Appendix B 1 Progress report of the network ”Mesoscopic solid state and molecular electronics”, Description of activities

a) Summary of year 2003, results compared with plans

The main planned activity for year 2003 was a network meeting in Röst, Norway. That workshop did take place as planned in conjunction with another Norfa network “Fundamental quantum processes in atomic and molecular systems”, coordinator Jan-Petter Hansen, Univ. of Bergen. The meeting was very successful and unique because it combined activities of two separate networks. Our network’s attendance was slightly lower than expected, thus not all the budgeted money was used. Also, several individual collaborative visits took place, measured in money these visits also didn’t quite reach the budgeted level. Thus, some surplus was accumulated in 2003.

b) Mobility within the network, 2003

The network’s mobility activity is described below group by group:

Lindelöf group:

There has been a considerable travelling between Lund (Chao's group) and Copenhagen (Lindelof's group) (typically 1-day meetings. This is also strongly encouraged by the so called Oeresund Initiative. A meeting (in Brussels) about a new European STREP project "ULTRA-1D" involving the Jyväskylä groups and the Copenhagen group and others can be considered a result of the intensive NORFA collaboration.

The Chalmers group had the following visits within the network:

J Kinaret	A.P. Jauho, Copenhagen, 2 days
C Huldt	A.P. Jauho, Copenhagen, 2 days
A. P. Jauho	J. Kinaret, Gothenburg, 2 days
R.I. Shekter	Y. Galperin, Oslo, 5 days
Y. Galperin	R.I. Shekhter, Gothenburg, 4 days

Helsinki groups had following visits:

Hakonen, Chalmers, Delsing + Kinaret, Nov. 2 - 5, 2003
Paalanen, Chalmers, Kinaret (+CARAMEL consortium members), Oct. 27, 2003.
Pekola: Several visits to Univ Jyväskylä, two visits to CTH. Savin (Pekola group) Visit to CTH Kiruna school organised by Leonid Kuzmin.

Jauho group:

Tomas Novotny and Andrea Donarini visited Chalmers in December/January.
Tomas Novotny and Christian Flindt attended the network meeting.

Chao group (Lund):

Vladislav Schlyapin attended the 2003 Annual Meeting and gave an oral presentation of our work. Prof. A. G. Mal'shukov visited Lund for three months (Oct-Dec 2003) with finances from other sources.
Dr. C. H. Chang visited Lund for three months (Oct-Dec 2003) with partial financial support from the Network Budget.

Galperin, Oslo

Daniel Shantsev (Ioffe Physico-Technical Institute, St.Petersbrug, Russia) works at the University of Oslo under supervision of Yuri M. Galperin
Period: 01.10.2002-30.09.2003

Thomas Kühn (Department of Physics, University of Jyväskylä) visits Y. M. Galperin and D. V. Anghel, at the University of Oslo.
Period: 5.05.2003 – 30.05.2003.

Brataas, Trondheim:

Participants from my surroudings to Roest where Jan Petter Morten and Jan Manschot from Trondheim and Gerrit E. W. Bauer and Alexey Kovalev from Delft.

Gudmundsson:

Jens H. Bardarson did participate in the Rost meeting
for the group.

Maasilta (new member)

Maasilta visited Chalmers 24.2 (1 day) and attended the Röst meeting End of August. In addition as described above, Thomas Kuhn (PhD student) spent a month in May with the Oslo group.

c) Supervision of research students and e) List of members of the network

Each member group is listed with its present supervised students listed:

1. Prof. Poul Erik Lindelöf
the Niels Bohr Institute, Oersted Laboratory, University of Copenhagen, Denmark

Finn Berg Rasmussen, lecturer
Jesper Nygaard, lecturer
Kurt Gloos, research lecturer
Pawel Utko, PhD student
Ane Jensen, PhD student
Brian Soerensen, PhD student
Soeren Erfurt Andresen, PhD student
Kasper Grove Rasmussen, PhD student
Martin Aagesen, PhD student

2. Prof. Antti-Pekka Jauho
Mikroelektronik Centret (MIC), Technical University of Denmark (DTU), Denmark

Mads Brandbyge, associate professor
Tomas Novotny, post-doc
Andrea Donarini, ph.d student

Thomas Frederiksen, ph.d student
Dan Bohr, Master's student
Christian Flindt, Master's student
Anders Mathias Lunde, Master's student

3. Prof. Pertti Hakonen
Low Temperature Laboratory, Helsinki University of Technology, Finland

M. Ahlskog, postdoc
T. Heikkilä, postdoc
T. Lehtinen, Master's student
R. Lindell, PhD student
M. Paalanen, Prof., director of the Low Temperature Laboratory
L. Roschier, PhD student
M. Sillanpää, PhD student
R. Tarkiainen, PhD student
V. Vaskelainen, Master's student

4. Prof. Jukka Pekola
Low Temperature Laboratory, Helsinki University of Technology, Finland

Alexander Savin, PhD, senior researcher
Anne Anthore, PhD, post-doc
Jani Kivioja, PhD student
Antti Niskanen, PhD student
Jouni Flyktman, PhD student
Tommi Nieminen, master's student

5. Dr. Ilari Maasilta
Department of Physics, University of Jyväskylä, Finland

Sampsa Hämäläinen, PhD student
Jenni Karvonen, PhD student
Kimmo Kinnunen, PhD student
Panu Koppinen, PhD student
Lasse Taskinen, PhD student
Thomas Kuhn, PhD student (together with Prof. Matti Manninen)

6. Prof. Detlef Heitmann
Institut fur Angewandte Physik, University of Hamburg, Germany

Can-Ming Hu, senior researcher + students
Christian Schuller, senior researcher + students
Dirk Grundler, senior researcher + students

7. Prof. Vidar Gudmundsson
Science Institute, University of Iceland, Iceland

Sigridur Sif Gylfadottir M.Sc. student
Jens H. Bardason M.Sc. student
Andrei Manolescu Dr. coworker

8. Prof. Algirdas Matulis
Semiconductor Physics Institute, Vilnius, Lithuania

Nerija Zurauskiene, senior researcher

9. Prof. Arne Brataas
Dept. of Physics, Norwegian University of Science and Technology, Trondheim, Norway

Jan Petter Morten, PhD student
Joern Foros, PhD student
Roman Shchelushkin, PhD student
Jan Manschot, Master's student
Victor Havik, project student
Torgeir Hansen project student

10. Prof. Eivind Hiis Hauge
Dept. of Physics, Norwegian University of Science and Technology, Trondheim, Norway

11. Prof. Yuri Galperin
Dept. of Physics, University of Oslo, Norway

Dragos-Victor Anghel, postdoc

12. Prof. Mats Jonson
Dept. of Applied Physics, Chalmers University of Technology and Göteborg University, Sweden

Robert Shekhter	Professor
Jari Kinaret	Associate professor
Leonid Gorelik	Researcher
Magnus Jonsson	PhD student
Caroline Huldt	PhD student
Jaeuk Kim	PhD student
Dmyrto Fedorets	PhD student
Sven Axelsson	Masters student

13. Prof. Koung-An Chao
Dept. of Theoretical Physics, University of Lund, Sweden

A.G. Mal'shukov, Visiting Professor
Vladislav Schlyapin, Postdoc
Anders Blom, (Ph.D.) Research Engineer
Karin Nilsson, Ph.D. Student

d) Information on scientific results 2003

Results are listed by groups:

Lindelöf:

The research in 2003 has concentrated on 1) transport in carbon nanotubes, 2) magnetic semiconductors and spin injection, and 3) SAW driven Quantum Point Contacts.We have in particular studied Raman spectroscopy in carbon nanotubes allowing determination of chiralities. Peapod nanotubes have been studied and we have succeeded to grow carbon nanotubes epitaxially into III-V heterostructures, - a result of considerable practical importance. Optimization of the injection of polarized electrons into III-V semiconductor promise well for the continuing studies of nanomagnetism. The project SAWPHOTON aiming at high frequency generation of single photons on demand is progressing.

Publications 2003:

"Direct Capacitive Coupling of Josephson Oscillations to a Quantum Point Contact", S.E. Andresen, A. Kristensen and P. E. Lindelof, in Toward the Controllable Quantum State (editors: H. Takayanagi and J. Nitta, World Scienctific, New Jersey 2003), p. 295 (2003).

"Effect of annealing on carrier density and Curie temperature in epitaxial (Ga,Mn)As thin films", B. S. Sørensen, J. Sadowski, R. Mathieu, P. Svedlindh, and P. E. Lindelof, Appl. Phys. Lett. 82, 2287 (2003).

"Spin-polarized electron tunneling across a Si delta-doped GaMnAs/n-GaAs interface", S. E. Andresen, B. S. Sørensen, F. B. Rasmussen, P. E. Lindelof, J. Sadowski, C. M. Guertler, and J. A. C. Bland, J. Appl. Phys. 94, 3990 (2003)

"Magnetization of ultrathin (Ga,Mn)As layers", R. Mathieu, B. S. Sørensen, J. Sadowski, J. Kanski, P.Svedlindh, P.E. Lindelof, D. Hrabovsky, and E. Vanelle, Cond-mat/0208411 (2003)

"Ferromagnetic GaMnAs Thin Films", B. S. Sørensen, J. Sadowski, S. E. Andresen, P. E. Lindelof, R. Matheu, P. Svedlindh and J. Kanski. Proceedings of the 26th International Conference on the Physics of semiconductors (ICPS) 2002. (Edited by J. H. Davies and A. R. Long. Institute of Physics 2003).

"Magnetic anisotropy of tunneling in GaMnAs based structures", S. E. Andresen, J. Sadowski, B. S. Sørensen and P.E. Lindelof, Proceedings of the 26th International Conference on the Physics of semiconductors (ICPS) 2002. (Edited by J. H. Davies and A. R. Long. Institute of Physics 2003).

"Screening behavior of the two-dimensional metallic state in

silicon-on-insulator structures", G. Pillwein, A. Prinz, G. Brunthaler, P.E.
Lindelof, and J. Ahopelto, Proceedings of the 26th International Conference
on the Physics of Semiconductors ICPS) 2002 (Edited by J. H. Davies and A.
R. Long. Institute of Physics 2003).

"Single-electron transportdriven by surface acoustic waves through shallow-etched point contacts", P. Utko, K. Gloos, J.B. Hansen, and P.E.
Lindelof, Acta Phys. Pol. In press (2003),

Jauho:

We have developed a quantum theory of the shuttle instability (invented by the Chalmers group in 1998) through a nanostructure with a mechanical degree of freedom. A phase space formulation in terms of the wigner function allows us to identify a crossover from the tunneling to the shuttling regime, thus extending the previously found classical results to the quantum domain. Further a new dynamical regime is discovered, where the shuttling is drivne exclusively by the quantum noise. Finally, we have developed a formalism to calculate the noise in a quantum dot array with internal mechanical motion.

Publications 2003:

1. Nonequilibrium Green Function
Modelling of Transport in Mesoscopic Systems, A.~P.~Jauho, in {\sl Progress in Nonequilibrium Green's Functions II}, pp. 181 -- 188, ed. M.~Bonitz, World Scientific (2003).

2. Quantum Shuttle in Phase Space,
T. Novotny, A. Donarini, and A. P. Jauho, Phys.
Rev. Lett. {\bf 90}, 256801 -- 256804 (2003).

3. Virtual photon contribution to frictional drag in double-layer devices},
A. Donarini, R. Ferrari, A. P. Jauho, and L. Molinari, Physics Letters A {\bf 312}, 123 -- 129 (2003).

4. TMR Effect in a FM-QD-FM system, F. M. Souza, J. C.
Egues, and A. P. Jauho, to appear in Brazilian Journal of Physics (2004).

5. Coulomb drag in multi-wall carbon
nanotubes, A. M. Lunde and A. P. Jauho, to appear in Semiconductor Science and Technology (2004).

6. Shuttle Instabilities: Semiclassical Phase Analysis, A. Donarini, T. Novotn{\'y}, and A. P. Jauho, to appear in Physica E (2004).

7. Quantum theory of shuttle instability}, T.
Novotn{\'y}, A. Donarini, and A. P. Jauho, to appear in Semiconductor Science and Technology (2004).

8. Conductance switching in a molecular device: the role

of sidegroups and intermolecular interaction,
Jeremy Taylor, Mads Brandbyge, Kurt Stokbro,
Phys. Rev. B 68, 121101 (2003)

9. Conductance of single-atom platinum contacts:
Voltage-dependence of the conductance histogram,
S.K. Nielsen, Y. Noat, M. Brandbyge, R.H.M. Smit, K. Hansen, L.Y. Chen, A.I. Yanson, F. Besenbacher, J.M. van Ruitenbeek
Phys. Rev. B 67, 245411 (2003).

10. Origin of current-induced forces in an atomic gold wire:
A first-principles study, Mads Brandbyge, Kurt Stokbro, Jeremy Taylor, José-Luis Mozos, and Pablo Ordejón
Phys. Rev. B 67, 193104 (2003).

Hakonen:

We have improved the sensitivity of the Bloch oscillating transistor (BOT) and shown that the equivalent input current noise may be less than the shot noise of its input base current. Simultaneously with the development of BOTs, we have studied the prospects of high-sensitivity noise spectroscopy using a Coulomb-blockaded, mesoscopic Josephson junction as a detector. We have also developed a new type of electrometer which is based on the measurement of kinetic inductance of a superconducting SET. This device yields similar characteristics as the rf-SET but it works at power levels of two orders magnitude smaller.

Publications:

1) J. Delahaye, J. Hassel, R. Lindell, M. Sillanpää, M. Paalanen, H. Seppä, and P. Hakonen, Low Noise Current Amplifier based on Mesoscopic Josephson Junction, Science 299, 1045 – 1048 (2003).

2) R. Lindell, J. Penttilä, M. Paalanen, and P. Hakonen, Spectroscopy of Mesoscopic Josephson Junction using Inelastic Cooper-pair Tunneling, Physica E 18, 13 – 14 (2003).

3) J. Delahaye, J. Hassel, R. Lindell, M. Sillanpää, M. Paalanen, H. Seppä, and P. Hakonen, Bloch Oscillating Transistor - a New Mesoscopic Amplifier, Physica E 18 , 15 – 16 (2003).

4) J. Delahaye, R. Lindell, M. Sillanpää, M. Paalanen, E. Sonin, and P. Hakonen, Coulomb-blockaded Josephson Junction as a Noise Detector, Journal of the Physical Society of Japan 72, Suppl. A, 187 – 188 (2003).

5) R. Lindell, J. Penttilä, M. Sillanpää, and P. Hakonen, Measuring the

Quantum States of a Mesoscopic SQUID using a Small Josephson Junction, Phys.
Rev. B 68, 052506 - 052509 (2003).

6) J. Delahaye, T. Heikkilä, R. Lindell, M. Sillanpää, T. Yamaguchi, P.
Hakonen, and E. Sonin, Ultrasensitive Noise Measurement Scheme for Mesoscopic Circuits using a Coilomb Blockaded Josephson Junction, Proc. of
17th Int. Conf. Noise and Fluctuations, pp. 455 - 460.

7) L. Roschier, P. Hakonen, K. Bladh, P. Delsing, K.W. Lehnerty, L. Spietz,
and R.J. Schoelkopf, Noise performance of the RF-SET, J. Appl. Phys. in
print.

8) R. Tarkiainen, M. Ahlskog, A. Zyuzin, P. Hakonen, and M. Paalanen, Transport in strongly disordered multiwalled carbon nanotubes, Phys. Rev. B.
in print.

9) J. Hassel, J. Delahaye, H. Seppä, and P. Hakonen, Control of Coulomb
Blockade in a Mesoscopic Josephson Junction using Single Electron Tunnelling, Phys. Rev. B to be published.

10) L. Roschier, T. Heikkilä, and P. Hakonen, Cyclostationary shot noise in
mesoscopic measurements, submitted to Appl. Phys. Lett.

Pekola:

I have founded a new research group ("PICO") at Low Temperature Laboratory at HUT in 2003, which works in close collaboration with the existing mesoscopic research group ("NANO") at LTL. The main activities of my group are within accurate Cooper pair pumping and its quantum corrections, thermal effects in mesoscopic structures, and macroscopic quantum tunnelling in Josephson junctions and SQUIDs for measurements of superconducting quantum bits.

Publications:

J. Kinnunen, P. Torma, and J. P. Pekola, Measuring charge-based quantum bits
by a superconducting single-electron transistor, Phys. Rev. B 68, 020506(R)
(2003).

A. Luukanen, K. M. Kinnunen, A. K. Nuottajärvi, H. F. C. Hoevers, W. M.
Bergmann Tiest, and J. P. Pekola, Fluctuation-limited noise in a transition-edge sensor, Phys. Rev. Lett. 90, 238306 (2003).

K. Gloos, P. J. Koppinen, and J. P. Pekola, Properties of native ultrathin
aluminum oxide tunnel barriers, J. Phys.: Condens. Matter 15, 1733 (2003).

P. Kivinen, A. Savin, M. Zgirski, P. Törmä, J. Pekola, M. Prunnila, and J. Ahopelto, Electron-phonon heat transport and electronic thermal conductivity in heavily doped silicon-on-insulator film, J. Appl. Phys. 94, 3201 (2003).

W. X. Huang, P. Dendooven, K. Gloos, N. Takahashi, J. P. Pekola, and J. Äystö, Extraction of radioactive ions across the surface of superfluid helium: A new method to produce cold radioactive nuclear beams, Europhys. Lett., 63, 687 (2003).

O. Buisson, F. Balestro, J. P. Pekola, and F. W. J. Hekking, One shot quantum measurement using a hysteretic DC-SQUID, Phys. Rev. Lett. 90, 238304 (2003).

A. Luukanen and J. P. Pekola, A superconducting antenna-coupled hot-spot microbolometer, Appl. Phys. Lett. 82, 3970 (2003).

R. Fazio, F. W. J. Hekking, and J. P. Pekola, Measurement of coherent charge transfer in an adiabatic Cooper pair pump, Phys. Rev. B 68, 054510 (2003).

M. Meschke, J. P. Pekola, F. Gay, R. E. Rapp, and H. Godfrin, Electron thermalization in metallic islands probed by Coulomb blockade thermometry, submitted to J. Low Temp. Phys. (2003).

F. Balestro, J. Claudon, J. P. Pekola, and O. Buisson, Evidence of two-dimensional macroscopic quantum tunneling of a current-biased DC-SQUID, Phys. Rev. Lett. 91, 158301 (2003).

Antti O. Niskanen, Jukka P. Pekola, and Heikki Seppä, Fast and accurate single-island charge pump: Implementation of a Cooper pair pump, Phys. Rev. Lett. 91, 177003 (2003).

J. P. Pekola, T. T. Heikkilä, A. M. Savin, J. T. Flyktman, F. Giazotto, and F. W. J. Hekking, Limitations of electron cooling, submitted (2003).

J. J. Toppari, G. S. Paraoanu, A. M. Halvari, and J. P. Pekola, Elastic cotunnelling of quasiparticles in superconducting Al/Nb/Al single electron transistor, submitted (2003).

J. J. Toppari, J. M. Kivioja, J. P. Pekola, and M. T. Savolainen, Turnstile behaviour of the Cooper-pair pump, submitted (2003).

F. Giazotto, T. T. Heikkilä, F. Taddei, Rosario Fazio, J. P. Pekola, and F.

Beltram, Tailoring Josephson coupling through superconductivity-induced
nonequilibrium, submitted (2003).

Maasilta:

We have studied thermal properties of mesoscopic metallic island with the help of SINIS tunnel junction thermometry. We have observed for the first time that in regular evaporated Cu, the energy loss rate between electrons and thermal phonons follows the expected power law in the disordered limit. We also see the transition to the clean limit when temperature is raised. In addition we have developed an ac technique to measure this electron-phonon interaction more accurately. We have also continued to develop superconducting transition-edge sensors (TES) for X-ray calorimetry. New low-noise SQUID-based amplifier setup has been developed for evaluation of the resolution limiting noise mechanisms in TESs.

Publications:

1.
Electrons and phonons at sub-Kelvin temperatures: validation of the disorder-mediated scattering theory
I. J. Maasilta, J. T. Karvonen, J. M. Kivioja, and L. J. Taskinen
submitted to Phys. Rev. Lett., cond-mat/0311031

2.
Modeling electric field sensitive scanning probe measurements for a tip of arbitary shape
I. Kuljanishvili, S. Chakraborty, I. J. Maasilta, S. H. Tessmer, and M. R. Melloch
submitted to Ultramicroscopy, cond-mat/0309667

3.
Imaging a two-dimensional electron system with a scanning charged probe
S. Chakraborty, I. J. Maasilta, S. H. Tessmer, and M. R. Melloch
submitted to Phys. Rev. B.

4.
Critical fluctuations as a source of excess noise in a TES in a Corbino geometry
A. Luukanen, W. M. Bergmann Tiest, H. F. C. Hoevers, K. M. Kinnunen, I. J. Maasilta, A. K. Nuottajärvi, and J. P. Pekola
to appear in Nucl. Instr. and Meth. A

5.
Direct observation of micron-scale ordered structure in a two-dimensional electron system
I. J. Maasilta, S. Chakraborty, I. Kuljanishvili, S. H. Tessmer, and M. R. Melloch
Phys. Rev. B. 68, xxx (2003), cond-mat/0205191.

6.
Tunneling images of a two-dimensional electron system in a quantizing magnetic field
I. J. Maasilta, S. Chakraborty, I. Kuljanishvili, S. H. Tessmer, and M. R. Melloch
Physica E: Low-dimensional Systems and Nanostructures 18, 167 (2003).

7.
Response time of a thermometer based on normal metal-insulator-superconductor (NIS) tunnel junctions
J. M. Kivioja, I. J. Maasilta, J. T. Karvonen, and J. P. Pekola
Physica E: Low-dimensional Systems and Nanostructures 18, 21 (2003).

Gudmundsson:

In cooperation with Andrei Manolescu at deCode in Reykjavik and C.-S. Tang in HsinChu in Taiwan I have focused the research on time-dependent phenomena in two-dimensional electron gas in nanostructures. We have investigated how a short THz pulse of electromagnetic radiation changes in the persistent current in quantum rings with finite width. We have calculated the nonlinear response of a short quantum wire to an intensive THz pulse, and found how both collective spin- and density oscillations can be excited. Together with Sigridur Sif we have compared the results for the finite width ring to a 1D ring. Jens H. Bardarson is working on transport through molecules.

Publications:

The orbital magnetization of single and double quantum dots in a tight binding model,
A. Aldea, V. Moldoveanu, M. Nita, A. Manolescu, V. Gudmundsson, B. Tanatar,
Phys. Rev. B67, 035324 (2003), (cond-mat/0207307).

Non-adiabatic current generation in a finite width semiconductor ring,
Vidar Gudmundsson, Chi-Shung Tang, Andrei Manolescu,
Phys. Rev. B67, 161301(R) (2003), (cond-mat/0301020).

Impurity and spin effects on the magneto-spectroscopy of a THz-modulated nanostructure,
Vidar Gudmundsson, Chi-Shung Tang, Andrei Manolescu,
Phys. Rev. B68, 165343 (2003), (cond-mat/0304571).

Non-adiabatic Current Excitation in Quantum Rings,
S. S. Gylfadottir, V. Gudmundsson, C. S. Tang, and A. Manolescu,
Physica Scripta T, submitted (2003),
20th Nordic Semiconductor Meeting, Tampere (2003), (cond-mat/0309661).

Brataas:

G. E. W. Bauer, A. Brataas, Y. Tserkovnyak, B. I. Halperin, M. Zwierzycki, P. J. Kelly, *Dynamic ferromagnetic proximity effect in photoexcited semiconductors,* submitted to Phys. Rev. Lett.

E. G. Mischenko, A. Brataas, and Y. Tserkovnyak, *Spin detection in quantum dots by electric currents,* submitted to Phys. Rev. Lett.

J. Johansson, V. Korenivski, D. B. Haviland, and A. Brataas, *Giant fluctuations of superconducting order paramter in Ferromagnet/superconductor single electron transistors,* submitted to Phys. Rev. Lett.

J. Manschot, A. Brataas, and G. E. W. Bauer, *Non-monotonic angular magnetoresistance in asymmetric spin valves,* submitted to Phys. Rev. B Rapid Communications.

1. A. Brataas, G. Zarand, Y. Tserkovnya, and G. E. W. Bauer, *Magnetoelectronic Spin Echo,* to be published in Phys. Rev. Lett. (2003).

2. B. Heinrich, Y. Tserkovnyak, G. Woltersdorf, A. Brataas, R. Urban, and G. E. W. Bauer, *Dynamic Exchange Coupling in Magnetic Bilayers,* Phys. Rev. Lett. 90, 187601 (2003).

3. G. E. W. Bauer, A. Brataas, and Y. Tserkovnyak, *Spin-torque Transistor*, Appl. Phys. Lett. 82, 3928 (2003)

4. A. A. Kovalev, G. E. W. Bauer, and A. Brataas, *Magnetovibrational Coupling in small Cantilevers,* Appl. Phys. Lett. 83, 1584 (2003).

5. G. E. W. Bauer, Y. Tserkovnyak, D. Huertas-Hernando, A. Brataas, *From Digital to Analogue Magnetoelectronics: Theory of Transport in Non-Collinear Magnetic Nanostructures*, to be published in Advance in Solid State Physics, edited by B. Kramer, Springer-Verlag, Berlin, 2003

6. Y. Tservkonyak, A. Brataas, and G. E. W. Bauer, *Dynamic Exchange Coupling and Gilbert Damping in Magnetic Multilayers*, J. Appl. Phys. 93, 7534 (2003).

7. G. Zarand, A. Brataas and D. Goldhaber-Gordon, *Kondo Effect and Spin Filtering in Triangular Artificial Atoms,* Solid State Commun. 126, 463 (2003).

8. Y. Tservkonyak, A. Brataas and G. E. W. Bauer, *Dynamic Stiffness of Spin Valves,* Phys. Rev. B Rap. Com. 67, 094421 (2003).

9. G. E. W. Bauer, Y. Tserkovnyak, D. Huertas-Hernando, A. Brataas, *Universal Angular Magnetoresistance and Spin Torque in Ferromagnetic/Normal Metal Hybrids*, Phys. Rev. B 67, 094421 (2003).

Galperin:

Below main projects carried out by the group are reported in the form of main published articles and brief abstracts. The period covered is from the last half of 2002 till the present time.

Nano-electromechanics

1. Shekhter, RI, Galperin, YM, Gorelik, LY. Isacsson, A, Jonson, M
"Shuttling of electrons and Cooper pairs" (review)
JOURNAL OF PHYSICS-CONDENSED MATTER, **15**, R441 (2003)

Properties of nanocomposite materials are affected by a coupling between mechanical deformations of the materials and electronic charge transport. In one of the simplest systems of this kind, a single electron transistor (SET) with deformable tunnel barriers (nanoelectromechanical SET), mechanically assisted charge transfer becomes possible. This can be viewed as 'shuttling of single electrons' between metallic leads by a movable small-sized cluster. In this article we review some recent theoretical and experimental achievements concerning shuttle transport, in normal as well as superconducting systems.

2. Isacsson, A, Gorelik, LY, Shekhter, RI, Galperin, YM, Jonson, M
"Mechanical cooper pair transportation as a source of long-distance superconducting phase coherence"
PHYSICAL REVIEW LETTERS, 89, 277002 (2003).

Transportation of Cooper pairs by a movable single Cooper-pair box placed between two remote superconductors is shown to establish coherent coupling between them. This coupling is due to entanglement of the movable box with the leads and is manifested in the suppression of quantum fluctuations of the relative phase of the order parameters of the leads. It can be probed by attaching a high resistance Josephson junction between the leads and measuring the current through this junction. The current is suppressed with increasing temperature.

3. Shekhter, RI, Gorelik, LY, Isacsson, A, Galperin, YM, Jonson, M
"Nanoelectromechanics of Coulomb Blockade nanostructures" (review)
PHYSICA SCRIPTA, **T102**, 13 (2002)

The aim of this paper is to emphasize the role of coupling between electronic and mechanical degrees of freedom taking place on a nanometer length scale. Such coupling affects significantly the electrical properties of nanocomposite materials which are usually heteroconducting and heteroelastic by their nature. As examples of nanoelectromechanics in normal and superconducting composites a self-assembled single electronic device exhibiting a dynamical instability leading to shuttling of electrical charge by a movable Coulomb dot is discussed along with an example of shuttling of Cooper pairs by a movable Single Cooper Pair Box.

Low-dimensional metallic and semiconductor systems

4. Drichko, IL, Diakonov, AM, Smirnov, IY, Preobrazhenskii, VV, Toropov, AI, Galperin, YM
"DX-centers and long-term effects in the high-frequency hopping conductance in Si-doped GaAs/Al0.3Ga0.7As heterostructures in the quantum Hall regime: acoustical studies"
PHYSICA E-LOW-DIMENSIONAL SYSTEMS & NANOSTRUCTURES, 17, 276 (2003).

It is discovered that both high-frequency (hf) hopping conductance and electron density in the 2D channel, n(s), in Si delta-doped and modulation-doped GaAs/Al0.3Ga0.7As heterostructures at the plateaus of the integer quantum Hall effect depend on cooling rate of the samples. Furthermore, consecutive IR illumination leads to a persistent hf hopping photoconductance, which decreases when the illumination intensity increases, while n(s) increases. The persistent hf hopping photoconductance occurs when the illumination frequency exceeds a threshold, which is between 0.48 and 0.86 eV. The results are attributed to two-electron defects (so-called DX-centers) located in the Si-doped layer of the $Al_{0.3}Ga_{0.7}As$ heterostructure.

5. Goppert, G, Galperin, YM, Altshuler, BL, Grabert, H

"Magnetic-field effects in energy relaxation mediated by Kondo impurities in mesoscopic wires"

PHYSICAL REVIEW B, **66**, 195328 (2002)

We study the energy distribution function of quasiparticles in short voltage biased mesoscopic wires in the presence of magnetic impurities and applied magnetic field. The system is described by a Boltzmann equation where the collision integral is determined by coupling to spin-1/2 impurities. We develop a theory of the coupling of nonequilibrium electrons to dissipative spins. This theory is valid as long as the characteristic smearing of the steps in the energy distribution function, which depends both on the bias voltage and the location of the probe, exceeds the Kondo temperature. We further address the renormalization of coupling constants by nonequilibrium electrons. Magnetic-field dependence of the energy relaxation rate turns out to be nonmonotonic. For low magnetic field an enhancement of energy relaxation is found, whereas for larger magnetic fields the energy relaxation decreases again meeting qualitatively the experimental findings by Anthore (cond-mat/0109297). This gives a strong indication that magnetic impurities are in fact responsible for the enhanced energy relaxation in copper wires. Our theoretical results are in good agreement with the experiment at large bias voltages where the theory is applicable. At the same time, at small bias voltages there are substantial quantitative deviations. Furthermore, the concentration of the spins, which follows from the energy relaxation for Cu, seems to to be substantially higher than the concentration estimated from weak localization (dephasing rate) measurements. Since the approach presented is valid only above Kondo temperature, it does not apply to the related problem of weak localization at low temperature in equilibrium.

Nanoscopic detectors

6. D. V. Anghel and L. Kuzmin,

"*Capacitively coupled hot-electron nanobolometer as far-infrared photon counter,*"

Appl.Phys. Lett. **82**, 293-295 (2003), *Virtual Journal of Nanoscale Science Technology*, vol.**7**, Issue 3 (2003), cond-mat/0212288.

We show theoretically that hot-electron nanobolometers consisting of a small pieceof normal metal, capacitively coupled to a superconducting antenna througha pair of normal metal–insulator–superconductor (NIS) tunnel junctions may beused as far-infrared photon counters. To make the device mosteffective at high counting rates, we suggest the use ofthe bolometer in the simplest configuration, when the NIS tunneljunctions are used as both an electron cooler and thermometer.The absorbtion of the photon in the normal metal producesa pulse in the electron temperature, which is measured bythe NIS junctions. The counter may resolve photons up to 0.3–0.4 mm wavelength and has a typical re-equilibration time constantof about 20 ns.

Statistical mechanics of mesoscopic systems

7. D. V. Anghel,

"*Gases in two dimensions: universal thermodynamics and its consequences,*"

J. Phys. A: Math. Gen. **35**, 7255-7267 (2002), cond-mat/0105089.

I discuss ideal and interacting quantum gases obeying general fractional exclusion statistics. For systems with constant density of single-particle states, described in the mean field approximation, the entropy depends neither on the microscopic exclusion statistics, nor on the interaction. Such systems are called *thermodynamically equivalent* and I show that the microscopic reason for this equivalence is a one-to-one correspondence between the excited states of these systems. This provides a method, different from the bosonization technique, of transforming between systems of different exclusion statistics. In the last section the macroscopic aspects of this method are discussed.

In appendix A, I calculate the fluctuation of the ground-state population of a condensed Bose gas in a grand-canonical ensemble and mean field approximation, while in appendix B I show a situation where although the system exhibits fractional exclusion properties on microscopic energy intervals, a rigorous calculation of the population of single-particle states reveals a condensation phenomenon. This also implies a malfunction of the usual and simplified calculation technique of the most probable statistical distributions.

8. D. V. Anghel,
"*Condensation in ideal Fermi gases,*"

J. Phys. A: Math. Gen. **36**, L577-L583 (2003); cond-mat/0310248.

I investigate the possibility of condensation in ideal Fermi systems of general single-particle density of states. For this I calculate the probability w_{N0} of having exactly N_0 particles in the condensate and analyze its maxima. The existence of such maxima at macroscopic values of N_0 indicates a condensate. An interesting situation occurs for example in 1D systems, where w_{N0} may have two maxima. One is at $N_0 = 0$ and another one may exist at finite N_0 (for temperatures below a certain condensation temperature). This suggests the existence of a first-order phase transition. The calculation of w_{N0} allows for the exploration of ensemble equivalence of Fermi systems from a new perspective.

Vortex Avalanches in Superconductors

9. D. V. Shantsev, P.E.Goa, F.L.Barkov, T.H.Johansen, W. N. Kang, S. I. Lee
"*Interplay of dendritic avalanches and gradual flux penetration in superconducting MgB2 film*"

Supercond. Sci. Technol. **16**, 566-570 (2003).

Magneto-optical imaging was used to study a zero-field-cooled MgB2 film at 9.6 K where in a slowly increasing field the Abrikosov vortices penetrate via an abrupt formation of dendritic structures consisting of narrow branching channels. Simultaneously, a gradual flux penetration takes place, eventually covering the dendrites, and a detailed analysis of this process is reported. We find an anomalously high gradient of the flux density across a dendrite branch, and a peak value that decreases as the applied field increases. This unexpected behaviour is reproduced by flux creep simulations based on the non-local field–current relation in the perpendicular geometry. The simulations also provide indirect evidence that flux dendrites are formed at an elevated local temperature, consistent with a thermo-magnetic mechanism of the instability.

10. F. L. Barkov, D. V. Shantsev, T. H. Johansen, P. E. Goa, W. N. Kang, H. J. Kim, E. M. Choi, S. I. Lee
"*Local threshold field for dendritic instability in superconducting MgB2 films*"

Phys. Rev. B **67**, 064513 (2003)..

Using magneto-optical imaging the phenomenon of dendritic flux penetration in superconducting films was studied. Flux dendrites were abruptly formed in a 300-nm-thick film of MgB2 by applying a perpendicular magnetic field. Detailed measurements of flux density distributions show that there exists a local threshold field controlling the nucleation and termination of the dendritic growth. At 4 K the local threshold field is close to 12 mT in this sample, where the critical current density is 10^7 A/cm^2 . The dendritic instability in thin films is believed to be of thermomagnetic origin, but the existence of a *local* threshold field and its small value are features that distinctly contrast with the thermomagnetic instability (flux jumps) in bulk superconductors.

Magneto-Elastic effects in Superconductors

11. Tom H. Johansen and Daniel V. Shantsev
"*Magnetostrictive behaviour of thin superconducting disks*"

Supercond. Sci. Technol., **16**, 1109-1114 (2003).

Vortex-pinning-induced stress and strain distributions in a thin disk superconductor in a perpendicular magnetic field are analysed. We calculate the body forces, solve the magneto-elastic problem and derive formulae for all stress and strain components, including the magnetostriction. The flux and current density profiles in the disk are assumed to follow the Bean model. During a cycle of the applied field the maximum tensile stress is found to occur approximately midway between the maximum field and the remanent state. An effective relationship between this overall maximum stress and the peak field is found.

1. Irina L. Drichko, Andrey M. Diakonov, Veniamin I. Kozub, Ivan Yu. Smirnov, Yuri M. Galperin, Andrew I. Yakimov, Alexander I. Nikiforov
"AC-Hopping Conductance of Self-Organized Ge/Si Quantum Dot Arrays"
cond-mat/0311267

Dense ($n=4 \times 10^{11}$ cm^{-2}) arrays of Ge quantum dots in Si host were studied using attenuation of surface acoustic waves (SAWs) propagating along the surface of a piezoelectric crystal located near the sample. The SAW magneto-attenuation coefficient, $\Delta\Gamma=\Gamma(\omega, H)-\Gamma(\omega, 0)$, and change of velocity of SAW, $\Delta V /V=(V(H)-V(0)) / V(0)$, were measured in the temperature interval T = 1.5-4.2 K as a function of magnetic field H up to 6 T for the waves in the frequency range f = 30-300 MHz. Basing on the dependences of $\Delta\Gamma$ on H, T and ω, as well as on its sign, we believe that the AC conduction mechanism is a combination of diffusion at the mobility edge with hopping between localized states at the Fermi level. The measured magnetic field dependence of the SAW attenuation is discussed basing on existing theoretical concepts.

2. A.V.Bobyl, D.V.Shantsev, Y.M.Galperin, A.A.F.Olsen, T.H.Johansen, W.N.Kang, S.I.Lee
"Mesoscopic flux jumps in MgB2 films visualized by magneto-optical imaging"
cond-mat/0304603

We report on the first spatially resolved observation of mesoscopic flux jumps in superconducting films. Magneto-optical imaging was used to visualize the flux penetration in MgB2 films subjected to a slowly varying perpendicular field. Below 10 K, flux jumps with typical size 10-20 microns and regular shape are found to occur at random locations along the flux front. The total number of vortices participating in one jump is varying between 50 and 10000. Simultaneously, big dendritic jumps with dimensions comparable to the sample size (10^6-10^8 vortices) are also found in this temperature range. We believe that both types of jumps result from thermo-magnetic instability.

3. A. A. F. Olsen, H. Hauglin, T.H.Johansen, P. E. Goa and D.V.Shantsev
"*Single vortices observed as they enter NbSe2*"
Physics C, in press; cond-mat/0307248

We observe single vortices as they penetrate the edge of a superconductor using a high-sensitivity magneto-optical microscope. The vortices leap across a gap near the edge, a distance that decreases with increasing applied field and sample thickness. This behaviour can be explained by the combined effect of the geometrical barrier and bulk pinning.

4. D. V. Anghel,
"*Exclusion Statistics Transformation and Ensemble Equivalence Tested From a Different Perspective*,"
cond-mat/0310377
The basic idea and main results of the ``exclusion statistics transformation'' (EST) are introduced. Using EST, an ideal Fermi gas of general density of states is transformed into a Bose gas by preserving only the excitations in the system. The Bose gas is not ideal, and at low temperatures exhibits Bose-Einstein condensation, which is related to the Fermi condensation [D. V. Anghel, J. Phys. A: Math. Gen **36**, L577-L583 (2003), cond-mat/0310248]. By emphasizing the excitations in the system and the collective behavior of the condensate, the

bosonic description of the Fermi system may be better suited to describe Fermi systems at low temperatures. In the low temperature limit, the EST resembles the bosonisation technique. The existence of the condensate challenges the Fermi canonical-grandcanonical ensemble equivalence from a new point of view.

Jonson:

Within the network we mainly work on mesoscopic transport problems in systems where nanomechanical and electrical degrees of freedom are coupled. Our 1998 PRL on "Shuttle mechanism for charge transfer in Coulomb blockade nanostructures" and the Nature article on "Coherent transfer of Cooper pairs by a movable grain" from 2001 has started a new field with by now some 100 published papers from a number of groups. In [1] we reviewed this activity and presented some of our most recent results, see also [11]. In [6,7] we studied shuttle transport through a single molecule and developed the quantum dynamics of both the mechanical and electronic degrees of freedom.

Nanoelectromechanics involving magnetic material is a more recent activity where a first PRL publication [2] presented a new type of exchange coupling between nanomagnets, controlled by electrostatic gate potentials. In [8] we proposed a new mechanism for a solid-state THz laser based on magnetic materials.

Another line of investigation has been nanoelectromechanical effects in carbon nanotubes, where a nanorelay structure has been proposed and

studied [5]. The nanorelay is a three-terminal device that acts as a switch in the GHz regime. Potential applications include logic devices, memory elements, pulse generators, and current or voltage amplifiers

Publications:

1. R.I. Shekhter, Y.M. Galperin, L.Y. Gorelik, A. Isacsson, and M. Jonson: "Shuttling of electrons and Cooper pairs", J. Phys. C15, 441-469 (2003).

2. L.Y. Gorelik, R.I. Shekhter, V. Vinokur, D. Feldman, V. Kozub, and M. Jonson: "Electrical manipulation of nanomagnets", Phys. Rev. Lett. 91, 088301 (2003).

3. K. Engstrom, J.M. Kinaret, R.I. Shekhter, et al.: "Influence of electron-electron interactions on supercurrent in SNS structures", Low Temp Phys 29 (7): 546-550 (2003)

4. J.U. Kim, I.V. Krive, J.M. Kinaret: "Nonequilibrium plasmons in a quantum wire single-electron transistor", Phys. Rev. Lett. 90, 176401 (2003)

5. J.M. Kinaret, T. Nord, S. Viefers: "A carbon-nanotube-based nanorelay", Appl Phys Lett 82 (8): 1287-1289 (2003)

6. D. Fedorets, "Quantum description of shuttle instability in a
nanoelectromechanical single-electron transistor",
Phys. Rev. B68, 033106 (2003)

7. D. Fedorets, L. Y. Gorelik, R. I. Shekhter, and M. Jonson:
"Quantum theory of shuttle phenomena in a nanoelectromechanical
single-electron transistor",
[cond-mat/0311105] (submitted to Phys. Rev. Lett.)

8. A. Kadigrobov, Z. Ivanov, T. Claeson, R. I. Shekhter, and M Jonson:
"Giant lasing effect in magnetic nanoconductors",
[cond-mat/0306522] (submitted to Phys. Rev. Lett.)

9. I.V. Krive, L.Y. Gorelik, R.I. Shekhter, and M. Jonson:
"Interplay of Rashba spin-orbit and Zeeman interactions in the
Josephson current through a ballistic Superconductor/Quantum
Wire/Superconductor junction,
(submitted to Phys. Rev. B)

10. L.Y. Gorelik, S.I. Kulinich, R.I. Shekhter, and M. Jonson:
"Resonant microwave properties of a voltage-biased
single-Cooper-pair transistor",
[cond-mat/0307568] (submitted to Phys. Rev. B)

11. T. Nord and A. Isacsson: "Impact of van der Waals forces on the
classical shuttle instability",
cond-mat/0304511 (submitted to Phys. Rev. B)

Chao:

Our research topic within the NorFA Network is in the area spintronics. We study the three major topics : life time of spin polarization, effieiency of spin injection and collection, and coherence length of polarized spin current transport.

The systems we investigate is III-V semconductor heterostructures in which the spin-orbit interaction (SOI) produces a large spin-split in electron energy levels. The spin polarized current can be transported in a 2D channel made from III-V semiconductor heterostructures, and can be controlled by a side gate. It is so far the proved system for spin transport. Recently, our theory suggested two new directions: 1) a combined system of III-V semiconductor quantum well and a pn-junction serves as a good room temperature spin injector, and 2) an AC gate applied to a 2D electron gas can generate circular polarized spin current. We thus created a new area of all-semiconductor functional system for spintronics. Our present research topics involve spin dephasing effects, geometric spin phase, spin entanglement, optical excitation of spin polarization, parametric spin pumping, and the role of optical phonons in spin relaxation. We have close collaboration with experimental groups.

Publications:

1) V. A. Froltsov, A. G. Mal'shukov, K. A. Chao, "Spin-orbit interaction and spin-charge interference in resonant Raman scattering from III-V semiconductor quantum wells", Phys. Rev. B {\bf 64} 73309 (2001).

2) A. G. Mal'shukov and K. A. Chao, "Optoelectric spin injection in semiconductor heterostructures without a ferromagnet", Phys. Rev. B - Rapid Commun. {\bf 65} 241308(R) (2002).

3) A. G. Mal'shukov, V. V. Shlyapin and K. A. Chao, "Quantum oscillations of spin current through a III-V semiconductor loop", Phys. Rev. B - Rapid Commun. {\bf 66} 081311(R) (2002).

4) W. M. Chen, I. A. Buyanova, G. Yu. Rudko, A. G. Mal'shukov, K. A. Chao, A. A. Toropov, Y. Ternet'ev, S. V. Sorokin, A. V. Lebedev, S. V. Ivanov, and P. S. Kop'ev, "Exciton spin relaxation in diluted magnetic semiconductor Zn$_{1-x}$Mn$_x$Se/CdSe superlattices: Effect of spin splitting and the role of longitudinal optical phonons", Phys. Rev. B {\bf 67} 125313 (2003).

5) A. G. Mal'shukov and K. A. Chao, "Comment on 'Aharonov-Bohm Oscillations with Spin: Evidence for Berry's Phase'", Phys. Rev. Lett. {\bf 90} 179701-1 (2003).