuroscience*, Integrative Neuroscience Course, Helsinki, Finland (17.9.)
Lecture, *Language and brain imaging*, Tutkijakoulu Langnet, Monitieteisyyskurssi (Langnet Graduate School, Course on Multidisciplinary Research), Helsinki, Finland (26.–27.11.)

Sillanpää

Participation, Electromechanical Quantum Coherent Systems, ERC grant interview, Brussels, Belgium (25.3.)
Participation, Nobel Symposium on Qu-bits for Quantum Information, Göteborg, Sweden (24.–27.5.)

Timofeev

Oral presentation, *Noise and full counting statistics in mesoscopic transport*, 431. WE-Heraeus Seminar, Physikzentrum Bad Honnef, Germany (18.–20.5.)

Todoshchenko

Invited talk, *Nuclear spin order and faceting of 3He*, International Symposium on Quantum Fluids and Solids, QFS2009, Evanston, Illinois, USA (5.–11.8.)

Tuoriniemi

Lecture, *Adiabatic demagnetization cooling*, Marie Curie Advanced Cryogenics Course, Lammi, Finland (7.–18.9.)

Vanni

Invited talk, *Omaging surround modulation in human visual cortex*, The Brain Institute Seminar Series, Unversity of Utah, Salt Lake City, USA (17.6.)
Oral presentation, *Extrastriate visual processing: Integration of computational, psychophysical and imaging approaches*, Academy of Finland: Neuro Mid-term Seminar, Helsinki, Finland (27.1.)
Poster, *Surrounding object structure modulates response to object centre in the ventral stream areas*, 15th annual Human Brain Mapping conference, San Francisco, USA (18.–23.6.)

Vartiainen

Oral presentation, *Functional and structural changes in central pain circuitry in patients with chronic pain and recurring herpes simplex virus infections*, European Pain School 2009, Siena, Italy (13.–20.6.)
Oral presentation, *Reading isolated words*, MEG & LANGuage, Paris, France (8.–9.10.)

Oral presentation, *Reading isolated words: an MEG-fMRI comparison*, Neurobiology of Language Conference, Chicago, US (15.–16.10.)
Participation, *Talk in NLC satellite: Reading isolated words: An MEG-fMRI comparison*, Society for Neuroscience Annual Meeting 2009, Chicago, US (17.–21.10.)
Lecture, *Kivun aivokuntaminen*, Kipuklinikan Seminaari, Helsinki, Biomedicum, Finland (10.12.)

Viljas

Invited talk, *Conductivity, shot noise, and hot phonons in bilayer graphene*, Karlsruhe, Germany (12.7.)
Poster, *Length-dependent conductance and thermopower in metal-molecule-metal junctions*, Physics Days, 2009, Espoo, Finland (12.–14.3.)

Virtanen

Poster, *Supercurrent in an irradiated hybrid weak link*, Physics Days 2009, Espoo, Finland (12.–14.3.)

Volovik

Invited talk, *Problems of horizon in effective gravity*, Workshop "Towards the Observation of Hawking Radiation in Condensed Matter Systems", Valencia, Spain (1.–7.2.)
Invited talk, *Dynamics of self-sustained vacuum*, Conference Landau Days - 2009, Chernogolovka, Russia (22.–24.6.)
Invited talk, *Dynamics of the self-sustained vacuum and cosmological constant*, Symposium on Theoretical and Mathematical Physics, St. Petersburg, Russia (3.–8.7.)
Invited talk, *Iordanskii force and quantum turbulence*, Iordanskii-80 Conference, Chernogolovka, Russia (25.9.)
Invited plenary talk, *High energy physics as low temperature physics*, 35 Conference on Low Temperature Physics (NT35), Chernogolovka, Russia (28.9.–2.10.)
Invited talk, *3He-B as topological insulator*, Seminar at Landau Institute, Chernogolovka, Russia (2.10.)
Invited talk, *Landau Khalatnikov hydrodynamics and phenomenology of dark energy*, Conference Khalatnikov-90, Chernogolovka, Russia (22.–23.10.)
Invited talk, *Possible solution of cosmological constant problem: Minkowski vacuum as attractor*, Seminar at Landau Institute, Chernogolovka, Russia (30.10.)
Participation, Editorial Board Meeting of JETP Letters, Moscow, Russia (2.4.)
Participation, Editorial Board Meeting of JETP Letters, Moscow, Russia (9.4.)
Participation, Editorial Board Meeting of JETP Letters, Moscow, Russia (25.6.)
Participation, Editorial Board Meeting of JETP Letters, Moscow, Russia (1.10.)
Participation, Editorial Board Meeting of JETP Letters, Moscow, Russia (29.10.)
Participation, Editorial Board meeting of JETP Letters, Moscow, Russia (24.12.)
Participation, Meeting of Dissertation Council of Landau Institute, Chernogolovka, Russia (25.12.)
Participation, Editorial Board Meeting of JETP Letters, Moscow, Russia (12.2.)

Voutilainen

Poster, *Projiximity josephson sensor for THz radiation*, International Workshop on Cryogenic Detectors, Björkliden, Sweden (29.3.–5.4.)

Vuokko

Poster, *Different mechanisms for subitizing and counting revealed by MEG*, Learning Mind and Brain, Helsinki, Finland (3.–4.12.)

EXPERTISE AND REFEREE ASSIGNMENTS

Aurelien

Chairman of the session: Devices II, ICNF 2009, 20th Interbnational Conference on Noise and Fluctuations, Pisa, Italy, 14.–19.6.

Belardinelli

Chairman of the session: HBM 2009, San Francisco, USA, 18.–23.6.

Carlson

Positions in scientific organizations:

- Member of the Steering Committee, European Research Network for Investigating Human Sensorimotor Function in Health and Disease (ERNI-HSF)
- Vice director of the Centre of Excellence of the Academy of Finland on "Systems Neuroscience and Neuroimaging"

Reviewer of a grant application:

- European Research Council Peer Review Evaluator
- Instrumentarium Foundation

Referee:

- Neuroscience
- Brain Research
- Human Brain Mapping
- Journal of Experimental Psychology

Hakonen

Position of trust in scientific organizations:

- Cordinator, EU FP6, CARDEQ, Bruxelles, Belgium, 1.3.2007–31.8.2009
- Cordinator, ESF Eurographene Programme, ENTS (Entangled Spin Pairs in Graphene), Strasbourg, France, 1.5.2009–30.4.2013
- Steering group member, ESF, Quantum Spin Coherence and Electronics (QSpiCE), Strasbourg, France, 1.9.2009–31.8.2012

Membership in distinguished societies:

- Finnish Academy of Sciences and Letters
- Fellow member, American Physical Society
- Academia Europaea

Chairman of the conference or organising committee:

- Programme Committee for the 43rd Annual Meeting of the Finnish Physical Society, Espoo, 12. –14.3.
- CARDEQ Annual Meeting, Dresden, Germany, 24.–26.3.

Chairman of the session:

- Quantum Transport III, Graphene Week 2009, Obergurgl, Austria, 2.–7.3.
- Engineering with single wall carbon nanotubes, CNTNE2009, Matsushima, Miyagi, Japan, 9.–12.6.
- Magnetic systems and spin manipulation, MESO-09 "Non-equilibrium and Coherent Phenomena at Nanoscale", Chernogolovka, Russia, 11.–16.6.

Organizing a conference outside TKK: CARDEQ Final Review, Copenhagen, Denmark, 29.–30.10.

Referee: Nature

Pre-examiner of a doctoral thesis: Marcus Rinkiö, Carbon nanotube memory devices with high-k gate dielectrics, University of Jyväskylä, Jyväskylä, Finland, 11.12.

Reviewer of a grant application:

- U.S.-Israel Binational Science Foundation, Jerusalem, Israel, 19.3.
- ESF Fundamental Science of Graphene and Applications of Graphene-based Devices (graphene Week 2011), Strasbourg, France, 16.10.

Interview: Radiaattori, YLE, Radio, Helsinki, Finland, 16.9.

Hari

Leader position in a scientific organization:

- Director of Advanced Magnetic Imaging Centre (AMI), TKK
- Chairman of LS5 (Neuroscience) ERC Advanced Grant Panel, European Research Council, Brussels, Belgium
- Chief physician, Dept. Clin. Neurophysiology, HUSLAB, HUCH (part-time)
- Member of Advisory Board, INFC (International Neuroinformatics Coordinatingship Facility), The INCF National Node of Finland, Finland
- Director of the Centre of Excellence of the Academy of Finland on “Systems Neuroscience and Neuroimaging”
- Coordinator of the aivoAALTO research application comprising all three schools of the Aalto University

Member of distinguished societies:

- National Academy of Sciences of the USA
- Finnish Academy of Sciences and Letters
- Academia Europaea

Chairman of the session: Learning and memory, from neurotrophic factors to social brain, NEURO Final Seminar, Helsinki, Finland, 25.–26.8.

Editor of scientific journal:

- Cerebral Cortex, Global, 28.12.2007–31.12.2009

- Proceedings of the National Academy of Sciences USA, Visiting editor, USA, several times

Member of the editorial board:

- Cerebral Cortex, Oxford Journals
- Neuroscience Research, Elsevier
- Brain Topography, Springer

Interview:

- Aivojen ja mielen muovautuminen, Aamulehti, Newspaper, Tampere, Finland, 10.1.
- Topic of presentation at Tieteen Päivät 2009, YLE broadcasting company/Yle Puhe, Radio interview, Helsinki, Finland, 11.–11.1.
- About progression of science. About aivoAALTO (2 interviews), Polyteekkari, Magazine, Finland, 27.3.
- About aivoAALTO, Seed Magazine, Magazine, New York, USA, 30.3. Radiaattori (aivotutkimuksesta), YLE, Radio, Helsinki, Finland, 21.5.
- Kemia-lehti, Magazine, Helsinki, Finland, 16.6.
- Tajuttoman aivotoiminnasta, Iltasanomat, Newspaper, Helsinki, Finland, 25.11.

Referee:

- Animal Cognition
- Autism Research
- Brain Research
- International Journal of Pediatric Otorhinolaryngology
- Nature Neuroscience
- Neuroscience Research
- PNAS (visiting editor)

Statement for the appointment of a professor: Full professor, Linköping University, Sweden, 3.11.

Heikkilä

Organising a conference at TKK: Physics Days 2009, Dipoli, Espoo, Finland, 12.–14.3.

Referee:

- Physical Review B
- Physical Review Letters
- Solid State Communications
- Superconductor Science and Technology

Interview:

- Radiaattori, Haastava heinäkuu: lämpötroniikan parissa, Yle Radio 1, Radio, Helsinki, Finland, 29.7.
- "Tutkijan lottovoitto - tulevaisuus viideksi vuodeksi", Polysteekki, Magazine, Espoo, Finland, 12.11.

Helenius

Member of scientific associations: Cognitive Neuroscience Society, 1.1.

Referee:
- Cortex
- Clinical Neurophysiology
- Brain and Language

Interview:

- Vaimenevat muistijäljet ja puheen kehitys, Polysteekki 3–4/2009, Teknillinen korkeakoulu, Magazine, Helsinki, Finland, 15.10.
- Aivokuvantaminen on selventänyt kielen kehityksen erityishäiriön neuraalisia taustoja, LukSitko 2/2009, Erilaisten Oppijoiden liitto, Magazine, Helsinki, Finland, 1.11.

Helle

Guest Editor: Journal of Low Temperature Physics

Hänninen

Referee:
- Physical Review Letters
- Physical Review B
- Journal of Low Temperature Physics

Membership of the organising committee: Physics Days 2009, the 43rd annual meeting of the Finnish Physical Society, Otaniemi, Espoo, Finland, 12.–14.3.

Jousmäki

Referee:
- Journal of Cognitive Neuroscience
- Journal of Neurophysiology
- Cerebral Cortex

Kirveskari

Leader position in a scientific organization: Chairman of a committee, International Society for the Advancement of Clinical MEG, Committee for clinical MEG report, 5.9.–31.12.

Chairman of the session: Clinical Neurophysiology, 19th Meeting of the European Neurological Society, Milan, Italy, 20.–24.6.

Referee: Clinical Neurophysiology

Member of scientific associations:

- International Society of Intraoperative Neurophysiology
- Society for the Advancement of Clinical MEG

Kopnin

Member of the scientific board: Landau Institute for Theoretical Physics of the Russian Academy of Science, Russia.

Member of dissertation council: Landau Institute for Theoretical Physics of the Russian Academy of Science, Russia.

Krusius

Member of the editorial board: Physica B: Condensed Matter

Leader position in a scientific organization: Chairman, Finnish Academy of Sciences and Letters, Section of Physics and Astronomy, 1.1.2007–31.12.2009.

Membership in distinguished societies:

- Finnish Academy of Sciences and Letters
- Academia Europea
- Fellow member, American Physical Society
- Institute of Physics, UK

Member of scientific associations:

- Finnish Physical Society
- Individual ordinary member, European Physical Society

Membership of the organizing committee: International Program Advisory Board, International Symposium on Quantum Fluids and Solids, Northwestern University, Illinois, USA, 5.–11.8.

Reviewer of a grant application:

- National Science Foundation (USA)
- Engineering and Physical Sciences Research Council EPSRC (UK)
- Georgia National Science Foundation

Referee:

- Physica C
- Physical Review A
- Physical Review E
- Physical Review Letters
- Physics Today
- Journal of Low Temperature Physics

Statement for the appointment of a professor:

- Lancaster University, Lancaster, UK
- University of California, USA
- The University of Manchester, UK
- Marie Curie Fellowship of EU's 7th Framework Programme

Chairman of the session:

- Theory of the decay of quantum turbulence at very low temperatures, Workshop on Topics in Quantum Turbulence, Trieste, Italy, 16.–20.3.
- Condensed matter: Structural properties, 43rd Annual Meeting of the Finnish Physical Society, Espoo, 12.–14.3.

Kujala Jan

Referee: Neuroimage

Kujala Miiamaaria

Referee: Human Brain Mapping

Interview: "Minkä tähren: miksi haukotus tarttuu?", YLE / Pohjanmaan radio, Radio, Finland, 6.8.

Möttönen

Pre-examiner of a doctoral thesis:

- Fermionic superfluidity in optical lattices, University of Jyväskylä, Jyväskylä, Finland, 1.11.2008
- Exotic superfluid states of ultra-cold Fermi gases, University of Helsinki, Helsinki, Finland, 1.5.

Nangini

Referee:

- Human Brain Mapping
- Journal of Cognitive Neuroscience

Paalanen

Position of trust in scientific organizations:

- Chairman of evaluation panel PE3, starting grant applications, European Research Council, Brussels, Belgium, 1.1.2008–31.12.2010.
- Chairman, Aalto University, Working Group on Research Service Needs and Research Infrastructure, Espoo, Finland, 2008–2010.
- Coordinator of MICROKELVIN, FP7 network of 12 low temperature laboratories funded by EC in transnational infrastructure program, Espoo, Finalnd, 1.4.2009–31.3.2013. .
- Member of Steering Board, Helsinki University of Technology, Advanced Magnetic Imaging Center, Espoo, Finland, 1.1.2005–31.12.2011.
- Member of Steering Committee, European Science Foundation, ESF Programme on Arrays of Quantum Dots and Josephson Junctions, Strasbourg, France, 1.1.2004–31.12.2009.
- Member of Board, Biomedicum, Helsinki, Finland, 1.1.2006–31.12.2009.
- Member of EURAMET, European Association of National Metrology Institutes, Scientific Advisory Board, Teddington, England, 1.1.2007–31.12.2010.
- Member of Working Group, Aalto University Research Assessment Exercise, Espoo, Finland, 2008–2009.
- Member, Joint Neuroresearch Working Group of Aalto University and Helsinki University, Chairman, Espoo, Finland, 2008–2009.
- Member of Board, Instrumentarium Foundation, Helsinki, Finland, 2008–.
- Member of Evaluation Committee, University of Karlsruhe, DFG-Center for Functional Nanostructures, Karlsruhe, Germany, 16.–17.3.

Editor: Journal of Low Temperature Physics

Membership in distinguished societies:

- Finnish Academy of Sciences and Letters
- Finnish Academy of Technical Sciences
- Fellow member, American Physical Society
- Academia Europaea

- The Royal Academy of Arts and Scences in Göteborg

Member of scientific associations: Finnish Physical Society

Chairman of the session: Fundamental aspects of quantum optics, Nobel Symposium on Qubits for Future Quantum computers, Gothenburg, Sweden, 25.–28.5.

Reviewer of a grant application: Internal research grants by Indian Institute of Technology, Mumbai, India, 31.10.

Statement for the appointment of a professor: Distinguished professor in physics, Indian Institute of Technology, Mumbai, India, 18.1.

Interviews:

- Birth of scientific discovery, YLE 1 Radio 1 (Toimittaja Sisko Loikkanen), Radio, Helsinki, Finalnd, 26.2.
- Basic Research and Aalto University, MTV3 Uutis- ja ajankohtaistoimitus, TV, Helsinki, finalnd, 6.4.

Paraoanu

Position of trust in scientific organizations:

- Advisory Board Member, Lifeboat Foundation (Physics Panel), U.S.A.
- Independent EU reviewer, Independent reviewer in the evaluation panel, Göteborg, Sweden, 5.–6.3.

Chairman of the session: Nanophysiccs and new materials, Physiccs Days 2009, Espoo, Finland, 12.–14.3.

Parkkonen

Referee: Human Brain Mapping

Parviainen

Organising a conference at TKK: member of the organising committee, 11. valtakunnallinen lukitutkijatapaaminen, Espoo, Finland, 7.–7.3.

Pekola

Leader position in a scientific organization:

- Vice President, Finnish Physical Society, Finland, 1.4.2007–31.3.2009
- President, Finnish Physical Society, Finland, 1.4.2009–31.3.2011

Membership in distinguished societies:

- Finnish Academy of Sciences and Letters
- Finnish Academy of Technical Sciences

Member of scientific associations: Finnish Physical Society

Member of the editorial board: Journal of Low Temperature Physics

Opponent: Quentin LeMasne, PhD thesis, CEA Saclay, France, October 2009

Pihko

Referee:

- Brain
- European Journal of Neuroscience

Salmelin

Membership in distinguished societies:

- Finnish Academy of Sciences and Letters
- Academia Europaea

Editor: Human Brain Mapping

Member of the editorial board: Brain Topography, Springer

Membership of the organising committee: Neurobiology of Language, Chicago, USA, 15.–16.10.

Interview: Poikkitieteisyyden ihanne ja todellisuus, Suomen Akatemia (Blogit), Electronic, Finland, 24.2.

Tuoriniemi

Member of the editorial board: Cryogenics

Referee: New Journal of Physics

Organizing a conference outside TKK: Marie Curie Advanced Cryogenics Course, Lammi, Finland, 7.–18.9.

Chairman of the session: Condensed matter: Structural properties 2, Physics Days 2009, Espoo, Finland, 12.–14.3.

Interviews: Tutkiva juttu: Kylmän kourissa, Yleisradio, TV, Espoo, Otaniemi, Finland, 30.4.

Vanni

Leader position in a scientific organization: Board member, Finnish Brain Research Society, Finland, 18.3.2009–17.3.2012.

Referee:

- Neuroimage
- International Journal of Psychophysiology
- Case Reports in Neurology
- Human Brain Mapping

Pre-examiner of a doctoral thesis: Ilmari Kurki, University of Helsinki, Helsinki, Finland, 29.10.

Virtanen

Referee:

- Physical Review B

Volovik

Membership in distinguished societies:

- Deutsche Academie der Naturforscher Leopoldina (the German Academy of Sciences Leopoldina)
- Finnish Academy of Sciences and Letters

Editor:

- JETP Letters
- Physical Review Letters, Divisional Associate Editor

Member of the editorial board:

- JETP Letters
- Phys. Rev. Lett

Chairman of the session:

- Eeditorial board meeting of JETP Letters, Moscow, Russia, 21.–21.5.
- Landau Days, Chernogolovka, Russia, 22.–24.6.
- Symposium on Theoretical and Mathematical Physics, St. Petersburg, Russia, 3.–8.7.
- Plenary session, 35th Conference on Low Temperature Physics (NT35), Chernogolovka, Russia, 28.9.

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APPENDIX 1

A?

Aalto-yliopisto

Keskustelutilaisuus Aalto-yliopiston erillisyksikköjen asemasta

Kokousmuistio

Keskustelutilaisuuden osanottajat

Veli-Matti Airaksinen	TKK/Micronova
Patrik Floreen	TKK ja HY/HIIT
Ari Kivimäki	TaiK/Mediakeskus Lume
Seija Kulkki	HSE/CKIR
Raine Mäntysalo	TKK/YTK
Mikko Paalanen	TKK/Kylmälaboratorio (pj)
Marja Toivonen	TKK/BIT
Merja Tornikoski	TKK/Metsähovi
Riitta Kosonen	HSE/CEMAT (osallistui muistion kirjoittamiseen).

HSE:ssa, TaiK:ssa ja TKK:ssa on useita ainelaitosten ulkopuolella toimivia erillisyksiköitä. Osa niiden johtajista kokoontui 18.12. 2009 TKK:n Kylmälaboratorioon tilaisuuteen, jonka tarkoitus oli kartoittaa erillisyksikköjen strategista merkitystä Aallolle ja keskustella niiden aseman ja rahoituksen järjestämisestä uudessa Aalto-organisaatiossa. Kokouksen osanottajat totesivat yksikköjensä olevan tehtäviltään varsin erilaisia ja täten allaesitettyjen toimenpide-ehdotusten koskettavan eri määrin heidän yksiköitään.

Erillisyksikköjen strateginen merkitys Aalto-yliopistolle

Yliopiston toiminnan jakaminen opetuslähtöisiin ainelaitoksiin, joissa jokainen professori opettaa, tutkii ja hallinnoi, ei edusta optimaalista työnjakoa. Myös yliopistoissa tarvitaan professorien ja laitosten erikoistumista tuottavuuden nostamiseksi. Erillisyksiköt ovat vakiinnuttaneet asemansa sekä monitieteisinä substanssiosaamisen keskuksina että tieteellisen syväosaamisen alustoina. Niistä on tullut monipuolinen työkalu osaamisen kehittämiseen ainelaitosten rinnalla. Esimerkiksi seuraavat Aalto-yliopiston toiminnat on parasta järjestää erillisyksiköissä ainelaitosten tai tiedekuntien ulkopuolella:

- kalliiden, pitkäjänteisiä investointeja vaativien ja/tai useita ainelaitoksia, tiedekuntia tai yliopistoja palvelevien infrastruktuurien kehittäminen ja ylläpitäminen,
- tutkimus nopeasti kehittyvillä monitieteellisillä laitos-, tiedekunta- tai yliopistorajat ylittävillä tutkimusalueilla ja
- laajat kansainväliset, kansalliset ja/tai alueelliset erikoistehtävät.

Erillisyksiköt ovat osoittautuneet erittäin tehokkaiksi myös seuraavissa tehtävissä, joissa ne voivat tarjota mallia ainelaitoksille ja auttaa omalta osaltaan Aaltoa nousemaan ripeästi merkittäväksi yliopistoksi maailmassa:

- matalan hallintorakenteen organisoinnissa,
- tieteellisen johtoaseman saavuttamisessa,
- ulkopuolisen rahoituksen hankinnassa,
- nopeissa avauksissa uusille monitieteisille tutkimusalueille,
- suurten kansallisten ja kansainvälisten tutkimusprojektien koordinoinnissa,
- monitieteisten maisteriohjelmien ja tohtorikoulujen koordinoinnissa,
- kansallisten ja kansainvälisten verkostojen luomisessa,
- yksittäisten Aallon tutkijoiden sitomisessa tiiviiksi osaksi yliopiston verkostoa ja
- yliopistojen nk kolmannessa tehtävässä eli yhteiskunnallisessa vaikuttavuudessa.

Ehdotuksia Aalto-yliopiston erillisyksikköpolitiikaksi

Erillisyksikköjen johtajat ovat syvästi huolissaan yksikkönsä ja sen henkilökunnan asemasta uudessa Aalto-organisaatiossa. He korostavat, että:

- HSE:n, TaiK:in ja TKK:n nykyisiä erillisyksiköitä ei ole perustettu sattumalta, vaan niiden syntyyn löytyy vahvat historialliset syyt. Niiden aseman muuttamiseen Aalto-yliopistossa täytyy löytyä vahvat perustelut.
- Uusien rakenteiden (mm. factoryt) lisäksi Aallon pitäisi hyödyntää erillislaitosten kokemus ja saavutukset monitieteisen tutkimuksen alueella. Uuden rakentamiseen liittyvän innostuksen vallassa käy helposti niin, että olemassa olevaa osaamista ei huomioida vaan lähdetään keksimään pyörää uudelleen.
- Erillisyksikköjen rooli ja asema Aallon organisaatiossa pitää käsitellä yksilöllisesti, harkiten ja hätiköimättä. Keskustelut erillisyksikköjen asemasta täytyy kuitenkin käynnistää alkukevään 2010 aikana, sillä vallitseva epätietoisuus ja erilaiset huhut rasittavat henkilökuntaa suhteettomasti.
- Aallon tenure track pitää ulottaa erillisyksiköihin. Muuten niiden huippututkijoiden rekrytointi ja ulkopuolisen rahoituksen hankinta kärsivät. Erillisyksiköissä toimiville professoreille pitää sallia yksikön tarpeet huomioonottaen joko tutkimus- tai opetuspainotteinen toimenkuva. Helsingin yliopiston nykyinen johtosääntö mahdollistaa professorien rekrytoinnin myös erillisyksiköihin.
- Erillisyksiköiden vaativimpiin erityistehtäviin tarvitaan myös ammattitutkijoita, jotka on sijoitettu senior scientist –urapolulle. Senior scientist -urapolku on tärkeä esimerkiksi suurten infrastruktuurien toiminnan kehittämisessä ja ylläpitämisessä.
- Erillisyksikköjen arvioinneissa käytettävää mittaristoa pitää kehittää niin, että ne huomioivat entistä paremmin näiden yksiköiden erityispiirteet.

Huomioita erillisyksikköjen kustannus- ja rahoitusrakenteesta

Infrastruktuurien, kansallisten ja kansainvälisten verkostojen ja muiden erityistehtävien kehittäminen ja ylläpitäminen rasittaa erillisyksikköjen kustannusrakennetta. Samalla useimmat erillislaitokset toimivat suurelta osin ulkoisella rahoituksella, mikä lisää projektien valmistelukustannuksia ja omarahoitusvaateita. Lisäksi esimerkiksi EU-hankkeiden rahoitusriskit ovat oleellisesti suuremmat kuin akateemisessa perustutkimuksessa.

- Erillisyksikköjen rahoitus on turvata myös siirtymävaiheessa. Eräiden erillisyksiköiden kansallisiin erityistehtäviin saama OPM:n korvamerkitty rahoitus on siirretty Aallon kokonaismäärärahaan. Aallon on huolehdittava OPM:n aiemmin korvamerkitsemän rahoituksen kohdentamisesta edelleen erillislaitoksille.

- Erillisyksikköjen nopeaa siirtymistä uusille monitieteisille aloille kannattaa tukea myös strategisen lisärahoituksen avulla, sillä nämä yksiköt ovat osoittaneet että sijoitetut panostukset on käytetty poikkeuksellisen tehokkaasti.

APPENDIX 2

Aalto University
Research Assessment Exercise 2009

Panel Reports

HSE TAIDETEOLLINEN KORKEAKOULU TKK

Low Temperature Laboratory, TKK

Frequently used abbreviations:
TKK – Helsinki University of Technology; LTL – Low Temperature Laboratory; PRU – Physics Research Units in LTL; BRU – Brain Research Unit in LTL; ULT – Ultralow Temperature Physics; MEG - Magnetoencephalography.

All numbers are for the full period of assessment, 01.01.2003 to 31.12.2008, unless stated otherwise.

1. Introduction and General Impressions

The LTL is doing research in the following three main areas:

- Ultralow temperature physics (since 1965; 20%; presently mostly liq./sol. He),
- Neuroscience (since 1980; 45%; presently mostly brain research),
- Quantum Electronics (since 1996; 30%; mostly nano- and microelectronics).

In all these areas, their results had and have substantial impact on the development of the field. The LTL is among the leaders worldwide in these areas and in several subareas they are the world-leaders. Consequently, "LTL Helsinki" has become an internationally well known trademark with high reputation in low-temperature condensed matter physics, in low-temperature quantum electronics as well as in brain research and instrumentation for it. The introduction of research on quantum electronics (mostly at the expense of ultralow temperature physics) by the new director when he started in 1996 has successfully opened a new, very promising research area, which is on top of the agenda in science worldwide, in Finland, and at TKK. The research at PRU is distinguished by the successful combination of theory and experiment (in particular for the helium and nanoscience projects) as well as strong equipment building efforts. In the BRU groups, the research is distinguished by cooperation of scientists with quite different experience (physicists and physicians; neuro-signal analysis and instrumentation scientists). There is fruitful cooperation within LTL and there are intensive and successful international cooperations.

The LTL has a highly motivated research staff of very high qualification on an international level. Structurally, the laboratory occupies a somewhat unusual separate

status and role within the university, which might be considered carefully in the strategic planning for the new Aalto University construct. The research infrastructure, partly home-built and partly unique, is at a high technical level but, of course, needs regular reinvestments to stay on top. The LTL performs very successfully as indicated by several indicators (publications, invitations and elections of staff members, external funding, etc); for details see below.

2. The Unit's Research and the Research Strategy of the Unit's Home University

The research topics of the LTL are mostly oriented on important, acute basic science goals, but also partly towards technological innovations and in priority areas of the home institution as well as of the country. The scientific results are at a very high international standard and are published in leading international journals. The LTL fully meets the general strategy of TKK as outlined in the "Executive Summaries":

- "...a strong commitment to high-quality research and education and close cooperation with industry. "
- "...research in all fields has to meet international standards and the University values and promotes excellence in research. "
- "...gives particular weight to research on the focus areas of Strategic Centers for Science, Technology and Innovation...".
- "...has stressed the importance of producing internationally peer-reviewed publications...".

Furthermore, research and development in the BRU groups cover important parts of the TKK's contribution to the national priority area of Health and Welfare. The work on quantum electronics in the PRU plays a leading role in the present priority area of TKK for Micro- and Nanotechnology.

3. Scientific Quality of the Unit's Research

Numerical Rating (1-5): **5** Outstanding International Level

The excellence in research of LTL is demonstrated by its leadership in a substantial number of important, highly up-to-date areas, both in basic science, partly close to applications as well as in instrumentation. In the latter, developments of LTL have opened new research areas for themselves as well as for other groups; examples are the first combination of superconducting magnets and dilution refrigeration for developing adiabatic nuclear refrigeration to a now almost routine technology (in about 50 laboratories worldwide) and the development of whole-head neuromagnetometers (in about 120 laboratories worldwide). In research, LTL had achieved many "Firsts", like the demonstration that the new phases of liquid 3He are indeed superfluid and the investigations of nuclear magnetic ordering in metals at extremely low nuclear-spin

temperatures (high nuclear polarization) as well as many observations in human brain imaging and functioning.

Presently, the PRU of LTL is the world-leader, or at least among the "top 3", in the following research areas:

- Studies of vortices and their dynamics in rotating superfluid 3He at ultralow temperatures with several new discoveries like vortex sheets, double quantization of circulation, as well as on turbulence; first rotating submillikelvin cryostat; results have impact on understanding of p-wave superconductors and Bose-Einstein-condensates (see their reviews Finne et al., Rev. Mod. Phys. 69, 3157(2006) and Rep. Prog. Phys. 69, 3157(2006); Eltsov et al., Prog. Low Temp. Phys. (2005), (2009)),
- Studies of the surfaces of crystalline 4He and 3He (and its interfaces with superfluid 3He) (see their review Balibar et al., Rev. Mod. Phys. 77, 317 (2005)),
- Superfluid 3He as a laboratory to study cosmology (see book by Volovik "The Universe in a Helium Droplet", Clarendon Press 2003)),
- Low-temperature quantum electronics; in particular nano-thermometry, micro-refrigeration and metrology; combination of very-low-temperature physics and nanotechnology; single-electron-transistors (see their review Giazotto et al., Rev. Mod. Phys. 78, 217 (2006)).

Some of the important achievements of the BRU of LTL which puts this unit into a worldwide outstanding position are:

- Development of MEG from a research tool to clinical applications; first whole-head neuromagnetometer, now with 306 channels; combination of MEG and 3-Tesla-fMRI,
- Use of MEG in neuroscience in perception and cognitive processes; for example, in language processing in the brain (see their review Salmelin et al., Trends in Cognitive Science 10, 519(2006)), and interaction between persons (faces recognition) as some of the highlights.

The high qualification and international standing of the staff is indicated by elections to national and foreign (3) academies, by high-prestige international awards (3), as well as by the memberships in important international boards and panels, by one ERC Advanced Grant and two ERC Starting Grants for two postdoctoral researchers in 2009 (out of 154 applicants). In addition, at present, 4 staff members have been Academy Professors. The high international reputation of LTL is also indicated by the large number of foreigners among its doctoral students (25%, but all in PRU) as well as among its postdoctoral researchers (43%).

The Laboratory, in particular the PRU, attracts regularly leading international scientists as visitors (nobel laureates, vice-president Russian Acad. Sciences, academicians); a substantial number of speakers in their weekly seminars are from abroad. The Laboratory also organizes regularly international conferences.

4. Scientific Impact of the Unit's Research

Numerical Rating (1-5): **5** Outstanding International Level

The quality of research in the LTL is indicated by the number and in particular the quality of publications. Since 2003 there have been 5 articles in *Nature* and *Science*, 3 review articles in *Review of Modern Physics* and many articles in *Physical Review Letters* published by the PRU. The BRU has published a substantial number of articles in the prestigious *Proc. Nat. Acad. Sciences USA* as well as 2 invited review articles; 8 out of the 20 most cited MEG-related publications are from LTL! Furthermore, more than half of the publications are with foreign co-authors. Publications from LTL often had a significant impact on the development of their field.

The Laboratory has been able to substantially increase both its State Funding (about double from 2003 to 2008) as well as its External Funding (mostly from the Academy of Finland), (about plus 1/3 from 2003 to 2008; now about 65% of total according to verbal information). There has been a continuous decrease of EU funds since 2006 to the rather low value of 0.3 M€ in 2008. However, according to verbal information the EU funding is expected to increase to about 10 M€ for the next 5 years (the 3 ERC grants mentioned above amount to 5 M€ for 2009 to 2014 already). Surprisingly, there has been no funding from Tekes since 2006.

The Laboratory has a very good record in placing its graduates as postdoctorals abroad (8) or in the private sector (8), and its postdoctorals in leading positions in industry (10) as well as in foreign universities and research institutions (9).

The Laboratory has been very successful in attracting and hosting national and international Centers of Excellence and networks. The LTL research unit has been a National Center of Excellence from 1995 to 2005. Both the PRU as well as the BRU are coordinating National Centers of Excellence from 2006 to 2011. Furthermore, the Cryohall, the Micronova, and the Neuroimaging installations are – as the only TKK infrastructures – on the map of the 22 Important National Infrastructures. The ULT unit in the PRU and the Brain Research Unit are funded by the European Union as EU Research Infrastructures, Transnational User Facilities or EU-Networks from 1995 to 2013 and 1995 to 2003, respectively.

Senior staff members of LTL have occupied a number of leading positions in international professional associations (Chairman IUPAP Commission on Low Temperature Physics and ERC Starting Grant Commission) as well as in international evaluation committees (Ecole Normal Superieure, Riken, Japan; Welcome Trust, UK; etc), in selection committees for

international awards, or have participated in evaluating research proposals (NSF, ESF, ERC, Royal Society) or in committees for filling professorships abroad. They are regularly invited speakers at international conferences (some of them of order 100 times) and have organized those conferences. They are also regularly asked to act as referees for the leading journals in their field (*Nature*, *Science*, *Physical Review Letters*, *Neuroscience Letters*, *Brain Research*, etc) or have acted as editors (presently 2) or as members of editorial boards of leading international journals.

5. Societal Impact of the Unit's Research

Numerical Rating (1-5): **4** Very Good International Level

The Laboratory has a good record in starting companies. A key highlight in the successful transitioning of basic science to technology where the germinating seeds reach deeply to the early era of the LTL was the founding of Elekta Neuromag which is today the leading manufacturer of whole-head multichannel brain imaging neuromagnetometers (now exceeding 300 channels). The synergy in the development of this pioneering technology involved world-class research teams at TKK, Neuromag and the State Research Centre VTT, and has installed them in more than 40 out of about 120 relevant institutions worldwide. The unit also provides equipment and training for clinical MEG applications. Other successful spin-off companies with a product on the market are Picowatt (before 2003), Nanoway Electronics and BlueFors Cryogenics (since 2003). Furthermore, there seems to be a substantial application potential in the Single-Electron Devices developed at LTL within several cooperations as a very sensitive detector of electronic charge. The LTL provides low temperature technology to 10 groups working at the other departments of TKK, at the National Metrology Institute Mikes, and at the Helsinki University Hospital District. Presently, the Laboratory has 3 contracts with 2 private companies (Nokia, Neuromag) and with Mikes, contributing 250.000 € annually to its budget. Only four patents were granted to the institute.

6. Research Environment at the Unit of Assessment

Numerical Rating (1-5): **4** Very Good International Level

In general, the number of scientific and technical staff members seems to be adequate for achieving the research goals. It is providing a good student/staff ratio, in particular when taking into account that the scientists have essentially no lecturing duties so they can fully concentrate on their research and on supervision of graduate students. However, the Laboratory needs more administrative support from the university administration and also more administrative staff within the LTL; for example grant managing and budget managing officers. This would reduce the administrative duties of the researchers connected with external fund raising and managing.

The percentage of foreigners among graduate students, postdoctorals, and senior researchers is presently 43(0), 43(38), 62(0) % in the PRU (BRU). Moreover, the diversity of the nationalities of the foreign staff appears to be somewhat limited. Among the high percentage of senior researchers in the PRU, only 3 out of 8 of group leaders are foreigners. In the 3 weekly seminars for the 3 major research areas of LTL, about half of the speakers in the PRU are foreigners. Both, the ultralow temperature as well as the brain research installations were supported by the European Union as transnational access sites which has opened the installations to and has financially supported substantial numbers of foreign groups as users. These are all important indicators for the international research leadership of LTL, of a good selection of important and promising research directions, as well as of an attractive and stimulating research atmosphere; this was stressed by the postdoctoral researchers and graduate students of LTL.

The work at LTL has from the beginning been strongly benefited from in-house development of sophisticated research instrumentation (dilution and nuclear refrigerators; low-temperature electronics; neuromagnetometers). This instrumentation has been put in use by other groups later on and had a substantial impact on the particular field of research worldwide. The Cryohall installation is offering an outstanding combination of equipment for research at ultralow temperatures. This applies as well to the unique installations of the BRU for MEG, including also equipment for fMRI and for stimulation. Of course, all these leading LTL installations need regular upgrading and innovation to stay among the leaders worldwide. In addition, LTL groups are essential partners in using the Micronova and Advanced Imaging Center of TKK. As mentioned above, LTL has been very successful in establishing National Centers of Excellence and securing positions on the National Map of important research installations. At the same time, the special status of the unit within TKK may have somewhat inhibited its potential maximal impact on the university community as a whole.

7. Future Potential of the Unit of Assessment

Numerical Rating (1-5): **4** Very Good

Based on:

- The qualification, experience and international reputation of the staff (partly with international background in the PRU),
- The numerous international cooperations,
- Its partly unique equipment,
- The proper attention to application and technology transfer,

It is obvious that, if a suitably far-sighted and specific strategic plan is developed, the Laboratory can become one of the flagships of research within Aalto University and will thus be able to continue a leading international role within all of its major research areas.

The Laboratory's proposed planning for the near future includes the following directions:

- Ultralow temperatures: Use of the unique rotating microkelvin cryostat (for studies of superfluid turbulence, for example). Then, in particular, two very promising possibly high-risk but surely high-gain experiments: search for superfluidity of 3He in 3He - superfluid 4He mixtures (would be a very fundamental discovery of two quite different, interpenetrating superfluids sought for by simpler approaches since about 2 decades by several groups) and surface waves at interfaces of superfluid and nuclear magnetically ordered solid 3He (would be first observation of combination of mass and magnetization waves). These are experiments which can be attacked at less than a handful of laboratories worldwide.

- Quantum Electronics: Check of the values of fundamental constants via a consistency check of results from measurements of Josephson Effect and Quantum Hall Effect as well as Single-Electron-Tunneling (a promising speciality of LTL), ("Quantum Metrology Triangle"). This is an important problem which can be and is otherwise only tackled by two or three of the leading national metrology institutions worldwide.

- Brain Research: This unit will continue to use their outstanding instrumentation and experience to the following promising, partly high-risk projects in brain research: combining temporally accurate MEG and spatially accurate fMRI, study of subjects under increasingly natural conditions, and, in particular, "two-person neuroscience".

All these projects are of high scientific and partly also of societal relevance, if implemented with a strategic view and vision which may need further thought and consideration. The translation of the existing expertise to continued leadership is then facilitated to keep research in low-temperature sciences, basic and applied, at a level that can only be performed at very few places worldwide. Their impact might be even more substantial and increase the effectiveness of resources with some possible strategic coupling within TKK with its other departments, such as the areas that involve nanoelectronics (with e.g. the Appl. Phys. Dept.) and the brain science areas (with Dept. of Biomedical Eng. and Comp. Sc.).

The successful activities of LTL in attracting promising foreign graduate students and postdoctoral researchers, particularly in PRU, even in an increasingly competitive environment should be supported and possibly more extended to the range of senior researchers with wider geographic distribution than today.

The LTL will substantially contribute to the joint efforts on brain research in the Aalto University. Actually, the BRU is already leading and coordinating the first specifically supported common project aivoAalto of the three founding schools of Aalto University. It seems to be a very exciting but somewhat risky project, focusing on the brain function during social interaction, decision making and cinema; the project is supported with 5 M€ for a 5 year period. The Laboratory may also act as a model for National Research Centers. Otherwise, the Laboratory may in particular benefit from the more autonomous

management and altered financing and funding system in Aalto University, as well as from a tenure track career system for young researchers. The new university may make it even more attractive for foreigners to work at LTL. The Laboratory will surely substantially contribute to the requirement laid down in the Charter of Foundation of Aalto University that its "activities are based on top-level research" (with regard to the international level).

8. Panel's Recommendations for the Future

Because of its excellent human and instrumentation resources and of its experiences, the Laboratory is encouraged to continue to look for outstanding high-risk / high-gain experiments which can hardly be done somewhere else. Conversely, important opportunities exist for the LTL to share its world-class expertise and knowledge more directly within both the TKK and the new Aalto University.

Presently, all three major research areas of LTL tackle very interesting and promising science problems, partly with application possibilities. They will keep the quantum electronics and the brain research groups busy and on top of their field for a long time. For the ULT groups strategic scientific planning for the future, when the present helium experiments reach their summit, might be appropriate.

An important step for the future of the Laboratory will be the search for a new director in several years. This again should be used for a critical review of the future prospects of present research projects and of the possibility to enter new promising research area(s). The Laboratory may consider keeping some of the positions which will become vacant within the coming years open for this step.

Besides improving its financial basis by the new, promising funding possibilities in Aalto University, the Laboratory should be encouraged to apply for Tekes funding which ended in 2005. Also, it seems that more of the research results might be a basis for applying for patents (only 4 in 2003 to 2008).
Increased integration within TKK and Aalto University will benefit both the LTL and the broader community of the new university and should be encouraged. Such coupling, if done rationally, and with proper care, to maximize future potential while maintaining overall scientific excellence should help the LTL community to remain invigorated and avoid potential pitfalls that can ensue from any possible partial isolation. Conversely, the LTL has much to offer to TKK and the Aalto community from more direct interactions than it is perhaps presently the case. For example, the LTL may consider getting more involved in teaching, in particular in graduate courses. This could partly be done together with other departments, for example, the Dept. of Applied Physics, the Dept. of Micro- and Nanosciences, or the Dept. of Biomedical Engineering and Computational Science. To reiterate, these common teaching activities may also intensify communication and cooperation with groups from other departments and may be a step to integrate the LTL more as a regular institute into Aalto University. Such interactions might even evoke discussions concerning a merger of the Brain Research Unit of LTL with the Dept. of

Biomedical Res. and Comp. Science. Such a merger in a few years appeared to be quite reasonable to the Panel because the excellent work of the two units complement each other very well; it may open new possibilities and could strengthen the scientific impact of both partners.

The outstanding achievements of the Low Temperature Laboratory, which are partly fascinating for the laymen as well, might be more popularized by inviting the public more regularly (more groups of high school students, open-door days with hands-on demonstrations, etc.) or writing popular articles to make the Laboratory even more visible.

Some further recommendations have been included in former sections.

APPENDIX 3

3rd Report of the Scientific Advisory Board of the Center of Excellence in Low Temperature Quantum Phenomena and Devices

We thank the Low Temperature Laboratory (LTL) for hosting an efficient and well-organized meeting of the Scientific Advisory Board (SAB) with many of the principals of the Center of Excellence (CoE) during our all-day visit to TKK on November 12, 2009. Observers in attendance were: Pasi Sihvonen, Science Advisor of the Academy of Finland; Outi Krause, Vice-Rector TKK; Heikki Mannila, Deputy President Aalto University; Aarne Oja, Research Director, VTT; and Jussi Tuovinen, Research Director, VTT.

The CoE is organized in seven focused research groups/teams, ROTA, μKI, NANO, PICO, KVANTTI, QUANTRONICS, and THEORY. In the following we offer comments on the past and future activities of these groups as part of the CoE. We will close with a summary and a brief discussion of broad issues relevant to the entire Center.

The SAB, where William Halperin of Northwestern University (USA) has replaced John Saunders since its last report, was provided with both the original CoE proposal (2005) and the current Activity Report and Research Plan 2008-2011. The latter document, dated November 6, 2009 and prepared by Mikko Paalanen, Director of the CoE, contains the two reports of the SAB written after its prior reviews of the Center (2007, 2008) and a response from the CoE to comments made by the SAB in their 2008 report.

Scientific Activity

The move of the LTL to its current location, in a then newly renovated building, began in November 2007, i.e. almost exactly two years ago. This has significantly interrupted all the experimental programs that have now been relocated. Especially affected are those facilities that have demanding requirements to provide extreme conditions such as ultra-low temperature, ultra-small heat leaks, ultra-low noise, protected electromagnetic environments, and experimental conditions maintained under controlled rotation. It is expected that these capabilities will only be fully restored a month or so after our site visit took place and that normal productivity will not resume until soon thereafter. The SAB finds, however, that all of these efforts are on a reasonable timeline based on similar experiences for such disruptions at other laboratories.

ROTA group

This group is the world leader in studies of ^{3}He superfluids under rotation. The technical capability for such ultra-low temperature studies exists at only a few outstanding institutions including the Institute for Solid State Physics at the University of Tokyo, the Low Temperature Laboratory at RIKEN in Japan, the University of California at Berkeley, and the University of Manchester. Previous seminal contributions from the Helsinki laboratory include work on vortex generation, phase diagrams, and structure and connections to models of the early universe. In this research it is notable that there is very close involvement with other low temperature research groups around the world whose research does not use the rotation technique but depend on such experiments for a

comprehensive picture of quantum turbulence and vorticity in condensed systems. These laboratories include the University of Lancaster, CNRS/ CRTBT Grenoble (now Institut Néel), the Kapitza Institute for Physical Problems in Moscow, Osaka City University, Charles University in Prague, and less directly many other institutions with theoretical and experimental research efforts in a number of areas such as vortices in ultra-cold Bose and Fermi condensates of atomic gases. The accomplishments of the Helsinki experimental group, directed by Krusius, are also intimately connected with, and amplified by, the theoretical efforts of Volovik, Kopnin, and Hänninen from the THEORY group of the CoE and their collaborators including Thuneberg at the University of Oulu. Most importantly the ROTA group has of late directed its research toward problems in quantum turbulence. Past accomplishments in this area have been summarized in their recent review in *Progress in Low temperature Physics*. Numerical simulations performed within the group are extremely valuable giving a detailed interpretative framework. Future efforts will be directed toward the fundamental problem of the nature of energy dissipation associated with vortex dynamics in the zero temperature limit using direct probes of quasiparticle generation and NMR characterization of vortex tangles.

μKI group

Moving to the new facilities in Nanotalo it was decided to merge the two ultra-low temperature efforts INTERFACE (interfaces of quantum crystals) and YKI (ultra-low temperature condensations), which are now collectively referred to as μKI under the direction of Tuoriniemi and Todoshchenko. Important recent work includes establishing the platform and protocol for cooling helium isotopic mixtures to unprecedented low temperatures using a novel adiabatic melting scheme to look for condensation of a degenerate dilute Fermi liquid (YKI), observation of superconductivity in lithium metal (YKI), direct observation of magnetic steps at the ^{3}He quantum solid surface associated with nuclear spin ordering at the surface (INTERFACE), and search for evidence of a phase transition to a supersolid state in pure ^{4}He (INTERFACE). The old interfaces cryostat was decommissioned and the ambitious plans for future work are being prepared first for the mixture experiment on the powerful YKI cryostat, to be followed by experiments on crystallization waves at very low temperatures. This program encompasses the long-range vision and ambitious programs characteristic of the LTL. It is clearly the world leader in this area. The only drawback of this program is that we anticipate a more extended time frame for performing the experiments in the planning stages, as compared to prior to the merger. It is not healthy for graduate students to have too long delays in their projects.

NANO group

This group does frontline research on mesoscopic quantum amplifiers, current fluctuations (noise) and fast electron dynamics in phase coherent systems, as well as on quantum transport in carbon nanotubes and graphene. A recent highlight is their work on shot noise in graphene. The group's expertise, especially in the challenging microwave-frequency measurement techniques necessary for most of their work, makes them an attractive partner in international collaborations. A recently completed EU-STREP project, coordinated by Hakonen, resulted in record-breaking, single-walled carbon

nanotube, radio-frequency, single-electron transistors and nanotube field-effect transistors. The recent arrival of Sillanpää with his ERC Starting Grant will put a further emphasis on studying nanomechanical and nanoelectromechanical systems (NEMS) in the quantum limit (it does seem wise to have him join the existing NANO group rather than burdening him with administrative work that would go into setting up his own group). The planned effort is very timely and highly interesting but one where there is a lot of international competition. However, the combined experience of Hakonen and Sillanpää makes us think the chance for success is high. Some future work on superconducting NEMS involving graphene will be done in collaboration with Cornell University (Craighead and Parpia). Work on suspended graphene structures is planned in a new EU project that also involves Nokia and another European (ESF) collaborative project on entangled spin pairs in graphene. This is expected to start in the spring of 2010. The increased effort in graphene research reflects a current trend in the community. NANO is a solid group with excellent international contacts.

PICO group

This group is at the international forefront in metrology applications of quantum devices in general and world leader in the fields of nano-thermometry and micro-refrigeration in particular. Early results on thermometry and refrigeration were summarized in an article they published in *Reviews of Modern Physics* 2006. Progress since the previous SAB report include: in thermometry – an improved tunnel-junction-based primary thermometer for the sub-kelvin to the ≈ 77 K regime; in microrefrigeration – demonstration of single-electron radio-frequency refrigeration by applying an AC gate voltage to a hybrid normal metal/superconductor tunnel junction; in metrology – a better hybrid single-electron turnstile device that takes them closer to realizing a new current standard (for the ampère) by achieving larger currents (above 100 pA) and a better understanding and control of parasitic contributions to the current. Since 2008 the group has published these and other results in an impressive number of papers in good journals, including ten in Physical Review Letters and one in Nature Physics. The group has good theoretical support, both from the THEORY team (Heikkilä, Kopnin) and from outside theoreticians who visit regularly. They collaborate with the NANO and QUANTRONICS groups as well as with MIKES on various aspects of their research program. We are confident that this group, well managed by Pekola, will continue to produce results that are at the very forefront of the quantum device physics field.

KVANTTI group

This group was formed less than two years ago as the result of a serendipitous opportunity to hire Academy Research Fellow Paraoanu in January 2008. The group has responded well to concerns raised in the 2008 SAB report that it may end up spreading its limited resources too thinly if all the experimental and theoretical research projects described during that review were pursued. A more focused approach was recommended by the SAB and they were also encouraged to take advantage of the possibility to collaborate with other groups inside and outside the CoE. A year and a half later we note that this is precisely what has happened. The main focus is now on the study of entanglement and dissipation in superconducting circuits, where a noteworthy recent result obtained in collaboration with the NANO group and NIST (Boulder) is their

observation of the so called Autler-Townes effect – known from quantum optics – in an irradiated "artificial atom" formed by a superconducting Josephson phase qubit. Future plans also include work on nanomagnetism in collaboration with the Molecular Materials group at the Department of Applied Physics at TKK and Nokia. Here synergies with their work on qubits will be useful. We believe the group is now on the right track.

QUANTRONICS (VTT) group

The main role of the Applied Quantum Electronics Group at VTT in this CoE as we see it is to provide an interface between the basic and applied academic research of the LTL groups and industry. This is a role they perform well, e.g. collaborating with the NANO, PICO and THEORY groups on the realization of a quantum current standard, micro-refrigeration and THz radiation detectors. Even so, common publications and patents are rather few – two papers and one patent since 2008 (Seppä's 28 patents during the same period is a remarkable achievement). In addition, the CoE funding and the quite large matching funds from the VTT enable the QUANTRONICS group to put much more effort than would otherwise be possible into long-term research. Research is focused on the development of quantum circuit compatible superconducting electronics for computing and metrology and on superconducting detector systems. The group also works on room temperature applications of carbon nanotubes and metallic nanoparticles. A spinoff company, Aivon, has been established to commercialize SQUID developments.

THEORY group

Until about three years ago the theory programme of the LTL was entirely embedded in its experimental group structure. This changed in 2006 with the formation of the THEORY team under Academy Research Fellow Heikkilä. By establishing this new group the theory support for the NANO, PICO, and KVANTTI teams has increased significantly, while the QUANTRONICS group has also benefited. Local theoretical support for the ROTA group is provided by Volovik, Kopnin and Hänninen who do not seem to be formally integrated with Heikkilä's THEORY group. At least for the much more senior Volovik and Kopnin, this is probably just as well: perhaps also in Hänninen's case as long as he has other theoreticians to talk to on a regular basis. In-house theoretical support for the μKI team is not available but relies on short-term visits by Parshin from Moscow. We strongly support the recent increase of the theory effort of the CoE and were pleased to learn that two more postdocs (now one, recently hired) and two graduate students (now two) will join the THEORY group in the near future. This is possible through Heikkilä's prestigious five-year ERC Starting Grant (the only one granted for theory this year) and the Academy Postdoctoral Fellowship of the returning Ojanen, both beginning in 2010. These additions will make the THEORY group well balanced and it should probably not increase in size further without the addition of another senior scientist. In addition to having local theorists it is vital for the CoE to have a strong visitors program that also includes theoreticians. This may have become less easy now following expiration of the ULTI program (1994-2008), replaced by MICROKELVIN (2009-2013), which has a different character and only can support 1/3 as many visitor-months. Nevertheless, adequate funds for a vigorous visitors program should be found. We think Heikkilä could and should take on the challenge and responsibility to provide for a broad and increased theory program for the whole CoE in

addition to managing his own group and making sure that its members develop and sharpen the tools of their trade.

Questions put to the SAB in the Activity Report and Research Plan 2008-2011
The Director, Mikko Paalanen, has identified a number of issues that should be factored into future planning and he has asked for suggestions from the SAB. His questions to the SAB are paraphrased below followed by our suggestions.

Personnel critical size:
The Director has argued that the laboratory should be cognizant of new opportunities, reflecting current trends wherein international efforts in quantum fluids and solids have decreased, on the one hand, and that nanoscience and quantum devices, both mechanical and superconducting, are currently more in vogue and have increased on the other hand. Personnel changes over the past five years in the LTL and the CoE reflect this perspective. However, it is our recommendation that current staffing levels in each group be held at their current levels and distribution of effort. They are presently at threshold in each area with the exception of THEORY, which is subcritical. We note that the different group efforts presently represented in the laboratory cannot be evaluated with a common metric for productivity. It has become increasingly popular to use bibliometric data to rate researchers and research groups. This is dangerous for many reasons, one being that these data directly reflect the size of the community (which is why papers in biology get more citations than those in physics). Each of the group efforts in the LTL must be evaluated on the basis of their respective intellectual contributions to their different communities, judged on an international scale. For example the experimental research at ultra-low temperature proceeds on a different time scale as that of research on quantum coherence in superconducting cubits, but is nonetheless just as important. This is reflected in the comments below.

International postdoc and student recruitment:
The balance between postdoctoral and graduate student research must be determined by the individual group culture and dynamics. The SAB does not have specific suggestions on this topic with the exception of the following comments. The THEORY group needs to have a more active postdoc and visitor program. Secondly, the graduate program can benefit from formal course offerings in many-body theory and in advanced modern condensed matter physics. There may be opportunities to create distinguished teaching fellowships as part of the reorganization of the new Aalto University that could address both of these concerns. The absence of these basic components of the standard physics curriculum limits possible academic career opportunities of graduate students and makes the program less attractive to prospective students.

Two new cryogen-free dilutions:
The Director proposes two new cryogen-free dilution refrigerators for the cryohall. This will serve local, national, and international researchers. This plan fits well with a vision of the LTL and the CoE in promoting new scientific opportunities as a service to a larger community. The significance of cryogen-free dilution refrigerator stations is that it substantially reduces maintenance costs at a time when liquid helium prices are in-

creasing, which correspondingly puts pressure on the limited financial resources of small users at other institutions. However, it is our recommendation that this outreach effort be conducted with full consideration of the local laboratory needs, in addition to the altruistic motivation of serving a broader physics community. These refrigerators will, despite their being cryogen free, take personnel time for running and/or maintenance. Secondly, there is a rich tradition at the LTL of developing state-of-the-art low temperature technology. Technology infrastructure support should be directed toward innovation as well as service. The establishing of BlueFors Cryogenics in 2007 is an excellent recent example of how this can pay off. Here are some specific, but *ad hoc*, suggestions for possible directions for technical development: experimental capability for low temperature in extreme environmental isolation, to promote measurements of quantum coherence; development of dilution refrigerators with much less requirement for ^{3}He to help address a serious problem in its availability; and, low-vibration platforms on cryogen-free dilution refrigerators that might be used for ultra-low-temperature scanning microscopy and other mechanically sensitive instrumentation.

Helium liquefier, yes or no?
The calculation of cost benefit is complex and varies from one institution to another. Nonetheless, the two arguments for local supply and distribution of helium are decreased cost and less vulnerability to shortage in supply. In 2007 and 2008 the effect of a global helium shortage was felt acutely by small users as well as, to some extent, the LTL. Requirements for 30,000 liters/year for helium such as in the LTL are generally viewed as being at the level for which a local facility is cost effective. We would recommend that a serious evaluation of the feasibility for establishing a liquefier facility be immediately conducted and not postponed until the current liquid helium contract expires in 2012.

Independence of LTL (budget) within the new Aalto University structure:
There are a number of persuasive arguments for the LTL/CoE to continue with an independent budgetary structure, reporting directly to the office of the Vice-rector. This type of organization is more efficient for complex personnel management for which there is a common technical basis. It allows for quick response to funding opportunities requiring local commitments in space or manpower. The LTL has from its foundation been a model for successful administration of world-class research, which has brought great recognition to the Technical University of Helsinki. We conclude that the independence of the LTL logically could, and should, be maintained in the new Aalto University.

Teaching responsibilities of the faculty in LTL:
There are a number of reasons why the LTL members in the CoE should be more engaged in teaching. First and foremost the university's mission is education. Graduate advising is one important contribution that is conducted in the LTL with considerable distinction. However, teaching in more formal classroom settings is also an important and complementary component of university education. On a perhaps more pragmatic note, we understand that the Aalto University will introduce a new multi-step tenure track system leading ultimately to an appointment as professor. Promotion almost certainly

will require (undergraduate) teaching and excellence in its performance. It would therefore be a considerable advantage for the LTL if its scientists were offered the possibility to teach in order to facilitate their eventual promotion to professors (at the LTL or elsewhere). We note that courses in superconductivity and nano-electronics are offered in alternate years and we suggest that, e.g., this offering could be expanded. There are significant ways that the graduate curriculum might be enhanced to the benefit of graduate students in physics and in the LTL. Consequently, the SAB recommends participation in teaching activities should become a more common part of the laboratory's responsibilities, particularly if more faculty lines are added to the LTL/CoE group.

Summary

We conclude that this is a very successful CoE which is at the international cutting edge of research in both ultra-low temperature physics and quantum device physics. It gets high scores on each criterion applicable to the CoE programs including excellence in research and researcher training. In view of changing circumstances and fast moving research fields, important decisions have to be made all the time to keep this high level. In this report we have made a number of suggestions and recommendations, some of which we summarize below.

The size of the LTL groups of the CoE are on the threshold of being subcritical. In particular the down-sizing of the ultra-low temperature effort (ROTA and μKI) can not continue further without serious consequences. The THEORY group is at present not well-balanced, with too few postdocs (the several postdocs expected to join in 2010 will be a welcome addition). We would also like to see an even more active visitor program. The retirement of the present director in five years should be used as an opportunity to review the possibility to add or change a major research program (as has been done in the past). The review should not be postponed too long. Any major change would obviously be related to the choice of the new director, who could be appointed early and work in parallel with the present director to facilitate a change if there were to be one.

We strongly feel that the LTL should continue to be an independent unit in the new Aalto University, with its own budget.

We recommend that the CoE respond to the new multi-level tenure track system to be used in the Aalto University by getting more involved in teaching activities rather than trying to maintain a different structure for faculty positions than exists in the rest of the university.

We recommend an immediate feasibility study for establishing a helium liquefier facility rather than waiting for the current helium contract to expire in 2012.

We support the director's proposal to acquire two new cryogen-free dilution refrigerators for the cryohall in order to serve local, national and international researchers, and to develop new world-class, cryogenic technologies.

Evanston, 21 December 2009 — Gothenburg, 21 December 2009

William Halperin — Mats Jonson

Evaluation Report for the Centre of Excellence for Systems Neuroscience and Neuroimaging

Centre of excellence programme 2006-2011
Centre of excellence on systems neuroscience and neuroimaging Scientific Advisory Board (SAB) meeting, ***November 3rd 2009***

SAB Members

Prof. Chris Frith (University College London, UK)
Prof. Nikos Logothetis (MPI Biol Cybernetics, DE)
Prof. Denis LeBihan (NeuroSpin, F)

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Prof. Mikael KNIP (Academy of Finland)
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Vice Rector Outi KRAUSE (TKK)
Prof. Olli JÄNNE (University of Helsinki)

General Information

The Centre of Excellence (CoE) at the Helsinki University of Technology (TKK) was selected by the Academy of Finland for the years 2006-2011. The center combines basic and translational research using a variety of methodologies. Its aim is to better understand brain function and dysfunction by means of an integrative approach, including the most advanced methods of spatiotemporally resolved non-invasive human neuroimaging.

Currently the centre comprises four units, the Brain Research Unit (BRU) of the Low Temperature Laboratory (TKK); the Advanced Magnetic Imaging Centre (AMI), TKK; the Department of Electronics, Faculty of Electronics, Communications and Automation, TKK and the Neuroscience Unit (NSU), Institute of Biomedicine/physiology, University of Helsinki. BRU has been the world's leading centre for magnetic encephalography (MEG) for more than 20 years, and is currently hosting a 306-channel neuromagnetometer. AMI is equipped with a 3-T functional magnetic resonance imaging (fMRI) facility, which is fully functional.

The current evaluation corresponds to the third quarter of the funded period. The role of the advisory board is to offer constructive criticism and make recommendations related to both the scientific program and the administrative/strategic organization of the centre. To enable the evaluation of CoE has provided a written report, five presentations by senior faculty members, i.e. by Drs Riitta Hari, Simo Vanni, Synnöve Carlson, Riitta Salmelin, and Raimo Sepponen, and two presentations by PhD Students, namely by Annika Hultén and Ville Renvall.

Scientific activity, production and progress of the CoE

The SAB unanimously agreed that the scientific productivity and activity of the CoE members continue to be outstanding, with an impressive progress in the numbers of papers published or in press in the period of 2008 to 2009.

The centre undoubtedly remains an international reference for MEG, with state-of-the-art equipment and leading experts, including the connection to Elekta NeuroMag. Not surprisingly, the CoE continues to be internationally highly visible, and it is attractive for foreign post-docs and visiting scientists.

The outstanding technical expertise of the center is now used for further developing integrative methodologies, such as for instance combined MEG-MRI measurements, which go beyond the usual constraining of the ill-pose problem of the spatial localization of MEG sources. To be specific, the Salmelin group has started a series of experiments examining differences in the cortical representation of verbs and nouns, initially using standard functional MR imaging. When the experiments were repeated under identical behavioral and experimental protocol conditions, but with imaging performed using MEG, these investigators found similarities in the fMRI and MEG maps (as expected), but also some interesting differences that might help the judicious interpretation of either set of data. Similarities and differences between fMRI and MEG are also being explored by the Hari group in their studies of brain responses to faces. Work is also in progress using combined EEG-MEG and EEG-fMRI, with the same experimental design, to study in detail such differences that might selectively reflect stimulus-related feedforward neural processing and top-down, state-dependent processing respectively. In our opinion such efforts will yield invaluable findings that critically help the interpretation of neuroimaging data and form a unique and very important contribution of the CoE to the international scene.

Of great interest also are the efforts of the Hari group to fathom the neurovascular coupling by dissecting signal-aspects that are due to metabolic and hemodynamic changes from those that might originate from the MR technology itself. The novel and interesting finding of Renvall and Hari, regarding the origin of transient overshoots and undershoots in the fMRI signal, on the basis of their technical developments (e.g. development of physical “fMRI phantoms” in which the fMRI signals relying on the blood-oxygen-level-dependent (BOLD) contrast can be simulated by accurately controlling current flow within a conducting medium), is likely to help the estimation of BOLD response from the underlying neuronal activity.

In addition to technology related projects, the center continues to pursue a number of highly interesting research lines in the field of systems neuroscience, linguistics, and social neuroscience. The work of the Carlson group on the neural basis of top-down control of attention makes innovative comparisons between human and non-human primates. The vision group lead by Vanni, through the use of sophisticated psychophysical techniques, have been able to deploy fMRI to reveal basic neural mechanisms in visual cortex. Importantly emphasis is placed on both basic and translational research. Of great interest are the developments of the Sepponen group related to the design of tools for neurophysiological rehabilitation and research, and of portable devices for autoadaptive recording of auditory even-related potentials. The Sepponen group has a highly interesting research and development program, but it apparently (and unfortunately) lacks of resources (e.g. students and postdocs).

The CoE group has strong engineering and mathematical input from within a collaborative network, and has established research agreements with industrial units (e.g. Elekta-Neuromag) that permit knowledge and cutting-edge technology transfer.

Development of the CoE profile

Since the last report of the SAB the COE has developed a well focused portfolio of research projects and is developing a profile that is distinctly recognizable on the international stage. The CoE continues to conduct a wide range of research, but the current activities can be seen as concentrating on specific domains of cognitive and systems neuroscience as well as on methodology. CoE is a world leading institution on MEG. However, as briefly mentioned above, the investigators at the center correctly wish to extent the MEG-MRI approach into a method that can be used to disambiguate the interpretation of the activation maps obtained with the two neuroimaging approaches rather than simply enhance the spatial localization of MEG or improve the temporal resolution of fMRI. Such an approach should be commended and takes advantage of the unique strengths of the CoE. However, this approach ideally requires qualified MR physicists to work on the development of new pulse sequences, the optimization of existing acquisition protocols, and the successful combination of fMRI with other electrophysiological measurements. It might also require the application of parallel imaging or extensive post-processing that correctly evaluates signals (e.g. navigator echoes) for compensating for diverse movement artifacts, etc. Unfortunately the center appears to lack sufficient such personnel at present. This is a general problem for everybody in imaging due to the fact that the booming of fMRI science over the last 20 years has dramatically altered the demand-and-supply relation in MR physicists. This is a problem the COE is currently trying to address.

Institutional support

Since our last report the situation for PhD students has further considerably improved since there are now an appropriate number of postdoctoral fellows to provide the necessary intellectual support. The problem, found in many other high level research units, is that most staff are, at present, on soft money. There really should be more tenured posts to provide continuity in technical expertise and crucial core support. There is every hope that this problem can now be addressed through the CoE becoming part of the new Aalto University. We would strongly encourage plans to improve career opportunities of university personnel, including well-defined tenure tracks.

International visibility

The CoE continues to publish in top-quality, high impact journals. The senior investigators have undisputed recognition at the international level.

Researcher career development

Researcher Career development remains a significant concern. There seems to be a considerable shortage of tenure-track positions after post-doctoral studies. However, as we have already mentioned above, there is every hope that this problem will be addressed through incorporation with the new Aalto University

International and national cooperation

International and national cooperation continues to be excellent.

Impact on society

Many of the projects currently underway at the CoE have clinical aspects which are of direct relevance to society. Such projects include those on chronic pain, dyslexia and schizophrenia. Since our last report, the senior members of the CoE have taken considerable trouble to engage with the public. In particular, the "Mind Forum" is an excellent endeavor directed by Prof Hari. This discussion forum provides a model for public engagement that could useful be applied in other countries.

The future of the CoE

CoE is expected to continue producing high quality scientific research that can compete with that produced by similar units anywhere in the world. The SAB was particularly pleased to hear that now a renewal of the support of the Academy of Finland is possible, and it strongly recommends such an extension of funding as several outstanding projects are "under way" and promise excellent research and novel and exciting findings. The proportion of funds coming from the Academy of Finland remains small (~15%). However, Salmelin has received 5 years of support as Academy Professor (2006-2011), support which we have every expectation will be renewed. Hari will be receiving support as Academy Professor from 2010-14). In addition, the CoE has been very successful in acquiring external funding. In particular Hari has received a 5 year grant form the ERC for the study of 'two-person neuroscience'. The formation of the new Aalto University also provides opportunities for additional funding and there seems to be a strong possibility that long term funding can be obtained for the core facilities. In general the future of the CoE for the next 5 years at least seems assured.

In summary, this is an outstanding research centre and a worldwide reference. The new developments in organization and funding make us optimistic that the centre will continue flourish and become even more productive in the coming years.

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