ANNUAL REPORT
2007

HELSINKI UNIVERSITY OF TECHNOLOGY
Low Temperature Laboratory
Brain Research Unit and
Physics Research Unit
http://ltl.tkk.fi

Annual Report 2007
# Table of Contents

PREFACE ...................................................................................................................... 3

SCIENTIFIC ADVISORY BOARD .................................................................................. 4

PERSONNEL .................................................................................................................. 4

  ADMINISTRATION AND TECHNICAL PERSONNEL ........................................ 4

  SENIOR RESEARCHERS ....................................................................................... 4

  GRADUATE STUDENTS - (SUPERVISORS) .......................................................... 5

  UNDERGRADUATE STUDENTS .......................................................................... 6

  VISITORS ................................................................................................................. 7

INTERNATIONAL COLLABORATIONS .................................................................. 9

  ULTI - ULTRA LOW TEMPERATURE INSTALLATION ..................................... 9

WORKSHOPS ............................................................................................................. 10

LOW TEMPERATURE PHYSICS RESEARCH ............................................................ 11

  NANO group .......................................................................................................... 11

  PICO group ............................................................................................................. 18

  YKI group .............................................................................................................. 21

  ROTA group ........................................................................................................... 22

  INTERFACE group ............................................................................................... 26

  THEORY group ....................................................................................................... 29

BRAIN RESEARCH UNIT ............................................................................................ 37

TEACHING ACTIVITIES ............................................................................................ 47

  COURSES ............................................................................................................... 47

  RESEARCH SEMINARS ON LOW TEMPERATURE PHYSICS AND
  NANOPHYSICS ....................................................................................................... 47

  RESEARCH SEMINARS OF THE BRU ............................................................... 49

  SPECIAL ASSIGNMENTS .................................................................................... 50

  ACADEMIC DEGREES ........................................................................................ 51

  PH.D. DISSERTATIONS ........................................................................................ 51

TECHNICAL SERVICES .............................................................................................. 52

ACTIVITIES OF THE PERSONNEL ......................................................................... 54

PUBLICATIONS .......................................................................................................... 71

APPENDIX 1 ................................................................................................................ 79
PREFACE

In 2007 three significant events took place in the history of Low Temperature Laboratory (LTL): the move of the laboratory from the Physics building to Nano house, the graduation of the laboratory’s 100th PhD student, and the reorganization of the Helsinki University of Technology (TKK). Since 1965, LTL has occupied the basement of the Physics building. In 40 years the space became crowded and impractical for the new research directions of the laboratory. The renovation of the old, 1963-built Puulaboratorio, into a modern research facility called Nano house was started at the beginning of 2005, and finished by November 2007. The personnel of the LTL moved into Nano house on November 13, 2007, and the last pieces of heavy equipment were transferred in January 2008. The 2105-m² area of the new LTL is roughly half of the total area of Nano house, and about 50% more than the area of the old LTL.

The LTL has a successful record in PhD education. The 50th PhD graduated in 1994, 29 years after the start of the laboratory. Since then, it took only 13 more years to reach the graduation of the 100th PhD, Fan Wu from the Chinese Academy of Sciences in Beijing. The distribution of the 100 PhDs is the following: 58 of the doctors studied ultra-low temperature physics and cryoengineering, 34 neuroimaging and systems-level neuroscience, and eight low-temperature nanoelectronics. At the end of 2007, LTL had altogether 28 graduate students: 15 in brain research, eight in nanoelectronics, and five in ultra-low-temperature physics.

In fall of 2007, TKK reorganized its teaching departments into four faculties. The reorganization took place in anticipation of the Aalto University, the merger of three capital-area universities: TKK, Helsinki School of Economics, and the University of Arts and Design Helsinki. The LTL remained outside the faculty structure, staying as an independent research unit directly under the rector of TKK. Thus TKK expressed its interest in supporting excellent basic science even after the reorganization that aimed to emphasize the role of applied research.

The Scientific Advisory Board of the Center of Excellence (CoE) in Systems Neuroscience and Neuroimaging held its first evaluation meeting on May 14, 2007. The meeting was attended by two members of the SAB, Professor Chris Frith from the University College London and Professor Nikos K. Logothetis from the Max Planck Institute, Tübingen. The evaluation report can be found in Appendix 1.

In 2007 the Brain Research Unit of the LTL organized two closed scientific meetings: Mieli-forum I in August 16–18 and Mieli-forum II in November 22–24, both supported by the Finnish Cultural Foundation and attended by about 30 scientists.

In 2007 several scientists of LTL received national and international recognition. Matti Krusius was awarded an honorary doctorate in Physics in Lancaster University, UK. Grigory Volovik was elected to Leopoldina, the German National Academy of Sciences. Rob Blaauwgeers and Pieter Vorselman entered the national Venture Cup competition with their business plan BlueFors Cryogenics. In December 2007 they won one of the five 1st round Prizes, later in February 2008 one of the four 2nd-round Prizes, and finally in May 2008 placed 3rd in the final 3rd round competition.

Mikko Paalanen
Director of the 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. John Saunders, Royal Holloway, University of London, UK

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

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
Peter Berglund, D.Sc. (Tech.), Docent, Technical Manager
Rob Blaauwgeers, Ph.D., special equipment designer
Teija Halme, secretary
Antti Huvila, technician
Mia Illman, MEG technician/nurse, on leave 15.8.2005-
Arvi Isomäki, technician
Juhani Kaasinen, technician
Antti-Iivari Kainulainen, technical assistant
Helge Kainulainen, technician
Jari Kainulainen, MEG technician/nurse, laboratory assistant
Tuire Koivisto, secretary
Markku Korhonen, technician
Leena Meilahti, secretary
Pirjo Muukkonen, financial secretary
Liisi Pasanen, secretary
Petteri Räisänen, system administrator, from 18.10.2007
Veli-Matti Saarinen, project engineer
Ronny Schreiber, research engineer
Pieter Vorselman, project manager, from 1.3.2007

SENIOR RESEARCHERS

*Physics Research Unit*

Harry Alles, D.Sc. (Tech.)
Romain Danneau, Ph.D.
Vladimir Eltsov, Ph.D.

Annual Report 2007
David Gunnarsson, Ph.D.
Pertti Hakonen, D.Sc. (Tech.), Professor
Tero Heikkilä, D.Sc. (Tech.), Docent
Meri Helle, D.Sc. (Tech.), on leave from 25.4.2007
Risto Hänninen, D.Sc. (Tech.)
Nikolai Kopnin, Ph.D., Professor
Matti Krusius, D.Sc. (Tech.), Professor
Matthias Meschke, Ph.D.
Mikko Möttönen, D.Sc. (Tech.)
Teemu Ojanen, D. Sc. (Tech.)
Gheorghe-Sorin Paraoanu, Ph.D., from 1.11.2007
Jukka Pekola, D.Sc. (Tech.), Professor
Alexander Savin, Ph.D.
Alexander Sebedash, Ph.D.
Mika Sillanpää, D.Sc. (Tech.), from 16.7.2007
Igor Todoschenko, Ph.D.
Juha Tuoriniemi, D.Sc. (Tech.), Docent
Juha Vartiainen, D.Sc. (Tech.), until 7.10.2007
Grigori Volovik, Ph.D., Professor

Brain Research Unit

Riitta Hari, M.D., Ph.D., Professor, Head of the Brain Research Unit
Paolo Belardinelli, Ph.D., from 10.11.2007
Gina Caetano, D.Sc. (Tech.)
Nina Forss, M.D., Ph.D., Docent, part-time
Marja-Liisa Halko, Ph.D., part-time
Päivi Helenius, Ph.D. (Psych), Docent
Yevhen Hlushchuk, M.D., Ph.D.
Veikko Jousmäki, Ph.D., Docent
Jaakko Järvinen, Ph.D., Mind-Forum coordinator, from 1.3.2007
Erika Kirveskari, M.D., Ph.D., part-time, on leave from 1.1.2006
Catherine Nangini, Ph.D., from 13.8.2007
Tiina Parviainen, Ph.D. (Psych.), from 1.11. 2007
Elina Pihko, Ph.D. (Psych.), Docent, 1.9. – 31.10.2007
Tuukka Raji, M.D., Ph.D., part-time
Riitta Salmelin, D.Sc. (Tech.), Academy Professor
Mika Seppä, D.Sc. (Tech.), from 1.11. 2007
Päivi Sivonen, D.Sc. (Psych)
Simo Vanni, M.D., Ph.D., Docent
Minna Vihla, M.D., Ph.D., part-time, on leave from 9.6.2006

GRADUATE STUDENTS - (SUPERVISORS)

Physics Research Unit

Robert de Graaf, M.Sc. - (Matti Krusius)
Tommy Holmqvist, M.Sc. (Tech.) - (Jukka Pekola)
Heikki Junes, M.Sc. (Tech.) - (Harry Alles)
Antti Kemppinen, M.Sc. (Tech.) - (Jukka Pekola)
Lorenz Lechner, M.Sc. - (Pertti Hakonen)

Annual Report 2007
Jian Li, M.Sc., from 1.11.2007 - (Gheorghe-Sorin Paraoanu)
Teemu Ojanen, M.Sc., until 31.10. 2007 – (Tero Heikkilä)
Antti Paila, M.Sc. (Tech.) - (Pertti Hakonen)
Elias Pentti, M.Sc. (Tech.) - (Juha Tuorinimi)
Anssi Salmela, M.Sc. (Tech.) - (Juha Tuorinimi)
Jayanta Sarkar, M.Sc. - (Pertti Hakonen)
Roman Solntsev, M. Sc. - (Matti Krusius)
Andrey Timofeev, M.Sc. - (Jukka Pekola)
Pauli Virtanen, M.Sc. Tech. - (Tero Heikkilä)
Fan Wu, M.Sc. - (Pertti Hakonen)

Brain Research Unit
Linda Henriksson, M.Sc. (Tech.) - (Simo Vanni)
Jaana Hiltunen, Phil. Lic. - (Riitta Hari)
Annika Huitê, M.Sc. (Psych.) - (Riitta Salmelin, Matti Laine)
Jan Kujala, M.Sc. (Tech.) - (Riitta Salmelin)
Hannu Laaksonen, M.Sc. (Tech.) - (Riitta Salmelin)
Satu Lamminmäki, M.D., on leave from 21.6.2007 - (Riitta Hari)
Mia Liljestrom, M.Sc. (Tech.) - (Riitta Salmelin)
Sanna Malinen, M.Sc. (Tech.), on leave from 19.12.2007 - (Riitta Hari)
Lauri Parkkonen, M.Sc. (Tech.) - (Riitta Hari)
Ville Renvall, M.Sc. (Tech.) - (Riitta Hari)
Miiamaaria Saarela, M.Sc. (Phil.) - (Riitta Hari)
Linda Stenbacka, M.D. - (Simo Vanni)
Topi Tanskanen, M.Sc. (Psych.) - (Riitta Hari)
Johanna Vartiainen, M.Sc. (Tech.) - (Riitta Salmelin)
Nuutti Vartiainen, M.D. - (Nina Forss, Riitta Hari)

UNDERGRADUATE STUDENTS

Physics Research Unit
Kurt Baarman, until 20.5.2007
Petri Heikkinen
Jaakko Hosio
Laura Korhonen
Matti Laakso
Laura MacDonald, until 30.4.2007
Matti Manninen
Juha Muhonen, from 3.9.2007
Joonas Peltonen
Antti Puska
Juho Rysti
Olli-Pentti Saira, until 30.6.2007
Juha Salmilehto, 21.5.- 31.8.2007
Matti Tomi
Juha Voutilainen
**Brain Research Unit**

Maarit Aro  
Liisa Helle, 4.6.-18.9.2007  
Lotta Hirvenkari, from 2.5.2007  
Antti Jalava  
Saana Jenu, 4.6.-31.8.2007  
Marika Kaksonen  
Leena Karvonen, from 21.5.2007  
Lauri Nurminen  
Miika Pihlaja, until 20.5.2007  
Pavan Ramkumar  
Timo Saarinen  
Sini-Maaria Sipponen  
Antti Tanner, 21.5.-16.9.2007  

**VISITORS**

**ULTI VISITORS (LOW TEMPERATURE AND NANO PHYSICS)**

Bunkov, Yury, Prof., 22.2 - 28.3., 1. - 21.12., Institute Néel, CNRS, Grenoble, France  
Clovecko, Marcel, MSc, 15.1. - 6.4., Centre of Low Temperature Physics, Institute of Experimental Physics SAV, Košice, Slovakia  
Courtois, Hervé, PhD, 19. - 20.4., CNRS, France  
Cuevas, Juan Carlos, Prof., 26.2. - 2.3., Universidad Autónoma de Madrid, Madrid, Spain  
Denisov, Dmitri, PhD, 11. - 14.9., University of Oslo, Oslo, Norway  
Giazotto, Francesco, PhD, 2. - 5.1., 12. - 20.2, Scuola Normale Superiore, NEST-INFM, Pisa, Italy  
Galperin, Iouri, Prof., 25. - 31.1., University of Oslo, Oslo, Norway  
Golov, Andrei, Prof., 26.8. - 8.9., University of Manchester, Manchester, UK  
Guichard, Wiebke, PhD, 28.7. - 24.8., Joseph Fourier University, LCMI-CNRS, Grenoble, France  
Haley, Richard, PhD, 15. - 30.9., Lancaster University, Lancaster, UK  
Hekking, Frank, Prof., 4. - 11.8., Joseph Fourier University, LPMMC-CNRS, Grenoble, France  
Kohler, Sigmund, PhD, 21. - 25.5., University of Augsburg, Augsburg, Germany  
Pickett, George, Prof, 28.10. - 10.11., Lancaster University, Lancaster, UK  
Schoepe, Wilfried, Prof., 10. - 31.1, 11. - 30.11., University of Regensburg, Germany  
Sonin, Edouard, Prof., 6. - 7.5, 25. - 27.8., Hebrew University of Jerusalem, Jerusalem, Israel  
Tirelli, Stefano, M.Sc., 15.8. - 14.9., Scuola Normale Superiore, NEST-INFM, Pisa, Italy  
Tsepelin, Viktor, PhD, 18. - 24.2., 27.5. - 2.6., 10. - 22.9., Lancaster University, Lancaster, UK  
Zaikin, Andrei, PhD, 17. - 21.4., University of Karlsruhe, Karlsruhe, Germany  

Annual Report 2007
OTHER VISITORS

Armour, Andrew, PhD, 21. - 27.10., University of Nottingham, Nottingham, UK
Averin, Dmitri, Prof., 20. - 22.9., State University of New York, Stony Brook, USA
Belardinelli, Paolo, PhD, 20. - 22.8., 19.11. - 31.12., University of Chieti, Italy
Buckle, Phil, Prof., 19. - 20.4., Imperial College of Science, London, UK
Clark, Anthony, PhD, 17. - 19.12., Penn State University, USA
Cole, Jonathan, Prof., 5. - 9.6., Poole Hospital, UK
de Gelder, Beatrice, Prof., 20. - 22.12., MGH/MIT, USA & Tilburg University, The Netherlands
Foa, Luis, PhD, 16. - 19.12., Tech. Univ. Dresden, Dresden, Germany
Frith, Chris, Prof., 13. - 14.5., University of College London, UK
Gaass, Markus, MSc, 15. - 31.10., University of Regensburg, Regensburg, Germany
Godfrin, Henri, PhD, 4.12. - 6.12., Institute Néel, CNRS, Grenoble, France
Goebel, Rainer, Prof., 16. - 18.9. 2007, Maastricht University, The Netherlands
Kawabata, Shiro, PhD, 22. - 24.11., Chalmers University of Technology, Gothenburg, Sweden
Klapwijk, Teunis, Prof., 19. - 20.4., Delft University, The Netherlands
Kondo, Yasushi, PhD, 9. - 20.3., Kinki University, Osaka, Japan
Krompiewski, Stefan, Prof., 25. - 30.11., Institute of Molecular Physics, Polish Academy of Sciences, Poland
Lambert, Colin, Prof., 19. - 20.4., University of Lancaster, Lancaster, UK
Lebedev, Vladimir, PhD, Director, 4. - 7.2., 6. - 9.5., Landau Institute for Theoretical Physics, Chernogolovka, Russia
Lesovik, Gordey, PhD, 6. - 15.6., Landau Institute for Theoretical Physics, Chernogolovka, Russia
Leturcq, Renaud, PhD, 19. - 21.4., ETH Zürich, Switzerland
Lindefö, Poul, Prof., 19. - 20.4., University of Copenhagen, Copenhagen, Denmark
Logothetis, Nikos, Prof., 13. - 15.5., Max Planck Institute, Tübingen, Germany
Lorincz, Andras, Prof., 24. - 26.1., NIPG, Budapest, Hungary
Makhlin, Yuriy, PhD, 23.1. - 3.2., 2. - 13.10., Landau Institute for Theoretical Physics, Chernogolovka, Russia
Mel’nikov, Alexander, PhD, 17.9. - 1.10., Institute for Physics of Microstructures, RAS, Nizhny Novgorod, Russia
Nakahara, Mikio, Prof., 12. - 22.3., 22.3. - 6.4., 7. - 20.8., Kinki University, Osaka, Japan
Olausson, Håkan, Docent, 4. - 8.6., Göteborg University, Sweden
Parshin, Alexander, Prof., 18.2. - 3.3., 21.5. - 9.6., 9. - 22.9., Kapitza Institute for Physical Problems, Moscow, Russia
Piana, Michelle, Prof., 17. - 20.12. University of Genova, Italy
Roebroek, Alard, PhD, 1.5. - 2.7., Maastricht University, The Netherlands
Romani, Gian Luca, Prof., 16. - 18.1., University of Chieti, Italy
Schürmann, Martin, Prof., 25.3. - 5.4., 17. - 31.8., University of Nottingham, UK
Sonin, Eduard, Prof., 6. - 7.5., Hebrew University of Jerusalem, Jerusalem, Israel
Sorrentino, Alberto, MSc, 17. - 20.12., University of Genova, Italy
Szirtes, Gabor, PhD, 24.1. - 26.1., NIPG, Budapest, Hungary
Tanaka, Yukio, PhD, 6. - 8.9., Nagoya University, Nagoya, Japan
Wessberg, Johan, Ass. Prof., 4. - 6.6., Göteborg University, Sweden

Annual Report 2007
Wiesner, Maciej, PhD, 15.11. 2007 - 15.8. 2008, Adam Mickiewicz University, Poland
Wilhelm-Mauch, Frank, Prof., 28.11. - 2.12., Institute for Quantum Computing, University of Waterloo, Waterloo, Canada
Vorselman, Pieter, MSc, 1. - 31.3., Leiden Cryogenic BV, The Netherlands
Yano, Hideo, Prof., 19. - 23.2., Osaka City University, Osaka, Japan
Zmeev, Dmitri, MSc, 9.11. 2007- 9.2. 2008, Kapitza Institute for Physical Problems, Moscow, Russia
Zwierzyski, Maciej, PhD, 25. - 30.11., Institute of Molecular Physics, Polish Academy of Sciences, Poland

GROUP VISITS
Center of Excellence visit organized by the Academy of Finland for journalists, 21 visitors (11 journalists), 28.5.
25 participants of the EUROMET Expert Meeting in Quantum Electrical Metrology, 26.6
Student group from Salo High-School, 31.7
Director Markku Mattila, Academy of Finland, and Rector Matti Pursula, TKK, 6.8.
Prof. Manuel Carreiras, Spain, 28.8.
Prof. Jarmo Hietala, Turku, 8.9.
Dr. Masaaki Sato and his group (5 persons), 24.9.
Exhibition designers from Science Center Heureka, 30.10.
Groups from various high schools in Finland

INTERNATIONAL COLLABORATIONS

ULTI - ULTRA LOW TEMPERATURE INSTALLATION
Coordinator: Mikko Paalanen
Funding: EU's 6th framework program, Transnational Access to Major Research Infrastructures. (EU contract # RITA-CT-2003-505313)
Duration: 1.4. 2004 - 31.3. 2008
Participating groups of the LTL: INTERFACE, NANO, PICO, ROTA, THEORY and YKI
The ULTI Large-Scale Facility continues the services of ULTI III for European scientists. It will provide them 72 visitor months in the LTL and full access to its research facilities.
During 2007 altogether 17 European visitors from 8 different countries used the facility for 118 months.
ULTI web page: http://ltl.tkk.fi/eu.html

Annual Report 2007
WORKSHOPS

The Mind Forum I: Exploring the limits of mind
Majvik Meeting and Convention Hotel, Kirkkonummi, Finland, August 16 - 18, 2007
This workshop was the first one in a series of five multidisciplinary workshops of the Mind Forum. The aim of the workshop was to find the common ground between many disciplines studying the mind and conversely, to find out if there were any major disagreements about the mind. The first two days of the workshop were held in Finnish and the third day was held in English. Thirty invited guests attended the workshop: one from the United States, one from Sweden, and 28 from Finland. Five of the Finns attending the workshop were PhD students. The scientific program contained 13 oral presentations in Finnish, three oral presentations in English and three sessions dedicated to discussions only (two in Finnish, one in English). The talks were given by experts in philosophy, brain research, comparative religion studies, sociology, psychiatry, psychology, neurobiology, history and cognitive science. In addition, experts in paleontology, theology and linguistics contributed to the discussions. An abstract booklet in Finnish was delivered to the participants at the start of the workshop; an English version of the abstract booklet (translated by the coordinator, Dr. Jaakko Järvinen) was provided to the overseas guests.

Website: [http://www.mieliforum.fi/english.html](http://www.mieliforum.fi/english.html)

The Mind Forum II: The changing mind
Siuntio Wellness & Conference Resort, Siuntio, Finland, November 22–24, 2007
This workshop was the second one in a series of five Mind Forum workshops (see previous entry). The aim of the workshop was to investigate through multidisciplinary discussions how the mind changes during an individual’s life span, and how the mind can be changed through therapy, medication, education, learning and manipulation. The first two days of the workshop were held in Finnish and the third day was held in English. Altogether 33 invited guests attended the workshop: one from Canada, one from Sweden, and 31 from Finland. Five of the Finns attending the workshop were PhD students. The scientific program contained 10 oral presentations in Finnish, three oral presentations in English and three sessions dedicated to discussions only (two in Finnish, one in English). The talks were given by experts in neurobiology, geriatry, educational psychology, psychiatry, social psychology and pharmacology. In addition, experts in sociology, comparative religion studies, brain research, philosophy and child psychiatry contributed to the discussions. An abstract booklet in Finnish was delivered to the participants at the start of the workshop; an English version of the abstract booklet (translated by the coordinator, Dr. Jaakko Järvinen) was provided to the overseas guests.

Website: [http://www.mieliforum.fi/english.html](http://www.mieliforum.fi/english.html)

Tieteen päivät
The following sessions were organized at Tieteen päivät by the LTL scientists:
- Klassisen mekaniikan ja kvanttimekaniikan rajalla, January 10, Mikko Paalanen;
- Kielen oppiminen ja aivot, January 11, Matti Laine, Elisabet Service and Riitta Salmelin;
LOW TEMPERATURE PHYSICS RESEARCH

NANO group


The research work of the NANO group is focused on three areas: 1) Mesoscopic quantum amplifiers and qubits, 2) Quantum transport in carbon nanotubes and graphene, and 3) Current fluctuations and fast dynamics in quantum circuits. In all of these categories, our measurements are centered at microwave frequencies, involving reflection measurements for qubits, transmission measurements for AC-conductance, and two channel noise recording for cross correlation studies. After the completion of a new pulse tube based dilution refrigerator, we have now three setups for low-noise microwave studies at 1 - 10 GHz: two down to 25 mK and one for 4.2 K.

During the past years our experimental efforts have become progressively collaborative in character within the domain of the European Union ruled research funding. Two projects are ongoing: one of them, coordinated by P. Hakonen, is an IST-STREP dealing with carbon nanotubes and the second one is an INTAS-project, coordinated by G. Schön, which deals with quantum information. In carbon nanotubes and graphene, we have also started a collaboration with Nokia. Most of our samples, especially the Josephson junction devices, are made in our own in-house semiclean 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 so far have been obtained via collaboration.

In the field of mesoscopic quantum amplifiers and qubits, we have further developed the dispersive charge detection techniques devised by our group recently for studies of the quantum measurement. We have fabricated novel on-chip ultra-small capacitors which eliminated spurious circuit elements that hampered our earlier studies. This enabled us, for example, to observe genuine sideband cooling and heating in a coupled superconducting qubit + oscillator system for the first time. We also continued our studies of Landau-Zener interference, and investigated the involved non-adiabaticity effects by observing changes in the so-called Stokes phase.

LANDAU-ZENER INTERFEROMETRY IN A COOPER PAIR BOX


Landau-Zener (LZ) interference is a quantum-mechanical phenomenon in a phase coherent system, taking place at the intersection of two energy levels that repel each other due to a weak interaction. In our measurements of qubit LZ interferometry, we employ the Josephson (quantum) capacitance to determine the state of a Cooper pair...
box. During the past year, we have paid attention to the Stokes phase that depend on the non-adiabaticity factor of the drives, $2\pi \frac{\Delta^2}{\hbar} \nu$, where $2\Delta$ is the energy gap and $\nu$ is the speed (energy rate of change) at which the crossing point is traversed. Clear differences in the interference patterns have been detected when $2\Delta/\hbar$ is changed from 3 to 10 GHz.

We have performed extensive modelling of a CPB dynamics using Bloch equations in order to calculate the role of Berry phase in the LZ-interference conditions. We find that Berry phase plays a clear role when the CPB is driven simultaneously by charge and phase drives. This would be the Berry phase in the stationary frame, in contrast to the usual case of a rotating frame.

**MULTIPHOTON SIDE BAND COOLING USING A CHARGE-PHASE QUBIT**


The coupling between the oscillating motion of an atom (e.g. LC-resonator) and atomic transitions (two level system) can be employed for sideband cooling, as has been demonstrated in quantum optics and nanomechanical resonators. By driving atomic transitions by a detuned rf-signal so that extra energy has to be supplied from the kinetic motion of the resonator, the vibrational motion can be slowed down. We have demonstrated that, the sideband cooling principle works using strongly coupled charge-phase qubits, and even multiphoton resonances can be employed for this purpose.

The relaxation of our charge-phase qubit is quite strong, leading to broad resonances, but individual sidebands can well be resolved. In contrast to the usual sideband cooling configurations, we are driving the oscillator to be cooled at its resonant frequency, in order to read out information out from the qubit + oscillator system. Consequently, sideband cooling and heating are visible in our measurements as damping and amplification of the oscillation amplitude of the resonator. Our analysis is based on semiclassical analysis, in which the dynamics of the qubit is simulated numerically on the basis of Bloch's equations and electrical circuit laws for the resonator. We find a pretty good agreement between the simulation and the experiment, which allows us to account accurately for the main experimental findings. Damping of motion is found up to multiphoton resonances of order 10.

**LANDAU-ZENER INTERFEROMETRY IN CIRCUIT QED**

P. Hakonen, A. Paila, J. Sarkar, and M. Sillanpää

We are developing a new version of the Landau-Zener interferometric measurement. The goal is to bring the qubit level separation near to resonance with the LC-resonator frequency, thereby strengthening the coherent phenomena between the two quantum objects. The realization of this experiment will be based on lumped elements, which facilitates exceptionally strong coupling between the qubit and the resonator.

**SQUID AMPLIFIERS**

D. Gunnarsson, P. Hakonen, and M. Sillanpää

We have continued the development of our second generation GHz SQUID amplifiers designed in collaboration with VTT. The amplifiers work as designed and they give a gain of 20 dB when using power matching circuits at the input and output. With noise matching at the input, a gain of 15 dB is expected from these devices. Improved ver-
sion of the amplifier is planned to be designed in summer 2008 in collaboration with the VTT spin-off company Aivon Ltd.

**BLOCH OSCILLATING TRANSISTORS (BOT)**

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

The first fully superconducting version of a Bloch oscillating transistor was measured in autumn 2007. The new design has a SIS junction on the base instead of a NIS junction. The resistance of the chromium thin film resistor in the collector was 40 kΩ, and the tunneling resistances of the junctions in the emitter and in the base were about 10 kΩ. The emitter consisted of two Josephson junctions in a SQUID-like geometry in order to tune the ratio $E_J/E_C$.

Despite the low, not yet optimized chromium resistance, the device gave promising results when compared with the original devices. The collector-emitter IV curves showed hysteresis that was suppressed when $E_J$ decreased. $P(E)$ peak consisted of two peaks instead of one as in the previous measurements of the former design. To be exact, the peak became doubled when $E_J$ increased to be of the same order as the $E_J$ of the base junction. However, the operation region, meaning the region where the gain is highest, is reached with $E_J$s of the same order. The highest observed current gain was about 30, when the base current was 200 pA. In noise measurements, $1/f$ noise seemed to increase when approaching the value of $E_J$ at which the IV curves become hysteretic. At the operation point, the input referred current noise level was on the order of 2 fA/√Hz.

![Fig. 1. Measured collector-emitter IV curves with different ratios of $E_J/E_C$. The base current is 200 pA and $E_J/E_C$ is of the order of 1, being highest in the blue curve. Hysteretic behaviour disappears when $E_J$ decreases.](image)

**QUANTUM TRANSPORT IN CARBON NANOTUBES AND GRAPHENE**

During the year 2007, we have successfully expanded our carbon-based quantum electron transport to samples of graphene. In our measurements, we have concentrated on studies of shot noise and superconductivity, both in CNTs and graphene. The current noise measurements together with conductance can be interpreted in terms of “transmission channel fingerprints” that have been a primary analysis method in the investigations of atomic point contacts. Moreover, ballistic Josephson junction theories can be then employed to test the observed supercurrents against the transmission channel eigenvalues. We find a rather good agreement between experiment and theory in our shot noise studies, both in single walled carbon nanotubes
(SWNTs) and graphene. In semiconducting samples, our results indicate that nano-
tube FETs are so good that they even rival SETs as the best electrometers available
today. In addition, high operation speed has been achieved in nanotube FETs.

SUPERCONDUCTING SWNT TRANSISTOR

R. Danneau, P. Hakonen, E. Kauppinen, P. Queipo, T. Tsuneta, and F. Wu

We have continued our investigations on proximity induced superconductivity in car-
bon nanotubes. We studied a SWNT sample contacted by superconducting Ti/Al
leads, 300 nm apart from each other. Initially, the sample showed Fabry-Perot pattern
with some asymmetry in the contact transparency (Fig. 2 a). The supercurrent, reach-
ing a maximum of 4.5 nA, was found to vary periodically with the gate voltage. The
results could be fitted using Breit-Wigner resonance model for the normal state con-
ductance and phase diffusion model for describing the voltage biased IV-curve in the
superconducting state.

We were able to reach the Kondo regime (i.e. intermediate contact resistance) with
the very same sample by cycling the cryostat several times form 290 K to 4.2 K. In
the Kondo regime, both the critical current and the zero-bias conductance were
smaller than in the Fabry-Perot regime; a comparison of the critical currents over
typical conductance resonances is displayed in Fig. 3 a. We also investigated the de-
pendence of the critical current on the Kondo temperature $T_K$. As seen in Fig. 3 b,
there are two distinct branches of $I_C(T_K)$. Theoretical explanation of these effects is
lacking at present.

The multiple Andreev peaks are quite smeared in our SWNT Josephson junctions,
though the value of the transmission coefficient at the contact interfaces should be
favorable for their appearance. Therefore, we have studied excess current $I_{ex}$, which is
a quantity integrating over all orders of multiple Andreev reflections. We find a quite
linear dependence between $I_{ex}$ and $I_C$, as predicted by the Josephson weak link theory.

![Fig. 2. Differential conductance versus bias voltage and gate voltage in (a) Fabry-Perot re-
gime, and (b) Kondo regime. These have been obtained on the same sample in separate cool-
downs.](image-url)
Fig. 3. a) Correlation between critical current $I_C$ and normal state conductance $G_N$. Black and red dots represent Fabry-Perot regime and Kondo regime, respectively. Lines are theoretical fits with 2-channel Breit-Wigner model, with $I_0 = 4.5\, \text{nA}$ for F-P and $I_0 = 3\, \text{nA}$ for Kondo. b) Critical current $I_C$ versus Kondo temperature $T_K$. The Kondo temperature is taken from the width of normal state zero-bias conductance.

**SEMICONDUCTING NANOTUBE FET**

ENS-group, P. Hakonen, and L. Lechner

In collaboration with ENS (Paris), we have worked on microwave operation of top-gated single carbon nanotube transistors. From transmission measurements in the 0.1-1.6 GHz range, we obtained a large and frequency-independent transconductance $g_m \sim 20\, \mu\text{S}$ on short devices, which meets the best dc results. The capacitance per unit gate length of 60 $\text{aF/\mu m}$ is typical of top gates on a conventional oxide with $\varepsilon \sim 10$. This value is a factor of 3-5 below the nanotube quantum capacitance which, according to recent simulations, favors high transit frequencies $f_T = g_m/2\pi C_g$. For the smallest devices, we find a large $f_T \sim 50\, \text{GHz}$ with no evidence of saturation in length dependence.

**FABRY-PEROT CARBON NANOTUBE RF-SET**

S. Andresen, R. Danneau, P. Hakonen, L. Lechner, and F. Wu

In addition to regular rf-SET operation of SWNT quantum dots, we have investigated similar rf operation of nanotubes in the Fabry-Perot regime. We have reached an excellent charge sensitivity of $2.0 \times 10^{-6}\, \text{e/Hz}^{1/2}$ with a carrier frequency of 715 MHz over a bandwidth of 80 MHz at 4.2 K. Unlike previously demonstrated SETs in the Coulomb blockade regime, our device can, however, work as an electron interferometer up to temperatures of 20 K above which the dephasing length becomes gradually too short.

Our device consists of a CVD-grown single wall carbon nanotube contacted by superconducting electrodes. To prevent parasitic capacitances that would limit the rf-operation, the SWNT is grown from patterned catalyst islands on an insulating (sapphire) substrate using an $\text{Al}_2\text{O}_3$-insulated gate electrode deposited on top of the tube.
We obtain a charge sensitivity of \( \delta q = \delta V_g/(2*\text{SNR}*\text{BW})^{1/2} = 2.0 \times 10^{-6} \text{ e/Hz}^{1/2} \). The corresponding energy sensitivity was estimated to be \( \delta E = \Delta E_c \delta q^2/e^2 = 30 \hbar \), where \( E_c \) denotes the charging energy. While this charge sensitivity is slightly better compared to our earlier Coulomb blockade region rf-SET, the energy sensitivity is slightly lower. However, since our measurements were conducted at 4.2 K, we can expect an improved behavior for lower temperatures.

**NOISE IN GRAPHENE**


Owing to its unique structure, graphene conduction occurs via massless Dirac fermions. Graphene is a gapless semiconductor: the conduction and the valence band are touching at two inequivalent points (K and K', usually called Dirac points) where the density of state vanishes. Nevertheless, the conductivity at the Dirac point remains finite as charge is carried by evanescent waves, i.e. by tunneling between the leads. These unique properties are also reflected in the shot noise properties of graphene. In perfect short and wide graphene strips (\( W/L \geq 3 \)), for heavily doped graphene leads, at the Dirac point both minimum conductivity and Fano factor are expected to reach universal values of \( 4e^2/\pi \hbar \) and 1/3 respectively. Astonishingly, the transmission coefficients at the Dirac point in perfect graphene show similar form as those found in diffusive systems.

We have studied shot noise in short and large graphene strips (with different width over length ratio \( W/L \)) prepared by Prof. A. Morpurgo and his collaborators in Delft. The samples were made of graphene sheets exfoliated from natural graphite and deposited on top of Si/SiO\(_2\) wafer, where the substrate is used as a back gate. Our measurements show that for strips with large \( W/L \), both minimum conductivity and Fano factor reach universal values of \( 4e^2/\pi \hbar \) and 1/3 respectively. We find that the Fano factor has a maximum at the Dirac point and it diminishes with increasing carrier density. We also see that for smaller \( W/L \) ratios, the Fano factor is lowered as expected by the theory. While the ballistic nature of conduction in graphene is strongly debated, our findings support the view that transport at the Dirac point occurs via evanescent waves, i.e. that carriers can propagate without scattering.

**NOISE IN MULTITERMINAL MWNTS**

P. Hakonen, T. Heikkilä, T. Tsuneta, P. Virtanen, and F. Wu

We have investigated shot noise in multiterminal, disordered multiwalled carbon nanotubes (MWNTs) at 4.2 K over the frequency \( f = 600 - 850 \text{ MHz} \). Quantitative comparison of our data to semiclassical theory, based on non-equilibrium distribution functions, indicates that a major part of the noise is caused by a non-equilibrium state imposed by the contacts. Our data exhibits non-local shot noise across weakly transmitting contacts while a low-impedance contact eliminates such noise almost fully. When neglecting inelastic effects, we obtain \( F_{\text{tube}} < 0.03 \) for the intrinsic Fano factor of our MWNTs. The reason for this behavior is unclear at present; it cannot be explained by the presence of ballistic channels.
Fig. 4. Measurements on a graphene sample with $W/L = 24$: (a) Resistance $R$ (left axis) and conductivity $\sigma$ (right axis) as a function of $V_{\text{gate}}$. (b) Differential resistance $dV/dI$ versus bias voltage $V_{\text{bias}}$ at the Dirac point (red curve) and at high density (blue curve). (c) Current noise per unit bandwidth $S_I$ as a function of bias at the Dirac point, at $T = 8.5$ K, fitted (red curve) using Khlus formula ($\phi = 0.318$). Note that the low bias data are perfectly fitted as well as the high bias (d) Mapping of the average Fano factor $F$ as a function of gate voltage $V_{\text{gate}}$ and bias voltage $V_{\text{bias}}$ at $T = 8.5$ K.
NEW HELIUM-FREE REFRIGERATOR

R. Blaauwgeers, P. Hakonen, L. Lechner, P. Vorselman, and M. Wiesner

Most of our effort in developing new high frequency techniques has gone to the construction of a new refrigerator setup. The core component of this apparatus is a pulse tube cooled $^3$He/$^4$He dilution refrigerator. The cryostat is a pre-series version built by BlueFors Cryogenics, a Low Temperature Laboratory spin-off company. It has successfully completed its test runs in December 2007. The system does not rely on liquid helium pre-cooling like conventional cryostats. This construction leaves more room for samples and electronics, and allows to carry out measurements in vacuum. Overall, the comparably short length and clean design make it ideal for the challenging integration of noise measurement circuitry.

PICO group

Meri Helle, Tommy Holmqvist, Antti Kemppinen, Matthias Meschke, Juha Muhonen, Mikko Mötönen, Jukka Pekola, Joonas Peltonen, Olli-Pentti Saira, Alexander Savin, Andrey Timofeev, and Juha Vartiainen

Visitors: Dmitri Averin, Francesco Giazotto, Wiebke Guichard, Frank Hekking, and Stefano Tirelli

The main highlights of the research in PICO group in 2007 were electronic refrigeration and thermometry, and charge pumping in superconducting and normal metal structures. We investigated the interplay of Coulomb effects and refrigeration; a heat transistor based on single-electron tunneling was developed. The highlight of the year was the concept and demonstration of a hybrid single-electron turnstile. One more achievement was the observation of the third moment of shot noise detected by a Josephson junction threshold detector.

NANOFRIDGE

Meri Helle, Matthias Meschke, Juha Muhonen, Jukka Pekola, Olli-Pentti Saira, Alexander Savin, and Andrey Timofeev

Collaborators: Francesco Giazotto (SNS), Wiebke Guichard (CNRS), Frank Hekking (CNRS), Nikolai Kopnin (LTL), and Stefano Tirelli (SNS)

The unifying topic in 2007 in the investigation of thermal effects in nanostructures was the influence of Coulomb interaction in electronic refrigeration. A gate controlled radio-frequency single-electron refrigerator was proposed. The simplest realization of this device is a nonbiased single-electron box with normal metal (N) island and a superconducting (S) lead, with just one NIS tunnel junction ($I = \text{insulator}$). Such a cyclic
refrigerator is expected to remove energy $kT$ at the frequency $f$ of the gate drive. Thus it yields a cooling power of order $kTf$. We demonstrated experimentally the influence of Coulomb blockade on refrigeration in a single-electron transistor in a device now coined “heat transistor”. Subsequently we discussed a NIS junction subjected to the thermal noise of a hot resistor: we showed that this simple device can act as a Brownian refrigerator. The system provides a particularly illustrative example to discuss “Maxwell’s demon”, yet not violating the second law of thermodynamics.

Fig. 1. Gate-controlled NIS refrigerator.

$I = nef$

Antti Kemppinen, Matthias Meschke, Mikko Möttönen, Jukka Pekola, Olli-Pentti Saira, and Juha Vartiainen

Collaborators: Dmitri Averin (Stony Brook), Antti Manninen (Mikes), and Yuri Pashkin (NEC)

The work on synchronized electron pumping dealt with three different systems in 2007. Work on the sluice, which is a fully superconducting current pump with combined magnetic flux and gate voltage control, resulted in record high pump current exceeding 1 nA. This promising device suffers, however, from supercurrent leakage, which is a topic of present and near future research. An experiment using the sluice in a closed superconducting loop has also been performed in 2007. It leads to the observation of Berry phase, which is obtained via its relation to the pumped current in a phase coherent configuration. A major discovery of the year was, however, the hybrid SNS turnstile, where accurately positioned current plateaus at $I = nef$ were measured, see Fig. 2. It is a single-electron transistor where charge states are stabilized by the superconducting gap of the leads. This device is extremely simple, and, surprisingly, it had not been realized earlier during the 20 years long quest for a quantum standard of electric current. Yet there is a long way to satisfy the stringent requirements of quantum metrology: in the first experiments the plateaus were determined with precision of $10^{-3} – 10^{-2}$ only, whereas a current standard requires $10^{-7} – 10^{-8}$ accuracy of pumped current.
Fig. 2. Current plateaus at $I = n ef$ of a hybrid single-electron turnstile measured at $f = 20$ MHz.

**OTHER PROJECTS**

Tommy Holmqvist, Matthias Meschke, Juha Muhtonen, **Jukka Pekola**, Joonas Peltonen, and Andrey Timofeev

Collaborators: Martti Heinonen (Mikes), Eeva Isosaari (Mikes), and Antti O. Niskanen (VTT)

We have continued the work on hysteretic Josephson junctions as threshold detectors of current noise. In particular, we managed to observe the third moment of shot noise of a tunnel junction by this technique. The full counting statistics of charge transport in mesoscopic structures has been under active theoretical investigation over the past years, but experimentally it has turned out to be hard to observe moments beyond the second one.

Other 2007 activities in the group were the further development of Coulomb blockade thermometer towards lower temperatures and, as a new direction, fabrication and experiments on suspended metallic structures. Both these activities faced challenges in 2007 and will most likely produce results in 2008.

**KVANTTI group**

Khattiya Chalapat, Jian Li, **Sorin Paraoanu**, and Kari Sarvala

Part of the KVANTTI group moved in November 2007 from the University of Jyväskylä to the LTL. In November and December Sorin Paraoanu and Jian Li of the group members worked in the LTL, while Khattiya Chalapat and Kari Sarvala remained in JyU. In the LTL, the KVANTTI group continued work started already at JyU on microwave properties of nano-structured materials and quantum coherence effects in superconducting devices based on the Josephson effect.
CONTROL OF SUPERCONDUCTING QUBITS
Khattiya Chalapat, Jian Li, and Sorin Paraoanu

We have studied a system consisting of a superconducting coplanar waveguide resonator capacitively coupled to two charge qubits. The resonator can be read out using a single Josephson junction. Using the simulated annealing method, we show that any two-qubit gate can be implemented by a suitable combination of microwave pulses with relatively large fidelities. We propose a quantum non-demolition (conditional) method to read out the qubits: we show that an entangled state is established between the qubits when no photon leaks out of the resonator, while for a generic microwave drive we characterize the photon-qubit-qubit entanglement.

MICROWAVE PROPERTIES OF NANOCOMPOSITES
Khattiya Chalapat, Jian Li, Sorin Paraoanu, and Kari Sarvala

Collaborators: University of Nottingham

Measurements of the S-parameters and calculation of the corresponding complex electromagnetic permittivity and permeability were done by the Nicholson-Ross-Weir method using a 18 GHz airline and custom-made and home-made toroidal samples. The samples measured were composites containing Co, Ni, and Au nanoparticles.

PHOTODEVICES
Sorin Paraoanu

Collaborator: Prof. J. Korppi-Tommola, Univ. of Jyväskylä

We have measured the IV characteristic and dI/dV at various bias voltages for a device combining the structure of a solar cell with that of a photodiode. We characterize the device under different illuminations and we point out that it can be used as a phototransistor.

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

Much of the experimental activity at the YKI cryostat this year was aimed to solve the technical shortcomings of the adiabatic melting experiment run previously. New superfiter filling lines were tested and a satisfactory result in terms of adiabatic flow was achieved. However, even more effort will be put to control the growth and melting of the solid phase in the cell without disturbances arising from the connection to warmer environment by assembling a bellows actuator system, where the fluid commuting to and from the cell will never be warmer than 10 mK.

Probing the state of the fluid under investigation by quartz fork oscillators was studied in order to replace the vibrating wire resonators in the experimental cell. The prospects for using such sensors for a variety of studies in the physics of helium liquids seem superb.

During these test measurements significant amount of data on the properties of helium mixtures at low temperatures were collected also. First, we determined for the first time the full solubility curve of $^3$He in $^4$He up to the crystallization pressure. Earlier measurements have not been extended above 22 bar due to the ordinary capillaries.
becoming blocked by solid He at some higher temperature, whereas our cell, equipped with the superfilter filling lines, could be loaded all the way up to the crystallization pressure at any temperature. Precise data was obtained by using the quartz oscillator as the sensing element, which is a new technique for this purpose. Another quantity investigated was the osmotic pressure of $^3$He in the mixture at the crystallization pressure as the function of $^3$He concentration. Unprecedently accurate data was obtained by using our ultra-sensitive pressure gauge, actually forming the experimental volume for this run. Both the solubility data as the function of pressure and the osmotic pressure data as the function of concentration, and their temperature dependences, of course, can be used to deduce the mutual interactions between the $^3$He quasiparticles in the liquid solution. This, in turn, is the essential starting point in order to make predictions upon the eventual superfluid transition temperature and of the pairing state of the dilute fermion system of $^3$He in $^4$He. Such analysis on the basis of our new data is under way.

Some other intriguing observations during these measurements, which have not yet been systematically treated, however, include (i) the observation of very strong second sound resonances exited and sensed by the quartz forks below and above one kelvin in the mixtures, (ii) quantum nucleation events of the pure $^3$He phase from the homogeneous mixture prepared into the state of supersaturation, and (iii) the possibility to operate the quartz resonators free from any attenuation at low temperatures both in vacuum and in pure superfluid $^4$He.

Towards the end of the year, the preparations to move to the new laboratory facilities forced to pause the experiments at the big cryostat. Before the turn of the year the installation was taken apart and its reconstruction at the new building was started.

**ROTA group**

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


**DYNAMICS AND TURBULENCE IN COHERENT QUANTUM SYSTEMS**

The low-temperature many-body particle systems with macroscopic quantum behaviour are generally associated with superfluidity, owing to the requirement of coherent particle motion. The hallmark is a persistent supercurrent, which flows unattenuated for ever. However, at higher flow velocity quantized vortex lines are formed and their motion becomes dissipative, even turbulent in the limit of low dissipation at low temperatures. The turbulence persists on approaching the zero temperature limit and, if the external drive is switched off, it decays. This situation, the existence of finite dissipation at absolute zero temperature, has been proven in a few different measurements during the past years. Such results demonstrate that there exist new mechanisms by which the motion of superfluid vortices becomes lossy even at the very lowest temperatures.

The second important property about the zero temperature limit is the coupling from the external reference frame to the superfluid fraction. This coupling vanishes exponentially as $T\rightarrow 0$. One might therefore think that a finite dissipation level is of little consequence since the usual superfluid response, the formation of vortices, is absent. However, when flow is externally applied, for instance, by setting the superfluid sam-
ple in rotation, it turns out that various mechanisms exist by which vortices are formed at some critical rotation velocity. Thus the superfluid zero temperature limit has turned out not to be qualitatively very different from finite temperatures, although the zero-temperature dissipation mechanisms are still largely unknown.

Our research group has provided much of the experimental proof which confirms the above scenario [1]. We use the isotropic B phase of superfluid $^3$He and a novel type of measurement for these studies. The new technique was developed for investigating vortex dynamics and turbulence in steady state conditions [2]. Here one or more vortex seed loops are injected by external means into a long cylinder of $^3$He-B which rotates at constant conditions in the vortex-free state. The ensuing dynamics is observed non-invasively with external NMR pick-up coils as a function of time. At high temperatures and high vortex damping, the dynamics is laminar in the sense that the number of quantized vortices is conserved and the seeds ultimately evolve to rectilinear lines which are stable in uniform rotation. At low temperatures and low damping, the seed loops become unstable, generate new vortices, which start interacting and give rise to a rapid turbulent burst. This process does not conserve the number of vortices, as shown by the evolution depicted in Fig. 1. The precursor to the turbulent burst is the single vortex instability in applied flow which was first identified in this context [3]. In the turbulent burst enough vortices are created so that the equilibrium vortex state can be reached. This is the final stable state where the dynamical evolution ends. It consists of a regular array of rectilinear vortex lines.

Fig. 1. Vortex instability and turbulence in a rotating column of $^3$He-B in the turbulent temperature regime. A seed vortex loop is injected in applied vortex-free flow and the subsequent evolution is depicted. Different transient states are traversed, until the stable rotating equilibrium vortex state is reached.

After the turbulent burst the expansion of the vortices takes place in the form of a front followed by a helically twisted bundle of vortex lines [4]. A steady state with turbulent fluctuations can be monitored while the vortex front propagates along the rotating column at constant velocity. The twisted structure is formed by the spiral motion of the propagating front [5]: while the vortices move in the axial direction, they also circle around the cylinder with azimuthal velocity. At lower temperatures the front moves at constant velocity with a stable time average structure. This steady state
of vortex propagation displays an increasing influence from turbulent fluctuations with decreasing temperature. Here the energy difference across the front, between the high-energy state of vortex-free flow ahead of the front and the twisted vortex state behind the front, is dissipated by the losses in vortex motion. The axial velocity of the front is obtained from its flight time while it travels the distance between the two NMR pick-up coils at each end of the long sample cylinder. In the laminar regime the losses prove to be caused by the well-known mutual friction dissipation while it acts on large length scales, comparable to the radius $R$ of the rotating column. In contrast, at lower temperatures in the turbulent regime, owing to nonlinear interactions, the hydrodynamic energy flows to shorter length scales. Along this cascade it is dissipated by mutual friction and ultimately at the shortest length scales (on the order of the superfluid coherence length $\xi$) by some new mechanisms. Experimentally at low temperatures below $0.4 \, T_c$, the total dissipation is observed to deviate orders of magnitude above the laminar extrapolation.

The velocity of the propagating vortex front has been compared to simulation calculations [2]. It has also led to a sophisticated analysis of the energy cascade which distributes the hydrodynamic kinetic energy in a Kolmogorov type of process over all length scales, starting from the largest hydrodynamic scale, given by the radius $R$ of the column at which the energy is pumped into the cascade. The length scale comparable to the inter-vortex distance $\ell$ defines the crossover from classical to quantum scales. At the quantum scale the energy is dissipated by helical Kelvin-wave excitations which expand on individual vortex lines and, by means of nonlinear interactions, allow the energy to be transferred down to ever shorter wave lengths. In this regime of scales the ultimate limit is the radius of the vortex core which is comparable to the superfluid coherence length $\xi$. The analysis by Victor L’vov [2] provides the first estimation of turbulent losses at the lowest temperatures, which is not restricted to isotropic homogeneous turbulence, but applies to flow with vortices constrained to an ordered configuration with high polarization along the rotation axis. The new element in this analysis is the appearance of a bottleneck in the energy cascade, in the transfer from the hydrodynamic scales larger than $\ell$ to the quantum scales smaller than $\ell$ where the Kelvin waves have to be excited. This model can now be fitted to the measurements of front propagation with a very reasonable choice of parameters.

Our measurements on the dissipation in vortex propagation in the turbulent temperature regime below $0.4 \, T_c$ depend on a number of new techniques, which have been developed in the course of this work. Among these are the NMR methods for counting vortices and for preparing states with a known number of vortices, the techniques to achieve high vortex-free counterflow and to inject vortex seed loops, and ways to reach and measure temperatures below $0.2 \, T_c$ in a long liquid $^3$He column. We now know how critical velocities, turbulent vortex formation, and vortex remanence can be dealt with to perform controlled measurements down to below $0.2 \, T_c$. A number of further open questions can be answered utilizing these techniques: Is the turbulent dissipation converted directly to heat and if so, how does it happen? Does the loss of coupling to the external frame of reference change the nature of the critical velocity of various types of instabilities? Are new types of topological defects formed in the zero temperature limit if the order parameter distribution is driven far out of equilibrium, for instance by the ultra-fast motion of the hyper-cooled AB interface or by the annihilation of different order-parameter structures?
NMR MEASUREMENT OF VORTICES AT THE LOWEST TEMPERATURES

The pattern of vortices and macroscopic counterflow in superfluid $^3$He is formed by the orbital part of the order parameter, which is coupled by weak spin-orbit interaction to the nuclear magnetic spin of the Cooper pair. Different NMR methods have been developed to probe the order-parameter texture. At best the resolution is sufficient to discern a change by one individual vortex line. Generally one monitors at low excitation level the local oscillator response which reflects the thermal equilibrium situation. Such a response becomes increasingly insensitive towards low temperatures. To continue using NMR detection of vortices at the lowest temperatures in the collisionless regime, an important goal becomes the search for better NMR methods, with improved resolution and sensitivity for the measurement of vortices and other topological defects in the B phase below 0.4 $T_c$. Here non-local collective resonances are the most attractive alternative.

![Graph](image)

Fig. 2. Macroscopic quantum oscillator: coherent spin wave resonances in the B-phase flare-out texture close to the top end plate in the rotating cylinder. The transverse component $M_\perp$ of the coherently precessing total magnetization is plotted as a function of the frequency shift from the Larmor value $f_0$. The series of NMR absorption lines correspond to harmonic oscillator eigenvalues for the horizontal potential well (closely spaced lines) and the axial well (separation into different series).

In the ballistic temperature regime a new coherent resonance mode appears, known as the Persistent Induction Mode, which corresponds to spin wave resonances in a potential well formed by a slowly changing distribution of order parameter orientations in the centre of the flare-out texture of a cylindrical sample, when monitored with continuous wave excitation (Fig. 2). At carefully adjusted low excitation level and precision magnetic field sweep the mode can be enhanced to dominate the NMR absorption. We have explored the use of this mode for the detection of vortices and vortex-free flow in rotation in collaboration with Yuriy Bunkov. The method has proven useful in certain applications and is competitive in sensitivity with our most frequently used method based on an analysis of the NMR absorption line shape. For better comparison, the method of line-shape analysis has now also been evaluated down to below 0.2 $T_c$. The reports on these measurements are in preparation.

References


Annual Report 2007
INTERFACE group

Harry Alles, Heikki Junes, Matti Manninen, and Igor Todoshchenko

INTERFACES IN QUANTUM SYSTEMS

Helium crystals are quantum crystals which exhibit several exotic properties. For instance, at low enough temperatures they can grow and melt so easily that a melting-freezing wave, a crystallization wave, can propagate along their surface. At the same time they represent an ideal model system to study general properties of the crystal surface, such as an equilibrium crystal shape, faceting-roughening transitions, growth kinetics, etc. Furthermore, the two stable helium isotopes, $^{3}$He and $^{4}$He, have different quantum statistics, that is bosonic and fermionic, correspondingly, resulting in quite different properties of the liquid-solid interfaces as well as of the bulk phases. In the case of $^{3}$He, due to nuclear spin, also the effect of the magnetic field could be investigated.

Recently the interest to the studies of the properties of solid helium has been lifted by the experimental results of Kim and Chan from Pennsylvania State University who reported on the evidence of superfluidity of solid $^{4}$He. They studied the rotational inertia of a torsional oscillator filled with solid $^{4}$He and discovered about 1% decoupling of mass below 200 mK. This decoupling, named as “non-classical rotational inertia”, has by now been confirmed by several other experimental groups. In later experiments that the size of decoupling is observed to be greatly influenced by crystalline defects within the solid $^{4}$He, as well as by the amount of $^{3}$He impurities. However, despite of extensive study it is not clear if this interesting phenomenon is really related to the supersolid state of the matter.

The INTERFACE group has been studying the surface of both $^{4}$He and $^{3}$He crystals by optical means. The shape of the crystals was imaged by a Fabry-Pérot interferometer built inside the nuclear demagnetization cryostat. One of the most important results obtained with the interferometric setup was that altogether 11 different types of facets (flat surface parts) have been observed on $^{3}$He crystals at 0.55 mK which could be looked as a proof of the devil’s staircase phenomenon which was predicted by Lev Landau in 1950s.

During last two years the INTERFACE group has been concentrated on the studies of $^{4}$He crystals. In order to search for the supersolid transition anomaly, accurate measurements of the melting curve of $^{4}$He were carried out. In addition, we have also searched for new facets on $^{4}$He crystals and measured the step energies of different facets.
MEASUREMENTS ON THE MELTING CURVE OF $^4$He — NO SIGN OF SUPERSOLID TRANSITION

Harry Alles, Heikki Junes, Matti Manninen, and Igor Todoshchenko

Collaborators: Alexander Parshin (Kapitza Institute for Physical Problems, Moscow, Russia) and Viktor Tsepelin (University of Lancaster, Lancaster, UK)

During first half of 2007 we completed our measurements on the melting curve of $^4$He which were started in the end of 2005. We have measured the melting pressure of both commercial and ultra pure $^4$He with the accuracy of about 0.5 $\mu$bar. We have found that in the temperature range from 10 to 320 mK the melting pressure of $^4$He follows the $T^4$ law due to phonons (see Fig. 1). Therefore the anomaly which was observed in our earlier measurements below 80 mK (Fig. 2, upper part) turned out to be due to the temperature dependence of the elastic modulus of Be-Cu from which our pressure gauge is made of. In order to get rid of this effect, we had to calibrate the sensitivity of our pressure gauge by measuring the variation of the pressure in liquid $^4$He at a constant volume. Our final results are presented in the lower part of Fig. 2.

Recently, Moses Chan and his team measured the heat capacity of solid $^4$He. After subtracting off the phonon $T^3$ contribution they found a broad peak in the heat capacity centered near 75 mK, and attributed it to the supersolid transition. The extra heat capacity under the peak would correspond to a deviation of about 5 $\mu$bar from the $T^4$ law in our melting curve measurement of $^4$He. The discrepancy with our results in Fig. 2 can be due to different sample quality: Our measurements were done for single crystals with good quality, while the samples in the heat capacity measurements were grown by blocked capillary method, known to lead to polycrystalline samples with poor quality.

Recent measurements of James Day and John Beamish have revealed that the shear modulus of solid $^4$He increases up to 10% as the temperature is reduced from 200 mK to 20 mK. The temperature dependence of the shear modulus value closely tracks the temperature dependence of the period in the torsional oscillator experiments of Kim and Chan. Day and Beamish interpret their results by the behavior of dislocations and trace $^3$He impurities in the solid $^4$He.

Fig. 1. Melting pressure of ultra pure $^4$He below $T = 0.32$ K. The line is not a fit to the data but consists of 1000 raw data points!
Fig. 2. Measurements on the melting curve of $^4$He. Upper part: Deviation of the melting pressure from the best $T^4$ fits measured with $^4$He of regular purity (80 ppb of $^3$He) and ultra pure $^4$He (0.3 ppb of $^3$He); the solid line is pressure in the liquid $^4$He at a constant volume. Lower part: Deviation of the difference between the melting pressure in the liquid $^4$He at a constant volume from the best $T^4$ fit. Symbols refer to the same crystals as in the upper part. All curves are offset for clarity.

In our melting curve measurements above 320 mK temperature we also detect the roton contribution to the specific heat of superfluid $^4$He. We extract a value of 6.8 K for the roton energy gap, in agreement with other methods. Because we did not observe any vacancy contribution in the melting pressure of $^4$He, we can set a lower limit of ~5.5 K for their activation energy. In addition, we have measured the thermal expansion coefficient of superfluid $^4$He in the range from 10 to 700 mK with a precision of $10^{-7}$ K$^{-1}$. This is two orders of magnitude better resolution than in the previous measurements. Unexpectedly, we found large deviations from the results of Grilly and Mills and Sydoriak.


Harry Alles, Heikki Junes, Matti Manninen, and Igor Todoshchenko

Collaborator: Alexander Parshin

After the melting curve measurements we have searched for new facets in $^4$He. Only three types of facets have been detected on hcp $^4$He crystals. The difficulty in observing higher order facets in $^4$He results from their small step energies. The critical over-pressure above which the facets roughen is proportional to the square of the step energy. Therefore the higher order facets can be seen only very close to the equilibrium conditions where the facets are still small. The facet size can be increased by adjusting their orientation close to horizontal. We have succeeded to create several such crystals. We have also succeeded to detect small higher order facets from interferograms where we have plotted histograms of the orientations of the crystal surface. As a result of our careful analysis, we have discovered the fourth and fifth facets on the surface of hcp $^4$He crystals in [10-12] and [11-20] directions, respectively.
MEASUREMENTS ON THE STEP ENERGIES OF $^4\text{He}$ CRYSTALS

Harry Alles, Heikki Junes, Matti Manninen, and Igor Todoshchenko
Collaborator: Alexander Parshin

Before our experiments only the step energy of the basal [0001] facet was known in $^4\text{He}$. We have succeeded in measuring the step energy of the second [10-10] facet and found it to be close to the value of the step energy of the basal facet. This was done with a novel method which we have developed in our studies of $^3\text{He}$ crystals. In this method the crystal is subjected to a very slow melting and the facet size is monitored until it reaches the critical size and collapses. The value of the critical size of the facet, together with the value of the overpressure on the facet, yields the step free energy of the facet. Measurements on the third, [10-11] facet show that its step energy is too small to be measured with this method. To measure the step energy of the [10-11] facet we have adopted another method which is based on the measurement of the growth threshold of the facet. In this method the crystal is grown slowly. The facet remains initially immobile until the overpressure exceeds a certain threshold value which depends on the step energy and the density of dislocations. The dislocation density can be found by measurements of the threshold for the facets with known step energy. We hope to complete the analysis of our data on $^4\text{He}$ crystals by the end of 2008.

CONSTRUCTING NEW EXPERIMENTAL CELL FOR THE SEARCH OF CRYSTALLIZATION WAVES IN $^3\text{He}$

Harry Alles, Heikki Junes, Matti Manninen, and Igor Todoshchenko
Collaborators: Alexander Parshin and Viktor Tsepelin

We have recently started to design and build a new experimental cell for the studies of liquid-solid interface of $^3\text{He}$ at ultra low temperatures. The ultimate goal of the following experiments is to observe magnetic crystallization waves which are predicted to exist in $^3\text{He}$ at a temperature of a few tenths of mK. The new cell will be placed into the YKI cryostat in 2009.

THEORY group

LTL has a long tradition of successful collaboration between theorists and experimental groups. The in-house theoreticians are also attacking substantial problems posed by experiments or theory made elsewhere, if these fall within their expertise.

Our experimental program in ultra low temperature quantum phenomena (ROTA team) has traditionally had the strongest theory support, which today is provided by Grigory Volovik, Nikolai Kopnin (50%) and Risto Hänninen. The INTERFACE group relies in its theory support mostly on the short term visits of Alexander Parshin from the Kapitza Institute.

As a new theory effort, we hired Tero Heikkilä in 2003 as a postdoc to work in the area of quantum electron transport. In August 2006 he was awarded by the Academy of Finland a five-year position as Research Fellow working in the LTL. At the same time he established his own THEORY team in the LTL. Nikolai Kopnin is also dedicating about half of his time to mesoscopic superconductivity. The increased theory support in low temperature quantum electronics is already bearing fruits.

Annual Report 2007
NONEQUILIBRIUM PROPERTIES OF MESOSCOPIC SUPERCONDUCTORS

N.B. Kopnin

Collaborators: Yu.M. Galperin (University of Oslo, Norway), V.M. Vinokur (Argonne National Laboratory, US), A.S. Mel'nikov (Institute of Microstructures, Nizhny Novgorod, Russia), and F. Taddei and F. Giazzotto (Scuola Normale Superiore, Pisa, Italy)

The electronic heat conduction along a vortex in a long ballistic mesoscopic superconducting cylinder with a radius of order of several coherence lengths has been studied theoretically. The vortex heat conduction in a mesoscopic superconductor is considerably enhanced as compared to its value in a bulk superconductor due to giant mesoscopic oscillations of the energy levels resulting from the interplay between the Andreev (at the vortex core boundary) and the normal (at the cylinder surface) reflection processes.

Charge transport and noise in a single-mode long SINIS junction (S stands for superconductor, I is an insulator, and N is a normal metal) has been investigated in the limit of low bias voltages and low temperatures. The kinetic equation for the quasiparticle distribution on the Andreev levels is derived taking into account both inelastic relaxation and voltage-driven Landau-Zener transitions between the levels. For a long junction when the number of levels is large, the transitions enhance the action of each other and lead to a drastic increase of the dc current. The Fano factor is also enhanced, being proportional to the number of times which particle flies before it escapes from the level due to inelastic scattering.

The influence of an AC drive on heat transport in a hybrid normal metal - superconductor tunnel junction in the photon-assisted tunneling regime has been investigated theoretically. The heat flux out from the normal metal is shown to be always reduced as compared to its magnitude under the static and quasi-static drive conditions. These results are useful for predicting the operative conditions of AC driven superconducting electron refrigerators.

SPIN SUPERFLUIDITY AND Q-BALL

G. Volovik

Collaborator: Yuriy Bunkov (Institut Néel, CNRS, Grenoble, France)

Q-ball is another representative of a state exhibiting the spin superfluidity, i.e. the phase coherent precession, similar to the well known Homogeneously Precessing Domain in \(^3\)He-B which we interpret as Bose condensation of spin waves – magnons, see reviews. A Q-ball is a non-topological soliton solution in field theories containing a complex scalar field. Q-balls are stabilized due to the conservation of the global U(1) charge Q. At the quantum level, Q-ball is formed due to suitable attractive interaction that binds the quanta of field into a large compact object. In some modern supersymmetric scenarios Q-balls are considered as a heavy particle-like objects, with Q being the baryon and/or lepton number. For many conceivable alternatives, Q-balls may contribute significantly to the dark matter and baryon contents of the Universe. Stable cosmological Q-balls can be searched for in existing and planned experiments. The Q-ball is a rather general physical object, which in principle can be formed in condensed matter systems.
The theoretical prediction of Q-balls in relativistic quantum fields is realized experimentally in superfluid $^3$He-B in collaboration with Professor Bunkov (Grenoble). The condensed-matter analogs of relativistic Q-balls are responsible for an extremely long lived signal of magnetic induction – the so-called Persistent Signal – observed in NMR at the lowest temperatures. At large Q the effect of self-localization is observed. In the language of relativistic quantum fields it is caused by interaction between the charged and neutral fields, where the neutral field provides the potential for the charged one. In the process of self-localization the charged field modifies locally the neutral field so that the potential well is formed in which the charge is condensed.

**NOVEL SUPERFLUIDITY OF $^3$HE IN AEROGEL**

G. Volovik

Collaborator: Yuriy Bunkov (Institut Néel, CNRS, France)

Investigation of the superfluid $^3$He has led to connection with another area of physics – physics of disordered systems. This is the investigation of the behavior of superfluid $^3$He confined in aerogel. Randomly oriented silicon strands of aerogel produce the random local anisotropy for the order parameter. Superfluid $^3$He-A confined in aerogel provides the first example of anisotropic superfluids, which exhibits the Larkin-Imry-Ma effect: the quenched random anisotropy destroys the long-range orientational order. This is confirmed by new NMR experiments on $^3$He-A in aerogel.

It has been also found that a sufficiently large uniaxial deformation applied to aerogel restores the orientational order. This occurs because the deformed aerogel acquires a global anisotropy along the axis of squeezing; this regular anisotropy suppresses the Larkin-Imry-Ma effect and induces a homogeneous orientation of the order parameter in the whole sample. Thus the squeezing of the aerogel is a unique tool for obtaining a uniform orientation of the order parameter in the whole sample in both phases of He. This allowed us to study the effects that are not possible in bulk $^3$He, in particular new modes of coherent precession which correspond to different types of magnon BEC have been observed in the deformed aerogel, also the geometry of the deformed aerogel stabilizes the spin superfluidity in $^3$He-A - the Bose condensation of magnons, which never occurs in pure $^3$He-A.

**CONNECTION TO COSMOLOGY AND PARTICLE PHYSICS**

G. Volovik

Collaborator: Frans Klinkhamer (University of Karlsruhe, Germany)

Physics of superfluid $^3$He 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 $^4$He, Bose-Einstein condensates (BEC) in ultra-cold gases, high-temperature and chiral superconductors, systems exhibiting quantum Hall and spin quantum Hall effects, etc. The other reason is that superfluid $^3$He belongs to the same universality class and is described by the same topology in momentum space as the Standard Model of weak, strong and electromagnetic interactions. This class is characterized by the existence of topologically stable Fermi 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.

The condensed matter experience tells us that there are two complementary schemes for the classification of quantum vacua, both are based on quantum mechanics which is assumed to be a fundamental theory. The traditional classification – the Grand Unification (GUT) scheme – assumes that fermionic and bosonic fields and gravity are also the fundamental phenomena. They obey the fundamental symmetry which becomes spontaneously broken at low energy, and is restored when the Planck energy scale is approached from below. The Fermi point scenario which we are developing provides a complementary anti-GUT scheme in which the ‘fundamental’ symmetry and ‘fundamental’ fields of GUT gradually emerge together with ‘fundamental’ physical laws when the Planck energy scale is approached from above. The emergence of the ‘fundamental’ laws of physics is provided by the general property of topology – robustness to details of the microscopic trans-Planckian physics. In this scheme, fermions are primary objects. Approaching the Planck energy scale from above, they are transformed to the Standard Model chiral fermions and give rise to the secondary objects: gauge fields and gravity. Below the Planck scale, the GUT scenario intervenes giving rise to symmetry breaking at low energy. This is accompanied by formation of composite objects, Higgs bosons, and tiny Dirac masses of quark and leptons. In the GUT scheme, general relativity is assumed to be as fundamental as quantum mechanics, while in the second scheme general relativity is a secondary phenomenon. In the anti-GUT scheme, general relativity is the effective theory describing the dynamics of the effective metric experienced by the effective low-energy fields. It is a side product of quantum field theory or of the quantum mechanics in the vacuum with Fermi point.

Developing this scheme in collaboration with Professor Klinkhamer from Karlsruhe we introduced the notion of the Lorentz-invariant self-sustained quantum vacuum which is characterized by the conserved extensive thermodynamic variable $q$. We found that in such vacuum the value of the cosmological constant in an emergent-gravity scenario is determined by the self-tuning of this variable. For the perfect quantum vacuum, the equilibrium value $q_0$ adjusts itself so that vacuum energy is nullified. In our considerations, a crucial role is played by the Lorentz invariance of the quantum vacuum, for which there is strong experimental support. A small nonzero value of the cosmological constant is proportional to the perturbation which violates the original Lorentz invariance of the perfect (unperturbed) quantum vacuum. Though the vacuum energy density is governed by processes in the deep ultraviolet vacuum, our approach demonstrates that the thermodynamics of the vacuum energy can be described by a relatively minor extension of the low-energy (infrared) effective theory. The introduction of an infrared thermodynamic variable, describing certain properties of the deep vacuum can be considered as the first step in a bottom-up approach (trying to go from the effective low-energy theory to the fundamental microscopic theory at Planck scale). This simple approach already allowed us to introduce the thermodynamic notion of the vacuum compressibility, which is a new fundamental constant, and to estimate the thermodynamic back reaction on the vacuum by low-energy phenomena. This also allows us to discuss the spectral function of vacuum energy, i.e. the contribution to the vacuum energy from different energy scales.
SIMULATION OF ROTATING BLACK HOLE

G. Volovik

Collaborator: Makoto Tsubota (Osaka City University, Osaka, Japan),

There are many challenges to simulate the phenomena on black holes by using condensed matter systems. One of them is to study an analogy between gravity and superfluidity, in which a superfluid ground state (superfluid vacuum) serves as the analog of the vacuum of relativistic quantum fields, while the flow of the superfluid liquid imitates the metric field acting on ‘relativistic’ quasiparticles (phonons, ripplons, fermionic excitations, etc.). The Hawking radiation from the black holes can be tested in this analogy. In collaboration with the group of professor Tsubota (Osaka, Japan) we suggested to exploit an atomic Bose-Einstein condensate (BEC) to simulate the similar effect – radiation by a rotating black hole, which is known as Zel’dovich - Starobinskii effect. We considered circular motion of a heavy object in a BEC at \( T = 0 \) K, and found that even if the linear velocity of the object is smaller than the Landau critical velocity, the object may radiate quasiparticles and thus experience the quantum friction. The radiation process is exactly similar to the radiation by a rotating black hole. This analogy emerges when one introduces the effective acoustic metric for quasiparticles. In the rotating frame this metric has an ergosurface, which is similar to the ergosurface in the metric of a rotating black hole. The calculated dependence of the radiation rate on the position of the ergosurface is in agreement with the Zel’dovich-Starobinskii scenario.

THERMAL AND NONEQUILIBRIUM EFFECTS IN NORMAL-SUPERCONDUCTING HETEROSTRUCTURES

Tero Heikkilä, Matti Laakso, Teemu Ojanen, Pauli Virtanen, and Juha Voutilainen

Collaborators: PICO group, M.S. Crosser, J. Huang, F. Pierre, N. O. Birge (Michigan State University), J.C. Cuevas (Autonomous University of Madrid), F. Giazotto (Scuola Normale Superiore, Pisa, Italy), P. Helistö and A. Luukanen (VTT), A.-P. Jauho (Laboratory of Physics, TKK), G. P. Pepe (University of Naples “Federico II”), I. Sosnin, J. Zou and V. Petrashev (Royal Holloway University of London, the UK), and F. K. Wilhelm (University of Waterloo, Canada)

Major part of our work on thermal and nonequilibrium effects is related to the study of these effects in superconducting proximity structures where the superconducting correlations leak into a normal metal, affecting its properties. For example, the whole thermoelectric response of these systems is modified due to this proximity effect. During 2007, we published our studies of the Peltier effect resulting essentially from the strong energy dependence of the supercurrent in superconducting proximity systems. In this work, we predicted that one may induce a finite heat current in the system by tuning the supercurrent flowing in it, either by externally applying it or controlling it via a magnetic flux. This supercurrent-controlled heat current results at suitable circumstances in a measurable cooling of the normal metal.
Fig. 1. Top: SEM picture of the multi-terminal normal-superconductor system. Bottom: stable phase configuration of the system vs. heating voltage.

We continued our collaboration with the experimental groups of I. Sosnin and V. Petrashov from the Royal Holloway University of London (RHUL) and the group of N.O. Birge from the Michigan State University (MSU). With the RHUL group, the attention was both in the thermoelectric response of superconducting proximity systems and in the nonequilibrium properties of multi-terminal normal-superconducting systems. Driving the system out of equilibrium with an external control current, the Josephson junctions realized by pairs of normal-superconductor contacts may turn into the pi-state where the supercurrent flows opposite to the gradient of the order pa-
parameter phase. In multi-terminal setups, it is possible to create many such pi-states, and depending on the range of control currents, a different combination of “0” and pi-states is possible (see Fig. 1 below). To our great regret, our fruitful collaboration with the RHUL group was terminated by the completely unexpected death of Dr Igor Sosnin in August 2007. We are all grateful to him for the many years of collaboration.

Our project with MSU continued with an article on nonequilibrium supercurrent and especially the effect of the supercurrent on the nonequilibrium state of the system. In this work, we also studied in detail the effect of a magnetic field on the SNS supercurrent in a previously unexplored regime.

We have generalized our earlier work on supercurrent transistors to the case of an all-superconducting SIS’IS system. Here S and S’ mark two different superconductors and I is an insulating layer between them. One interesting aspect of this work, not yet found experimentally, is the nonequilibrium-induced hysteretic superconductor-normal metal transition.

When discussing nonequilibrium or thermal effects in nanostructures, a very relevant topic is the characteristics of energy relaxation. At low temperatures the electrons and phonons are effectively decoupled and additional relaxation mechanisms become important. It was found that especially relevant is the coupling between the electrons and the surrounding electromagnetic modes. We showed how the heat current between the two systems can be calculated directly from the microscopic Hamiltonian and showed how this relaxation mechanism works in a nonequilibrium system.

Very recently, we have suggested a novel type of a radiation detector based on the strong temperature dependence of the supercurrent in superconductor-normal-metal-superconductor (SNS) systems. This “Proximity Josephson Sensor” seems to outperform the widely used superconducting transition edge sensors in some device aspects. This work was done together with the VTT Quantronics group, and groups from SNS-Pisa and University of Naples.

**CURRENT FLUCTUATIONS AND THEIR MEASUREMENT**

Tero Heikkilä, Teemu Ojanen, and Pauli Virtanen

Collaborators: the NANO and PICO groups, and M. P. Stenberg (Laboratory of Physics, TKK)

Our research on the nature of current fluctuations in mesoscopic systems concentrated during 2007 on the study of two effects: the effect of supercurrent on the nonequilibrium shot noise in multi-terminal normal-superconducting systems and to the study of the contact effects on the noise in carbon nanotubes, the latter in collaboration with the NANO group. In the work on carbon nanotubes, by taking into account the contact effects on the noise we were able to show that the intrinsic Fano factor of the disordered multi-wall nanotubes is very small, in contrast to previous expectations.

One of our main research topics on current fluctuations has been their measurement, and especially that of non-Gaussian noise. In 2007 we showed how the relaxation rate of quantum bits can be employed to “measure” the frequency dependent third cumulant of current fluctuations. It turns out from the full quantum theory of these fluctuations that the detailed description of these effects is very sensitive to the proper ordering of the current operators employed in the theory. In this work we showed that depending on how the fluctuations are connected, a quantum bit can act both as a “quan-
“quantum observer” for the fluctuations, in which case it detects a non-classical ordering of
the current fluctuations, or as a “classical observer” in which case it is only sensitive
to the fluctuations that correspond to the “classical” ordering. Connected to this work,
we also participated in the analyzing of the experimental results from the PICO group
on the third-cumulant effects on the supercurrent escape process.

**OPEN QUANTUM CIRCUITS**

**Tero Heikkilä**, Matti Laakso, and Teemu Ojanen

Collaborators: V. Bergholm and J. Salo (Laboratory of Physics, TKK), P. Helistö, A.
Luukanen and A.O. Niskanen (VTT), and A. A. Abdumalikov and Y. Nakamura
(NEC, Tsukuba, Japan)

Large part of our research on open quantum circuits is summarized in the doctoral
thesis of Teemu Ojanen. During the year 2007 our group studied for example effects
related to relaxation and decoherence in quantum bits. The effects of quantum and
classical noise on qubit dynamics were compared and it was shown how pairs of
qubits coupled to the same fluctuating bath can be efficiently decoupled from the
noise. Our group also studied the squeezing of quantum states with on-chip elements,
an effect which allows measuring position or momentum coordinates more accurately
than what is predicted by the Heisenberg’s uncertainty principle. These works were
done in collaboration with the Laboratory of Physics of TKK and with the NEC Fun-
damental and Environmental Research Laboratories, Japan.

Recently, we studied the reactive response of single-electron transistors (SET) and
showed that the correlations induced by the Coulomb energy in the system can make
rise to a gate-dependent capacitance contribution in the SET response (see Fig. 2).

![Imaginary part of the admittance of a SET vs. frequency and gate voltage.](image_url)

Fig. 2. Imaginary part of the admittance of a SET vs. frequency and gate voltage.
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 functions of the human cerebral cortex 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 (Vectorview, Elekta-Neuromag Ltd), functional since 1998, 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 Human Brain Imaging, 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.

In association with the lab's move to Nanotalo at the end of 2007, our MEG operations moved very smoothly to a new facility. Our brand-new three-layered magnetically shielded room provides several technical improvements compared with the old two-layered magnetically shielded room. During the design and construction phase, special attention was paid to passive shielding of environmental noise. As a part of the BRU's research agreement with Elekta-Neuromag, the MEG sensors and the data acquisition system were upgraded to the newest technology, allowing sampling frequencies up to 5000 Hz. As a result of the upgrade, our MEG facility is one of the most advanced sites in the world, with gratifying low noise figures.

The new location of the BRU provides better working facilities and more closely located office space, which greatly improves group cohesion.

We list below our achievements from 2007 in the form of published papers.

HUMAN SYSTEMS NEUROSCIENCE


We quantified rhythmic brain activity, recorded with whole-scalp magnetoencephalography (MEG), of 13 healthy subjects who were performing, seeing, or hearing the tapping of a drum membrane with the right index finger. In the actor's primary motor (M1) cortex, the level of the approximately 20-Hz brain rhythms started to decrease,
as a sign of M1 activation, approximately 2 s before the action and then increased, with a clear rebound approximately 0.6 s after the tapping, as a sign of M1 stabilization. A very similar time course occurred in the M1 cortex of the observer: the activation, although less vigorous than in the actor, started approximately 0.8 s before the action and was followed by a rebound. When the subject just heard the tapping sound, no preaction activation was visible, but a rebound followed the sound. The approximately 10-Hz somatosensory rhythm, which also started to decrease before own and viewed actions, returned to the baseline level approximately 0.6 s later after own actions than observed actions. This delay likely reflects proprioceptive input to the cortex, available only during own actions, and therefore could be related to the brain signature of the sense of agency. The strikingly similar motor cortex reactivity during the first and third person actions expands previous data on brain mechanisms of intersubjective understanding. Besides motor cortex activation before own and observed (predicted) actions, the M1 cortex of both the viewer and the listener stabilized in a very similar manner after brisk motor actions.


The ability of magnetoencephalography (MEG) to accurately localize neuronal currents and obtain tangential components of the source is largely due to MEG's insensitivity to the conductivity profile of the head tissues. However, MEG cannot reliably detect the radial component of the neuronal current. In contrast, the localization accuracy of electroencephalography (EEG) is not as good as MEG, but EEG can detect both the tangential and radial components of the source. In the present study, we investigated the conductivity dependence in a new approach that combines MEG and EEG to accurately obtain, not only the location and tangential components, but also the radial component of the source. In this approach, the source location and tangential components are obtained from MEG alone, and optimal conductivity values of the EEG model are estimated by best-fitting EEG signal, while precisely matching the tangential components of the source in EEG and MEG. Then, the radial components are obtained from EEG using the previously estimated optimal conductivity values. Computer simulations testing this integrated approach demonstrated two main findings. First, there are well-organized optimal combinations of the conductivity values that provide an accurate fit to the combined MEG and EEG data. Second, the radial component, in addition to the location and tangential components, can be obtained with high accuracy without needing to know the precise conductivity profile of the head. We then demonstrated that this new approach performed reliably in an analysis of the 20-ms component from human somatosensory responses elicited by electric median-nerve stimulation.


OBJECTIVE: To describe a novel non-magnetic hand-held device to stimulate various parts of the skin and to evaluate its performance in magnetoencephalographic (MEG) recordings. METHODS: The hand-held part of the device consists of an optic fiber bundle that forms a small brush. Half of the fibers emit modulated red light and the other half detect the reflected light from the skin so that the brush-to-skin contact is detected by means of reflectance. RESULTS: Light tapping of the back of the hand
at the innervation area of the radial nerve elicited clear responses in all 10 subjects studied, with the main deflections peaking 40-70 ms after the stimulus. The earliest responses, obtained with a higher number of averaged trials, peaked 27-28 ms after the tap to the left hand dorsum. Source analysis of the MEG signals indicated neuronal sources at the primary somatosensory (SI) cortex, with a clear somatotopical order for face vs. hand. CONCLUSIONS: The device seems feasible for both MEG and functional magnetic resonance imaging experiments to address functional anatomy of the human somatosensory system with a real-life like stimulation. SIGNIFICANCE: Non-magnetic and artefact-free tactile stimulator with a selective stimulus offers new possibilities for experimental designs to study the human mechanoreceptor system.


In search for suitable tools to study brain activation in natural environments, where the stimuli are multimodal, poorly predictable and irregularly varying, we collected functional magnetic resonance imaging data from 6 subjects during a continuous 8-min stimulus sequence that comprised auditory (speech or tone pips), visual (video clips dominated by faces, hands, or buildings), and tactile finger stimuli in blocks of 6-33 s. Results obtained by independent component analysis (ICA) and general-linear-model-based analysis (GLM) were compared. ICA separated in the superior temporal gyrus one independent component (IC) that reacted to all auditory stimuli and in the superior temporal sulcus another IC responding only to speech. Several distinct and rather symmetric vision-sensitive ICs were found in the posterior brain. An IC in the V5/MT region reacted to videos depicting faces or hands, whereas ICs in the V1/V2 region reacted to all video clips, including buildings. The corresponding GLM-derived activations in the auditory and early visual cortices comprised sub-areas of the ICA-revealed activations. ICA separated a prominent IC in the primary somatosensory cortex whereas the GLM-based analysis failed to show any touch-related activation. "Intrinsic" components, unrelated to the stimuli but spatially consistent across subjects, were discerned as well. The individual time courses were highly consistent in sensory projection cortices and more variable elsewhere. The ability to differentiate functionally meaningful composites of activated brain areas and to straightforwardly reveal their temporal dynamics renders ICA a sensitive tool to study brain responses to complex natural stimuli.


Phantom-based evaluation of geometric distortions in functional MRI and diffusion tensor imaging (DTI) was investigated. An acrylic water-filled phantom with a grid structure was designed and manufactured to provide accurate geometric information over the volume measured in human brain imaging. The grid structures were well detected in data acquired using a 3-T MRI scanner with echo-planar imaging (EPI) sequences commonly applied in functional MRI and DTI. A method for quantifying distortions in the phantom data was presented and applied for the images. The validity of the phantom for EPI was evaluated by quantitatively comparing the distortions present in and induced by the phantom and a human brain when imaged under identical conditions. The results suggest that the new phantom can reveal geometric dis-
tortions easily undermined by standard MRI phantoms. For example, prominent va-
riability in the distortions was found as a function of the orientation of the diffusion-
sensitizing gradient. Possible future applications for this type of phantom include
quality assurance and calibration of the hardware and software used in EPI-based
functional MRI and DTI.

Saarela MV, Hlushchuk Y, de C Williams AC, Schürmann M, Kalso E, and Hari
R: The compassionate brain: Humans detect intensity of pain from another’s face. Ce-

Understanding another person's experience draws on "mirroring systems," brain cir-
cuitries shared by the subject's own actions/feelings and by similar states observed in
others. Lately, also the experience of pain has been shown to activate partly the same
brain areas in the subjects' own and in the observer's brain. Recent studies show re-
markable overlap between brain areas activated when a subject undergoes painful
sensory stimulation and when he/she observes others suffering from pain. Using func-
tional magnetic resonance imaging, we show that not only the presence of pain but
also the intensity of the observed pain is encoded in the observer's brain-as occurs
during the observer's own pain experience. When subjects observed pain from the
faces of chronic pain patients, activations in bilateral anterior insula (AI), left anterior
cingulate cortex, and left inferior parietal lobe in the observer's brain correlated with
their estimates of the intensity of observed pain. Furthermore, the strengths of activa-
tion in the left AI and left inferior frontal gyrus during observation of intensified pain
correlated with subjects' self-rated empathy. These findings imply that the intersub-
jective representation of pain in the human brain is more detailed than has been pre-
viously thought.

Schürmann M, Järveläinen J, Avikainen S, Cannon TD, Lönnqvist J, Huttunen
M, and Hari R: Manifest disease and motor-cortex reactivity in twins discordant for

Schizophrenia is often associated with difficulties in distinguishing between actions
of self and of others. This could reflect dysfunction of the mirror neuron system
which directly matches observed and executed actions. We studied 11 people with
schizophrenia and their co-twins without manifest disease, using stimulus-induced
changes in the magnetoencephalographic approximately 20 Hz rhythm as an index of
activation in the motor cortex part of the mirror neuron system. During action obser-
vation and execution, motor cortex reaction was weaker in those with schizophrenia
than in their co-twins, suggesting a disease-related dysfunction of motor cognition.

Seppä M: High-quality two-stage resampling for 3-D volumes in medical imaging.

This paper introduces a simple method of two-stage resampling where Fourier-
domain up-sampling is followed by traditional resampling. Practical aspects as well as
efficient implementation techniques are considered. A new version of pruned FFT
algorithms to calculate the up-sampling stage is also introduced. The suggested two-
stage resampling method provides very high-quality results exceeding those of the
previous algorithms. It excels with higher dimensional datasets due to its ability to
employ small-support kernels. The applied FFT algorithms make the method most
efficient with dataset sizes of powers of two. These reasons and the importance of mi-
Animal resampling artifacts make the suggested method especially suitable for 3-D volumes in medical imaging. Furthermore, for repeated uses, only the second stage is recalculated allowing an increase in performance for motion correction applications in functional magnetic resonance imaging (fMRI), for example.


To clarify the relationship between face perception and cortical activation, we manipulated the face recognition performance of 9 subjects by varying the duration (DUR) of stimuli while cortical neuromagnetic responses were recorded. A face image replaced a continuous pixel-noise mask for 17-200 ms, and the subject reported which of the pre-learned faces had been presented. Two cortical responses were clearly stronger to intact than phase-scrambled faces: the temporo-occipital response peaking at 140-200 ms (M170) and a more widely distributed response peaking at 200-500 ms (M300). For the shortest DURs (17-33 ms), face recognition was at chance level and the cortical responses negligible. For DURs of 50-83 ms, the proportion of recognized faces as well as the strength of cortical responses increased steeply. Recognition performance saturated at DURs of around 100 ms, whereas cortical responses continued to increase until the longest DUR of 200 ms. Amplitudes of both M170 and M300 were thus tightly correlated with recognition performance (r=0.98), but comparison of the increment rates as a function of DUR showed the recognition performance to have an even closer similarity to M170 than to M300. In single-trial analysis the variability of response strengths increased in a direct proportion to response amplitude, demonstrating the averaged responses to be composed of graded rather than of all-or-nothing-type single responses.


Coherence between electromyography (EMG) and electroencephalography (EEG) or magnetoencephalography (MEG) is frequently examined to gain insights on neuromuscular binding. Commonly, EMG signals are rectified before coherence is computed. However, the appropriateness of EMG rectification in computing EMG-EEG/MEG coherence has never been validated. Since rectification is a non-linear operation and alters the EMG power spectrum, such a validation is important to ensure the accuracy of coherence calculation. In this study we experimentally investigated the effects of EMG rectification on EMG power spectra and its coherence with EEG/MEG signals. Subjects performed sustained isometric index finger abduction at approximately 5-10% maximal voluntary force (in both EEG-EMG and MEG-EMG experiments) and index finger tapping at approximately 2-4Hz (in EEG-EMG experiment only). Bipolar surface EMG data from the first dorsal interosseus (FDI) and EEG/MEG signals from the contralateral primary sensorimotor area (C3) were recorded simultaneously. Power spectra and coherence with the EEG/MEG were calculated before and after EMG rectification. The results show that rectification shifts EMG power to lower frequencies, possibly enhancing peaks of motor unit firing. Coherences with the EEG/MEG signals were not significantly changed by EMG rectification, indicating EMG rectification is overall an appropriate procedure in power and coherence analyses.

Annual Report 2007
Words forming a continuous story were presented to 9 subjects at frequencies ranging from 5 to 30 Hz, determined individually to render comprehension easy, effortful, or practically impossible. We identified a left-hemisphere neural network sensitive to reading performance directly from the time courses of activation in the brain, derived from magnetoencephalography data. Regardless of the stimulus rate, communication within the long-range neural network occurred at a frequency of 8-13 Hz. Our coherence-based detection of interconnected nodes reproduced several brain regions that have been previously reported as active in reading tasks, based on traditional contrast estimates. Intriguingly, the face motor cortex and the cerebellum, typically associated with speech production, and the orbitofrontal cortex, linked to visual recognition and working memory, additionally emerged as densely connected components of the network. The left inferior occipitotemporal cortex, involved in early letter-string or word-specific processing, and the cerebellum turned out to be the main forward driving nodes of the network. Synchronization within a subset of nodes formed by the left occipitotemporal, the left superior temporal, and orbitofrontal cortex was increased with the subjects’ effort to comprehend the text. Our results link long-range neural synchronization and directionality with cognitive performance.

Parafoveal-on-foveal priming refers to the presentation of an item (the prime) in parafoveal vision followed by the presentation of an item (the target) in foveal vision. In natural reading, the 'parafoveal preview benefit' suberves fluent reading as, e.g., reading times increase when such information is not available. Yet, the neural correlates of reading are mostly studied with foveally presented stimuli and little is known of this parafoveal influence. Here, we used complementary information from a behavioral study and a magnetoencephalography experiment to clarify the relationship between parafoveal-on-foveal and foveal priming. Unlike foveal priming, parafoveal-on-foveal priming was present only at short prime-to-target delay (<100 ms). Behaviorally, the parafoveal priming effect was influenced by the prime visual field (left/right) and target lexical type (word/non-word), suggesting emphasis on perceptual analysis for LVF primes and on conceptual analysis for RVF primes. At the neural level, the overall sequence of activation was similar for foveal and parafoveal primes followed by foveal word targets, but the priming effects were bilateral for foveal primes versus left-lateralized for RVF primes. No neural effects of priming appeared for LVF primes, in line with the RVF preference imposed by the Western writing system. These results highlight the role of the left hemisphere in linguistic analysis and point out possible limitations of foveal stimulus presentation for drawing conclusions about natural reading.
Clinical evaluation of language function and basic neuroscience research into the neurophysiology of language are tied together. Whole-head MEG systems readily facilitate detailed spatiotemporal characterization of language processes. A fair amount of information is available about the cortical sequence of word perception and comprehension in the auditory and visual domain, which can be applied for clinical use. Language production remains, at present, somewhat less well charted. In clinical practice, the most obvious needs are noninvasive evaluation of the language-dominant hemisphere and mapping of areas involved in language performance to assist surgery. Multiple experimental designs and analysis approaches have been proposed for estimation of language lateralization. Some of them have been compared with the invasive Wada test and need to be tested further. Development of approaches for more comprehensive pre-surgical characterization of language cortex should build on basic neuroscience research, making use of parametric designs that allow functional mapping. Studies of the neural basis of developmental and acquired language disorders, such as dyslexia, stuttering, and aphasia can currently be regarded more as clinical or basic neuroscience research rather than as clinical routine. Such investigations may eventually provide tools for development of individually targeted training procedures and their objective evaluation.


Electrophysiological methods have been used to study the temporal sequence of syntactic and semantic processing during sentence comprehension. Two responses associated with syntactic violations are the left anterior negativity (LAN) and the P600. A response to semantic violation is the N400. Although the sources of the N400 response have been identified in the left (and right) temporal lobe, the neural signatures of the LAN and P600 have not been revealed. The present study used magnetoencephalography to localize sources of syntactic and semantic activation in Finnish sentence reading. Participants were presented with sentences that ended in normally inflected nouns, nouns in an unacceptable case, verbs instead of nouns, or nouns that were correctly inflected but made no sense in the context. Around 400 msec, semantically anomalous last words evoked strong activation in the left superior temporal lobe with significant activation also for word class errors (N400). Weaker activation was seen for the semantic errors in the right hemisphere. Later, 600-800 msec after word onset, the strongest activation was seen to word class and morphosyntactic errors (P600). Activation was significantly weaker to semantically anomalous and correct words. The P600 syntactic activation was localized to bilateral sources in the temporal lobe, posterior to the N400 sources. The results suggest that the same general region of the superior temporal cortex gives rise to both LAN and N400 with bilateral reactivity to semantic manipulation and a left hemisphere effect to syntactic manipulation. The bilateral P600 response was sensitive to syntactic but not semantic factors.

VISION SYSTEMS PHYSIOLOGY

BACKGROUND: Patients with homonymous hemianopia often have some residual sensitivity for visual stimuli in their blind hemifield. Previous imaging studies suggest an important role for extrastriate cortical areas in such residual vision, but results of training to improve vision in patients with hemianopia are conflicting. OBJECTIVE: To show that intensive training with flicker stimulation in the chronic stage of stroke can reorganise visual cortices of an adult patient. METHODS: A 61-year-old patient with homonymous hemianopia was trained with flicker stimulation, starting 22 months after stroke. Changes in functioning during training were documented with magnetoencephalography, and the cortical organisation after training was examined with functional magnetic resonance imaging (fMRI). RESULTS: Both imaging methods showed that, after training, visual information from both hemifields was processed mainly in the intact hemisphere. The fMRI mapping results showed the representations of both the blind and the normal hemifield in the same set of cortical areas in the intact hemisphere, more specifically in the visual motion-sensitive area V5, in a region around the superior temporal sulcus and in retinotopic visual areas V1 (primary visual cortex), V2, V3 and V3a. CONCLUSIONS: Intensive training of a blind hemifield can induce cortical reorganisation in an adult patient, and this case shows an ipsilateral representation of the trained visual hemifield in several cortical areas, including the primary visual cortex.


BACKGROUND: Blindness of a visual half-field (hemianopia) is a common symptom after postchiasmatic cerebral lesions. Although hemianopia severely limits activities of daily life, current clinical practice comprises no training of visual functions in the blind hemifield. OBJECTIVE: To find out whether flicker sensitivity in the blind hemifield can be improved with intensive training, and whether training with flicker stimulation can evoke changes in cortical responsiveness. METHODS: Two men with homonymous hemianopia participated in the experiments. They trained with flicker stimuli at 30 degrees or with flickering letters at 10 degrees eccentricity twice a week for a year, and continued training with more peripheral stimuli thereafter. Neuromagnetic responses were registered at 1-2-month intervals, and the Goldmann perimetry was recorded before, during and after training. RESULTS: Flicker sensitivity in the blind hemifield improved to the level of the intact hemifield within 30 degrees eccentricity in one participant and 20 degrees eccentricity in the other. Flickering letters were recognised equally at 10 degrees eccentricity in the blind and intact hemifields. Improvement spread from the stimulated horizontal meridian to the whole hemianopic field within 30 degrees. Before training, neuromagnetic recordings showed no signal above the noise level in the hemianopic side. During training, evoked fields emerged in both participants. No changes were found in the Goldmann perimetry. DISCUSSION: Results show that sensitivity to flicker could be fully restored in the stimulated region, that improvement in sensitivity spreads to the surrounding neuronal networks, and that, during training, accompanying changes occurred in the neuromagnetic fields.

We aimed to study cortical responses to uniform luminance stimulus in different conditions. We stimulated the central visual field with luminance flicker and reversal of checkerboard pattern contrast and mapped the visual field representation up to 50 degrees of eccentricity. Our results show spreading of cortical BOLD responses when visual stimulus contains mean luminance change in dark surround and no spreading when the stimulus surround has bright illumination. No cortical region was more sensitive to luminance flicker than to pattern reversal during both stimulation setups. We suggest that the spread of luminance responses in retinotopic cortical areas results from intraocular scattering of light. Light scattered inside the eye spreads visual stimulation on the retina, and the contrast of the scattered light is strongest when the surround of the stimulus is dark. The stray light is potential and often neglected source of an artefact in visual experiments, and the responses due to stray light can erroneously be interpreted as indicators for local cortical sensitivity to luminance.


OBJECTIVE: Despite mapping tools for central visual field, delineation of peripheral visual field representations in the human cortex has remained a challenge. Access to large visual field and differentiation of retinotopic areas with robust mapping procedures and automated analysis are beneficial in basic research and could accelerate development of clinical applications. METHODS: We constructed a simple optical near view system for wide visual field stimulation, and examined the topology of retinotopic areas. We used multifocal (mf) design, which enables analysis with general linear model and standard fMRI softwares and is easily automated. RESULTS: Our stimulation method enabled individual mapping of visual field up to 50 degrees of eccentricity and showed that retinotopic visual areas extended through posterior cerebrum. In addition, we located a separate peripheral upper visual field representation in parieto-occipital (PO) sulcus. CONCLUSIONS: These functional results are in line with earlier histological data, and support recent findings on human V6, a retinotopic area in the medial PO sulcus with an apparent emphasis on peripheral visual field. SIGNIFICANCE: Our projection system and mf-design together enable efficient and robust retinotopic mapping of wide visual field, which can at low cost be adapted to any clinical environment with visual back-projection system.

OTHER USERS of BRU FACILITIES


A recently introduced Bayesian model for magnetoencephalographic (MEG) data consistently localized multiple simulated dipoles with the help of marginalization of spatiotemporal background noise covariance structure in the analysis [Jun et al., (2005): Neuroimage 28:84-98]. Here, we elaborated this model to include subject's individual brain surface reconstructions with cortical location and orientation constraints. To enable efficient Markov chain Monte Carlo sampling of the dipole locations, we adopted a parametrization of the source space surfaces with two continuous variables (i.e., spherical angle coordinates). Prior to analysis, we simplified the likelihood by exploiting only a small set of independent measurement combinations obtained by singular value decomposition of the gain matrix, which also makes the
sampler significantly faster. We analyzed both realistically simulated and empirical MEG data recorded during simple auditory and visual stimulation. The results show that our model produces reasonable solutions and adequate data fits without much manual interaction. However, the rigid cortical constraints seemed to make the utilized scheme challenging as the sampler did not switch modes of the dipoles efficiently. This is problematic in the presence of evidently highly multimodal posterior distribution, and especially in the relative quantitative comparison of the different modes. To overcome the difficulties with the present model, we propose the use of loose orientation constraints and combined model of prelocalization utilizing the hierarchical minimum-norm estimate and multiple dipole sampling scheme.


In recent simulation studies, a hierarchical Variational Bayesian (VB) method, which can be seen as a generalisation of the traditional minimum-norm estimate (MNE), was introduced for reconstructing distributed MEG sources. Here, we studied how non-linearities in the estimation process and hyperparameter selection affect the inverse solutions, the feasibility of a full Bayesian treatment of the hyperparameters, and multimodality of the true posterior, in an empirical dataset wherein a male subject was presented with pure tone and checkerboard reversal stimuli, alone and in combination. An MRI-based cortical surface model was employed. Our results show, with a comparison to the basic MNE, that the hierarchical VB approach yields robust and physiologically plausible estimates of distributed sources underlying MEG measurements, in a rather automated fashion.

OTHER PUBLICATIONS by BRU PERSONNEL


Elements in the alkali metal series are regarded as unlikely superconductors because of their monovalent character. A superconducting transition temperature as high as 20 K, recently found in compressed lithium (the lightest alkali element), probably arises from pressure-induced changes in the conduction-electron band structure. Superconductivity at ambient pressure in lithium has hitherto remained unresolved, both theoretically and experimentally. Here we demonstrate that lithium is a superconductor at ambient pressure with a transition temperature of 0.4 mK. As lithium has a particularly simple conduction electron system, it represents an important case for any attempts to classify superconductors and transition temperatures, especially to determine if any non-magnetic configuration can exclude superconductivity down to zero temperature. Furthermore, the combination of extremely weak superconductivity and relatively strong nuclear magnetism in lithium would clearly lead to mutual competition between these two ordering phenomena under suitably prepared conditions.
TEACHING ACTIVITIES

COURSES

Nanoelectronics (Tfy-3.491)  
(Kyl-0.108 Nanophysics, Kyl-0.108 Nanofysiikka)  
Lectures: Doc. Tero Heikkilä 26 hours  
Teaching assistant: Matti Laakso

Quantum computing (Tfy-44.140)  
Lecturer: Mikio Nakahara 20 hours (visiting professor, Kinki University, Japan)  
Teaching assistant: M.Sc. Tech. Juha Voutilainen

Human systems neuroscience (University of Helsinki, Neoroscience Center & BRU, LTL, TKK)  
Lecture course “Brain and thinking: What brain imaging can tell about human brain function” by Prof. Riitta Hari  
Teaching assistant: M.Sc. Tech. Sanna Malinen

RESEARCH SEMINARS ON LOW TEMPERATURE PHYSICS AND NANOPHYSICS

Coordinators: Vladimir Eltsov, Pertti Hakonen, Tero Heikkilä, and Jukka Pekola

Alexander Savin, LTL, Finland, Parity effect in Al and Nb single electron transistors in a tunable environment, Dec 18

Tomas Novotny, Charles University in Prague, Czech Republic, Full counting statistics for interacting non-Markovian nanosystems, Dec 13

Teemu Ojanen, LTL, Finland, Journal club on cavity quantum electrodynamics, Dec 11

Alexey Starobinsky, Landau Institute for Theoretical Physics, Moscow, Russia, Reconstructing dark energy properties from observations, Dec 10

Nikolai Kopnin, LTL, Finland, NIS coolers in photon-assisted tunneling regime, Dec 4

Teemu Ojanen, LTL, Finland, Quantum fluctuations and transport in mesoscopic systems, Nov 30

Frank Wilhelm, Institute for Quantum Computing, Waterloo, Canada, Dynamical tunneling in macroscopic systems, Nov 29

Maciej Zwierzycki, Institute of Molecular Physics, Polish Academy of Sciences, Poland, Spin polarized transport from first principles. From magnetic multilayers to graphene, Nov 28

Stefan Krompiewski, Institute of Molecular Physics, Polish Academy of Sciences, Poland, Theoretical studies of tunnel magnetoresistance and shot noise in carbon nanotubes, Nov 27

Shiro Kawabata, Chalmers University of Technology, Sweden, Theoretical and experimental research on MQT in high-Tc Josephson junctions, Nov 22

Andrew Armour, University of Nottingham, UK, Dynamics of nanomechanical Single-Electron Transistors, Oct 23

Matthias Meschke, LTL, Finland, Nano Journal Club, Oct 16

Tommy Holmqvist, LTL, Finland, Improved Coulomb Blockade Thermometer, Oct 9

Annual Report 2007
Mika Sillanpää, LTL, Finland, Coherent quantum state storage and transfer between two-phase qubits via a resonant cavity, Oct 2
Vladimir Zakharov, University of Arizona, USA, Kolmogorov spectra of weak turbulence, Sep 27
Jayanta Sarkar, LTL, Finland, Improvement to the LSET qubit design, Sep 25
Dmitri Denisov, Department of Physics, University of Oslo, Norway, Thermomagnetic instabilities in MgB2 superconductors, Sep 11
Yukio Tanaka, Department of Applied Physics, Nagoya University, Japan, Odd-frequency pairing state in superconducting junctions, Sep 7
Jukka Pekola and Fan Wu, LTL, Finland, Nano Journal Club, Sep 4
Teemu Ojanen, LTL, Finland, Photon heat transport in nanostructures, Aug 28
Pertti Hakonen and Andrey Timofeev, LTL, Finland, Nano Journal Club, Aug 21
Wiebke Guichard, France, Tunable coupling between a charge qubit and an anharmonic quantum oscillator, Aug 14
Antti Kemppinen and Jayanta Sarkar, LTL, Finland, Nano Journal Club, Aug 7
Pauli Virtanen, LTL, Finland, Multiple pi-states in multiprobe NS structures, Jun 19
Gordey Lesovik, L.D. Landau Institute of Theoretical Physics, Russia, Noise and statistics of charge transport in quantum conductors, Jun 13
Juha Voutilainen and Teemu Ojanen, LTL, Finland, Nano Journal Club, Jun 12
Gordey Lesovik, L.D. Landau Institute for Theoretical Physics, Russia, On the possibility of magnetic flux detection by Andreev quantum dot, Jun 8
Fan Wu, LTL, Finland, Shot noise in SWNTs and MWNTs, Jun 5
Antti Niskanen, VTT, Finland, Quantum coherent tunable coupling of superconducting qubits, May 31
David Gunnarsson and Alexander Savin, LTL, Finland, Nano Journal Club, May 29
Sigmund Kohler, Universität Augsburg, Germany, Landau-Zener tunneling in circuit QED and dissipative environments, May 22
Olli-Pentti Saira and Pauli Virtanen, LTL, Finland, Nano Journal Club, May 15
David Gunnarsson, LTL, Finland, Harmonic oscillator interactions with the Single Cooper Box, May 8
Vladimir Lebedev, Landau Institute, Moscow, Russia, Patch coalescence as a mechanism for eukaryotic directional sensing, May 8
Tero Heikkilä, LTL, Finland, Nano Journal Club, Apr 24
Juha Voutilainen, LTL, Finland, Nonequilibrium charge transport in quantum SINIS structures, Apr 17
Dmitry Podolsky, Helsinki Institute of Physics, University of Helsinki, Finland, Large scale properties of the Universe, Apr 12
Romain Danneau, LTL, Finland, Single wall carbon nanotube Josephson junctions, Apr 10
Meri Helle, Matthias Meschke, LTL, Finland, Nano Journal Club, Mar 27
Fan Wu, Romain Danneau, LTL, Finland, Nano Journal Club, Mar 20
Yuriy Bunkov, CNRS, Grenoble, France, Superfluid 3He in anisotropic aerogel, Mar 14
Yasushi Kondo, Kinki University, Japan, Quantum teleportation without irreversible detection: NMR-experiment, Mar 13
Marcel Clovecko, Institute of Experimental Physics, Kosice, Slovakia, Andreev reflection measured by quartz tuning fork - A new tool to study superfluid 3He-B, Mar 7
Juha Vartiainen, Tommy Holmqvist, LTL, Finland, Nano Journal Club, Mar 6
Pertti Hakonen, LTL, Finland, *Gate-controlled superconductivity in a diffusive multiwalled carbon nanotube*, Mar 2
Juan Carlos Cuevas, Universidad Autonoma de Madrid, Spain, *Atomic contacts: A test-bed for mesoscopic superconductivity*, Feb 27
Makoto Tsubota, Osaka City University, Japan, *Topics on quantum turbulence*, Feb 22
Olli-Pentti Saira, LTL, Finland, *Coulomb blockade in electronic refrigeration*, Feb 20
Hideo Yano, Osaka City University, Japan, *Generation and detection of quantum turbulence by a vibrating wire in superfluid 4He*, Feb 20
Andrey Timofeev, Mikko Möttönen, LTL, Finland, *Nano Journal Club*, Feb 13
Juha Vartiainen, LTL, Finland, *Nanoampere pumping of Cooper pairs*, Feb 6
Lorenz Lechner and Pertti Hakonen, LTL, Finland, *Nano Journal Club*, Jan 30
Yuri Galperin, University of Oslo, Norway, *Many electron theory of 1/f-noise in hopping conductivity*, Jan 29
Mikko Möttönen, LTL, Finland, *Observation of the Berry phase in superconducting circuits*, Jan 23
Alexander Savin and Jayanta Sarkar, LTL, Finland, *Nano Journal Club*, Jan 16

**RESEARCH SEMINARS OF THE BRU**

Gina Caetano, *Brain mechanisms of audiotactile and audiomotor interactions*, Dec 21
Mikko Viinikainen, LCE (Laboratory of Computational Engineering, TKK), *Observed emotional valence is processed non-linearly in the human brain*, Dec 17
Gina Caetano, *BBQ*, Dec 14
Lauri Parkkonen, Linda Stenbacka, Johanna Vartiainen, *Literature reviews and conference greetings*, Dec 10
Linda Henriksson, Annika Hulten, Hannu Laaksonen, Pavan Ramkumar, *Conference Greetings from SfN*, San Diego, Dec 3
Lauri Nurminen, *Prediction of single-cell receptive field properties from fMRI data*, Nov 26
Topi Tanskanen, *From local to global: cortical dynamics of contour integration*, Nov 19
Iiro Jääskeläinen, LCE, *Short-term plasticity in auditory cognition*, Nov 5
Jan Kujala, *BBQ, Localization and characterization of rhythmic activity and cortico-cortical connectivity with magnetoencephalography*, Oct 29
Tiina Parviainen, *Cortical correlates of language perception - neuromagnetic studies in adults and children*, Oct 15
Jouko Lampinen, LCE, *Bayesian approach for studying the brain*, Oct 8
Tiina Parviainen, *BBQ*, Oct 4
Liisa Helle, Lotta Hirvenkari, Tom Rosenström, Antti Tanner, *Students present their work*, Oct 1
Mika Seppä, *BBQ*, Sep 11
Harri Valpola, LCE, *Reverse engineering the brain*, Sep 10
Päivi Helenius, Annika Hulten, Miitu Saarela, *Conference greetings*, Sep 3
Paolo Belardinelli, University of Chieti, Italy, *From where to how: A wayfinding to neural functions*, Aug 21
Cathy Nangini, *Primary somatosensory cortex as seen by fMRI and MEG: a simple model*, Aug 20

Annual Report 2007
Veli-Matti Saarinen, Marika Kaksonen, Eye tracking: Equipment and methods, Jun 11
Aapo Nummenmaa, LCE, Sparse neuromagnetic inverse solutions via hierarchical Bayesian modeling, Jun 4
Alard Roebroeck, Department of Cognitive Neuroscience, Faculty of Psychology, Maastricht University, The Netherlands, Magnetic resonance imaging of brain connectivity: Diffusion tensor imaging and granger causality, May 21
BRU Seniors, Center of Excellence SAB meeting, May 14
Lauri Parkkonen, State-of-the-art minimum norm estimation in MEG source modeling: Introduction to the 'MNE suite' free software package, May 7
Pavan Ramkumar, Marja-Liisa Halko, Päivi Helenius, Literature review, Apr 23
Marc Schoenwiesner, Department of Neuropsychology, Montreal Neurological Institute, Canada, Spatial perception and pattern recognition in the hearing system, Apr 16
Ole Jensen, F.C. Donders Centre for Cognitive Neuroimaging, The Netherlands, The role of posterior alpha activity for neuronal processing and the generation of ERFs, Mar 29
Satu Lamminmäki, Auditory system. Frequency tagging of natural stimuli, Mar 26
Jaakko Järvinen, Recovery of light responses in mouse rod photoreceptors recorded with the suction pipette, Mar 19
Mia Liljestrom, Action and object naming, Mar 12
Sanna Malinen, Miimaaaria Saarela, Reviews of recent literature, Mar 5
Antti Yli-Krekola, LCE, A bioinspired computational model of covert attention and learning, Feb 26
Teemu Rinne, Department of Psychology, University of Helsinki, The effect of attention on human auditory cortex and the inferior colliculus, Feb 21
Katri Koskentalo, LCE, Brain activation networks during natural viewing conditions, Feb 5
Mark Andermann, LCE and BRU, Probing prestimulus predictors of perception, Jan 29
Päivi Sivonen, Annika Hulten, Johanna Uusvuori, Reviews of fresh literature: The Birds, Jan 22
Hannu Laaksonen, Using DICS to investigate rhythmic activity in MEG, Jan 15
Yevhen Hlushchuk, BBQ, Jan 5

SPECIAL ASSIGNMENTS

Jaakko Hosio, Nonlinear damping of vibrating objects in 3He-B. Instructor: Dr. Vladimir Eltsov.
Jaakko Hosio, Quantum turbulence and thermal transport in the ballistic regime of superfluid 3He-B. Instructor: Dr. Vladimir Eltsov.
Laura Korhonen, Fabrication of a Bloch Oscillating Transistor. Instructor: Prof. Pertti Hakonen.
Matti Laakso, Frequency dependent conductance of a single-electron transistor. Instructor: Doc. Tero Heikkilä

Annual Report 2007


Matti Tomi, *Controlled deposition of carbon nanotubes by dielectrophoresis*. Instructor: Prof. Pertti Hakonen.

**ACADEMIC DEGREES**

**DIPLOMA THESES**

Antti Paila graduated as M.Sc. from the Department of Engineering Physics and Mathematics on August. His diploma thesis *Landau-Zener interferometry using a superconducting quantum bit* was done in the LTL. Supervisor: Prof. Risto Nieminen, Instructor: Prof. Pertti Hakonen.

Olli-Pentti Saira graduated as M.Sc. from the Department of Engineering Physics and Mathematics on May 30th. His diploma thesis *Thermal effects in Coulomb-blockaded nanostructures with superconductor-insulator-normal metal junctions* was done in the LTL. Supervisor: Prof. Matti Kaivola, Instructors: Prof. Jukka Pekola and Dr. Sc. (Tech.) Mikko Möttönen.

Juha Voutilainen graduated as M.Sc. from the Department of Engineering Physics and Mathematics on February 5th. His diploma thesis *Charge transport with Andreev reflection* was done in the LTL. Supervisor: Prof. Risto Nieminen, Instructor: Prof. Nikolai Kopnin.

**PH.D. DISSERTATIONS**

Yevhen Hlushchuk defended his Ph.D. thesis *Tactile processing in human somatosensory and auditory cortices* on January 17th, 2007 at the Department of Radiology, University of Helsinki. His opponent was Professor Gian Luca Romani, Institute of Advanced Biomedical Technologies, University of Chieti, Italy, and supervisor Professor Riitta Hari

Fan Wu defended his Ph.D. thesis *Shot noise and transport properties of carbon nanotubes* on July 7th, 2007 at the Institute of Physics, Chinese Academy of Science. His opponents were Researcher Jun-Ming Zhou, Institute of Physics, CAS, China, Professor Da-Peng Yu, Department of Physics, Peking University, China, Researcher Bao-Qin Chen, Institute of Microelectronics, CAS, China, Researcher Bing-Suo Zou, Institute of Physics, CAS, China, Researcher, Yan-Guo Wang, Institute of Physics, CAS, China and supervisors Professor Pertti Hakonen and Professor Tai-Hong Wang

Mika Seppä defended his Ph.D. thesis *Quality improvements for multi-modal neuroimaging* on September 17th, 2007 at the Department of Engineering Mathematics and Physics, Helsinki University of Technology. His opponent was Professor Rainer Goebbel, Department of Neurocognition, Maastricht University, Netherlands, and supervisors Professor Matti Hämäläinen and Professor Riitta Hari

Tiina Parviainen defended her Ph.D. thesis *Cortical correlates of language perception - Neuromagnetic studies in adults and children* on October 15th, 2007 at the De-
partment of Psychology, University of Helsinki. Her opponent was Professor David Poeppel, Department of Linguistics, Department of Biology, University of Maryland, Washington, USA, and supervisor Academy Professor Riitta Salmelin.

Teemu Ojanen defended his Ph.D. thesis Quantum fluctuations and transport in mesoscopic physics on November 30th, 2007 at the Department of Engineering Mathematics and Physics, Helsinki University of Technology. His opponent was Professor Frank Wilhelm, Institute for Quantum Computing, University of Waterloo, Waterloo, Canada, and supervisor Docent Tero Heikkilä.

Gina Caetano defended her Ph.D. thesis Brain mechanisms of audiotactile and audiomotor interactions on December 21st, 2007 at the Department of Engineering Mathematics and Physics, Helsinki University of Technology. Her opponent was Professor Beatrice de Gelder, Cognitive and affective neuroscience lab, Tilburg University, the Netherlands and MGH/MIT/HMS Athinoula A. Martinos Center for Biomedical Imaging, Charlestown, USA, and supervisor Professor Riitta Hari.

TECHNICAL SERVICES

MACHINE SHOP

Kauko Herold, Seppo Hiltunen, Antti Huvila, Arvi Isomäki, Juhani Kaasinen, Seppo Kaivola, Hannu Kaukelin, and Markku Korhonen


The Machine Shop of Department of Electrical Engineering, with its two technicians Kauko Herold and Seppo Hiltunen was merged in December 2007 with the joint Machine Shop of Low Temperature Laboratory (Huvila, Isomäki, Kaasinen and Korhonen) and Department of Engineering Physics (Hannu Kaukelin).

The distribution of workshop usage. Total hours were 1769 h

Annual Report 2007
**CRYOGENIC LIQUIDS**

*Arvi Isomäki* and *Antti Huvila*

**Liquid helium**

The total amount of liquid helium purchased was 47 610.4 l and 32 572 l were delivered to the users. The losses of liquid He were 31.6%. The user distribution is depicted above. 10% of liquid He was sold to external users.

**Liquid nitrogen**

Total production of liquid nitrogen was 45000 l.
ACTIVITIES OF THE PERSONNEL

AWARDS AND HONORS

Blaauwgeers Rob and Vorselman Pieter, 1st Prize on 1st stage of Venture Cup competition about best business plan, 11.12.

Caetano Gina, Bolsas de estudo para investigação no estrangeiro, Fundação Calouste Gulbenkian, Serviço de Educação e Bolsas, Lisboa, Portugal, 1.1. - 1.7.

Hari Riitta, Kirjoittajapalkinto, Duodecim, Helsinki, Finland, 16.11.

Krusius Matti, Doctor of Science honoris causa, University of Lancaster, University of Lancaster, Lancaster, UK, 19.7.

Volovik Grigory, membership in German National Academy of Sciences, 28.3.2008.

PERSONNEL WORKING ABROAD

Hlushchuk Yevhen

- RIKEN Brain Science Institute (Summer lecture course), Research Center, Tokyo, Japan, 22.7. - 4.8.
- PENS 2007 Training center on Neuroimaging, University, Geneva and Lausanne, Switzerland, 9. - 30.9.

Jousmäki Veikko

- Elekta Neuromag Oy, System Integration at Erasme Hospital, Private Company, Brussels, Belgium, 28.2. - 6.3.
- Teaching, Elekta Neuromag Oy, System Start-Up, Private Company, Erasme Hospital, Brussels, Belgium, 16.3. - 4.4.

Kopnin Nikolai

- Research, Argonne National Laboratory, University of Chicago, Research Center, Chicago, USA, 19.3. - 20.4.
- Research, University of Oslo, University, Oslo, Norway, 27.8. - 7.9.

Virtanen Pauli

- Institut für Theoretische Festkörperphysik, Universität Karlsruhe; startup visit for collaboration, University, Karlsruhe, Germany, 22.5. - 4.6.
- Institut für Theoretische Festkörperphysik, Universität Karlsruhe: visit for collaboration, University, Karlsruhe, Germany, 30.9. - 27.10.

CONFERENCE PARTICIPATION AND LABORATORY VISITS

Alles

Invited talk, Measurements on the melting curve of 4He down to 10 mK, APS March Meeting, Denver, USA (5. - 9.3.)

Oral presentation, Melting curve of helium-4: No sign of a supersolid transition down to 0.01 K, XLI Annual Conference of the Finnish Physical Society, Tallinn, Estonia (15. - 17.3.)

Invited talk, Supersolid helium? (in Estonian), XXXVII Estonian Physics Days, Tartu, Estonia (20. - 21.3.)

Caetano

Oral presentation, Audiotactile integration and activation of auditory areas by vibrotactile stimuli, 7th International fMRI meeting and Autumn School & Brain Voyager Course, Sorrento, Italy (15. - 18.11.)
Danneau
Participation, Physique du Graphene, Laboratoire de Physique des Solides, Orsay, France (22. - 23.5.)
Poster, *Carbon nanotubes in the Fabry-Perot and the Kondo regime*, EP2DS 17, Genova, Italy (15. - 20.7.)
Posters, a) *Carbon nanotubes in the Fabry-Perot and the Kondo regime* and b) *0.7 structure and zero bias anomaly in 1D hole systems*, EP2DS 17, Genova, Italy (15. - 20.7.)
Oral presentation, *Shot noise in graphene*, Workshop on Electrons in Graphene, Laboratoire de Physique des Solides, Orsay, France (3. - 5.12.)

de Graaf
Participation, Short Course: Vortices and Turbulence at Very Low Temperatures, Udine, Italy (2. - 6.7.)
Poster, *Transient states of quantum turbulence in rotating superfluid 3He-B below 0.3Tc*, International Symposium on Quantum Fluids and Solids (QFS2007), Kazan, Russia (1. - 6.8.)

Eltsov
Invited talk, *Propagation of turbulent front in rotating superfluid*, International Symposium on Quantum Fluids and Solids (QFS2007), Kazan, Russia (1. - 6.8.)

Forss
Invited talk, *Miten aivot muovaavat kipuaistimusta?*, Kroonisen kivun seminaari, Helsinki, Finland (24.9.)
Invited talk, *Muutokset CRPS-potilaan aivojen toiminnassa*, Kirurgian koulutuspäivät Biomedicum, Helsinki, Finland (5.10.)
Invited talk, *Contribution of fMRI and MEG to the assessment and understanding of central pain*, 5th Benelux Neuromodulation Society Scientific Meeting, Brussels, Belgium (9. - 10.10.)
Invited talk, *Voiko kuntoutumista kuvantaa?*, Valtakunnallinen AVH symposium, Helsinki, Finland (17. - 19.10.)
Invited talk, *Sensorimotor cortical functions in chronic pain*, 1st Conference of International Soc. for the Advancement of Clinical MEG (ISACM 2007), Matsushima, Japan (27. - 30.10.)
Invited talk, *Brain Mapping*, Moderni aivokuvantaminen/Suomen neurologisen yhdistyksen koulutus, Tampere, Finland (15. - 16.11.)

Gunnarsson
Oral presentation, *Harmonic oscillator driven interference in a single Cooper Pair Box*, XLI Annual Conference of the Finnish Physical Society, Tallinn, Estonia (15. - 17.3.)

Hakonen
Invited talk, *Kohti kvanttimittauksia*, Tieteen Päivät, Helsinki, Finland (10. - 14.1.)
Invited talk, *Gate-controlled superconductivity in a diffusive multivalled carbon na-
notube, APS 2007 March Meeting, Denver, Colorado, USA (5. - 9.3.)
Invited comment, CARDEQ introduction, CARDEQ review meeting, Barcelona, Spain (26. - 28.4.)
Invited comment, WP2 Nanotube rf-SET, CARDEQ Review Meeting, Barcelona, Spain (26. - 28.4.)
Invited comment, Management report, CARDEQ Review Meeting, Barcelona, Spain (26. - 28.4.)
Invited talk, Properties of Josephson junctions made out of single and multiwalled carbon nanotubes, Physics of Nanoscale Superconducting Heterostructures, Leiden, The Netherlands (2. - 6.7.)
Invited talk, Transport in nanocarbons, NanoMaterial Hot Topics, Espoo, Finland (31.8.)
Invited talk, Towards quantum measurements with Josephson junctions, Nanoscience Days 2006, Jyväskylä, Finland (26. - 27.10.)

Hari
Invited plenary talk, MEG in the study of higher cortical functions, ERPs and other techniques, Kyoto, Japan (11. - 13.10.)
Invited plenary talk, Aivot ja mieli, Akuuti psykiatria VIII, Helsinki, Finland (16.11.)
Invited talk, Sosiaalinen vuorovaikutuksen aivoperustaa, Tieteen Päivät 2007, Helsinki, Finland (12.1.)
Invited talk, Aivokuvantamisen näkymät; Views of human brain imaging, Turun sotaveteraanien torstaiseura, Turku, Finland (9.2.)
Invited presentation, Aivot tärkein pääomamme, Life Science Center, Keilaniemi, Espoo, Finland (15.3.)
Invited talk, Brain in time: Temporal scales of human cognition and interaction, From Molecular Imaging to System Neuroscience, Magnetresonanzzentrum Symposium, Tübingen, Germany (12. - 13.7.)
Invited talk, Aivotutkijan puheenvuoro - löytyykö mieli aivoista, Mieli-forum I. Mielen rajoja etsimässä, Espoo, Finland (16. - 18.8.)
Invited talk, How to image the human brain, Music Meets Medicine, Helsinki, Finland (20. - 22.9.)
Invited talk, Keynote address: Can neuroscience and social sciences converge?, FIS-CAR’07, The Third Finnish Conference on Cultural and Activity Research, Helsinki, Finland (27. - 28.9.)
Invited talk, Ihmisen toiminnan ja käyttäytymisen selittämisestä, Jan Rydmanin muistoseminaari "Monitieteinen ihmisyy", Turku, Finland (5.10.)
Invited talk, Brain in time: Temporal scales of human communication and interaction, Neuroscience Finland 2007, Espoo, Finland (26.10.)
Invited talk, Motoriikan merkitys kognitiossassa, Tuesday Seminar, Department of Neurology, Helsinki University Central Hospital, Helsinki, Finland (11.12.)
Invited talk, Systeeminen neurotiede ja aivokuvantaminen Otaniemessä, TAYS Radiologian klinikan seminaari, Tampere, Finland (19.12.)
Invited comment, Sosiaaliset aivot. Neurotieteen seuraava haaste., Aivot tärkein pääomamme. Aivosäätiön perustamisseminaari., Espoo, Finland (15.3.)
Lecture, Ihmisaivojen kuvantamisesta (Imaging the human brain), Neurobiologian luento, Helsingin yliopisto, lääketieteellinen tiedekunta, Helsinki, Finland (19.9.)
Oral presentation, Päivystävä professori; Professor on call, Tieteen Päivät 2007, Helsinki, Finland (12.1.)
Participation, [Partner presentation], PERCEPT/fMRI workshop & regular meeting,
Groningen, The Netherlands (22. - 24.3.)
Participation, Workshop on structural and functional MRI in psychiatric disorders, Aalborg, Denmark (24. - 25.4.)
Participation, Panel member: Perustutkimus Suomessa - ylellisyytä vai välttämättömyys?, Tiedefoorumi 2007, Helsinki, Finland (9.5.)
Participation, 5th Nordic Neuroinformatics Workshop, Espoo, Finland (27.10.)

Heikkilä
Invited talk, Nonequilibrium and thermoelectric effects in normal and superconducting heterostructures, Condensed Matter and Materials Physics Conference, Leicester, UK (11. - 13.4.)
Participation, Nanoscopic Transport: Quantum Noise, Josephson Junctions, and Molecular Electronics, Freiburg, Germany (1. - 3.11.)
Poster, Photon heat transport in low-dimensional nanostructures, XLI Annual Conference of the Finnish Physical Society, Tallinn, Finland (15. - 17.3.)
Poster, Quantum transitions in nonequilibrium environments & Photon heat transport in low-dimensional nanostructures, Noise Information, Complexity and Quantum Scale, Erice, Italy (4. - 10.11.)

Heikkinen
Poster, Frictionless rotation in liquid helium, XLI Annual Conference of the Finnish Physical Society, Tallinn, Estonia (15. - 17.3.)

Helenius
Participation, Neuroscience Finland 2007, Espoo, Finland (26.10.)
Participation, Mieli-forum II: Miten mieli muuttuu, Siuntio, Finland (22. - 24.11.)
Poster, The cognitive profile of SLI in early adulthood, 9th Nordic Meeting in Neuropsychology, Gothenburg, Sweden (19. - 22.8.)

Henriksson
Oral presentation, Representation of spatial frequency in human retinotopic areas, Neuroscience 2007 (37th Annual Meeting of the Society for Neuroscience), San Diego, California, USA (3. - 7.11.)

Hiltunen
Participation, Joint Annual Meeting ISMRM-ESMRMB 2007, Berlin, Germany (18. - 25.5.)
Participation, 2nd 3.0T Users Meeting, GE Healthcare, York, UK (14. - 15.2.)

Hlushchuk
Invited talk, Tactile processing in somatosensory and auditory cortices, Physicians' meeting at the Department of Clinical Neurophysiology, Helsinki, Meilahti Hospital, Finland (20.2.)
Invited talk, Tactile processing in human somatosensory cortex, BioMag Seminar, Meilahti sairaala, Helsinki, Finland (8.2.)
Participation, Phasic suppression of ipsilateral primary somatosensory cortex during tactile finger stimulation, PENS (FENS/IBRO) training center 2007: Imaging Brain Function: From Behaviour to Diseases, Lausanne Geneva, Switzerland (9. - 29.9.)
Poster, Phasic suppression of ipsilateral primary somatosensory cortex during tactile

**Hosio**

Poster, generation and detection of quantum turbulence with a quartz tuning fork, XLI Annual Conference of the Finnish Physical Society, Tallinn, Estonia (15. - 17.3.)

**Hultén**

Invited talk, Language learning and the brain, Post-Graduate Workshop on Cognition, Turun Yliopisto, Finland (21. - 22.5.)

Oral presentation, Accessing newly acquired phonological and semantic information: an MEG study, 9th Nordic Meeting in Neuropsychology, Göteborg, Sweden (19. - 22.8.)

Oral presentation, Neural correlates of word learning and forgetting. A MEG study, Neuroscience 2007 (SfN), San Diego, USA (2. - 7.11.)

**Hänninen**


Poster, Transition to superfluid turbulence: wall-induced instability, Internation Symposium on Quantum Fluids and Solids (QFS2007), Kazan, Russia (1. - 6.8.)

**Joussé**

Oral presentation, Audiotactile interactions in normal hearing subjects, Nokia Research Center, Helsinki, Finland (22.1.)

Oral presentation, Systeeminen neurotiiteen ja aivokuvantamisen huippuyksikkö, VI Lääketieteellisen fysiikan ja teknikan päivä, Espoo, Finland (7.2.)

Lecture, Overview on Elekta Neuromag Vectorview, System start-up, Leipzig, Germany (15. - 19.1.)

Lecture, Stimulators in MEG, Elekta Neuromag - Introductory Training Course, Helsinki, Finland (22. - 26.1.)

Poster, Natural tactile stimuli for MEG experiments, First Conference of International Society for the Advancement of Clinical Magnetoencephalography, Sendai, Japan (27. - 30.8.)

Participation, Moderni kuvantaminen neurologisissa sairauksissa, Tampere, Suomi (15. - 16.11.)

**Junes**

Poster, 3He Crystals: From strong to weak coupling between surface and lattice, XLI Annual Meeting of the Finnish Physical Society, Tallinn, Estonia (15. - 17.3.)

Poster, Search for new facets on 4He crystals, International Symposium on Quantum Fluids and Solids (QFS2007), Kazan, Russia (1. - 6.8.)

**Kaksonen**

Participation, PENS-Hertie Winter School, Kitzbühel, Austria (10. - 17.12.)

**Krusius**

Invited talk, Instability of vortex motion, generation of new vortices, and transition to turbulence in applied superfluid counterflow, Workshop on Superfluids under Rotation, Jerusalem, Israel (15. - 19.4.)

Annual Report 2007

Invited talk, *Vortex instability and transition to turbulence in applied flow of 3He-B*, International Conference on Quantum Fluids and Solids - QFS2007, Kazan, Tatarstan, Russia (1. - 6.8.)

Invited comment, *Stability of vortex lines in rotating counterflow of 3He-B*, International Symposium on Quantum Fluids and Solids - QFS2007, Kazan, Russia (1. - 6.8.)

Invited talk, *Vortex generation and transition to turbulence as a function of vortex damping in applied flow of 3He-B*, International Symposium on Quantum Fluids and Solids, Kazan, Russia (1. - 6.8.)

Invited talk, *Structure and dynamics of quantized vortices in helium superfluids*, FetterFest: A Symposium on Quantum Fluids, in honour of prof. A.L. Fetter, Stanford University, California, USA (10.11.)

**Laakso**

Poster, *Nonequilibrium characteristics in all-superconducting tunnel structures*, XLI Annual Conference of the Finnish Physical Society, Tallinn, Estonia (15. - 17.3.)

Participation, The 17th Jyväskylä Summer School, Jyväskylä, Finland (13. - 24.8.)

**Laaksonen**


**Lechner**

Oral presentation, *Towards the quantum limit: Carbon nanotubes as nanomechanical resonators*, SCANDEM 2007, Espoo, Finland (18. - 20.6.)

Poster, *Carbon nanotube Josephson junctions in the Fabry-Pérot and the Kondo regime*, Spin & Qubit 2007, Copenhagen, Denmark (28.8.)

Oral presentation, *Gate-controlled superconductivity in multiwall carbon nanotubes*, CARDEQ Review Meeting, Barcelona, Spain (26. - 29.4.)


Participation, Nanoscience Seminar, National Graduate School for Nanoscience, (9. - 11.12.)

Participation, 2. FIB Workshop: Focused Ion Beams in Research, Science, and Technology, Graz, Austria (2. - 3.7.)

Participation, EFUG Meeting 2007, Arcachon (Bordeaux), France (8.10.)

Participation, European FIB User Group Meeting 2007, Arcachon (Bordeaux), France (8.10.)

**Malinen**

Participation, Independent Component Analysis at the Neuroimaging Cocktail Party, Maastricht, Netherlands (12. - 13.3.)

**Meschke**

Participation, "NanoFridge" kick-off meeting, Grenoble, France (15. - 16.1.)

Participation, 2nd Meeting of the NanoFridge Project, Pisa, Italy (10. - 12.12.)

Annual Report 2007
Muhonen
Oral presentation, *Suspended SINIS structures*, 2nd Meeting of the NanoFridge Project, Pisa, Italy (10. - 12.12.)

Möttönen
Invited talk, *Recent progress on Cooper pair sluice*, EUROMET Experts Meeting, Espoo, Finland (25. - 27.6.)
Poster, *Equivalent qubit dynamics under classical and quantum noise*, XLI Annual Conference of the Finnish Physical Society, Tallin, Estonia (15. - 17.3.)
Poster, *Vortex pumping in dilute Bose-Einstein condensates*, Bose-Einstein Condensation 2007: Frontiers in Quantum Gases, Sant Feliu, Spain (15. - 20.6.)

Paalanen
Invited talk, *Nanoelectronics at Low Temperature Laboratory*, ELKOM 07 ECT Forum, Messuhalli, Helsinki, Finland (4. - 6.9.)
Oral presentation, *Closing the metrological triangle*, March Meeting of American Physical Society, Denver, Colorado, USA (5. - 9.3.)
Oral presentation, *How to select competitive research topics*, 50th Birthday Seminar of Esko Kauppinen, TKK, Espoo, Finland (31.8.)
Oral presentation, *Nanoelectronics at Low Temperature Laboratory*, TUTKAS seminar, TKK, Espoo, Finland (19.9.)
Lecture, *From transistor to single electron transistor*, Reunion of 1967 Physics Class, Nuclear power station at Olkiluoto, Finland (24.8.)
Lecture, *The future of nanotechnology*, Colloquium series on the challenges of new technologies, National Institute on Occupational Health, Helsinki, Finland (22.10.)
Lecture, *From transistor to single electron transistor*, The Board Meeting of Finnish Science Writers Union, TKK, Espoo, Finland (20.11.)
Lecture, *Research mindset*, NRC CTC PhD Program Kick-Off, Helsinki, Finland (24.9.)
Participation, Annual Meeting of Royal Society of Arts and Sciences in Göteborg, Göteborg, Sweden (24.1.)
Participation, Council and Commission Chairs Meeting of IUPAP, Rio de Janeiro, Brasil (4. - 6.10.)

Paraoanu
Participation, Nobel 2007 Physics in Helsinki: Professor Grünberg's lecture at House of Estates, followed by a formal dinner, Helsinki, Finland (17.12.)

Parviainen
Oral presentation, *Cortical processing of speech and nonspeech sounds in 7- to 8-year-old children*, 9th Nordic Meeting in Neuropsychology, Göteborg, Sweden (19. - 22.8.)

Pekola
Invited talk, *Flux and charge controlled Cooper pair pumping*, Quantum Pumping, Haifa, Israel (6. - 13.1.)
Invited talk, *Electrons, phonons and photons in nanostructures at low temperatures*, UMK, Center for New Materials, Colloquium, Espoo, TKK, Finland (21.3.)

Annual Report 2007
Invited talk, *Refrigeration, energy relaxation and thermometry in electronic mesoscopic structures*, kTlog2: Fluctuations Theorems and the Physics of Information, Segovia, Spain (2. - 5.5.)

Invited talk, *Nanoelektroniikkaa*, Elektroniikkainsinöörien seuran kokous, Espoo, TKK, Finland (9.5.)


Invited talk, *Thermodynamics and refrigeration with electrons in mesoscopics*, Colloquium at Weizmann Institute, Weizmann Institute, Rehovot, Israel (14.6.)


Invited talk, *Observation of shot noise and its third moment with a Josephson junction threshold detector*, Nanoscopic Transport: Quantum Noise, Josephson Junctions, and Molecular Electronics, Freiburg, Germany (1. - 3.11.)

Invited talk, *Thermometry by micro- and nano-devices*, Quantum Metrology and Fundamental Constants, Les Houches, France (2. - 12.10.)

Invited talk, *Metal - superconductor tunnel junctions as kT and e pumps*, Linnaeus Colloquium, Göteborg, Chalmers University of Technology, Sweden (11.10.)

Invited talk, *Thermodynamics and refrigeration with electrons in mesoscopics*, Department seminar, University of Regensburg, Germany (7.12.)

Oral presentation, *Activities of the LTL group in Nanofridge in 2007*, NanoFridge Progress Meeting, Pisa, Italy (11.12.)

Oral presentation, *Hybrid superconducting nano-refrigerators*, Physics of Nanoscale Superconducting Heterostructures, Lorentz Cetre, Leiden, the Netherlands (2. - 6.7.)

Lecture, *Nanoelektroniikkaa*, TUTKAS vierailee Micronovassa, Espoo, Micronova TKK, Finland (19.9.)

Participation, Kick-off Meeting of the NanoSciERA Project NanoFridge, Grenoble, France (14. - 17.1.)

**Peltonen**

Poster, *Detecting current noise with a hysteretic josephson junction*, XLI Annual Conference of the Finnish Physical Society, Tallin, Estonia (15. - 17.3.)

Participation, The 17th Jyväskylä Summer School, Jyväskylä, Finland (13. - 24.8.)

Participation, International workshop - Nanoscopic Transport: Quantum Noise, Josephson Junctions, and Molecular Electronics, Freiburg, Germany (1. - 3.11.)

**Pentti**

Poster, *Quartz tuning fork measurements in helium liquids*, International Symposium on Quantum Fluids and Solids (QFS2007), Kazan, Russia (1. - 6.8.)

**Ramkumar**

Poster, *Independent component analysis of neuromagnetic data reveals extrinsic and intrinsic cortical networks during natural stimulation*, Nordic Neuroinformatics Workshop 2007, Espoo, Finland (27.10.)

Poster, *Independent component analysis of neuromagnetic data reveals extrinsic and intrinsic cortical networks during natural stimulation*, Nordic Neuroinformatics Workshop 2007, Espoo, Finland (27.10.)

Poster, *Identification of stimulus-related and intrinsic networks by spatial indepen-
dent component analysis of MEG signals, Society for Neuroscience Annual Meeting 2007, San Diego, USA (3. - 7.11.)

**Saarela**

Invited talk, *Neural correlates of visual and auditory social cognition*, Post-Graduate Workshop on Cognition, Turku, Finland (21. - 22.5.)

Invited talk, *Aivot ja sosiaalinen vuorovaikutus*, Keskushermo symposiumi, Helsinki, Finland (7. - 8.9.)

Invited talk, *Basics of magnetoencephalography*, Finnish Graduate School of Neuroscience Student Symposium 2007, Espoo, Otaniemi, Finland (25.10.)

Poster, *Neuromagnetic responses to viewing facial expressions of pain*, 7th IBRO World Congress of neuroscience, Melbourne, Australia (12. - 18.7.)

Participation, Mieli-forum I, Kirkkonummi, Finland (16. - 18.8.)


Participation, FinBioNet PhD-Student Symposium 2007, Helsinki, Finland (22. - 23.11.)

**Saarinen**

Participation, 1st PERCEPT fMRI Workshop, University Medical Center Groningen, The Netherlands (22. - 23.3.)

**Saira**

Poster, *Coulomb-blockade effects on SINIS coolers*, Nanofridge Kick-Off Meeting, Grenoble, France (15. - 16.1.)

**Salmela**

Poster, *Adiabatic melting of$^3$He crystal to superfluid$^4$He: Progress report*, XLI Annual Conference of the Finnish Physical Society, Tallin, Estonia (15. - 17.3.)

**Salmelin**


Invited talk, *Aivot ja kielen ymmärtäminen* (*Brain and language comprehension*), Tieteen päivät 2007, Helsinki, Finland (10. - 14.1.)

Invited talk, *Language in the brain: timing, location and connectivity*, New Directions in Cognitive Neuroscience, London, United Kingdom (2.4.)

Invited talk, *MEG in the study of language: timing, location and connectivity*, FENS/IBRO Summer School. Imaging Brain Function: From Behaviour to Diseases, Lausanne, Switzerland (9. - 14.9.)


**Savin**

Oral presentation, *RSFQ circuits at millikelvin temperatures: implications of dissipation on design priorities*, RSFQubit Workshop, Erlangen, Germany (21. - 22.2.)

Annual Report 2007
Sebedash
Poster, *Osmotic pressure of $^3$He-$^4$He solutions at 25.3 bar and low temperatures*, International Symposium on Quantum Fluids and Solids (QFS2007), Kazan, Russia (1. - 6.8.)

Stenbacka

Timofeev
Poster, *Josephson junctions as detectors of high frequency shot noise in mesoscopic conductors*, European School on Nanosciences & Nanotechnologies 2007, Grenoble, France (26.8. - 15.9.)

Todoshchenko
Invited talk, *Elementary excitations in solid and liquid 4He at the melting pressure*, International Symposium on Quantum Fluids and Solids (QFS2007), Kazan, Russia (1. - 6.8.)

Tuoriniemi
Invited plenary talk, *Superconductivity in lithium*, XLI Annual Conference of the Finnish Physical Society, Tallin, Estonia (15. - 17.3.)

Vanni
Oral presentation, *Topography of fMRI response for spatial frequency*, European Conference on Visual Perception, Arezzo, Italy (27. - 31.8.)

Vartiainen

Volovik
Invited talk, *The general principles of emergent physics and application to cosmological constant problem*, Dresdner Physikalischen Kolloquium, Dresden, Germany (30.1.)
Invited talk, *The general principles of emergent physics and application to cosmological constant problem*, Seminar at Leipzig University, Leipzig, Germany (1.2.)
Invited talk, *Investigation of Larkin-Imry-Ma effect: random anisotropy of aerogel destroys the long-range orientational order in superfluid 3He-A*, Seminar in Landau and Kapitza Institutes, Moscow, Russia (22.3.)
Invited talk, *Emergent physics: general principles and applications*, From Quantum to Emergent Gravity: Theory and Phenomenology, Trieste, Italy (10. - 15.6.)
Invited talk, *Euler equations and quantum gravity*, Workshop on Theoretical and Mathematical Physics devoted to 300th birthday of Leonhard Euler, Petersburg, Russia (13. - 18.7.)
Invited talk, *On Larkin-Imry-Ma state of 3He-A in aerogel*, International Conference
on Quantum Fluids and Solids (QFS2007), Kazan, Russia (1. - 6.8.)
Invited talk, Fermi point scenario of emergent physics, Workshop "Condensed Matter Meets Gravity", Leiden, Holland (27. - 31.8.)
Invited talk, Gap nodes protected by topology in momentum space and quantum phase transitions, Seminar at International Center of Theoretical Physics, Trieste, Italy (9.10.)
Invited talk, On Larkin-Imry-Ma state of superfluid 3He, Seminar at International Center of Theoretical Physics, Trieste, Italy (11.10.)
Lecture, The general principles of emergent physics and application to cosmological constant problem, Kepler Vorlesung, Tuebingen, Germany (6.6.)
Lecture, Fermi point: topology and symmetry, Chernogolovka, Russia (21.12.)
Participation, Editorial Board Meeting of JETP Letters, Moscow, Russia (8.2.), (26.4.), (21.6.), (26.7.), (9.8.), (25.10.), (20.12.), (27.12.)
Participation, Dissertations Council Meeting of Landau Institute, defences of PhD thesis by I.V. Protopopov and K.S. Turitsin, Chernogolovka, Russia (22.6.)
Participation, Sessions of Scientific Council of Landau Institute, Chernogolovka, Russia (29.6.)
Participation, Dissertations Council Meeting of Landau Institute, defence of PhD thesis by R.B. Saptsov, Chernogolovka, Russia (28.12.)

Voutilainen
Oral presentation, Nonequilibrium charge transport in quantum transport in quantum SINIS structures, XLI Annual Conference of the Finnish Physical Society, Tallin, Estonia (15. - 17.3.)
Participation, The 17th Jyväskylä Summer School, Jyväskylä, Finland (13. - 24.8.)

Wu
Participation, CARDEQ Annual Meeting, Barcelona, Spain (26. - 28.4.)
Poster, Shot noise with interaction effects in single walled carbon nanotubes, EP2DS 17 + MSS 13, Genova, Italy (15. - 20.7.)
Poster, Carbon nanotube Josephson junction in the Fabry-Perrot and the Kondo regime, EP2DS 17 + MSS 13, Genova, Italy (15. - 20.7.)

EXPERTISE AND REFEREE ASSIGNMENTS

Alles
Referee:
- Europhysics Letters
- Journal of Low Temperature Physics

Hakonen
Chairman of the conference or organising committee: CARDEQ Annual Meeting, Barcelona, Spain, 26. - 28.4.
Referee: Nature
Interview: Klassisen ja kvanttifysiikan rajalla, YLE, Radio, Helsinki, Finland, 11.1.
Statement for the appointment of a professor: Assistant Professorship, Chalmers University of Technology, Department of Physics, Gothenburg, Sweden, 3.11.

Annual Report 2007
Halko

Interview: Simpanssi päihittää ihmisen voiton etsijänä, Aamulehti, Newspaper, Tampere, Suomi, 27.10.

Hari

Leader position in a scientific organization:

- Director of Advanced Magnetic Imaging Centre (AMI), TKK
- Adjunct professor, Neuroscience Center, University of Helsinki
- Chief physician, Dept. Clin. Neurophysiology, HUSLAB, HUCH (part-time)
- Member of Medical Advisory Board, General Electric, General Electric Health Care (Europe; 3T MRI devices), Italy
- Coordinator of Functional Brain Mapping, Finland-Taiwan Scientific Cooperation in the Academy of Finland, Bilateral Exchange Programme, Taiwan
- Member of Advisory Board, INFC (International Neuroinformatics Coordinating Facility), The INCF National Node of Finland, Finland, 1.5. - 31.12.

Member of a distinguished society:

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

Membership of the organising committee: Developing Brain Emerging Mind, Helsinki, Finland, 12. - 14.9.

Chairman of the session:

- Session 3, Workshop on Structural and Functional MRI in Psychiatric Disorders, Aalborg, Denmark, 24. - 25.4.
- Kurkistetaan aivoihin, Tieteen Päivät 2007, Helsinki, Finland
- Developing Brain Emergin Mind, Helsinki, Finland, 12. - 14.9.
- Music Meets Medicine, Helsinki, Finland, 20. - 22.9.
- ERPs and Other Techniques, Event Related Potentials in Patients with Epilepsy (ERPE), Kyoto, Japan, 11. - 13.10.

Interview:

- Aivojen liikeavivokuoren toiminta; Esitys 31.5. ja uusinta 3.6., YLE Radio 1, Tieteen viikko, Radio, Espoo, Finland, 31.5.
- Tiedeohjelma, about Caetano et al. PNAS 2007 paper, Yle, Radio, Helsinki, Finland, 20.5.
- Voikko tietokone lukea ajatuksiasi? Yle tiedelinko, Radio, Helsinki, Finland, 12.10.

Editor of a scientific journal:

- PNAS, National Academy of Sciences USA
- Cerebral Cortex

Annual Report 2007
Referee:
- Brain and Language
- Journal of Neuroscience
- Nature Neuroscience
- Nature Reviews of Neuroscience
- Neuroimage
- Trends in Cognitive Science

Member of the editorial board:
- Cerebral Cortex, Oxford Journals
- Neuroscience Research, Elsevier
- Brain Topography, Springer
- NeuroImage, Elsevier

Statement for the appointment of a professor:
- Fellow of the Royal Society, The Royal Society, United Kingdom, 28.1
- Full Professor of Neuroscience, Weizmann Institute, Israel, 8.3
- Associate Professor, University of Trento, Faculty of Cognitive Science, Trento, Italy, 17.6
- Tenured Associate Professorship, Max Planck Institute, Germany, 10.9
- Associate Professor, Massachusetts Institute of Technology, Department of Brain and Cognitive Sciences, Boston, USA, 31.10.

Heikkilä


Referee:
- Physical Review B, American Physical Society, USA
- Physical Review Letters, American Physical Society, USA

Helenius

Referee: Neuroimage, Elsevier

Hultén

Interview:
Också hjärnan ska vårdas, Hufvudstadsbladet, Newspaper, Helsinki, Finland, 14.3.
Unohtaminen on yksilöllistä, Tekniikka & Talous, Newspaper, Helsinki, Finland, 7.6.

Järvinen

Secretary of the conference or organising committee:
- Mieli-forum II: Miten mieli muutuu, Siuntio, Finland, 22. - 24.11.
Jousmäki
Referee:
- NeuroImage, Elsevier, London, UK
- Biomed Central

Kirveskari
Referee: Clinical Neurophysiology, Elsevier, Ireland

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

Krusius
Member of the board: European Physical Society, Low Temperature Physics, France
Chairman: Finnish Academy of Sciences and Letters, Dept. of Physics, Finland
Member:
- Finnish Academy of Sciences and Letters
- Academia Europea
- Fellow member, American Physical Society
- Finnish Physical Society
- Individual ordinary member, European Physical Society
- Editorial Board, Physica B: Condensed Matter, Elsevier, The Netherlands
- Institute of Physics, UK
- Advisory Editorial Board, Physica B: Condensed Matter
Referee:
- Physical Review Letters
- Physical Review B
- Journal of Low Temperature Physics
- Europhysics Letters
- Engineering and Physical Sciences Research Council (UK)
- Royal Society (UK)
- University of Manchester (UK)
- University of Lancaster (UK)
- University of California (Berkeley)
- Physics Today

Membership of the organising committee: International Symposium on Quantum Fluids and Solids (QFS2007), Kazan, Russia, 1. - 6.2.
Chairman of the session:
- Beyond conventional superfluidity, Superfluids under Rotation, Jerusalem, Israel, 15. - 19.4.

Paalanen

Position of trust in scientific organizations:

- Member of Organising Committee of XLI Annual Conference of the Finnish Physical Society, Tallinn, Estonia (15. - 17.3.)
- Member of Nanoscience Working Group, International Union of Pure and Applied Physics (IUPAP)
- Board, Biomedicum, Helsinki, Finland, 1.1. - 31.12.

Editor: Journal of Low Temperature Physics, Springer, New York, USA

Referee: Physical Review Letters

Chairman of the session:

- Klassisen fysiikan ja kvanttimekaniikan rajalla, Tieteen päivät, University of Helsinki, Finland, 10. - 14.1.

Statement for the appointment of a professor: Physics, Gothenburg University, Department of Physics, Gothenburg, Sweden, 20.11.

Interviews:

- Klassisen mekaniikan ja kvanttimekaniikan rajalla, YLE, Radio 1, Helsinki, Finland, 11.1.
- Tieteen viikko, kolumnistina Mikko Paalanen, YLE, Radio 1, Helsinki, Finland, 7.6.
Pekola

Leader position in a scientific organization: Vice President, Finnish Physical Society, Finland, 1.4.2007 - 31.3.2009.

Member of the editorial board: Journal of Low Temperature Physics, Springer,


Reviewer of a grant application: Suomen kulttuurirahasto, Helsinki, Finland

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

Chairman of the session: Fluctuations and Phase Transitions in Superconductors, Nazareth Ilit, Israel, 10. - 14.6.

Interview:
- TKK etsii uutta ampeeria, Tekniikka ja Talous 14.12.2007
- Cooling electrons one by one, Nature Nanotechnology, September 2007
- TKK:n tutkijat rakensivat lämpötransistorin, Prosessori, 6 August 2007
- First "heat transistor" unveiled, PhysicsWeb, 13 July 2007
- Maailman pienin jääkaappi, Yle Radio 1 Tiedeutiset, 12 July 2007
- TKK:n tutkijat rakensivat maailman pienimmän jääkaapin, Tekniikka & Talous, 12 July 2007
- Maailman pienin jääkaappi rakennettiin Suomessa, MTV3, 12 July 2007
- The Tiniest Refrigerator, Science, 10 July 2007
- Scientists develop heat transistor that someday could cool chips, TgDaily, 6 July 2007

Pentti

Interview: Prisma, YLE, TV, Helsinki, Finland, 9.5.

Salmelin

Editor: Human Brain Mapping, Wiley.

Member of the editorial board: NeuroImage, Elsevier.

Annual Report 2007
Referee:

- Neuroimage
- Journal of Cognitive Neuroscience
- Cerebral Cortex,
- Nature Neuroscience

Membership of the organising committee:


Chairman of the session:

- Advanced MEG/EEG Course, 13th Annual Meeting of the Organization for Human Brain Mapping, Chicago, USA, 10. - 14.6

Statement for the appointment of a professor: Assistant Professor in Neurocognition of Language, University of Potsdam, Department of Neurolinguistics, Potsdam, Germany, 9.1.

Saarela

Interview:

- Kylmää tietoa aivoista, Mediuutiset, Newspaper, Espoo, Finland, 19.5.
- "Priima"- ohjelma, Yleisradio 1, TV, Espoo, Finland, 7.3.

Tanskanen

Referee:

- Neuroimage, Academic Press, United States
- Cortex, Masson, Italy

Tuoriniemi

Editor: Cryogenics, Advisory Editor, 1.2. - 31.12.

Interviews:

- Tiedeuutiset, YLE, Radio, Helsinki, Finland, 17.5.

Vanni

Referee:

- Human Brain Mapping
- European Journal of Neurology
- Journal of Neuroscience
- Neuroimage

Annual Report 2007
Vartiainen J.

Referee:
- Physical Review B, APS, New York, USA
- Physical Review Letters, APS, New York, USA
- Quantum Information & Computation, Rinton Press, Paramus, NJ, USA

Volovik

Chairman of the session:
- Workshop on Theoretical and Mathematical Physics Devoted to 300th Birthday of Leonhard Euler, Petersburg, Russia, 13. - 18.7.


Editor:
- Physical Review Letters, DAE (Divisional Associate Editor)
- Journal of Low Temperature Physics, Guest Editor

Member of the editorial board: JETP Letters, Pleiades Publishing Inc., Russia

Membership in distinguished societies:
- Deutsche Academie der Naturforscher Leopoldina (the German Academy of Sciences Leopoldina), Halle, Germany, 30.4.

Interview: Quant und Kosmos, Physiker Grigori Volovik als Kepler-Dozent, Tagblatt, Tuebingen, Germany, 2.6.

PUBLICATIONS

BRAIN


**BRAIN (textbook articles, Finnish language, etc)**


**CERN**

**INTERFACE**


**NANO**


**PICO**


**THEORY**


APPENDIX 1

Centre of excellence programme 2006-2011
Centre of excellence on systems neuroscience and neuroimaging
SAB meeting, May 14th 2007-05-03

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

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. Its aim is to study brain function and dysfunction by means of an integrative approach, including the most advanced spatiotemporal methods of non-invasive human neuroimaging.

The current evaluation corresponds to the initial one quarter of the funded period and it is intended to be advisory on both the scientific program and the administrative/strategic organization of the centre.

Currently the centre comprises three well-established units, the Brain Research Unit (BRU), the Advanced Imaging Centre (AMI) and the Neuroscience Unit (NSU). BRU has been the world's leading centre for 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.

Scientific activity, production and progress of the CoE

The CoE successfully combines the development of methodologies with highly interesting neuroscientific applications. It has a core of outstanding scientists who work on sensory and perceptual processing, on cognition, and on the neurophysiological mechanisms underlying social interaction.

We find the principal investigators, the research projects, and the presentations we followed during our visit excellent. The centre conducts world-class research on timely and highly interesting topics.

For example, methodologically, the attempts to combine MEG and fMRI in humans are highly promising as this group has more experience with MEG than any other. The group has already developed a great deal of software for acquisition, on-line evaluation and off-line detailed analysis of the data. The 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.

Their specific technical projects, including the multifocal fMRI, the dynamic imaging of coherent sources (with MEG), the combination of fMRI and diffusion tensor imaging (DTI), as well as the generation of quality-phantoms for probing the effects of local susceptibility changes on the MRI signal are all innovative, interesting and promising as methods that could be adapted world-wide in the neuroimaging community.

Annual Report 2007
Equally interesting and important are the scientific projects, including fMRI studies on early sensory processing (e.g. spatial achromatic and chromatic selectivity in early visual areas), plasticity and rehabilitation from hemianopia, perceptual processing (neural activity during bistable perception, studied with fMRI), language perception and development, as well as social interaction.

The latter subject is likely to dominate the field of human neuroimaging, as many of the human behaviors may be probably best understood within the right context, including emotional state, empathy, and cooperative or competitive interaction. The timing of neural activity during social interactions is of major importance for understanding the underlying processes. The CoE’s experience with MEG gives the group a major advantage in such studies.

**Development of the CoE profile**

High quality neuroimaging research is not possible without collaborations between many disciplines including physics, neurophysiology and psychology. The three units brought together to form the CoE create the ideal combination and the scientific success of the CoE attests to the excellent integration and cooperation between the units in the centre.

**Added value**

As is clear from our comments above the CoE has created added value by bring together the three units. The added value is most obvious in the projects on combining MEG and fMRI and in the development of the fMRI phantom.

**Institutional support**

We have a major concern regarding support for the CoE relating to the distribution of expertise (and age) in the centre. There is a clear lack of certain stages in the research hierarchy. To be specific, the BRU currently has about 13 young PhD students (full time), but has only 3 postdoctoral fellows (full time) who can bridge the gap between the PhD students and the principal investigators. As a comparison, at the Functional Imaging Laboratory we try to keep the numbers of PhD students and post-doctoral fellows roughly equal. This is ideal for the transmission of the complex techniques required for neuroimaging studies. This problem for the CoE in Helsinki is largely due to the lack of tenure track positions. The problem is further exacerbated by the fragmentation of funding since only ~16% comes from the Academy of Finland. As a result the PIs must devote much of their time to fund raising, rather than research.

Furthermore, we gained the impression that there were no permanent positions of appropriate status for the leaders of the CoE. This is not a good basis for the continuation of international level research groups in Finland. This level of research requires a guarantee of funding for a permanent core group.

**International visibility**

The research group in the CoE publishes in top, high impact journals (several publications in PNAS, Cerebral Cortex, J. Neuroscience, and NeuroImage) and the principal investigators are frequently invited for public or plenary lectures. Investigators like Riitta Hari and Riitta Salmelin have an undisputable international recognition and are considered pioneers and leaders in their field. The election of Riitta Hari to the National Academy of Sciences in 2004 is a scientific accolade awarded to very few.
In short, the above brief description should make it clear that the CoE has a high profile internationally and is scientifically excellent with very little if anything to criticize regarding its scientific activities.

**Researcher career development**
From a scientific standpoint, the CoE is the ideal place in which to pursue a career in systems neuroscience. Good PhD candidates are being attracted and the gender equality is exemplary. However, the CoE appears unable to offer attractive future prospects even to the best of the graduates from their PhD program as no hard positions exist and the soft positions available from the Finland academy are only for 10% of the graduated students.

It is of paramount importance for research in Finland to have post-doctoral fellows, junior groups (led by outstanding graduates) and some tenure-track positions.

We believe that some faculties (e.g. the Physics department) have been successful in establishing a few tenure-track positions, but it is not clear whether this will happen anywhere soon in the TKK. Without such positions the CoE cannot be internationally competitive.

**International and national cooperation**
International and national cooperation is very good. For many years people have come from all over the world to learn about MEG. While the increasing availability of MEG may have some effect, the CoE is maintaining its lead in methodology and will continue to attract foreign students. However, this success can also create problems. Visitors to the centre stay for just long enough to acquire the desired expertise on MEG and then leave, an outcome that can be a burden rather than a benefit for the centre. Visitors should be encouraged to stay for longer. One option would be to develop joint PhD courses with centres abroad with complementary strengths in, for example, social psychology or computational neurobiology.

**Impact on society**
Many project currently underway at the CoE have direct relevance for health and for technical developments in neuroimaging. More indirectly, increasing our understanding of relationships between the brain and the mind and especially neural mechanisms of social interaction will have major impact in society in the longer term.

**The future of the CoE**
In the short term the research career structure for post-doctoral students and above must be improved.

In the long term a proper funding base has to be established for the continued support of this top class research group.

---

Prof Chris D Frith  
Wellcome Trust Centre for NeuroImaging  
University College London  
12 Queen Square, WC1N 3BG  
UK

Prof. Nikos K. Logothetis  
MPI for Biological Cybernetics  
Spemannstr. 38  
72076 Tuebingen  
Germany