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Edited by
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TEKNILLISEN KORKEAKOULUN KYLÄLABORATORIO

Vuosi 1996 oli tärkeä taitekohta Teknillisen korkeakoulun kylälaboratorion yli 30-vuotisessa historiaassa. Laboratorion perustaja ja sen johtaja, akateemiaprofessori Olli V. Lounasmaa jäi eläkkeelle, ja samalla palasi itse, 17 vuoden tauon jälkeen, takaisin entiseen opinajooni, nyt sen johtajaksi.


Nobel-palkinnon myöntäminen jollekin alalle ei tarkoita sitä, että kyseinen kohde olisi tutkinut loppuun. Suprafaasen 3He:n menestyksellistä tutkimusta jatketaan kylmälaboratoriossa, tosin uusilla alueilla. Esimerkiksi viimeisinissä kokeissa on pyritty mallintamaan pyörivän 3He:n avulla alkuvuotuuden Big Bang-riitätyksen jälkeistä nopeaa jäähtymistä.

Tammikuussa 1996 valmistui Olli Lounasmaan opetusministeriön pyynnöstä laatima raportti "Huippuyksikköä ei perusteta vaan se syntyy", joka sisältää ehdotuksia matematiikan, fysiikan, kemian ja tietojenkäsittelytieteen opetuksen ja tutkimuksen kehittämiseksi Suomessa sekä automaat-tisiin indikaatoreihin perustuvat arviot näiden alojen laboratorioidien tasosta maamme korkeakoululaisuus.

Olli Lounasmaa toivotti minulle edellisen vuosikertomuksen esipuheessaan onnea tulevassa tehtävässäni. Olen hänelle monessa kiitoksen velkaa, sillä hänen rakentamaltaan pohjalta on helppo jaan. Hän on voinutant tienne monilla klassisilla neuvollaan, joita noudattamalla pystynne säilyttämään kylmälaboratorion korkean tieteellisen tason.

Jukka Palonen
Kylmälaboratorion johtaja

LOW TEMPERATURE LABORATORY (LTL)

GENERAL REMARKS

The main fields of research in the LTL are ultralow temperature physics, neuromagnetic studies of the human brain, nanophysics, and cryogenic applications. Studies of superfluid 3He in rotation, nuclear magnetism in metals, and neuromagnetism are well established, whereas optical measurements of interfaces in quantum fluids and solids, electron transport studies on mesoscopic samples, and the present collaboration with CERN represent relatively new fields of study. The choice of these research
areas is not a coincidence, but the result from a realistic judgement of resources available in a small country and our desire to contribute visibly to the scientific endeavor on a world-wide scale. Therefore, in all our topics of research, relatively limited effort translates to a commanding position in the selected subfield. The difficulty herein lies in how to identify narrow topics with sufficiently important scientific implications. This is a process which requires vision, expertise, and a certain amount of continuity. In all cases, the selection has been partially driven by technology, i.e., a new experimental approach, based on home-made innovative measuring instruments to bridge some critical gap, has provided the central starting point.

Superfluid $^3$He in rotation: The ROTA project was the first to start studies of quantized vortex lines in the superfluid phases of liquid $^3$He. In 1981 the construction of a rotating nuclear de-magnetization cryostat was completed. Much of the ROTA work has concentrated since then on identifying the topology and structure of the different objects in the superfluid order parameter field, formed in the rotating state. Superfluid $^3$He is the most versatile laboratory system where such principles as topological stability and confinement, nucleation of singularities, and interactions between objects of different topologies can be investigated. There now exist two rotating nuclear demagnetization cryostats in the laboratory, and for several years both have been used for experiments on superfluid $^3$He.

Quantized vortex lines of many different structures exist in the $^3$He superfluids. They can be divided into singular and continuous textures. The former type of vortex consists of a line singularity about which a quantized curl-free superflow circulates. The familiar vortices of superfluid $^4$He and of conventional superconductors belong to this class. In the $^3$He superfluids, singular vortices with at least $3$ different core structures give rise to vorticity in the B-phase. A continuous vortex line, in turn, is devoid of a singular core and carries two quanta of superfluid circulation. In the A-phase we have found so far $4$ structures belonging to this class.

A natural extension to continuous vortices is the vortex sheet. It is formed from a domain wall in the order parameter texture, into which continuous vortices are confined. 50 years ago, when Lars Onsager first proposed quantization of circulation in the superfluid component of $^4$He, he was thinking in terms of coaxially organized cylindrical vortex sheets, which are aligned parallel to the rotation axis. The model was further developed by Fritz London and by Landau and Lifshitz. Later research has proven that in an isotropic superfluid a vortex sheet is unstable with respect to break-up into individual Feynman vortex lines. In the anisotropic $^3$He-A a continuous meandering vortex sheet was discovered in the LTL in 1994.

A new field of interest is the use of the $^3$He superfluids as a laboratory model system for testing quantum field theoretical problems. Motivated by theories on the formation of large structures in the early universe, a new phenomenon was recently discovered: The nucleation of vortex rings when $^3$He-B superflow is locally heated with the nuclear absorption reaction $n + ^3$He $\rightarrow ^3$H + p + 764 keV. This process has made it possible to study in detail the formation of topological defects in the fastest 2nd order phase transition probed to date. Here the normal-to-superfluid phase front sweeps so fast through the heated volume that other more conventional vortex formation mechanisms are suppressed. Instead, the measurements are an illustration of a new process which is far out of equilibrium and has been suggested as the origin for cosmic string formation in cosmological phase transitions after the Big Bang.
Interfaces in quantum systems: In this project we study helium interfaces at millikelvin temperatures by means of optical interferometry. In our scheme conventional optical windows are avoided. Laser light is guided into the cryostat via a single-mode optical fiber and images are taken using a CCD sensor mounted inside the 4 K vacuum jacket.

Helium crystals in contact with the superfluid phase provide an extraordinarily good model for studying interfacial phenomena in solids. In conventional crystals the growth of an interface is strongly influenced by the bulk properties, since the flow of mass and heat are the limiting factors. In quantum crystals such as helium, the latent heat of solid formation is close to zero and the highly mobile superfluid phase transports heat away very effectively. As a result, the interface relaxes quickly and it becomes possible to study directly its equilibrium properties. From a practical point of view, detailed knowledge of possible surface formations and their thermodynamical properties is important since these characteristics are mainly responsible for the growth properties of a crystal.

In our recent experimental work the equilibrium shape of $^4$He crystals has been an object of very precise measurements. We have discovered that, contrary to predictions of current theories, the crys-talline interface, next to the edge of a $c$-facet, contains a well defined border line separating two regions characterized by different behaviour of the surface stiffness. The observed tremendous increase of stiffness in close vicinity to the facet may be considered as strong evidence of a new interfacial state. We have studied the growth of facets in $^4$He crystals using our accurate optical interferometers in combination with a sensitive pressure gauge. Normally, the growth of facets is associated with screw dislocations. Contradictory to the conventional concept, we found that when large driving forces are present the spiral growth model can be applied only if the kinetic energy of the moving steps and their tendency to localization are taken into account. Crystals of good quality, without screw dislocations, reveal a novel burst like growth. All such mechanisms were found to become increasingly effective with lowering the temperature below 0.2 K.

Nuclear magnetism: In our YKI project, nuclear magnetism of copper, silver, and rhodium has been investigated since 1978 by NMR measurements under extreme low temperature conditions. In 1990 the measurements on silver, both at positive and at negative spin temperatures, showed that the nuclei in this metal order antiferromagnetically at $T_n = 560$ pK in zero external field; this is the lowest phase transition temperature observed so far. An even more striking discovery was that the same interactions, which produce antiferromagnetic order at positive temperatures, give rise to ferromagnetism at negative spin temperatures, above $T_c = -1.9$ nK. Still lower nuclear temperatures have been produced in our experiments on rhodium: The current low and 'high' temperature world records are 280 pK and 750 pK, respectively.

The last two years have been devoted for the construction and testing of a new YKI cryostat. Owing to its versatile design, the apparatus will be well suited for different types of ultralow temperature experiments. The unit features a powerful dilution refrigerator working in series with two nuclear demagnetization cooling stages and it provides a far better decoupling from outside vibrations than the old apparatus. According to its measured performance, the new cryostat is one of the most powerful units ever built. Cryogenic parameters promise a considerable cooling power even at electronic and lattice temperatures in the low microkelvin range. A rhodium single crystal sample has been installed into the apparatus for studies of nuclear magnetism and its possible interplay with superconductivity.
Pioneering neutron diffraction studies have been made over the last 10 years to determine the spin structures of ordered nuclei in copper and silver. These experiments were truly challenging since never before had neutron diffraction been applied at nanokelvin temperatures. The studies on copper nuclei were made by a team consisting of ultralow temperature experts from the LTL and neutron diffraction specialists from the Risø National Laboratory (Roskilde, Denmark) and the Hahn-Meitner Institute (HMI, Berlin); the actual measurements were performed at Risø with essential participation from the LTL. The combination of experimental data and theoretical calculations has allowed us to determine the antiferromagnetic spin configurations of copper in a large region of the $T$-$B$ phase diagram.

In 1991 the neutron diffraction experiments were moved from Risø to the Hahn-Meitner-Institute in Berlin. The collaboration of Finnish, German, and Danish scientists, headed by physicists from the LTL, observed in 1994 long range antiferromagnetic nuclear ordering in a $^{109}$Ag single crystal. The measured phase diagram for the (001) ordered state agrees well with that determined for polycrystalline natural silver by earlier NMR experiments in the LTL. Transmission measurements based on spin dependent neutron absorption were developed to measure the spin polarization of the silver sample. This technique, which can be used both with polarized and unpolarized neutrons, provides a very convenient primary thermometer. The silver experiments have extended the range of the neutron diffraction technique to two orders of magnitude lower temperatures. In the future the feasibility of utilizing a polarized neutron beam for measurements in the ordered state at negative spin temperatures will be studied.

**Neuramagnetic brain research:** Our Brain Research Unit has, with its work over the last 15 years, laid a solid foundation for recent breakthroughs in instrumentation, data analysis, and scientific research of human brain functions by means of the magnetoencephalographic technique. In MEG one records the very weak magnetic fields produced by the human brain. The measurements are made outside the head by means of SQUID arrays and thus healthy and diseased brains can be studied totally noninvasively during various stimulation and task conditions. The advantages of MEG include an excellent temporal and a reasonable spatial resolution.

Following the LTL’s long-term tradition of instrument development, the first whole-scalp SQUID neuromagnetometer was completed in 1992 by Neurorad Ltd in our laboratory and taken into immediate use. This pioneering 122-channel instrument, the first of its kind worldwide, allows signals to be measured simultaneously from the whole cortex. It has been decisive for successful studies of the neural basis of human cognitive functions, exploration of spontaneous brain rhythms, and studies of patient groups with various neurological disorders. The device is now in commercial production by Neurorad Ltd and has already been sold to eight research and clinical laboratories.

The success of the 122-channel device prompted the development of a new 306-channel neuromagnetometer. The Brain Research Unit has collaborated in the design of this instrument; its construction will be completed by Neurorad Ltd during 1997 and the prototype immediately installed in the LTL. This new Vectorview™ device covers a wider brain area than any of its predecessors, and with its combined gradiometer-magnetometer sensor configuration it provides a 'bifocal' view to brain functions: one focuses to superficial cortical activity and another to deeper brain regions.

Our neuramagnetic research has a broad range, attempting at a better understanding of human brain functions in health and in disease. Extensive studies have been carried out on brain activation associated with processing of sensory information. All modalities (audition, somatosensation, vision,
olfaction, and pain) have been investigated and the corresponding cortical dynamics characterized. Our research of higher brain functions includes recordings aimed at revealing the neural basis of speech perception and production, and identification and characterization of the neural machinery underlying mental imagery. Recently strong emphasis has been directed to studies of the functional significance of brain rhythms. Reactivity of the rhythms has been found to give valuable and complementary information to conventional evoked response recordings. We have also continued studies of cortical functions in different brain disorders (epilepsy, dyslexia, depression, and infarctions) to understand the underlying pathophysiology and also to clarify how the healthy brain might work.

Our research has extended MEG imaging to hippocampus, thalamus, and cerebellum. MEG responses to median nerve stimulation demonstrated sequential activation of thalamic and cortical networks, whereas cerebellar responses to this purely sensory input occurred in parallel with the first thalamic response. The identification of waveforms and spectra generated during mental calculation initiated our study of the functional role of oscillatory activity in normal human hippocampus. Significant clinical applications may arise from the study of these novel brain areas.

Hand-in-hand with the experimental program, new data analysis methods have been extensively developed, including, e.g., improved source modelling, new source characterization methods, co-registration of MRI and MEG, integration of EEG and MEG data, and analysis of the brain’s spontaneous activity.

The group is highly interdisciplinary, consisting of physicists, medical doctors, neuroscientists, psychologists, mathematicians, and linguists.

**Nanophysics research:** The scientific program of the LTL has always been directed to challenge unknown frontiers. The introduction of nanophysics as a new research direction in 1996 is a good example, which is expected to open up great opportunities for both basic and applied studies. Nanophysics covers a wide field; in the LTL we will concentrate on nanoelectronics in the low temperature corner of that field. We shall study electron transport in small, under 100 nm size superconducting or normal metal samples. At low temperatures, the electrical conductivity of the nanodevices is dominated by Coulomb repulsion and quantum mechanical interference, two phenomena which, in their own right, are interesting objects to study but may also be exploited in ultra-sensitive detectors. These will eventually benefit the other research programs of the LTL.

**Applied projects and industrial co-operation:** Ever since the LTL was started, it has been evident that knowledge in cryogenics is one of the cornerstones of the Laboratory. Our pioneering research has been possible largely because of the development of new instruments hitherto unavailable commercially. To generate and probe interest in new techniques, considerable effort has been put into applied projects with industrial co-operation. The incentives for this activity have multiplied over the years. One of the world’s largest producers of superconducting wire is now the Finnish company Outokumpu Ltd, and SQUID-based superconducting magnetometers (built by Neuromag Ltd using SQUIDs made by the VTT) reach unprecedented sensitivities. In most cases, financing of applied projects has been provided by industry, by an external research institute, or by governmental organisations like SITRA and TEKES. The industrial needs for highly developed technology in cryogenics are today greater than ever, and one of the tasks of the Laboratory is to maintain and improve its capabilities to satisfy these needs. Another important function of the LTL is to generate crosstalk between users of low temperature technology in research institutes and to provide
information needed for industrial R&D activities. Highly qualified engineers trained in cryogenics must be available from the LTL.

**European Union’s ULTI and BIRCH programs**: The LTL has been successful in obtaining funds granted by the European Union’s Science Directorate. Under the auspices of the Human Capital and Mobility (Mob) Program, two Large-Scale Facilities were started in the LTL in May 1994: the programs will continue to the end of January 1998. The Ultra Low Temperature Installation (ULTI), with a total funding of 1 million ecus, and the biomagnetism program BIRCH, with its 0.9 million ecus (2/3 for biomagnetic studies in the LTL and 1/3 for cardiomagnetic studies in the Laboratory of Biomagnetic Engineering of HUT), are the only Large-Scale Facilities, together with the Jyväskylä Cyclotron Laboratory which in 1996 obtained this status, financed by the Mob program in Finland. Since 1994, 33 European scientists have been supported through the BIRCH project to collaborate with the AIVO-group, altogether for 51 months. The joint projects have dealt with cortical mechanisms of auditory sensory memory, face recognition, somatosensory cortical functions associated with object exploration, cortical mechanisms of olfaction, and with motor learning. Since 1994, 19 European scientists have been supported through the ULTI project to collaborate with the INTERFACE, NANO, ROTA, and YKI-groups, altogether for 79 months. The joint projects have dealt with cryogenic applications in the liquid helium temperature range, studies of topological defects in rotating $^3$He superfluids, investigations of phase boundaries in helium quantum systems using high resolution optical interferometry, and studies of magnetic ordering in the nuclear spin systems of metallic specimens at lowest currently attainable temperatures.

**Other international contacts and collaboration**: From the beginning, the LTL has been fortunate in attracting many foreign scientists whose contributions have been highly beneficial to our development. Usually at least one fifth of the research staff in the Laboratory is from abroad. At our Ph.D. thesis examinations the official opponent nearly always has been a foreign scientist, and our weakly seminars and colloquia invariably have been conducted in English; both these practices were innovations in Finland when they were first initiated by the LTL almost 30 years ago. Members of our staff frequently travel abroad for attending conferences and visiting laboratories. The senior scientists of the LTL have a multitude of international assignments. Many members of our staff have spent 1 – 3 years abroad on sabbatical or postdoctoral appointments.

In 1975, the LTL was the host for the 14th International Conference on Low Temperature Physics (LT 14). In 1984, the 10th International Cryogenic Engineering Conference (ICEC 10) was organized by the LTL. In 1987, the Laboratory was heavily involved in the preparations and running of the 7th General Conference of the European Physical Society. Over the years, about a dozen smaller international conferences have been arranged by the Low Temperature Laboratory. The LTL will continue its traditions as an organizer of major conferences: the 22nd International Conference on Low Temperature Physics (LT 22) will be held in Otaniemi in August 1999.

The LTL has also been involved in international research collaborations: the ROTA project with the USSR (later Russian) Academy of Sciences since 1978, a collaboration with the polarized target group at CERN since 1980 and the SMC since 1991, the Danish-Finnish-German project, carried out in Risø and in Berlin under the sponsorship by the EU’s Science Program, for neutron diffraction studies on nuclear-spin ordered copper and silver since 1985, and a collaboration with the IBM Thomas J. Watson Research Center in Yorktown Heights (NY) on SQUID instrumentation for biomagnetic research, started in 1986. In 1985, the Körber-Stiftung of Hamburg granted DM 750 000 for our
research in connection with the Prize for the Advancement of European Science, awarded to four senior members of our staff. In 1996, our Brain Research Unit was awarded a $450,000 grant by the US National Institute of Health.

**Graduate training in the LTL:** One of the long-standing and serious problems in the system of higher education in Finland is that the median age for obtaining the Ph.D. degree, 31.4 years in natural sciences and technology, is still too high. Various remedies have been suggested in the past. Finally, in the beginning of 1995 a new program, the Graduate School system was started. The LTL joined in two of the Graduate Schools, one in materials science and the other in neuroscience. The LTL has had its own doctoral program for a long time: Over the years, 61 Ph.D.’s have been trained with a median age of 29 years at graduation. Two of our Ph.D.’s are Japanese and two Estonians. We currently have 22 graduate students, 10 in the low temperature and 12 in the brain sections of the Laboratory. Therefore, our Ph.D. production will be high in 1997 and 1998. Through ULTI and BIRCH, many European undergraduate and graduate students will continue to work in the LTL. Our fresh Ph.D.’s usually spend 2 – 3 years on postdoctoral appointments abroad.

**Evaluations and Center-of-Excellence status:** Evaluations are an important part of sound decision making in national science policy and they are slowly finding their way to Finland, too. The academic world has a long tradition in competitive ranking of candidates when filling professorships. In England and Holland continuous peer reviews have been extended to include science departments, universities, and even whole areas of science. One can relatively easily agree about the quantitative criteria which should be used in these evaluations, i.e., the number of scientific publications, the number of graduating students, etc. In contrast, the qualitative criteria are still under heavy debate and it will take some time before general rules for evaluations and their connection to funding emerge. At the request of the Ministry of Education, Olli Loukasmaa made an evaluation of the departments of mathematics, physics, chemistry, and computer sciences of Finnish universities, published in January 1996. This report (“Huipputyösköö ei perustaa vaan se syntyy”) contains many suggestions for improvements in the Finnish university system and is also an attempt of evaluation using automatic indexes, such as impact factors of journals where the research was published.

The LTL is one of the first institutes in Finland which has already gone through a rigorous peer review by high ranking outside experts. In 1994, the Academy of Finland initiated, at the request of HUT, an impartial evaluation of the Laboratory’s international standing. The evaluation was called for by the 1996 retirement of Academy Professor Olli Loukasmaa, the founder and long time director of the Laboratory. In the very favorable evaluation report the experts, Profs. Hans R. Ott (ETH, Zürich, Chairman), Rodolfo R. Linas (New York University), and Douglas D. Osheroff (Stanford University), found the LTL to be an international Center-of-Excellence both in ultra low temperature physics and in neuroscience. The report was published as an Appendix to our Annual Report for 1995.

Recently, more emphasis has been put in Finland to selective allocation of additional funds to the most successful and productive laboratories. In 1994, the Academy of Finland selected 12 national Centers-of-Excellence for a two year period, and the LTL was one of them. This Center-of-Excellence status was renewed in 1996 for two more years. As a result, HUT has increased its funding of the LTL by more than 20% for 1994 – 96 and has promised to continue this extra allocation for the 1997 – 98 period.
THE BOARD

The Board of LTL in 1996 had the following members (with deputys)

Chairman: Prof. Rainer Salomaa
Vice Chairman: Prof. Pekka Haatujärvi
Members: Prof. Mikko Paalanen
Doc. Kaj Nummila (Mr. Jussi Ruutu)
Doc. Riitta Salmelin (Doc. Matti Hämäläinen)
Mr. Simo Vanni (Ms. Piivi Kiesilä)

The term of the board ended on Dec 31. It was then abolished in accordance with a general rationalizing program of the HUT government.

PERSONALIA

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

SENIOR RESEARCHERS

Mikko Paalanen, Dr. Tech., Professor, Director of the LTL
Peter Berghand, Dr.Tech., Docent, Technical Manager
Maria Holmström, Lic.Phil., Laboratory Administrator
Alexei Baikin, Ph.D.
Nina Fors, MD, Ph.D.
Pertti Hakonen, Dr.Tech., Docent
Riitta Hari, MD, Ph.D., Professor
Matti Hämäläinen, Dr.Tech., Docent
Matti Kajola, M.Sc.
Jari Karna, M.D., Ph.D., Oct 1 – Nov 30
Matti Kruusus, Dr.Tech., Professor
Sari Levänen, Dr. Psych.
Olli Lounasmaa, Ph.D., Academy Professor Emeritus
Jyrki Makela, MD, Ph.D., Docent
Kaj Nummila, Dr.Tech., Docent
Ritva Paattini, MD, Ph.D., Jan 1 – 14 and Aug 19 – Dec 31
Ülo Punt, Dr.Tech.
Jussi Ruutu, Dr.Tech., until Sep 6
Ville Ruutu, Dr.Tech., until Nov 14
Jukka Särinnen, Ph.D., until May 31
Riitta Salmelin, Dr.Tech., Docent
Claudia Tesche, Ph.D., Visiting Professor
Erkki Thuneberg, Dr.Tech., Docent
Juha Tuominen, Dr.Tech.
Grigor Volovik, Ph.D., Visiting Professor
Reko Vuorrinen, Dr.Tech.
LONG TERM VISITORS
(More than 4 weeks, total effort 7.1 person-years)

Academician Alexander Andreev, Kapitza Institute for Physical Problems, Moscow, Aug 19 – Sep 22
Prof. Yuri Bunkov, CRTBT-CNRS, Grenoble, Feb 1 – 2, Jun 1 – 2, and Jun 13 – Jul 25
Dr. Per Davidsson, University of Jyväskylä, Finland, Nov 4 – Dec 31
Dr. Alasdair Gill, Imperial College, London, Jan 14 – Apr 7
Dr. Yasushi Kondo, Universität Bayreuth, Germany, Jan 1 – Dec 3
Dr. Nikolai Kopnin, L.D. Landau Institute for Theoretical Physics, Russia, Jan 1 – 13, Jan 29 – Feb 3, Oct 1 – Nov 1, and Dec 10 – 31
Dr. Kim Lefmann, Riso National Laboratory, Roskilde, Denmark, Jan 1 – Aug 23
Dr. Norman Loveless, University of Dundee, UK, Oct 11 – Nov 10 and Dec 2 – 3
Dr. Michel Martin, CNRS-CRTBT, Grenoble, Sep 7 – 13 and Dec 1 – 31
Dr. Linda McEvoy, University of Dundee, UK, Jan 1 – Apr 10
Dr. Livio Narici, Università di Roma “Tor Vergata”, Italy, Aug 8 – Sep 7
Dr. Bernard Plaçais, École Normale Superieure, Paris, Jan 1 – Aug 20
Dr. Dmitry Ponorin, Kapitza Institute for Physical Problems, Moscow, Oct 1 – Nov 30
Prof. Fred Sharifi, University of Florida, Jul 7 – Aug 7
Mr. Jeremy Sullivan, Linde Cryogenics Ltd, Aldershot, UK, Jan 22 – Feb 21
Mr. Igor Todorovchenko, Kapitza Institute for Physical Problems, Moscow, Dec 1 – 31
Dr. Leonid Tsymbalenko, I.V. Kurchatov Institute of Atomic Energy, Moscow, Jan 4 – 8
Dr. George Tvalashvili, Universität Bayreuth, Germany, Jan 1 – Nov 11 and Dec 13 – 31
Dr. Wen Xu, Jiao Tong University, Shanghai, Jan 1 – Dec 31

GRADUATE STUDENTS

Veikko Jousmäki, MSc
Päivi Kiesilä, M. Psych
Tauno Knuttila, MSc
Jaakko Koivuniemi, MSc
Juha Kopu, MSc
Juha Martikainen, MSc
Jussi Numminen, MSc until Jun 13
Lauri Parkkonen, MSc
Jari Penttilä, MSc
Karin Portin, MSc

Tommi Raji, M.D
Jaakko Ruohio, MSc
Stephan Salenius, M.D.
Jari Saramäki, MSc
Mika Seppä, MSc
Viktor Tsepelin, MSc
Mikko Uusitalo, MSc
Kimmo Uutela, MSc
Simo Vanni, M.D
Weijun Yao, MSc
Jyri Ylöstalo, MSc
UNDERGRADUATE STUDENTS
Michael Danielides, from May 1
Kai Barck
Markus Herrgård
Jörkki Hyvönen
Risto Hänninen
Juho Härme
Jussi Ikäheimo
Hanna Koivikko
Salla Kivusalo
Mimmi Kajala
Jokka Lahinen
Pekka Laatinen
Lotta Lehdelä
Reeta Luusalo
Samu Laitteenmäki
Riikka Miettinen
Teemo Pohjola
Leif Roschier
Jarkko Salojärvi
Jonas Saranne
Tero Setälä
Antti Tarkiala
Teemu Toroi
Kaarlo Väisänen

SECRETARIAL AND TECHNICAL PERSONNEL
Kirsti Hakonieni, secretary, until May 31
Teija Halme, secretary
Antti Huvila, technician
Mia Ilmarinen, laboratory assistant
Arvi Tonon, technician
Jani Ikkala, assistant, until Jun 27
Juhan Kaasinen, technician
Tuire Koivisto, secretary
Markku Korhonen, technician
Rasko Leinonen, secretary, until Jan 12
Lisi Pasanen, secretary
Kari Rauhanen, technician
Antero Salminen, technician
Seppo Utriainen, technician, until Jan 31

SHORT TERM VISITORS
(Less than 4 weeks, total effort 1.4 person-years)
Dr. Harry Alles, Manchester University, UK, Jan 3 – 8 and Jul 4 – 10
Prof. Vinay Ambegaokar, Cornell University, NY, Dec 16 – 19
Dr. Dmitri Averin, State University of New York at Stony Brook, Aug 27
Dr. Sebastian Balibar, CNRS, Paris, Jan 4 – 7
Dr. Simon Bandler, University of Heidelberg, Germany, Jul 23 – 28
Mr. Barry Bayliss, The Open University, Milton Keynes, UK, Jun 29 – Jul 2, Aug 23 – 27, and Sep 26 – Oct 8
Dr. Sergey Boldarev, P.N. Lebedev Physical Institute, Moscow, May 20 – 26, Jun 15 – 16, Oct 4 – 13, Oct 18 – 30, and Dec 23 – 29
Dr. Roger Bowley, University of Nottingham, UK, Jan 4 – 7
Mr. Emanuele Centurioni, CNR-LAMEL, Bologna, Italy, Oct 2 – 6
Ms. Hilde Chantrain, Katholieke Vlaamse Hogeschool, Antwerpen, Holland, Mar 15
Dr. John Connelly, Dalhouse University, Canada, Jun 22 – 25 and Jun 29 – Jul 3
Mr. Derek Cousins, Lancaster University, May 13 – 24 and Oct 3 – 5
Dr. Ann Davis, University of Cambridge, UK, Mar 30 – Apr 6
Dr. Vladimir Dmitriev, Kapitza Institute for Physical Problems, Moscow, May 16 – Jun 7
Prof. Gregory Goltsman, Moscow State Pedagogical University, Feb 2
Dr. John Hook, Physics Department, Manchester University, Sep 18 – 22
Mr. Walter Huber, RWTH Aachen, Germany, Mar 15
Dr. Andreas Ioannides, Jülich Research Center & Open University, Germany, Aug 21 – 25
Dr. Theodore Jacobson, University of Utrecht, Holland, Jan 15 – 21
Prof. Antti-Pekka Jaaho, Technical University of Denmark, Lyngby, Nov 25 – 27
Dr. Reyher Jochemsen, University of Leiden, The Netherlands, Jan 4 – 7
Dr. Enno Joon, Institute of Chemical Physics and Biophysics, Tallinn, Oct 8 – 13
Prof. Sergei Kapitza, Kapitza Institute for Physical Problems, Moscow, Dec 12 – 13
Dr. Konstantin Keshishiev, Kapitza Institute for Physical Problems, Moscow, Jan 4 – 8
Dr. Alexander Korotkov, Nuclear Physics Institute, Moscow State University, Dec 1 – 6
Prof. David Lee, Cornell University, Ithaca, NY, Dec 15 – 17
Dr. Paul Leiderer, Universität Konstanz, Germany, Sep 26 – 28
Dr. Mario Liu, University of Hannover, Germany, Jan 4 – 7
Dr. Alexei Marchenkov, University of Leiden, Holland, Jan 4 – 8
Dr. François Mauguière, Neurological Hospital, Lyon, Nov 9
Dr. Barry McSweeney, Research Fellowship Programmes, European Commission, Apr 25
Dr. Isabelle Merlet, Neurological Hospital, Lyon, Feb 23 – Mar 15
Dr. Vladimir Mzhov-Deglin, Institute for Solid State Physics, Russian Academy of Sciences, Moscow, Jan 4 – 8
Prof. Yoshio Okada, University of New Mexico School of Medicine, USA, Jul 23 – Aug 15, Sep 3 – Oct 1, and Oct 9 – 29
Prof. Douglas Osheroff, Stanford University, California, Dec 15 – 17
Prof. Richard Packard, University of California, Berkeley, Jun 15 – 19
Prof. Alexander Parshin, Kapitza Institute for Physical Problems, Moscow, Jan 4 – 11, Mar 1 – 22, Jun 6 – 20, Sep 28 – Oct 20, and Dec 12 – 21
Dr. Yuri Pushkin, Lebedev Physical Institute, Moscow, Mar 21
Prof. George Pickett, SPAM, Lancaster University, UK, Jan 4 – 7 and Sep 26 – 29
Dr. Emil Poltuvak, Technion - Israel Institute of Technology, Haifa, Jan 4 – 7
Dr. Peter Praamstra, Institute of Neurology, University Hospital Nijmegen, The Netherlands, Jan 1 – 25
Dr. Luciano Reatto, Universita di Milano, Italy, Jan 4 – 7
Prof. Robert Richardson, Cornell University, Ithaca, NY, Dec 14 – 17
Dr. Yashiko Sakamoto, Metrology Fundamentals Division, Japan, Jun 24
Dr. Osamu Sasaki, New Energy and Industrial Technology Development Organization, Japan, Jun 24
Prof. Wilfried Schoepke, University of Regensburg, Germany, Feb 22 – Mar 1
Mr. Josef Sebek, Institute of Physics, Prague, Oct 5 – 12
Prof. Norman Simon, Department of Physics and Astronomy, University of Nebraska, Jun 10 – 11
Mr. Vladimir Stepankin, General Physics Institute, Russia, Jan 30 – Feb 1 and Oct 5 – 6
Dr. Stephen Swithinby, The Open University, Milton Keynes, UK, Jun 16 – Jul 2, Aug 23 – 27, and Sep 27 – Oct 7
RESEARCH

RESEARCH PARTNERS

Physical research

Bayreuth
Bohr
CERN
CNRS
ENS
Florida
FUB
HEI
IC
Ioffe
JGU
Kapita
KuY
Landau
Picowatt
Riso
Turk
VTT

University of Bayreuth, Germany
Niels Bohr Institute, University of Copenhagen
European Laboratory for Particle Physics, Geneva
CNRS-CRTBT, Grenoble
Ecole Normale Superieure, Paris
University of Florida
Freie Universitaet, Berlin
Hahn-Meitner Institut, Berlin
Imperial College, London
Ioffe Physical Technical Institute, St. Petersburg
Jiao Tong University, Shanghai
University of Jyvaskyla
Kapitza Institute for Physical Problems, Moscow
University of Kuopio
L.D. Landau Institute for Theoretical Physics, Russia
Picowatt Ltd, Vantaa
Riso National Laboratory, Roskilde, Denmark
University of Tartu, Estonia
Technical Research Centre of Finland

Neuromagnetic research

Dalhousie
Dundee
Dusseldorf
Erlangen
Lyon
Milton Keynes
MRC

Department of Psychology, Dalhousie University, Halifax, Canada
University of Dundee, UK
University of Dusseldorf, Germany
University of Erlangen, Germany
Neurological Hospital, Lyon
The Open University, Milton Keynes, UK
MRC Institute of Psychiatry, London
NUCLEAR ORDERING IN RHODIUM (YKI PROJECT)


Nuclear ordering in rhodium and its interplay with superconductivity. In order to reach the magnetically ordered state in Rh, not seen in our earlier experiments, it was crucial to improve the thermal conductivity of the sample and to increase its spin-lattice relaxation time in low magnetic fields. For this purpose we have performed an extensive study of the selective oxidation technique in Rh. The residual resistivity ratio of the new single crystal sample is 750 which should be compared with the RRR of 530 for the polycrystalline foils used in the earlier set-up. We have also run tests on diffusion and electron-beam welding between Rh and Ag which have resulted in a considerably reduced resistance at the joint. Detailed numerical simulations show that the new sample combined with the improved cooling facilities, especially the longer hold-time of the helium dewar, should suffice for reaching the ordered state. The experimental set-up has been installed into the cryostat and the measurements will be performed using novel dc-SQUIDs manufactured by VTT.

A so far almost completely unexplored effect is the interplay between superconductivity and nuclear ordering. Rhodium is a unique system for this purpose owing to its record low superconducting transition temperature, probably caused by spin density fluctuations. It becomes superconducting at $T_c = 325 \mu K$ in zero field, while the critical field for superconductivity $B_c = 5 \mu T$. The critical field for nuclear ordering is likely to be higher. Therefore, it should be possible to investigate how the presence of nuclear order affects the occurrence of the Meissner effect.

Search for superfluidity in $^3$He/$^4$He mixtures. Observation of this transition is one of the outstanding goals of ultralow temperature physics today. The obstacles in reaching low temperatures are the large Kapitza thermal boundary resistance between the mixture and a metallic surface, and the intrinsic heat input of unknown origin to the liquid.

The superfluid transition in the dilute $^3$He will be observed, if it exists, with a vibrating wire. It is possible to reduce the heat leak in the vicinity of the wire by insulating it with an anodization technique instead of epoxy. First versions of the cell have been designed and are under construction.
and testing. The $^3\text{He}/^4\text{He}$ mixture work will be performed, under the auspices of the ULTI program, in collaboration with Prof. George Pickett’s group at the University of Lancaster.

**NEUTRON DIFFRACTION STUDIES OF NUCLEAR MAGNETISM (B-YKI PROJECT)**

K. Clausen (Risø), K. Lefmann (Risø), L. Lipinski (HMI), **O. Lounasmaa**, A. Metz (HMI), K. Nummila, F. Rasmussen (Bohr), K. Siemensmeyer (HMI), M. Steiner (HMI), J. Tuoriniemi, R. Vuolet.

During 1996, this project at the Hahn-Meitner-Institut in Berlin suffered from several difficulties. The helium dewar started to leak at the beginning of the year. After unsuccessful repair attempts a new dewar was purchased. It was delivered only in the end of June, which left essentially no time for experiments before a long reactor maintenance shutdown started in the middle of July. The break lasted until the middle of October, after which there were two three-week reactor periods before Christmas. During this time the cryostat suffered from blockages and one of the pumps broke down. In addition, the stepping motor of the monochromator failed.

Members of the group largely concentrated their activities to other projects or were writing review papers.

**TOPOLOGICAL OBJECTS IN QUANTUM FLUIDS (ROTA PROJECT)**

V. Eltov (Kapitza), J. Ikäheimo, J. Koivuniemi, Y. Kondo (Bayreuth), **M. Krusius**, J. Lahtinen, B. Plačič (ENS), D. Pomarin (Kapitza), J. Ruohio, V. Ruutu, Wen Xu (JTU)

Common experience tells us that rapid phase transitions are associated with a high degree of disorder and inhomogeneity. Generally, this is caused by heterogeneous extrinsic influence, such as the presence of boundaries, impurities, etc. Phase transitions are therefore usually studied in the adiabatic limit, as close to equilibrium as possible, to minimize the density of defects. But suppose we have an ideal infinite homogeneous system which is rapidly expanding and cooling through a second order phase transition, from a symmetric high temperature state to a low temperature state of reduced symmetry, the broken-symmetry phase. What happens? Is the system going to remain homogeneous after the transition? After all this was the situation in the early universe when it rapidly expanded through a series of symmetry reducing phase transitions. The standard theory of cosmology assumes that the expansion started from an initial homogeneous state with only micro-structure, but was transformed by some mechanism to the present inhomogeneous state with well-documented large scale structure, consisting of galaxies, galaxy clusters, and superclusters with large intervening voids empty of visible matter.

In 1996, our work has concentrated on the study of phase transitions which are far out of equilibrium and sufficiently rapid to become time dependent. The second order transition from the normal to the superfluid state at the pressure-dependent critical temperature $T_c(P)$ in liquid $^3\text{He}$ provides the environment for such measurements. Liquid $^3\text{He}$ can be locally heated with the absorption reaction of a thermal neutron,

$$n + ^3\text{He} \rightarrow p + ^3\text{H} + 764 \text{ keV},$$
where a major fraction of the reaction energy of 764 keV ends up as quasiparticle excitations and heat. Owing to the large absorption cross section of thermal neutrons in liquid $^3\text{He}$ their mean free path is only 100 $\mu$m. The absorption reaction produces a small bubble of liquid with a radius $R_0 \approx 50$ $\mu$m which warms from $^3\text{He}$-B to above $T_c$ into the normal phase and then, with a thermal relaxation time of order $\tau_0 = 1$ $\mu$s, cools back into $^3\text{He}$-B. If the heated bubble is embedded in superfluid flow, which is generated by rotating the cylindrical $^3\text{He}$ chamber, vortex rings are observed to emerge from the bubble if the flow velocity exceeds a critical threshold value. In the rotating superfluid the rings expand to rectilinear vortex lines which in the experiment can be counted with NMR one by one.

The most important question in the measurements has been the dependence of the nucleation process on flow velocity, the bias, which also preserves the newly formed vortex lines in stable state in the rotating container. As shown in the figure, a successful neutron absorption event, which leads to the formation of vortex rings, is observed as a discontinuous change in the NMR absorption. The size of the jump gives the number of vortex rings which manage to escape from the bubble. At a low rotation velocity, just above the threshold value, the number of vortex rings per event is one or two, but with increasing velocity more vortices are extracted from each event. From plots such as in the figure, the number of vortex rings per neutron absorption event can be obtained as a function of the experimental variables. These are the flow velocity, temperature, pressure, and magnetic field. The measurements have so far concentrated into the Ginzburg-Landau temperature regime ($T_c > T > 0.8 T_c$), but will now be continued to lower temperatures. The final goal is to study the nucleation process in the zero temperature limit, where vortex dissipation from mutual friction approaches zero and the lifetime of the initial vortex rings, or any other defects, becomes long even in the absence of a bias field.

![Graph showing neutron source on and off](image)

**Vortex nucleation in neutron irradiation.**

The phenomenon represents a new nucleation mechanism for quantized vortex rings inside the bulk superfluid, far from the walls of the container, which we discovered in late 1994. It appears to be
the fastest 2nd order phase transition which has been probed to date and in which the density of one species of defects has been measured. A number of different processes can be suggested which might lead to defect formation in this particular experiment. The only mechanism which has been found to explain quantitatively the formation of vortex rings as a function of the flow velocity is the theory proposed by T. Kibble and W. Zurek. According to these authors defects will be formed in a 2nd order phase transition if it propagates faster than the order parameter in the broken-symmetry phase is able to follow. The reason for this is that the broken-symmetry phase starts to form simulta-neously in different causally disconnected regions. In these separated pockets the order parameter state may settle in any of the many degenerate minima of the Ginzburg-Landau energy functional, since the pockets have no information of each other or of the outside ambient conditions, i.e., of the boundary at the edge of the warm bubble. The disconnected pockets grow when the temperature relaxes within the warm bubble and cools towards the ambient temperature. At the boundaries, where adjacent pockets ultimately meet, the order parameter orientations may not match and a domain structure with different types of intervening defects will be created. As suggested by Zurek in 1985 and shown by our experiment, suitable condensed matter systems exist in which a quench in the mechanical or thermal conditions to the regime of the broken-symmetry phase can be propagated much faster than the order parameter is able to relax. Thus the theory on time-dependent phase transitions can be tested with laboratory measurements.

INTERFACES IN QUANTUM SYSTEMS

A. Bakkin, P. Hakonen, J. Hyvönen, R. Luusalo, J. Saramäki, V. Tsepelin (Tarto), G. Tvalashvili

The interface between the liquid and solid phases of helium provides a unique object to investigate physics at a phase boundary, in a situation where thermal processes do not disturb the kinetic behavior of basic surface excitations, viz., linear elementary steps and the atomic kinks carried by them. By investigating the static and dynamic properties of the interface we strive to clarify mutual interactions between the surface excitations, as well as to determine how well the characteristics of the interface can be understood by employing the theoretical concepts of elementary kinks and steps. For these investigations we use high-resolution interferometric techniques developed in our laboratory.

The interferometric resolution of our static measurements has been improved considerably and we are now able to distinguish height differences well below 5 nm. The equilibrium shape of 4He crystals was measured with this enhanced vertical resolution. We found that the profile of the interfacial boundary, close to an almost horizontal c-facet, has a well-defined slope discontinuity point, separating two angular regions with drastically different behavior of the surface stiffness and indicative of a phase transition and an unexpected state of the interface. This implies a reconstructed surface configuration to lower the free energy of stepped interfaces at small angles, but plausible theoretical models for such a reconstruction have not been proposed as yet.

The liquid-solid interface of 4He has been investigated down to the millikelvin range using our optical interferometer, in combination with a precise pressure gauge. The c-facets with about 10 screw dislocations/cm2 grew with spiral growth, which could be understood by including inertial terms and the localization of steps to the standard theory. Samples without screw dislocations reveal a novel growth mechanism: these high quality crystals grew in a burst-like way, creating abruptly up to
several thousands of new atomic layers. Addition of $^3$He impurities reduced the speed of both growth modes. Studies of $a$-facets yielded a $v$ vs. $\Delta p$ dependence which is relevant to the spiral growth mechanism. The shape of the entire $e$-facet has been monitored down to 2 mK without evidence of the freezing of kinks. Indications of new facetting transitions were not observed down to 2 mK.

THEORY OF SUPERFLUID $^3$He

A. Andreev (Kapitza), A. Gill (IC), R. Hänninen, M. Herrgård, T. Kibble (IC), N. Kopnin (Landau), I. Kupu, A. Parshin (Kapitza), T. Setälä, E. Sonin (Ioffe), E. Thuneberg, G. Volovik

The majority of theoretical work in the LTL is closely connected to the experimental effort of the laboratory. Only a few of the ongoing theoretical projects are listed below.

An extensive summary of the periodic vortex structures in rotating superfluid $^3$He-A has been prepared. There are five different vortex structures which are stable at different magnetic fields and rotation velocities. The symmetry of the vortex structures can be expressed using crystallographic space groups.

The critical velocities for vortex formation in superfluid $^3$He-A differ essentially from other superfluids. Instead of being determined by the container wall, the nucleation process in $^3$He-A arises from instabilities in the bulk liquid. We have studied the critical velocity with one-dimensional simulation using different initial configurations. These calculations provide an understanding of the measured critical velocities, whose values differ by a factor of six depending on the initial texture in the measuring container.

Evidence of superfluidity of $^3$He in 98% aerogel has been found in torsional oscillator experiments at Cornell university and in NMR experiments at Northwestern University. We have studied theoretically how the aerogel affects the superfluid properties of $^3$He using a model that is similar to impurity scattering in superconductors. We found that the simplest version of this model, although qualitatively correct, fails to predict quantitatively the measured suppression of the superfluid order parameter. Studies of more detailed models are in progress. Possible glass states of superfluidity in aerogel are discussed and phase transitions between them are suggested during a sweep of the magnetic field or the tilting angle during NMR experiments.

The apparent curving of facets in the liquid-solid interface of $^4$He has been investigated. It is suggested that this arises from steps in the facet that are pinned to some unknown defects.

Vortex creation upon the absorption of thermal neutrons in a rotating $^3$He-B is interpreted in terms of defect formation during a nonequilibrium phase transition according to the Kibble-Zurek mechanism, which is similar to the formation of cosmic strings and domain walls during cosmological phase transitions in the early Universe. The nuclear reaction $n + ^3$He $\rightarrow p + ^3$H + 0.76 MeV heats a region of the superfluid into the normal phase. The subsequent fast cooling of this hot bubble back through the second order transition results in the nucleation of quantized vortices.

To study the effect of the boundary condition at the surface of the hot bubble on the vortex nucleation, dynamics of the phase ordering behind the propagating front of the second order transition has been investigated. It was shown that vortex formation due to the Kibble-Zurek mechanism essentially depends on the propagation velocity of the front. A critical velocity exists below which the
vortex formation is suppressed. It was also shown that the velocity of the temperature front in the neutron experiments is large enough for the vortex formation after cooling.

The dynamics of vortices in superfluids and superconductors is investigated. All forces acting on a vortex in $^3$He-B, $^3$He-A, and in superconductors were calculated. The mechanism of the linear momentum production during vortex motion is proved to be equivalent to the baryon production during the dynamics of cosmic strings. This allows to model the electroweak baryogenesis in $^3$He-B and $^3$He-A. Other analogies between the standard Weinberg-Salam model of the electroweak interactions and the quantum field theory in superfluid $^3$He are developed.

The fermions localized on the half quantum vortices are calculated with application to the Abrikosov vortices with $\frac{1}{2} \Phi_0$ of the quantum of the magnetic flux, which were recently observed in high-temperature superconductors. A flat fermionic band was found which produces an anomalous electronic density of states.

The fermions in the vortex core were also calculated for the integer Abrikosov vortices in the d-wave superconductors. The $1/E$ singularity in the electronic density of states was found at low energy E which arises due to the gap nodes in the presence of vortices. This leads to the scaling behavior of the heat capacity in high-temperature superconductors in a magnetic field, which is experimentally confirmed.

It was shown that the interface between $^3$He-B and $^3$He-A can serve as a model for the Casimir effect in quantum vacuum.

A theory of double resonance was developed for description of the new stable states of the Larmor precession, which include the observed spin precession at one half of the equilibrium magnetization. The latter is the novel state of the phase coherent spin superfluidity.

**Nanophysics Research**

M. Danielides (FUB), P. Davidsson (JY), M. Herrgård, S. Lähteenmäki, M. Martin (CNRS), M. Paatelainen, Ü. Parts, J. Penttilä, F. Sharifi (Florida)

The nanophysics research program was introduced in the end of 1995.

In the study, we intend to make small normal metal and superconducting samples, whose dimensions are less than 100 nm, and investigate their electrical conductivity.

During 1996 the NANO group has built up lithographic facilities, which are located in the clean room of the Technical Research Centre of Finland (VTT). Our main tool is an electron beam writer which is based on the JEOL 6400 scanning electron microscope. This instrument and the software for the beam writer were assembled in February and in early May we demonstrated the first Single Electron Transistors (SETs) with submicron dimensions. The SETs were made out of small Al/AI0x/Al tunnel junctions which were processed on oxidized silicon substrates by the two angle evaporation method. In July, we managed to make a 25 nm wide aluminium line on a silicon substrate. This is the narrowest feature one can produce with a JEOL 6400-based electron beam writer. For making even narrower lines, one needs to use other methods, e.g., lithography which is based on the Atomic Force Microscope (AFM). In December the NANO group acquired such an instrument, made by Park Scientific Co, and is planning to use it for lithographic purposes.
The resistance of the nanoscale samples is affected by the Coulomb repulsion and by quantum mechanical interference. Especially interesting is the Coulomb blockade phenomenon in one and two dimensional arrays of small metallic islands, which are separated from each other by metal oxide tunnel junctions. The simplest Coulomb blockade system, the SET, comprises of one island and two tunnel junctions separating it from the drain and the source leads of the transistor. Our intention is to study the integration of SETs both with FET and SQUID based amplifiers. These wide bandwidth circuits have potential applications as ultra sensitive charge and current meters, and therefore, TEKES is supporting this part of our research program.

We are also interested in understanding the properties of a single nanoscale Josephson junction. The Ambegaokar-Baratoff formula predicts that the critical supercurrent of a current biased junction is inversely proportional to the normal state resistance of the junction. We believe that this relation breaks down, due to quantum mechanical fluctuations, and that for junctions with higher resistance than the quantum resistance \( R_Q = h/4e^2 \approx 6.5 \, \text{k} \Omega \), the Josephson coupling breaks down resulting in a superconductor-insulator transition.

**CERN - COLLABORATIONS**

**TERMO**

J. Ylöstalo, P. Berglund, T. Niinikoski (CERN), R. Voutilainen (Picowatt)

The project aims at developing a data acquisition and monitoring instrument specifically designed for large-scale cryogenic systems. We believe that a need for accurate and relatively fast temperature measurement in the liquid helium temperature range (below 4.2 K) will arise with the construction of the CERN Large Hadron Collider and similar massive superconducting devices.

A third prototype version of the TERMO AC resistance bridge thermometry system was created during this year. The new version features improved EMI protection and increased modularity and ease of use. The measurement cards can now be mounted on a motherboard, which provides power and computer signals to the cards. A new four-layer version of the measurement card was designed, with reduced size and component count.

The user has a choice between 16 or 20 bit A/D converter and three different card types: general purpose card, low resistance card, and diode card. An entirely new oscillator circuit provides the measurement frequency and ADC operating frequency and also drives the data acquisition. All these frequencies are synchronized to avoid beats or offsets.

A new solution was found to solve the switch transient problem associated with square wave AC resistance measurements. This solution enables the measurement of high impedance sensors while maintaining a good S/N ratio. The noise model created for the measurement circuit has enabled us to optimise component values, thereby improving the noise performance of the system.

**SMC collaboration**

P. Berglund, J. Ylöstalo

The SMC collaboration studies the spin of the nucleons through deep inelastic scattering of high energy polarized muons on polarized neutrons or protons. The valence quark contribution to the spin
content has been measured to be about 20% of the total spin content with negative strange quark contribution (fairly large, about 1–10%). The results support well the Bjorken sum rule. The target material this year has been ammonia. It was prepared by the group from Bochum and Bonn.

LTL’s participation in SMC was initiated in 1989. Our target, which is the largest polarised target in the world, was in operation from spring 1993 to autumn 1996. The performance of the dilution refrigerator was excellent (the lowest temperature obtained in the mixing chamber containing the target has been around 22 mK) and it made a very successful series of runs possible until the end of the experiment in October 1996.

RD39 collaboration
P. Berglund, T. Niinikoski (CERN), R. Wedenig (CERN), I. Suni (VTT), H. Seppälä (VTT), J. Salminen (VTT)

The continuous-flow 4He refrigerator was modified in Helsinki.

All thermometers were calibrated against a secondary Pt reference standard and a factory calibrated Ge resistor. The cabling external to the cryostat was improved and new hermetic seal receptacles, all with RF filters, were installed. A new chip carrier was designed with provisions for contacting the pads on the chip, by ultrasonic wedge bonding with 75 μm thick Al wire, to a probe card with coplanar transmission lines for the high frequency signals.

The bonding machine which was set up in the end of 1995 was tuned up for the wire and the chips using chips damaged in the course of earlier tests. Very reliable operation was achieved with the same bond force for the gold plated lines of the probe card and the palladium and NbN contacts on the chips, without special cleaning or preparation of the surfaces. Some of the existing chips were tested using the improved equipment. The results were identical to the earlier ones, confirming the critical current densities determined in 1995.

NEUROMAGNETIC RESEARCH

BRAIN RESEARCH UNIT, Head R. Hari. Members of the unit are:


BIRCH visitors: A. Bailey (MRC), B. Bayliss (Milton Keynes), S. Braeutigam (Milton Keynes), N. Loveless (Dundee), F. Mauguière (Lyon), I. Merlet (Lyon), L. McEvoy (Dundee), L. Narici (Roma), P. Praamstra (Nijmegen), S. Switchenby (Milton Keynes)

Functions of the human cerebral cortex have been studied by measuring magnetic fields outside the head. Our recording device, a helmet-shaped 122-channel SQUID neuromagnetometer covering the whole scalp, was manufactured by Neuromag Ltd in the LTL. The magnetoencephalographic (MEG) method allows totally non-invasive studies of healthy and diseased human brains during dif-
Spontaneous cortical activity in healthy subjects

R. Hari, V. Jousmäki, M. Kajola, L. Lehtelä, L. Narici (Roma), K. Portin, S. Salenius, R. Salmenlinna, A. Schnitzler (Düsseldorf)

An extensive ongoing study compares the driving of various cortical rhythms after trains of visual, somatosensory, and auditory stimuli. New indicators have been developed to quantify phase-locking of cortical signals during stimuli presented at different rates.

Reactivity of spontaneous brain rhythms has been further investigated in association with various other sensory stimulations and tasks. Temporally isolated visual stimuli were found to suppress rhythmic 10-Hz activity, both in the occipital lobe and in the region of the parieto-occipital sulcus; the latter area was significantly more strongly affected by luminance than by checkerboard stimuli. New supportive evidence has been obtained for the existence of a reactive auditory 'tau' rhythm, generated in the supratemporal auditory cortex. Tau seems to be right-hemisphere dominant.

Rhythmic activity at approximately 20 Hz, generated in the primary motor cortex, was found to be coherent with motor unit firing from a muscle during isometric contraction in several subjects. The cortical signal preceded the motor unit signal in time, thereby suggesting that signals descending from the cortex to the spinal level are able to modify the timing of the motor neuron pool. The sites of maximum coherence in the motor cortex could probably be used as clinical tools to reliably locate the motor cortex.

Sensory systems of healthy subjects


Auditory system. Auditory cortical responses to illusory sound movements, generated by varying interaural amplitude modulations, indicated that both hemispheres are able to analyze the movement of sound sources. In the case of a single moving source, the balance of activation between the hemispheres may be important. Response amplitudes followed closely the modulation rate; however, the N100m amplitudes to transition were not exactly related to perception.

The subject's own voice was found to delay responses of the auditory cortex to simultaneously presented probe tones. Such a mechanism is probably related to the feedback control of the voice.

A project has been started to study whether the auditory cortex of deaf subjects responds to somatosensory stimuli. Preliminary results suggest that vibratory stimulation of the palms may activate the auditory cortices of deaf persons but not of normal controls.
Somatosensory system. Analysis of somatosensory evoked responses to stimulation of peripheral nerves in the upper limbs has suggested activation of an extensive neural network involving the frontal lobes bilaterally, and the mesial central lobule. These areas were differentiated, in addition to previously known source areas, in the contralateral primary somatosensory cortex, the second somatosensory cortex bilaterally, and the contralateral posterior parietal cortex. The mesial paracentral lobule was shown to participate in processing of relevant somatosensory information in a somatosensory target detection task.

Variations of intensity in somatosensory stimuli had a different effect on activation of primary, secondary, and posterior parietal somatosensory cortices. Other results suggest that motor activity facilitates tactile input from mixed nerve to SII and to a lesser extent to posterior parietal cortex, emphasizing the importance of these sites in sensorimotor integration.

Responses to painful CO₂ stimulation of the nasal mucosa were found in the region of the second somatosensory cortex of both hemispheres, with significant right-hemisphere dominance. Since no such asymmetry was observed to airpuff stimulation of the nostrils nor of the face, it was concluded that the right-hemisphere dominance was associated with the unpleasantness of the painful stimuli and with the role of the trigeminal pathway as a general warning system.

Neural basis of visual perception and vision-related brain activation. The extrastriate visual cortex was found to be activated bilaterally, but with strong contralateral dominance after checkerboard hemi-field stimuli but with only 2:1 contralateral/ipsilateral ratio after luminance stimuli. The latter stimulus predominantly activated the parieto-occipital region, with the maximum effect occurring about 90 ms later than in the occipital areas.

Viewing visual objects in an object/nonobject discrimination task activated medial and bilateral occipital and superior temporal areas, and the left parietal lobe. Interestingly, activity in the right lateral occipital cortex was significantly correlated with the proportion of correct object detections, suggesting that this area has an important role in visual awareness of objects.

Visual motion 'popouts' evoked bilateral activity in the V5 complex and in the parietotemporal border. Similar activity was associated with visual search, both in popout localization and in identification tasks.

Visual imagery of letters seemed to activate temporo-occipital, frontoparietal, and parietal cortex bilaterally but predominantly in the left hemisphere. Some of these brain areas were also activated by passive viewing of similar visual stimuli; certain areas even further increased their activity during visuospatial tasks.

In a recent study we tested whether the prominent activation of the medial parieto-occipital sulcus, after voluntary blinks, is related to the perceived visual stability, in spite of the 100 – 200 ms interval of interrupted visual input during the blinks. A landscape, moving at varying speeds, was presented while the subjects made voluntary blinks. In a second study the subjects were presented with pictures which were or were not changed during the eyeblink. The results suggest that the activation of the parieto-occipital sulcus is fundamentally related to the eyeblink itself and not affected by changes in the visual input; thus its relation to visual stability of perception is questionable.

Response recovery studies have been applied to reveal functional organization of visual cortical sites by determining for each area a lifetime, characterizing how long the preceding stimulus affects the response to the next stimulus. Brief checkerboard stimuli activated sources with lifetimes of 0.1 –
0.6 s in the occipital and of 7 – 30 s in the parietal, temporal, and frontal areas, suggesting that the higher the area is in the hierarchy of visual processing, the longer is its lifetime. Stimulation with moving gratings activated the motion-specific V5 cortex and indicated an average lifetime of 0.8 s. Thus area V5 belongs to the upper part of the lower hierarchy group of visual sites, in agreement with its assumed place in the hierarchy of visual information processing.

Cortical responses and rhythmic activities have been studied during a spatial working memory task. Attention strongly modulated the responses during a delay period. However, responses did not differ between "memory" and "no-memory" conditions. Furthermore, alpha rhythm was suppressed, whereas mu rhythm was enhanced during the delay. In addition, the mu rhythm was strikingly enhanced during a saccade of the target.

New signals have been observed which were suggested to reflect activity of the human cerebellum in association with saccadic eye movements, starting 30 ms before the saccade onset and peaking with a large reflection about 170 ms after the onset.

Studies of language perception and production
J. Connolly (Dalhouse), P. Kiesilä, W. Levelt (Nijmegen), P. Praamstra (Nijmegen), R. Salmelin, E. Service (HU), K. Utela

We have further clarified cortical involvement during picture naming by combining spatiotemporal patterns of brain activation with a psycholinguistic stage model of picture naming, ranging from recognition through lexical decision to articulation, as derived from reaction time studies. The results on picture naming have been compared with data of verbal and non-verbal mouth and tongue movements, which emphasise the role of the left, but not of the right, dorsolateral prefrontal cortex in word production.

Our recent experiments have moved towards increasingly natural reading situations: the subjects are reading sentences, presented word by word, with either semantically congruent or non-congruent final words. Preliminary analysis has revealed definite word-content related activation around the left posterior Sylvian fissure, detected reliably in individual subjects. This finding holds great promise for further studies of language processing in healthy and diseased brains.

Brain abnormalities

A group of epileptic children were studied to identify the cortical sources of interictal epileptiform spikes from simultaneous whole-scalp MEG and EEG recordings. MEG and EEG spikes had similar timing and source locations in 30% of the data. In the remaining 70%, MEG appeared to peak slightly before EEG spikes which, however, were preceded by a small early deflection at the time of the MEG peak. It was concluded that fissural activity is better discerned with MEG than with EEG, and that the time lag represents fissural onset of epileptiform activity in two thirds of the spikes.
Children with acquired epileptic aphasia were studied to characterize the source areas and spread patterns of the epileptic activity. Preliminary results suggest that the posterior intrasylvian cortex is an important pacemaker in this disorder.

In addition, candidates for epilepsy surgery were studied to localize naming-related cortical areas, which were compared with other language lateralizing and localizing techniques. The results are currently being analyzed. MEG localization of epileptic spikes has been compared with localization of the epileptic focus by means of positron emission tomography (Turku) and intracranial electrode recordings (Kuopio). Whenever PET and MEG localizations agree, the intracranial recordings were in line. Therefore, combination of PET and MEG data may diminish the need of invasive techniques in preoperative localization of the epileptogenic cortex.

Studies of dyslexic subjects have been continued using both MEG and psychoacoustical methods. Our preliminary analyses of the semantic processing task, described above, have revealed both quantitative and qualitative differences between dyslexics and normal subjects in the cortical processing of sentences. In contrast to a recent fMRI study, we observed that the motion-sensitive visual cortex V5 was activated in dyslexic subjects as frequently as in healthy control subjects. The disagreeing results were suggested to be methodology-driven: MEG is most sensitive to synchronous neuronal activity, whereas fMRI signals reflect overall change in the mean firing level through associated metabolic changes. In an ongoing study of auditory perception in a pitch streaming task, dyslexic subjects perceived rapid tone sequences, in a clearly different manner than controls. As speech is also a rapid succession of sounds, these observations may clarify the relationship between elementary defects in the processing of rapid auditory information and difficulties in phonological processing, previously reported in dyslexic subjects.

A study has been started to correlate the brain's spontaneous activity with the Apo E genotype which is a predictor for the appearance of Alzheimer's disease. The aim is to find whether the brain's spontaneous rhythms display some changes already in premorbid subjects. In an ongoing study, the effects of circumscribed cortical lesions on activation of the somatosensory neural network have been studied in stroke patients. Another project has been started to investigate the possible changes in brain function after prolonged peripheral vibration stimuli in patients suffering from occupational vibration syndrome. Monkey studies predict that such a long-term stimulation would cause changes in the sizes of the receptive fields of the somatosensory cortical neurons.

Face recognition has been investigated both in normal subjects and in autistic patients brought to the LTH, Child Psychiatry Unit, London. Preliminary results suggest profound differences between controls and autistics.

Spontaneous brain activity has been recorded from patients undergoing electroconvulsive therapy (ECT) for treatment of major depressive disorders. The data suggest that clinical improvement is often accompanied by massive ECT-related increase of rhythmic activity below about 7 Hz, which disappears within 1 month after the last ECT treatment. We have quantified the spectral changes in different cortical areas and localized generators of the anomalous rhythmic activity to characterize and understand the cortical processes related to ECT.
Hippocampal and other deep brain activity

J. Karhu (KuY), C. Tesche

Many MEG studies report on the detection and characterization of activity in relatively well-localized regions of fissural cortex. Our research has focused on the development and application of tools for the characterization of activity in other brain areas: hippocampus, thalamus, and cerebellum. Sources in deep areas, such as the thalamus, are difficult to detect by MEG using standard analysis methods. The pattern of magnetic activity observed at the scalp appears as a widespread distribution of signals in the MEG array, rather than a localized response. Moreover, the signal in any one channel may be very small compared to the intrinsic noise of the MEG device. Therefore, the signal may be very difficult to divine the presence of these sources using conventional methods. However, magnetic field patterns may be computed for a specific current distribution in any brain area, provided that reasonably accurate model for the conducting volume of the brain is utilized. Source locations are determined from anatomical or functional imaging information. The MEG data is utilized to determine spectral and temporal characteristics.

The thalamus plays an essential role in sensation and motor control. Most sensory pathways project to cortex through well-defined relay nuclei in lateral thalamus. We have identified for the first time early biphasic MEG thalamic responses to median nerve stimulation at the wrist. The responses begin at about 15 – 17 ms, followed by the arrival of information at the cortex at about 16 – 19 ms. Significant clinical applications of this method may arise in the assessment of thalamic function in movement disorders, stroke, and central pain.

The hippocampus participates in a multitude of cognitive tasks, and is essential for the encoding of new memories. Oscillatory electric field potentials at 4 – 12 Hz (theta) are a prominent feature of normal hippocampal function in rodents. However, there are only two reports of theta in human subjects, both obtained using depth electrodes prior to surgery. We have extracted for the first time waveforms and spectra for ongoing activity in normal human hippocampus. Spectral components below 12 Hz included task-dependent peaks superimposed on a broadband background of increasing amplitude at decreasing frequency. This observation initiates the investigation of the role of ongoing spontaneous activity in the function of normal human hippocampus.

The traditional role of cerebellum is a motor organ which adjusts and improves motor performance. However, our detection of early (13 – 19 ms) responses in human cerebellum to median nerve stimulation indicate a role for cerebellum in the processing of purely sensory data. This result, combined with the observation of cerebellar activation associated with visually-guided saccades, performed simultaneously by another group in the LTL, initiate the study of human cerebellum with non-invasive neurophysiological methods.

Methodological development


Other methodological studies include simulations of source localization accuracy in a realistic head model. Moreover, analysis has been developed for several simultaneous sources: global optimi-
ization methods have been applied to estimate the parameters of multipole models, and the characteristics of distributed current source models have been examined.

The measurement noise has been analyzed, including correlations across channels. The Bayesian inverse theory has been utilized to compute realistic confidence limits for dipole locations under various conditions.

Versatile, semi-automated tools for MRI segmentation and advanced visualization have been developed. The new segmentation tools greatly facilitate the use of MRI data in forward and inverse modelling as well as in visualization of MEG results.

Several time-frequency analysis methods have been evaluated using simulated and true MEG data. On the basis of these results, a sequence of useful procedures have been implemented to the MEG software. These methods can be used, e.g., in determining short-time changes of rhythmic brain activity.

Methods for bicoherence analysis of MEG signals were developed. One aim is to separate the Rolandic mu rhythm into locked and independent components and to identify their cortical generator areas.

HARDWARE AND SOFTWARE DEVELOPMENT FOR BRAIN RESEARCH (NEUROMAG PROJECT)

M. Häätiala, M. Kajola (Neuromag), L. Parkkonen (Neuromag)

The project aims at a data acquisition and analysis system which can be used with the new 306-channel neuromagnetometer to be installed in the LTL during 1997. The work consists of the following parts: (1) Development of a compact data acquisition system with an embedded controlling workstation. (2) Improvement of the on-line data processing. (3) Optimization of data storage and the definition and realization of a measurement database. (4) Application of digital signal processing methods to neuromagnetic data. (5) Refinement of conductor and source modelling on the basis of anatomical information provided by magnetic resonance images. (6) Extension of the software to include EEG data in the analysis.

Our data-acquisition system utilizes a Hewlett-Packard 743rL real-time embedded controller in a VME instrument rack. The digitization of the signals is taken care of by proprietary analog-to-digital converters provided by a subcontractor. The signals are initially sampled at a high rate. Subsequently, digital low-pass filtering is applied and the signals are downsampled according to the needs of the particular experiment. The increased processing demands are met by using several VME controllers in parallel, by applying data compression, and by extending the bandwidth of the local-area network connecting the real time system to the UNIX workstations taking care of the control of the measurements and the storage of data.

We have developed our off-line analysis software to meet the challenges of the 306-channel whole-cortex measurements. The configuration of the magnetometer can now include a combination of planar gradiometers, axial gradiometers, and simple magnetometers. A project aiming at a seamless inclusion of the EEG data has been started. As an initial step, effective code for the EEG forward model and electric potential mapping has been developed.
TEACHING

While the LTL is, in the first place, a research organisation, some teaching has always been carried out by our scientific staff. This has included supervision of special assignments, M.Sc.Tech., Licenciate, and Ph.D. theses and lecturing. Some of our graduate students have also been teaching assistants on related laboratory courses.

COURSES AND OTHER TEACHING ACTIVITIES

Doc. Erkki Thuneberg gave a special course in Microscopic theory of superconductivity (Matialien lämpötilojen erikoiskurssi, Tfy-3.252, 3 ov.). Mr. Juha Kopu acted as his teaching assistant.

Prof. Mikko Paalanen was a co-organizer of the licentiate seminar "Nanophysics seminars I" with the Department of Physics.

Prof. Riitta Hari and Doc. Riitta Salmelin gave a lecture series on Human cortical functions – Signal processing in the human brain (Kyl-0.001, 3 ov).

Mr. Kimmo Uutela and Mr. Antti Turkuainen acted as teaching assistants for bioelectronic measurements, a laboratory experiment belonging to the practical training program in the Department of Technical Physics and Mathematics (Tfy-99.219).

ACADEMIC DEGREES

Lauri Parkkonen graduated as M.Sc.Tech. from the Department of Information Technology on June 3. His diploma thesis Control and data acquisition system for a neuromagnetometer (Neuromagnetometrin ohjaus- ja tiedonkeruujärjestelmä) was done in the LTL.

Juha Kopu graduated as M.Sc.Tech. from the Department of Engineering Physics and Mathematics on Dec 3. His diploma thesis Calculation of critical velocity in superfluid $^3$He-A (Kriittisen virtausnopeuden laskeminen supraneste $^3$He-A:ssa) was done in the LTL.

PH.D. THESIS

Ms. Sari Levänen defended her Ph.D. thesis Sensory memory traces in the human auditory cortex: Neuromagnetic studies on Nov 30 at the University of Helsinki. The opponent was Prof. Kenneth Hugdahl from University of Bergen. The work, carried out in the LTL, was guided by prof. Mikko Sams and supervised by prof. Riitta Hari.

Mr. Jussi Ruutu defended his Ph.D. thesis Optical interferometry on interfaces in quantum fluids and solids on Sep 20. The opponent was Acad. Alexander Andreev from the Kapitza Institute for Physical Problems. The work, carried out in the LTL, was guided by Doc. Perri Hakonen and supervised by Prof. Mikko Paalanen.

Mr. Ville Ruutu defended his Ph.D. thesis NMR experiments on topological defects in $^3$He superfluid on Sep 21. The opponent was Prof. John Hoke from Manchester University. The work, carried out in the LTL, was guided by Prof. Matti Krusius and supervised by Prof. Mikko Paalanen.
SUPERVISION OF SPECIAL PROJECTS

Doc. Erkki Thuneberg supervised Juha Kopu’s special project *Simulation of random field* (Samaanaiskenttämälliin simulointi).

Doc. Matti Hämäläinen supervised Leif Roschier’s special project *Optimized transformation between magnetic-resonance imaging coordinates and head coordinates* (Optimoitu koordinaatti-tilojen magnetoresonanssi-koordinatiotoiminnot magneettiresonanssi-koordinaatteihin).

Doc. Riitta Salminen supervised Riikka Miettinen’s special project *Blink-related response in the posterior parietal cortex to a changing picture stimulus* (Silmänraajapyyksiin liittyvä päälähenkön takasuun arvokorivaste muuttuvalle kuvaesityksele).

Doc. Riitta Salminen supervised Antti Tarkkainen’s special project *A program for calculating a bispectrum estimate* (Tietokoneohjelma bispekktistiimatin laskemiseksi).

Doc. Riitta Salminen supervised Lotta Lehteli’s special project *Temporal spectral evolution method: Spontaneous rhythm of the auditory cortex* (Kansioavukaaren spontaanirytmän MEG-mittaus analyysointi TSE-menetelmällä).

Doc. Pertti Hakonen supervised Jarkko Salojärvi’s special project *Different methods to improve the resolution of a 2-beam-interferometer* (Erin menetelmät interferometrin erotuskyvyn parantamiseksi).

TECHNICAL SERVICES

THE WORKSHOP

Distribution of the workload by the various groups of the laboratory is presented in the following graph.
The use of liquid helium in 1996 by the various groups is shown by the graph above. The total amount of liquid helium delivered was 58000 liters.

Nitrogen

The total production of liquid nitrogen in 1996, by the new machine Linit 25, was 35200 liters from the start-up in February.
NEW INSTRUMENTS AND OTHER INVESTMENTS

The largest single purchase in 1996 was the nitrogen liquefier LINIT 25 from Linde Cryogenics of Aldershot, U.K. This machine produces on the average 22 liters of liquid nitrogen per hour (see the graph of user distribution on previous page). Four new high pressure tanks for helium gas, with a volume of 1.5 m³ each was purchased from Vihäsilta Oy. Compared to our previous storage capacity, this doubles the maximum volume of stored gas to the equivalent of 3000 liters of liquid helium.

The new nanophysics research group needed several significant investments: Among the most important ones are an atomic force microscope AFM for nanolithography from Park Scientific, with structured dimensions between 100 and 20 nm, and a vacuum deposition facility for metallic films.

For the construction of cryogenic equipment two new leak detectors were purchased. The larger one, an Alcatel ASM 81T2, is equipped with two turbopumps for rapid evacuation of large volumes. The smaller device, Alcatel ASM 120H, is easily portable to more difficult locations. In addition, a turbopumped vacuum station was bought from Vacuum-service Ltd.

Computing capacity was significantly increased. The largest single item was an HP Visualize C460 workstation. Several new Macintoshes and PC’s were bought, among them two Power Tower Pros and two Power Centers (Apple licensed machines manufactured by Power Computing Co in the US).
OTHER ACTIVITIES

MINISYMPOSIUM ON LIQUID/SOLID INTERFACES IN HELIUM

Otaniemi, Jan 5 – 7, Chairman Pertti Hakonen, number of participants 33 (16 from abroad)
Sponsored by the EUROPEAN SCIENCE FOUNDATION

The purpose of this meeting was to gather experimentalists and theorists working on helium crystals. The LTL was a very proper place for the symposium because most of the recent findings on static and dynamic properties of $^4$He crystals have been obtained in Otaniemi. Our results had aroused interest among theorists prior to the meeting, which led to an exceptionally lively and useful workshop.

The interface between liquid and solid phases of helium provides a unique object to investigate physics in a situation where thermal processes do not disturb the kinetic behavior of elementary surface excitations. Highly mobile kinks and steps have provided the standard framework for theoretical explanations of interfacial phenomena in this system. Typically, such descriptions have been very successful in explaining experimental results, e.g., melting/freezing waves of $^4$He. However, recent work in Otaniemi on equilibrium crystal shapes and on facet growth have given indications of subtle deficiencies in the standard theoretical treatment.

Reconciliation of theory and experiments was discussed and debated lively at the symposium. Several possible explanations for the observed equilibrium shapes with curved facets were proposed but no final conclusions could be made yet. Likewise, no definite explanations could be given for observations of facet growth without dislocations at ultra low temperatures. New aspects of spiral growth were suggested in the case of screw-dislocation-mediated growth: kink localization at large driving forces may result in saturation and even in reductions of the facet velocity. It is clear that theoretical work on these problems will go on actively in the near future.

New results on equilibrium shapes of $^3$He crystals below 1 mK were presented by the Leiden group. These experiments are under fast development at present and important results are expected in the near future. Theorists are interested in mobility data in strong magnetic fields because the magnetic degrees of freedom in $^3$He will enhance the complexity of interfacial behavior, but pertinent predictions are not available at the moment. The resemblance between the A/B-interface of superfluid $^3$He and the liquid/solid interface was discussed in detail at the symposium. It was concluded that the theory developed for the A/B-interface provides a good starting point for the work on the superfluid/solid interface in $^3$He. New experimental techniques, when trying to extend experiments of quantum crystals to lower temperatures, were discussed. These problems are very important if melting/freezing waves are to be found on the superfluid/solid interface in $^3$He.

Recent Monte-Carlo simulations on helium crystals were discussed as well. Prof. Reatto’s results were impressive and gave hope for the possibility that, in the end, processes at the liquid solid interface can be understood using first-principles calculations.

One important aspect of the workshop was education of graduate students. This had been mentioned in advance to the speakers who presented carefully prepared introductions to their topics. Moreover, one of the talks (by Roger Bowley) was completely dedicated to an introduction of theoretical concepts. The workshop served its educational purpose very well.
VISIT OF A FRENCH DELEGATION

On Sep 24, a delegation consisting of ten distinguished representatives of French cultural, economic, and industrial organizations visited the LTL under the auspices of the Franco-Finnish Association for Science and Technology. The delegation was led by Mr. Gösta Diehl, President of the Finnish side of the association, Mrs. Nora Kalso, secretary, and Mr. Lazare Paupert, cultural attache at the French embassy.

THE NOBEL PRIZE WINNERS VISIT TO THE LTL

A NOBEL-SYMPOSIUM in physics for the general public was arranged on Dec 16 at the House of Estates (Skäitytalo), where welcoming remarks were presented by Mikko Paalanen and the rector of HUT, Prof. Paavo Uronen. Olli Lounasmaa gave a presentation on $^3$He research in the LTL, directly related to the Nobelists' work, and the Nobel laureates then gave their own $^3$He lectures:

- David Lee: The extraordinary phases of superfluid $^3$He,
- Douglas Osheroff: Superfluidity in $^3$He: discovery and understanding,
- Robert Richardson: The Pomeranchuck effect.
The symposium drew much attention in the press and the occasion was attended to the full capacity of the auditorium.

Contributions by the following sponsors are gratefully acknowledged: Suomalainen Tiedekomitea, Suomen Tiedekomitean Valtuuskunta, and Suomen Tiedeseura.

AWARDS

Olli Louhasmaa received the Mendelsohn Award and Gold Medal, presented at the International Cryogenic Engineering Conference on May 22 in Kitakyushu, Japan.

PUBLIC RELATIONS AND GENERAL INFORMATION

NEW BROCHURE

A new brochure giving an introduction to the activities of the LTL in a short and semi-popular way was published in August 1996, in collaboration with the agency Yksikkö-yhtiö. The brochure is a continuation of our effort to produce a summary of activities in the LTL every third year on a general level. Peter Berglund was the co-ordinator of the project.

LTL ON THE INTERNET

The LTL WWW home page, http://boojum.bat.fi/ has been accessible since the end of 1994.

The purpose of the WWW-pages is to give up-to-date information on the research and other activities in the LTL. Peter Berglund has been the co-ordinator of the contributions from the research groups.

ACTIVITIES OF PERSONNEL

PERSONNEL WORKING ABROAD

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution and Dates</th>
</tr>
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<tbody>
<tr>
<td>Berglund</td>
<td>CERN, Geneva, Feb 25 – Mar 3, May 8 – 13, and Jun 12 – 26</td>
</tr>
<tr>
<td>Hakonen</td>
<td>CEA, Saclay, Sep 1 – Dec 31</td>
</tr>
<tr>
<td>Hämmäinen</td>
<td>Ruprecht-Karls-Universität, Heidelberg, May 5 – 12, Sep 2 – 8, and Nov 4 – 29</td>
</tr>
<tr>
<td>Louhasmaa</td>
<td>Hahn-Meitner Institut, Berlin, Mar 7 – Nov 2</td>
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<tr>
<td>Salmelin</td>
<td>Heinrich-Heine University, Düsseldorf, Aug 25 – Sep 24</td>
</tr>
<tr>
<td>Tesche</td>
<td>University of Salzburg, Salzburg, Oct 4 – 30, Nov 5 – 16, and Nov 25 – Dec 13; Los Alamos Scientific Laboratory, NM, Jul 29 – Aug 8 and Aug 26 – Sep 4</td>
</tr>
<tr>
<td>Vuorinen</td>
<td>Hahn-Meitner Institut, Berlin, Jan 1 – Aug 31, Oct 23 – Nov 9, and Nov 19 – Dec 14</td>
</tr>
<tr>
<td>Ylöstalo</td>
<td>CERN, Geneva, Jan 1 – Dec 31</td>
</tr>
</tbody>
</table>
EXPERTISE AND REFEREE ASSIGNMENTS

Bergland  member, International Cryogenics Engineering Committee, ICEC
          member, Finnish Academy of Technical Sciences
          member, SMC executive committee (CERN NA47), CERN, Switzerland
          advisory editor, Cryogenics, Butterworth Heinemann, UK
          member, Institute of Particle Physics Technology, HUT, Jan 1 – Mar 30
          chairman, organizing committee of “30th Annual meeting of Finnish Phys. Soc.”
          fellow, American Physical Society
          referee, European Physical Society
          referee, Journal of Low Temperature Physics
          referee, Physical Review Letters
          referee for the US National Science Foundation
          leader of neumagnetic research in EU Large-Scale Facility BIRCH, Helsinki
          member, Finnish Academy of Sciences and Letters
          member, Academia Europaea
          chairperson, Finnish Brain Research Society
          founding member, European Dana Alliance for the Brain
          member, Advisory Board: 10th International Conference on Biomagnetism, Albuquerque, NM, 1996
          member, Advisory Board of the Biomag Installation in Helsinki University Central Hospital
          member, Advisory Panel (Human Cognition) of the James S. McDonnel Foundation Centennial Fellow Awards Program
          member, Editorial Board of Brain Topography
          member, Editorial Board of Electroencephalography and Clinical Neurophysiology
          member, Editorial Board of Human Brain Mapping
          member, Editorial Board of Psychiatry Research (Neuroimaging)
          member, Scientific Advisory Board, 3rd International Conference on Functional Mapping of the Human Brain, Copenhagen, May 1997
          member, Scientific Advisory Board, Human Brain Mapping Conference, Boston, Jun 1996
          member, Scientific Advisory Board of the National PET Center, Turku
          member, Scientific Advisory Board, XX European Conference on Visual Perception, Helsinki, Aug 1997
          member, Scientific Committee, 3rd International Hans Berger Congress, Jena, Oct 1996
          organizer, Brain Imaging Symposium in association with the XX European Conference on Visual Perception, Helsinki, 1997
          organizer (with Prof. Marcus Raichle), Symposium on ‘Non-Invasive Study of Higher Brain Functions’ in the 33rd International Congress of Physiological Sciences, St. Petersburg, Jun 30 – Jul 5, 1997
          organizer and chair, Workshop on Magnetoencephalography, 8th European Congress of Clinical Neurophysiology, Munich, Oct 9 – 11, 1996
          referee, Brain
          referee, Brain Research
referee, Electroencephalography and Clinical Neurophysiology
referee, Experimental Brain Research
referee, Journal of Clinical Neurophysiology
referee, Journal of Neurophysiology
referee, Neuroimage
referee, The European Journal of Neuroscience
referee, The Journal of the Acoustical Society of America
referee, Trends in Cognitive Sciences
referee, Vision Research
reviewer, Docentship, University of Tampere
reviewer, Neuroscience Research
reviewer, Thesis, University of Tampere

Krusius

chairman of Commission C5 on Low Temperature Physics, International Union of Pure and Applied Physics (IUPAP) from Sep 1996
chairman of Program Committee, LT 22, Otaru, Aug 5 – 11, 1999
leader of low temperature research in EU Large-Scale Facility ULTI, Helsinki
member, Finnish Academy of Sciences and Letters
fellow, American Physical Society
member, European Physical Society
member, Finnish Physical Society
advisory editor, Physica B: Condensed Matter
chairman and discussion leader of session on "Liquid $^3$He: Collective Modes and Vortices", Ultralow Temperature Conference, Stará Lesná, Slovakia, Aug 14 – 17, 1996
chairman of session on "Excitations and Phase Transitions in $^3$He", XXI International Conference on Low Temperature Physics, Prague, Aug 9, 1996
member, International Advisory Board, Symposium on Quantum Fluids and Solids, Paris, July 1996
member, International Committee, XXI International Conference of Low Temperature Physics, Prague, Aug 8 – 14, 1996
member, Low Temperature Section, Condensed Matter Division, European Physical Society
panelist, 1996 Nobel Prize Panel Discussion, Royal Institute of Technology, Stockholm, Dec 12, 1996
referee, Journal of Low Temperature Physics
coordinator, EU Large-Scale Facilities BIRCH (neuro- and cardiomagnetism) and ULTI (ultralow temperature physics)
evaluator appointed by the Ministry of Education to prepare a memorandum on education and research in mathematics, physics, chemistry, and computer sciences. Report published on Jan 30, 1996
member, Finnish Academy of Sciences and Letters
member, Finnish Academy of Technical Sciences
member, Royal Swedish Academy of Sciences
member, Societas Scientiarum Fennica
member, Academia Europaea

Lounasmaa
honorary member, Finnish Physical Society
fellow, American Physical Society,
honorary fellow, Indian Cryogenics Council
member, European Physical Society
member, Center for Ultra-Low Temperature Research, University of Florida
member, Comité International des Poids et Mesures, Paris
member, Commission A1/2, International Institute of Refrigeration
member, Editorial Board of Europhysics Letters
member, Editorial Board of Journal of Low Temperature Physics
member, Organizing Committee, LT22, Otaniemi, Aug 5 – 11, 1999
chairman, LT 22, Otaniemi, Aug 5 – 11, 1999
chairman, Finnish Physical Society
member, Finnish Academy of Sciences and Letters
fellow, American Physical Society
chairman, Coordination Group of Swedish Graduate School in Nanoscience and Quantum Devices
member, Board of the Swedish Joint Strategic Program in High Speed Electronics, Photonics, Nanoscience, and Quantum Devices
member, Editorial Board of Journal of Low Temperature Physics
referee, appointment of professor, Brown University
referee, appointment of professor, Lund University
referee, appointment of professor, Rice University
referee, appointment of professor, University of Jyväskylä
referee, appointment of research professor, University of Grenoble
referee, EU science programs
referee, National Science Foundation, USA
referee, Physical Review and Physical Review Letters
referee, Epilepsia
referee, Ph.D. Thesis, University of Helsinki
referee, Perception & Psychophysics
referee, Vision Research
referee, Electrocencephalography and Clinical Neurophysiology
referee, European Journal of Neuroscience
referee, Experimental Brain Research
referee, Human Brain Mapping
referee, Neuroimage
referee, Physical Review B
referee, Physical Review Letters
referee for the Academy of Finland
editor, JETP Letters, Russia
opponent for Etienne Janod, Université Joseph Fourier - Grenoble I, Nov 29
referee, appointment of Alexander von Humboldt fellowship, Germany
referee, appointment of assistant professor in physics, Amherst College, USA
Babkin
poster presentation Observation of a new surface state on $^4$He crystal interfaces at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

talk Future optical experiments in $^3$He solid at Ultralow Temperature Conference, Stará Lesná, Slovakia, Aug 14 – 17

session chairman at Workshop on Liquid/Solid Interfaces in Helium, Otaniemi, Finland, Jan 4 – 6

invited talk Observation of new surface state on the crystal of superfluid interface at Workshop on Liquid/Solid Interfaces in Helium, Otaniemi, Finland, Jan 4 – 6

invited talk Magnetoencephalography at International Symposium on Epilepsy Surgery, Madrid, Jun 6 – 7


oral presentation Activation of human mesial cortex during somatosensory target detection task at Society for Neuroscience, 26th Annual Meeting, Washington DC, Nov 16 – 21

Forss

oral presentation Activation of human mesial cortex during somatosensory target detection task at Society for Neuroscience, 26th Annual Meeting, Washington DC, Nov 16 – 21

organizer of meeting of ESF Network on Quantum Fluids and Solids: Liquid/Solid Interfaces in Helium, Otaniemi, Jan 5 – 7; invited talk Facet growth of $^4$He crystals at mK-temperatures

Hakonen

participation at 30th Annual Meeting of the Finnish Physical Society, Espoo, Mar 21 – 23

lecture Interferometric studies of interfaces at ultra low temperatures at Physikalisches Kolloquium, Bayreuth, Germany, Jun 4

Hari

poster presentation Spiral growth of c-facets in $^4$He crystals at mK-temperatures at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

invited talk Interferometric studies of interfaces at millikelvin temperatures at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

colloquium talk Interferometric studies of interfaces in quantum fluids and solids during visit to ENS, Paris, Nov 13

colloquium talk Interferometric studies of interfaces in quantum fluids and solids during visit to S. P. E. C., Gif-sur-Yvette, France, Nov 13

seminar talk Neuromagnetic evaluation of human somatosensory function at Wednesday meeting of the Department of Neurology, Heinrich-Heine University, Düsseldorf, Germany, Jan 31
seminar talk *Neuromagnetic studies of human cortical functions* at Wednesday meeting of the Department of Neurophysiology, Heinrich-Heine University, Düsseldorf, Germany, Jan 31
visit to several laboratories in Heinrich-Heine University, Germany, Jan 31 – Feb 1
session chair and member of scientific organizing committee of BIOMAG '96, 10th International Conference on Biomagnetism, Santa Fe, New Mexico, Feb 16 – 21
invited lecture *Tracking dynamics of human cortical functions by magnetoencephalography (MEG)* at Kongress der Neurowissenschaftlichen Gesellschaft, Berlin, Feb 24 – 25
invited talk *Dyslexia – processing of rapid auditory information* at Biosynthesi II: Biologia ja kiel, Helsinki, Mar 4 – 5
invited talk *Neuromagnetic evaluation of human somatomotor function* at International Symposium of Brain Imaging Techniques, Madrid, Mar 11 – 13
colloquium talk *Activation of human mesial cortex during somatosensory attention task* at Kyoto University, Japan, Apr 3
invited plenary talk *Neuromagnetic approach to human auditory cortical functions, with emphasis on subjects with cochlear implants* at The First Asia Pacific Symposium on Cochlear Implant and Related Sciences, Kyoto, Apr 3 – 5
participation at The Opening Symposium of The Wellcome Department of Cognitive Neurology, Institute of Neurology, London, Apr 22 – 23
invited talk *A neuroscientist's view to the nonuniqueness of the neuromagnetic inverse problem* at MEG/EEG workshop in association with the 2nd International Conference on Functional Mapping of the Human Brain, Boston, Jun 17
oral presentation *Time-varying activation of the human SI foot area* at 2nd International Conference on Functional Mapping of the Human Brain, Boston, Jun 17 – 21
invited plenary talk *Human cortical reactivity revealed by neuromagnetic recordings* at Uehara Memorial Symposium "From Molecular to Integrative Brain Functions", Tokyo, Jun 24 – 26
session chairman at Uehara Memorial Symposium "From Molecular to Integrative Brain Functions", Tokyo, Jun 24 – 26
participation at 8th World Congress of International Organization of Psychophysiology, Tampere, Finland, Jun 25 – 30
invited plenary talk *Neuromagnetic characterization of human brain functions* at 8th World Congress of Psychophysiology, Tampere, Finland, Jun 28 – 29
invited plenary talk *Temporal aspects of human auditory cortical processing* at International Symposium 'Acoustical Signal Processing in the Central Auditory System', Prague, Sep 4 – 7
session chair at International Symposium 'Acoustical Signal Processing in the Central Auditory System', Prague, Sep 4 – 7
invited comment *Neuromagnetic characterization of human cortical functions* at Finnish-Japanese Science & Technology seminar, Espoo, Sep 23
invited talk *Neuromagnetic approach to reorganization of human auditory cortical functions* at 2nd European Neuroscience Conference, Strasbourg, France, Sep 25 – 28
invited plenary talk *Somatomotor MEG rhythms* at Third International Hans Berger Congress 'Quantitative and Topological EEG and MEG Analysis', Jena, Germany, Oct 3 – 6
session chairman at Third International Hans Berger Congress 'Quantitative and Topological EEG and MEG Analysis', Jena, Germany, Oct 3 – 6
organizer & chair of a Workshop on Magnetoencephalography at 8th European Congress of Clinical Neurophysiology, Munich, Oct 9 – 11

invited talk How magnetoencephalography can be used in association with psychoacoustical research at Symposium on Psychoacoustics ad Schizophrenics, Lund, Sweden, Oct 11 – 13

invited talk MSI in cognitive neuroscience at Magnetic Source Imaging (MSI): Clinical Applications Opening Workshop of the Neuromag-125TM Whole-Head -MEG System at the University of Heidelberg, Germany, Oct 25

invited talk Neuramagnetic characterization of human cortical functions at Siltavuori Seminars & Lectures, Helsinki, Nov 6

oral presentation Right-hemisphere preponderance of responses to painful CO2 stimulation of nasal mucosa at Society for Neuroscience, 26th Annual Meeting, Washington DC, Nov 16 – 21

Hämäläinen

member of discussion panel Workshop on the Biomagnetism Inverse Problem at BIOMAG '96, 10th International Conference on Biomagnetism, Santa Fe, New Mexico, Feb 16 – 21


Jousmäki

participation at Biologia ja kieli, Biosynteesi II, Helsinki, Mar 4

participation at measurement session, Heinrich-Heine Universität, Düsseldorf, Germany, Jun 9 – 12

participation at 8th World Congress of International Organization of Psychophysiology, Tampere, Finland, Jun 25 – 30

participation at 8th Annual Meeting of the Finnish Society of Clinical Neurophysiology, Kuopio, Finland, Sep 19 – 21

poster presentation Nonlinear detection of human cerebellar actions associated with visually-guided saccades at Society for Neuroscience, 26th Annual Meeting, Washington DC, Nov 16 – 21

Kajola

consultation at Institute of Medicine, Research Centre Jülich, Germany, Aug 10

Karhu

poster presentation Characterization of photosensitive discharge by oscillatory response to driving stimulus at BIOMAG '96, 10th International Conference on Biomagnetism, Santa Fe, New Mexico, Feb 16 – 21

Kiesila

oral presentation Lukihäiririisten papu-illuusio at Helsinki Graduate School of Neurobiology, Helsinki, Feb 8

invited talk Lukihäiririisten aikaisten takimus TKK:n kylmälaboratorioissa at Helsingin erialaisten oppilaiden jäsentilaisuus, Teknillisen fysiikan laitos / TKK, Helsinki, May 6

poster presentation Prolonged perception of sound movement illusory in dyslexic adults at 8th World Congress of International Organization of Psychophysiology, Tampere, Finland, Jun 25 – 30

invited talk Lukihäiririitä ja MEG at Lastenneurologian klinikan jakto- ja täydenyksikoulutusohjelma, Helsinki, Sep 12

invited talk Sanjojen kaulut sympyttävät aivokuoriaktivatoio lukivaieksisillä henkilöillä at Opetusviraston lukoiden luki-projektin luki-iltapäivity, AV-keskus, Helsinki, Oct 15

invited talk Lukivaieksisien aikaisten takimus TKK:n kylmälaboratorioissa at Aivor- ja illusio – mitä lakiokilpailun aivoissa, Tiedekeskus Heureka, Helsinki, Oct 26 – 27

invited talk Sanjojen kaulut herättävät aivokuoriaktivatoio lukivaieksiillä aikaimized at Helsingin IV terveydenhuolto-oppilaitos, Nov 20
participation at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

Kivi poster presentation DC SQUID preamplifier for low temperature NMR at 30th Annual Meeting of the Finnish Physical Society, Espoo, Mar 21 – 23

posterm presentation DC SQUID amplifier for low temperature NMR at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

posterm presentation Vortex arrays of coexisting singly and doubly quantized vortex lines in $^3$He-A at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

Kondo poster presentation Optimization of high-Q low frequency NMR measurements at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

Kopu poster presentation Calculations on vortex formation in $^3$He-A at 30th Annual Meeting of the Finnish Physical Society, Espoo, Mar 21 – 23

Krasius invited talk Nucleation of quantized vortices in superfluid $^3$He and $^4$He at 15th General Conference of the Condensed Matter Division of the European Physical Society, Baveno-Stresa, Italy, Apr 22 – 25
talk Big Bang simulation in superfluid $^3$He-B: Neutron-adsorption-mediated vortex nucleation at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

Ko included talk Nucleation and annihilation of vortices in rotating superfluid $^3$He at Ultra Low Temperature Conference, Stará Lesná, Slovakia, Aug 8 – 14

Kol included talk Experimental summary: Topological defects in a rapidly quenched normal-to-superfluid transition in liquid $^3$He at Workshop on Topological Defects in Cosmology and Condensed Matter Systems, Grenoble, Sep 14 – 18

colloquium talk Discovery of superfluid $^3$He - Nobel Prize in 1996 at Physics Department, University of Turku, Finland, Oct 21
colloquium talk Superfluid transition and the Big Bang - Topological defect formation in rapidly quenched phase transition at Physics Department, University of Turku, Finland, Oct 21
colloquium talk Discovery of superfluid $^3$He - Nobel Prize in 1996 at Physics Department, University of Helsinki, Nov 11
colloquium talk Superfluid transition and the Big Bang - Topological defect formation in rapidly quenched phase transition at Physics Department, University of Helsinki, Nov 11

invited talk Nucleation of quantized vortices at the superfluid transition: A model of cosmological large scale structure formation at Low Temperature Physics Symposium, Gothenburg, Sweden, Dec 5 – 6

Lefman participation at Nobel-ceremonies, Stockholm, Dec 11

poster presentation Improving the "electronic purity" of rhodium samples by heat treatment at 30th Annual Meeting of the Finnish Physical Society, Espoo, Mar 21 – 23

poster presentation Neutron thermometry of highly polarized silver nuclei at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

poster presentation Evidence for reactive magnetic 10-Hz rhythm in the human auditory cortex at 8th World Congress of the International Organization of Psychophysiology, Tampere, Finland, Jun 25 – 30

poster presentation Neutron Thermometry of Highly Polarized Silver Nuclei at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

Lehtela poster presentation Evidence for reactive magnetic 10-Hz rhythm in the human auditory cortex at 8th World Congress of the International Organization of Psychophysiology, Tampere, Finland, Jun 25 – 30

Levenen participation at 8th World Congress of International Organization of Psychophysiology, Tampere, Finland, Jun 25 – 30
poster presentation View of pantomimic hand movements activates human visual motion area at 2nd International Conference on Functional Mapping of the Human Brain, Boston, Jun 27

Lounasmaa

participation at XXIV Symposium for Humboldt Research Awardees, Bamberg, Germany, Mar 21 - 24

oral presentation as Guest of the Ruben Stiller Radio Show on Research at Finnish universities, Helsinki, Apr 9

plenary talk Medical applications of SQUIDs in neuro- and cardiomagnetism at EPS Condensed Matter Division Meeting, Baveno-Stresa, Italy, Apr 22 - 24

plenary talk 122-channel SQUID magnetometer for studies of information processing in the human brain at ICEC16/ICMC Conference, Kitakyushu, Japan, May 20 - 24

participation at EU Round Table Meeting on Large-Scale Facilities for Life Sciences, Florence, Italy, Jun 5 - 6

presentation Huippukesikköä ei perusteta vaan se syntyy at Ministry of Education Seminar, Helsinki, Jun 17

participation and chairman of plenary session at XXI International Conference on Low Temperature Physics, Prague, Aug 8 - 14

participation and invited plenary talk Nuclear magnetic ordering in metals at Symposium on Magnetism in Metals, Copenhagen, Aug 25 - 29

colloquium talk Information processing in the human brain: Neuromagnetic approach at NORDITA, Copenhagen, Aug 30

participation at Meeting of Comité International des Poids et Mesures, Paris, Sep 24 - 26

chairman of EU Round Table Meeting on Large-Scale Facilities in High Magnetic Fields, NMR, Low Temperatures, and High Pressures, Otaheim, Finland, Sep 27

colloquium talk Magnetoencephalography: Technique and some results on studies of information processing in the human brain at Berliner Tiefenraum-Kolloquium, Berlin, Oct 15

visit to CERN, Geneva, Oct 29

colloquium talk Nuclear magnetic ordering in copper and silver at positive and negative spin temperatures in the nano- and picokelvin ranges at University of Konstanz, Germany, Oct 29

plenary talk Magnetic ordering of nuclei in metals at ultralow temperatures at Low Temperature Physics Symposium, Chalmers University of Technology, Gothenburg, Dec 5 - 6

participation at Nobel-ceremonies, Stockholm, Dec 8 - 11

introductory talk 3He-tutkimusestä TKK:n kylälaboratoriossa at Nobel Symposium in Physics, Helsinki, Dec 16

Martikainen

participation at XXI International Conference on Low Temperature Physics, Prague, Aug 8 - 14

talk Plans for new experiments on 3He-4He solutions at Ultra Low Temperature Conference, Stará Lesná, Slovakia, Aug 14 - 17

Mikkelä

talk clinical applications of MEG at BIOMAG '96, 10th International Conference on Biomagnetism, Santa Fe, New Mexico, Feb 16 - 21

session chairman at BIOMAG '96, 10th International Conference on Biomagnetism, Santa Fe, New Mexico, Feb 16 - 21

invited talk Magnetoencephalography in neurological research at Joint Meeting Between the British Society for Clinical Neurophysiology and Section of Neurology of the American Academy of Medicine, London, Jun 27 - 28
Nurminen

- poster presentation *Neutron experiments on nuclear order in silver at pK temperatures* at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14
- invited talk *Neutron diffraction studies of nuclear order in silver at picokelvin temperatures* at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14
- participation at 8th World Congress of the International Organization of Psycho-physiology, Tampere, Finland, Jun 25 – 30
- participation at Opening Ceremonies of the Physics Building of University of Jyväskylä, Finland, Jan 31

Paisanen

- lecture *Nanotechnology and device applications* at NEC corporation, Fundamental Research Laboratory, Tsukuba; at Institute of Solid State Physics, Tokyo University; at Nippon Telephone and Telegraph Corporation (Atsugi-shi), Japan, Feb 15 – 19; and at Seminar Series of the Radio Laboratory, Helsinki University of Technology, Mar 6
- participation at Meeting of Nordic-Baltic Co-operation between National Physical Societies, Copenhagen, Mar 9
- board meeting Consultation to Write up a Joint Graduate School Plan for Swedish Nanoscience at Lund University, Sweden, Mar 12
- lecture International experience and career development at Seminar on Graduate Studies & Research Abroad, Otaniemi, Mar 19
- participation in TV show "Good Morning Finland", MTV3, Helsinki, Mar 22
- participation at Meeting on Evaluation of LTL and HMI: Planning of Future Collaboration, Hahn-Meitner Institute, Berlin, Apr 30 – May 2
- participation at Nobel-symposium on semiconductor heterostructures, Lund University, Sweden, Jun 5 – 6
- consultation to select a professor in solid state physics, Lund University, Sweden, Jun 10 – 11
- invited talk *Nanophysics and device applications* at 17th Nordic Semiconductor Meeting, Trondheim, Norway, Jun 17 – 20
- participation at Scientific Evaluation of EU-Network SETTRON (nanophysics), Brussels, Jul 11 – 12
- invited talk *Electron transport: three 10-array tunnel junctions* at International Conference on Electron Quantum Transport, Jaszkowce, Poland, Aug 2 – 6
- session chairman at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14
- chairman of Co-ordination Group of Nanoscience and Quantum Device Graduate School, Gothenburg, Sweden, Sep 2
- participation at 22nd General Assembly of IUPAP at Uppsala, Sweden, Sep 18 – 21
- invited plenary talk *Nanotechnology and Device Applications* at Annual Meeting of Norwegian Physical Society, Konslablikk, Sep 21 – 22
- invited comment *From Basic Research to Applications* at Finnish-Japanese Science & Technology Seminar, Espoo, Sep 23
- participation at the meeting of the Board of Joint Strategic Program in High Speed Electronics, Photonics, and Nanoscience at Gothenburg, Sweden, Oct 16
- participation in Nobel-ceremonies, Stockholm, Dec 11

Pottu

- oral presentation *Cortical sources of magnetic 3-Hz spike-waves in childhood absence epilepsy* at 22th International Congress of Epileptology, Den Haag, The Netherlands, Sep 1 – 5
Parkkonen: participation at BIOMAG '96, 10th International Conference on Biomagnetism, Santa Fe, New Mexico, Feb 16 – 21
visit to Albert Einstein College of Medicine, New York, Feb 23 – 26
consultation for the University of Heidelberg MEG Laboratory, Heidelberg, Germany, Jul 16 – 23
participation at Electronica 96, München, Nov 13 – 16

Parts: poster presentation Vortex arrays of coexisting singly and doubly quantized vortex lines in $^3$He-A at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14
participation in annual meeting of Electrochemical Society (section “Single Electron Nanoelectronics”) San Antonio, Texas, Oct 9 – 11

Penttilä: poster presentation Nucleation of helium-4 crystals at millikelvin temperatures at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

Placais: poster presentation Annihilation of vortex lines in rotating superfluid $^3$He at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

Portin: poster presentation Distinct reactivity of cortical evoked responses and rhythms to luminance and pattern stimuli at Society for Neuroscience, 26th Annual Meeting, Washington DC, Nov 16 – 21

Raij: poster presentation Human auditory cortex is activated by omissions of auditory stimuli at BIOMAG 96, 10th International Conference on Biomagnetism, Santa Fe, New Mexico, Feb 16 – 21
poster presentation Human auditory cortex is activated by omissions of auditory stimuli at 8th World Congress of the International Organization of Psychophysiology, Tampere, Finland, Jun 25 – 30

poster presentation Anomalous growth of c-facets in $^4$He crystals at mK-temperatures at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

Ruutu, V.: poster presentation Critical velocity of continuous vortex formation in rotating $^3$He-A at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14
poster presentation Annihilation of quantized vortex lines in rotating $^3$He-A at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14
poster presentation Nucleation of vortices in superfluid $^3$He-B at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

Salenius: member of discussion panel Oscillatory brain dynamics at BIOMAG '96, 10th International Conference on Biomagnetism, Santa Fe, New Mexico, Feb 16 – 21
participation at 8th World Congress of the International Organization of Psychophysiology, Tampere, Finland, Jun 25 – 30
oral presentation Motor cortex may drive the motoneuron pool during sustained contraction at Society for Neuroscience, 26th Annual Meeting, Washington DC, Nov 16 – 21

Salmelin: plenary talk Oscillatory brain dynamics at BIOMAG '96, 10th International Conference on Biomagnetism, Santa Fe, New Mexico, Feb 16 – 21
plenary talk MEG Studies of cognition at BIOMAG '96, 10th International Conference on Biomagnetism, Santa Fe, New Mexico, Feb 16 – 21
invited talk Dyslexia – cortical activation elicited by visually presented words at Biosynteesi II, Helsinki, Mar 4 – 5
poster presentation Cortical activation related to verbal and non-verbal mouth movements at Second International Conference on Functional Mapping of the Human Brain, Boston, Jun 17 – 21
oral presentation "Cortical correlates of impaired reading in dyslexia" at 8th World Congress of the International Organization of Psychophysiology, Tampere, Finland, Jun 25 – 30

invited talk "Magnetoencephalographic studies of rhythmic brain activity" at Heinrich-Heine University, Düsseldorf, Sep 18

invited talk "Reactivity of human spontaneous cortical rhythms" at 8th European Congress of Clinical Neurophysiology, München, Oct 9 – 11

poster presentation "Human brain rhythms and electroconvulsive therapy" at 26th Annual Meeting of the Society for Neuroscience, Washington D.C., Nov 16 – 21

invited talk "Magnetoencephalography in the study of human brain function" at McDonnell-Pew Cognitive Neuroscience Colloquium Series, Boston, Dec 5

invited talk "Neuromagnetic studies of language" at Neurolinguistic Friday Seminar, MIT, Boston, Dec 6

Saramäki
poster presentation "Evidence of a new surface state on the 4He crystal interface" at 30th Annual Meeting of the Finnish Physical Society, Espoo, Mar 21 – 23

poster presentation "Spreading of superfluid 4He on MgF2" at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

Seppälä
poster presentation "Use of 3D MRI data for advanced modelling and visualization in MEG studies" at Second International Conference on Functional Mapping of the Human Brain, Boston, Jun 17 – 21

Sonin
oral and poster presentation "Vortex modes in layered superconductors" at International Workshop on Vortex Dynamics in High-Temperature Superconductors, Shores, Israel, Jun 23 – 27

Tarkka
poster presentation "Comparison of spherical and realistically shaped conductor models in magnetoencephalography" at 8th World Congress of the International Organization of Psychophysiology, Tampere, Finland, Jun 25 – 30

Tesche
member of discussion panel "Oscillatory brain dynamics at BIOMAG '96, 10th International Conference on Biomagnetism, Santa Fe, New Mexico, Feb 16 – 21

poster presentation "A Technique for the identifications of hippocampal theta from MEG data" at BIOMAG '96, 10th International Conference on Biomagnetism, Santa Fe, New Mexico, Feb 16 – 21

poster presentation "MEG imaging of thalamic responses to median nerve stimulation" at BIOMAG '96, 10th International Conference on Biomagnetism, Santa Fe, New Mexico, Feb 16 – 21

member of discussion panel "Signal-space projection at BIOMAG '96, 10th International Conference on Biomagnetism, Santa Fe, New Mexico, Feb 16 – 21

poster presentation "MEG detection of hippocampal theta in normal human subjects" at Second International Conference on Functional Mapping of the Human Brain, Boston, Jun 17 – 21

invited talk "Thalamic and cortical responses to median nerve stimulation" at First Berlin Workshop on Cortical Plasticity, Berlin, Jun 27 – 29

invited talk "Frequency-domain analysis on MEG data" at BIOPHYSICS GROUP, Los Alamos, New Mexico, Aug 7

invited talk "Frequency-domain analysis of magnetoencephalographic data" at Institute for Nonlinear Dynamics, University of California, San Diego, Aug 20

invited talk "Frequency-domain analysis of magnetoencephalographic data: can we see human hippocampal theta?" at Neurosciences Institute, San Diego, Aug 20

invited talk "Modelling of subcortical electromagnetic sources at Kliniken Neurofysiologian Päivät, Kuopio, Finland, Sep 19 – 21

Tunen
invited talk "How should we understand curved facets?" International workshop: Liquid/solid interfaces in helium, Espoo, Jan 5 – 7

invited talk "Scattering models for superfluid 3He in aerogel". First international workshop on quasicalssical methods in superconductivity and superfluidity, Verditz, Austria, Mar 11 – 13
invited talk, Vortex sheet in superfluid $^3$He - A, International Conference on Low Temperature Physics (LT-21), Prague, Aug 8 – 14

Tvalashvili
poster presentation, Localized vs. delocalized scattering in superfluid $^3$He-aerogel at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

Uusitalo
member of the organizational team of the 30th Annual Meeting of the Finnish Physical Society, Espoo, Mar 21 – 23
participation at 8th World Congress of the International Organization of Psychophysiology, Tampere, Finland, Jun 25 – 30

Uutela
poster presentation, Global optimization in the localization of brain activity at BIOMAG'96, 10th International Conference on Biomagnetism, Santa Fe, New Mexico, Feb 16 – 21

Vanni
session chairman and invited talk, About brain mechanisms of an conscious object at Symposium on Upward and Downward Contributions to the Perception Processes, Isle of Ischia, Italy, Oct 22 – 26

Volovik
invited talk, Cosmological experiment in superfluid $^3$He at Landau Institute Seminar, Moscow, Feb 1

invited talk, Superfluid $^3$He in aerogel at Landau Institute Seminar, Chernogolovka, Russia, Feb 2

participation at JETP Letters Editorial Board Meeting, Moscow, Mar 21

session chairman at Meeting on Mesoscopic and Strongly Correlated Systems, Kapitza Institute, Moscow, Apr 23 – 25

member of discussion panel at Editorial Board Meeting of JETP Letters, Moscow, Apr 30

invited talk, Fermions on quantized vortices in superfluids and superconductors and session chairman at Summer School on Condensed Matter Physics "Symmetry of the Order Parameter in High Temperature Superconductors", Bilkent, Turkey, Jun 16 – 23.

member of discussion panel at editorial board meetings of JETP Letters, Moscow, Jul 4 and Jul 18

invited talk, Cosmology, particle physics, and $^3$He at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

poster presentation, Spectral flow and vortex dynamics in superfluids, superconductors, and ferromagnets at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

poster presentation, Nucleation of vortices in superfluid $^3$He-B at XXI International Conference on Low Temperature Physics, Prague, Aug 8 – 14

oral presentations, Fermions on vortices, mutual friction and anomalies in QFT, event horizons and black holes in $^3$He experiments, and $^3$He in aerogel: superfluid glass? at Ultralow Temperature Conference, Stará Lesná, Slovakia, Aug 14 – 18

invited talk, Superfluid $^3$He and particle physics and session chairman at Topological Defects in Cosmology and Condensed Matter Systems, Grenoble, Sep 14 – 18

session chairman (Oct 24 and Dec 19) and member of discussion panel (Oct 31 and Dec 26) at Editorial Board Meeting of JETP Letters, Moscow

invited talk, Effect of gap nodes in d-wave superconductors at Meeting on High-Temperature Superconductivity, Grenoble, Nov 28
LTL SEMINAR SERIES

RESEARCH SEMINARS ON LOW TEMPERATURE PHYSICS

Organized by Matti Krusius and Mikko Paalanen

Koichi Kopnin, Landau Institute of Theoretical Physics: One week lecture course on Vortices in superconductors: structure and dynamics (Jan 8 – 15)

Edouard Sonin, A.F. Ioffe Institute for Physical Problems: Vortex annihilation and surface modes of a vortex cluster in a rotating cylindrical container (activation barrier for annihilation, single-vortex processes, collective annihilation, edge waves) (Jan 12)

Ted Jacobson, University of Maryland: Black holes and supersonic fluid flow: a curious analogy (Jan 17)

Alasdair Gill, Imperial College London: Analogue between the electro-weak transition and the AB transition in superfluid 3He (Jan 23)

Wilfried Schoepe, University of Regensburg: Superconducting levitation: Elastic and frictional forces between a permanent magnet and a high Tc superconducting surface (Feb 26) and Laminar, ballistic, and turbulent drag of superfluid helium on an oscillating microsphere (Feb 27)

Mikko Paalanen, LTL: Nanoscience in Japan - Travel report (Mar 4)

Gösta Ehnholm, Datex - Instrumentarium: NMR imaging of molecular oxygen in biological tissue using dynamic polarization (Mar 11)

Veikko Jousmäki, LTL: Quality control (Mar 11)

Erikk Thuneberg, LTL: Scattering model for superfluid 3He in aerogel (Mar 19)

Posters, LTL: Posters were presented by Jaakko Koivuniemi, Juha Kopa, Kim Lefmann, Jari Saranmäki, and Jussi Ruutu. On each poster there was a 3 min talk (1 or 2 viewgraphs) plus a short explanation, in front of the poster, on its contents. (Mar 20)

Edouard Sonin, A.F. Ioffe Institute for Physical Problems: The Magnus force in superfluids and superconductors (Mar 28)

Eikehard Teske, Konstanz University: Macroscopic structures on the surface of a charged layer of liquid helium (Apr 1)

Anne Davis, University of Cambridge: Cosmic strings in cosmology (Apr 4)

Jussi Ruutu and Edouard Sonin, LTL and A.F. Ioffe Institute for Physical Problems: 4He crystallization via quantum tunneling at mK temperatures (Apr 18)

Gorgeri Volovik and Volodya Dmitriev: New modes of spin precession and coherent dynamical order parameter states in superfluid 3He-B (Jun 4)

Bernard Plaïsais: Annihilation of vortex lines in rotating superfluid 3He-B (Jun 14)
Richard Packard, University of California, Berkeley: The creation of vortices in superfluid $^4$He (Jun 17) and The role of the Josephson-Anderson equation in superfluid helium (Jun 18)

Alexander Parshin, Kapitza Institute for Physical Problems: Emission of excitations when a kink moves along a step on the solid-liquid interface in the $^4$He system (Jun 18)

Edouard Sonin, A.F. Ioffe Institute for Physical Problems: Coherent spin precession and superfluid spin transport (Jul 9)

Simon Bandler, University of Heidelberg: Particle detection with a metallic magnetic calorimeter (Jul 24)

James Faller, Joint Institute for Laboratory Astrophysics: G. g. and the death of the fifth force (Aug 23)

Dmitri Averin, State University of New York at Stony Brook: Supercurrent noise in quantum point contacts (Aug 27)

Michel Martin, Centre de Recherches Sur les Très Basses Températures, Grenoble: NIS tunnel junctions for fast bolometers (Sep 10)

George Esa, Universität Bayreuth: Nuclear quadrupole hyperfine interaction in gallium single crystals at millikelvin temperatures: NMR, specific heat, and thermometry (Sep 26)

John Owens-Bradley, University of Nottingham: Medical imaging using hyperpolarised $^3$He gas (Sep 26)

Wilfried Schoepe, Universität Regensburg: Oscillating microspheres in $^3$He: How to measure and how not to measure? (Sep 26)

Kolya Koptin, Landau Institute for Theoretical Physics: Vortices in anisotropic superconductors - A lecture course consisting of 7 x 2 hours (Oct 7 - 14)

Enno Joon, Institute of Chemical Physics and Biophysics, Tallinn: Electronic properties and band structure of high $T_c$ compounds (Oct 9)

Alexander Parshin, Kapitza Institute for Physical Problems: Influence of $^3$He impurity atoms on the modality of steps on the $^4$He crystal facet and its implications to crystal growth (Oct 17)

Úlo Parts, LTL: Travel report from the Single Electron Nanoelectronics Session in the Fall Meeting of the American Electrochemical Society, San Antonio, Texas (Nov 19)

Antti Niemi, Uppsala Universität: Knots and solitons (Nov 21)

Anti-Pekka Jauho, MIC, Lundby, Denmark: Parallel transport properties of two-dimensional electron gas in semiconductor heterostructures (Nov 26) and Perpendicular transport in semiconductor heterostructures (Nov 28)

Alexander Korotkov, Moscow State University: Coulomb blockade and digital single-electron devices (Dec 3) and Shot noise in single-electron tunneling (Dec 5)

Vinay Ambegaokar, Cornell Institute: Effect of level statistics on superconductivity in ultrasmall metallic grains (Dec 19)

RESEARCH SEMINARS OF THE BRAIN GROUP

Organized by Nina Forss, Linda McEvoy, and Jukka Saarinen

Ritva Paetau, LTL: Picture naming in epilepsy: A case study (Jan 8)

Michael Smith, EEG Systems Laboratory, San Francisco: High resolution EEG mapping of cortical activity related to working memory: Effects of task difficulty, content, and practice (Jan 15)

Claudia Tesche, LTL: The inverse problem (Jan 22)

Leif Roschier, LTL: Sound volume control (Jan 29)

Antti Tarkainen, LTL: Spherical model and realistically shaped conductor model: Comparison of two models used in the localization of brain activity (Jan 29)
Journal Connoisy, Department of Psychology, Dalhousie University, Halifax, Canada: *Event-related brain potential studies of language and their application to clinical populations* (Feb 5) 
Veikko Jousmäki, LTL: *Saving and restoring data* (Feb 12) 
Linda McEvoy, EEG Systems Laboratory, San Francisco: *Book review: "Descartes' Error - Emotion, Reason, and the Human Brain" by A.R. Damasio* (Feb 12) 
Riitta Hari, LTL: *Kongress der Neurowissenschaftlichen Gesellschaft, Berlin, Germany* (Feb 26) 
Stephan Salenius, Riitta Salmelin, Matti Hämäläinen, and Jukka Knuttila, LTL: *Biomag conference reports* (Feb 26) 
Veikko Jousmäki, LTL: *Quality control* (Mar 11) 
Kimmo Utela and Tommi Raji, LTL: *Biomag conference reports* (Mar 11) 
Simo Vanni, LTL: *Perceiving an object* (Mar 18) 
Karin Portin, LTL: *Visual responses to luminance and pattern stimuli* (Mar 25) 
Ritva Paetau, LTL: *Rehearsal lecture: Cortical sources of magnetic 3-Hz spike-waves in childhood absence epilepsy* (Aug 26) 
Riitta Hari, Matti Hämäläinen, Karin Portin, Tommi Raji, Mika Seppä, and Mikko Uusitalo, LTL: *Reports from Tampere Conference on International Organization of Psychophysiology* (Sep 2 and Sep 16) 
Päivi Kieslää, LTL: *MEG measurements in dyslexic subjects* (Sep 23) 
Simo Vanni, LTL: *The emerging experimental study of the neural correlates of conscious visual perception* (Sep 30) 
Tommi Raji, LTL: *Brain mechanisms of imagery* (Oct 7) 
Antti Tarkkainen, LTL: *BiSpectrum* (Oct 14) 
Veikko Jousmäki, LTL: *Saccade related MEG-signals* (Oct 28) 
Yoshio Okada, University of New Mexico, USA: *Cellular basis of MEG systems* (Oct 28) 
Sari Levänen, LTL: *Rehearsal for oral examination: MEG and the auditory system* (Nov 4) 
Helen Neville, University of Oregon, Eugene: *Specificity and plasticity in human brain functions* (Nov 5) 
*Video: Adapting Brain* (Nov 11) 
Nina Fors, Riitta Hari, Veikko Jousmäki, and Riitta Salmelin, LTL: *Neuroscience reports I* (Nov 25) 
Karin Portin, Stephan Salenius, Mikko Uusitalo, and Simo Vanni, LTL: *Neuroscience reports II* (Dec 2) 
Riitta Hari, LTL: *European compartitized brain atlas* (Dec 9) 

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APPENDIX


The Royal Swedish Academy of Sciences awarded the 1996 Nobel Prize in Physics jointly to

Professor David M. Lee, Cornell University, Ithaca, New York, USA
Professor Douglas D. Osheroff, Stanford University, Stanford, California, USA
Professor Robert C. Richardson, Cornell University, Ithaca, New York, USA

for their discovery of superfluidity in helium-3.

A BREAKTHROUGH IN LOW-TEMPERATURE PHYSICS

When the temperature sinks on a cold winter's day water vapour becomes water and water becomes ice. These so-called phase transitions and the changed states of matter can be roughly described and understood with classical physics. What happens when the temperature falls is that the random heat movement in gases, liquids and solid bodies ceases. But the situation becomes entirely different when the temperature sinks further and approaches absolute zero, -273.15°C. In samples of liquid helium what is termed superfluidity occurs, a phenomenon that cannot be understood in terms of classical physics. When a liquid becomes superfluid its atoms suddenly lose all their randomness and move in a co-ordinated manner in each movement. This causes the liquid to lack all inner friction: it can overflow a cup, flow out through very small holes, and exhibits a whole series of other non-classical effects. Fundamental understanding of the properties of such a liquid requires an advanced form of quantum physics, and these very cold liquids are therefore termed quantum liquids. By studying the properties of quantum liquids in detail and comparing these with the predictions of quantum physics, low-temperature researchers are contributing valuable knowledge of the bases for describing matter at the microscopic level.

David M. Lee, Douglas D. Osheroff and Robert C. Richardson discovered at the beginning of the 1970s, in the low-temperature laboratory at Cornell University, that the helium isotope helium-3 can be made superfluid at a temperature only about two thousandths of a degree above absolute zero. This superfluid quantum liquid differs greatly from the one already discovered in the 1930s and studied at about two degrees (i.e. a thousand times) higher temperature in the normal helium isotope helium-4. The new quantum liquid helium-3 has very special characteristics. One thing these show is that the quantum laws of microphysics sometimes directly govern the behaviour of macroscopic bodies also.

THE ISOTOPES OF HELIUM

In nature the inert gas helium exists in two forms, isotopes, with fundamentally different properties. Helium-4 is the commonest while helium-3 occurs only as a very small fraction. Helium-4 has a nucleus with two protons and two neutrons. The nucleus is surrounded by an electron shell with two electrons. The fact that the number of particles constituting the atom is even makes helium-4 what is termed a boson. The nucleus of helium-3 also has two protons, but only one neutron. Since its electron shell also has two electrons, helium-3 consists of an odd number of particles, which makes it what is termed a fermion. Since the two isotopes of helium are built up of different numbers of particles, dramatic differences in their behaviour arise when they are cooled to temperatures near absolute zero.
THE PROPERTIES OF THE ISOTOPES

Bosons such as helium-4 follow Bose-Einstein statistics which, among other things, means that under certain circumstances they condense in the state that possesses the least energy. A phase transition process in which this occurs is termed Bose-Einstein condensation. The first person to manage to cool helium-4 gas to such low temperatures that it liquidised was Heike Kamerlingh-Onnes (Nobel Prize in Physics 1913). This happened at the beginning of the 1900s. He noted even then that when the temperature came closer to absolute zero than about 2 degrees something special happened in the liquid. But it was not until the end of the 1930s that Pyotr Kapitza (Nobel Prize in Physics 1978) discovered experimentally the phenomenon of superfluidity in helium-4, a phenomenon first explained schematically by Fritz London and then in detail by Lev Landau (Nobel Prize in Physics 1962). The explanations are based on the fact that the superfluid liquid, which appears at a phase transition when the temperature is only 2.17° above absolute zero, is a kind of Bose-Einstein condensate of helium atoms.

Fermons such as helium-3 follow Fermi-Dirac statistics and should not actually be condensable in the lowest energy state. For this reason superfluidity should not be possible in helium-3 which, like helium-4, can be liquidised at a temperature of some degrees above absolute zero. But fermions can in fact be condensed, but in a more complicated manner. This was proposed in the BCS theory for superconductivity in metals, formulated by John Bardeen, Leon Cooper and Robert Schrieffer (Nobel Prize in Physics 1972). The theory is based on the fact that electrons are fermions (they consist of one particle only, an odd number) and therefore follow Fermi-Dirac statistics just as helium-3 atoms do. But electrons in greatly cooled metals can combine in twos to form what are termed Cooper pairs and then behave as bosons. These pairs can undergo Bose-Einstein condensation to form a Bose-Einstein condensate. Starting with the experience of superfluidity in helium-4 and superconductivity in metals, it was expected that the fermions in liquid helium-3 should be capable of forming boson pairs and that superfluidity should be obtainable in very cold samples of the isotope helium-3. Although many research groups had worked with the problem for years, particularly during the 1960s, none had succeeded and many considered that it would never be possible to achieve superfluidity in helium-3.

THE DISCOVERY

The researchers at Cornell University were low-temperature specialists and had built their apparatus themselves. With it they could produce such low temperatures that the sample was within a few thousands of a degree of absolute zero. David Lee and Robert Richardson were the senior researchers while Douglas Osheroff was a graduate student in the team. Actually they were looking for a different phenomenon: A phase transition to a kind of magnetic order in frozen helium-3 ice. To find this phase transition, they were studying the pressure measured within the sample as a function of the time during which the volume was slowly increased and reduced. It was Osheroff’s vigilant eye that noted small extra jumps in the curve measured. It is easy to consider such small deviations as more or less inexplicable characteristics of the apparatus, but this student and his older co-workers became convinced that it was a true effect. In a first report published in 1972 the result was interpreted as a phase transition in the solid helium-3 ice which can also form at these low temperatures. But since the interpretation did not correspond precisely with the results of measurement, a rapid series of supplementary measurements were undertaken and in the same year the researchers were able to show in a second publication that there were in fact two phase transitions in liquid helium-3. The discovery heralded the start of intensive research on the new quantum liquid. A particularly important contribution was made by the theoretician Anthony Leggett, who assisted in the interpretation of the discovery. This thus assumed great significance for our knowledge of how the laws of quantum physics, formulated for microscopic systems, sometimes directly govern macroscopic systems also.

SUPERFLUIDITY IN HELIUM-3

That the new liquid really was superfluid was confirmed soon after the discovery, among others by a research team under Olli Louusmaa at the Helsinki University of Technology. They measured the damping of an oscillating string placed in the sample and found that the damping diminished by a
factor of one thousand when the surrounding liquid underwent the phase transition to the new state. This shows that the liquid is without inner friction (viscosity).

Later research has shown that helium-3 has at least three different superfluid phases, of which one occurs only if the sample is placed in a magnetic field. As a quantum liquid helium-3 thus exhibits a considerably more complicated structure than helium-4. It is, for example, anisotropic, which means that it has different properties in different spatial directions, which does not occur in classical liquids but more resembles the properties of liquid crystals (cf. Nobel Prize in Physics 1991 to Pierre-Gilles de Gennes).

If a superfluid liquid is caused to rotate at a speed exceeding a critical value, microscopic vortices arise. This phenomenon, which is also known from superfluid helium-4, has in helium-3 led to extensive research since its vortices can assume more complicated forms. Finnish researchers have developed a technique using optical fibres to observe directly how vortices affect the surface of rotating helium-3 at temperatures only one thousandth of a degree from absolute zero.

A FASCINATING APPLICATION OF SUPERFLUIDITY IN HELIUM-3

The phase transitions to superfluidity in helium-3 have recently been used by two experimental research teams to test a theory regarding how what are termed cosmic strings can be formed in the universe. These immense hypothetical objects, which are thought possibly to have been important for the forming of galaxies, can have arisen as a consequence of the rapid phase transitions believed to have taken place a fraction of a second after the Big Bang. The research teams used neutrino-induced nuclear reactions to heat their superfluid helium-3 samples locally and rapidly. When these were cooled again, balls of vortices were formed. It is these vortices that are presumed to correspond to the cosmic strings. The result, which must not be taken as proof of the existence of cosmic strings in the universe, is that the theory tested appears to be applicable to vortex formation in superfluid helium-3.

EXCERPTS FROM ADDITIONAL BACKGROUND MATERIAL ALSO RELEASED BY THE ROYAL SWEDISH ACADEMY OF SCIENCES

The fact that the new phases of helium-3 really were superfluid and could flow without resistance was shown by two groups soon after the discovery. A group at the University of Technology in Helsinki, led by Olfi Louhasmaa, measured the damping of a string vibrating in the liquid. They showed that the damping diminished by a factor of about 1 000 as the liquid was cooled from above 2 mK to 1 mK. The group led by the late John Wheatley at La Jolla detected and measured the velocity of the so-called fourth order sound. This is not a pressure or density wave, as in ordinary sound, but a temperature wave at constant pressure appearing in fine pores. A persistent flow experiment in Helsinki showed that the flow of superfluid helium-3 in a torus, with packed powder and helium-3 inside, did not decay, at least on the scale of a few days, in the B phase (but not in the anisotropic A-phase). This implied a viscosity at least 12 orders of magnitude smaller than the one in the normal fluid helium-3.

The most convincing experiments testing the coherence of a superfluid are probably those showing the appearance of quantized vortices. When a superfluid is set in rotation and the velocity of rotation exceeds a critical value, microscopic vortices appear. The circulation around such a vortex cannot take on any arbitrary value, but is quantized. This is known from "ordinary" superfluid helium. In helium-3 the vortices can take on complicated appearances, in fact eight different types of vortices have been seen with discontinuous or continuous flow in the vortex cores. Each of them represents a novel topological object with peculiar symmetry and structure. NMR, vibrating strings and other methods have been applied to study the detailed structure of vortices. Their appearance can even be observed directly, through an optical fibre and a cooled CCD camera, as done by the Finnish group which looked on the surface of a rotating sample.

Another topical field of study is textures, similar to those appearing in liquid crystals, with nuclear spins and orbital angular momenta pointing indifferent directions in different domains of the liquid.
The influence of boundary surfaces on the orientation of the liquid, the nucleation and time dependence of phase transitions are also studied.

The phase transitions in helium-3 have recently been used by two different experimental groups (Genoble and Helsinki) in attempts to simulate the formation of cosmic strings in the early universe. These hypothetical strings might have appeared as topological defects in the rapid phase transitions that are thought to have broken the symmetry of the originally unified interaction and given rise to the four fundamental forces as we know them today (strong, electromagnetic, weak, gravitational). Both groups used neutron induced nuclear reactions to heat their samples locally in such an abrupt way that the well localised phase transitions were accompanied by vortex formation, these vortices being the analogues of the cosmic strings. The validity of a theory formulated by Zurek, following an idea by Kibble, thus seems to have been confirmed. The cosmic strings are believed to be of importance, e.g., for the formation of galaxies.