Part A – Research Results
A.1 Scientific Highlights

München: Analysis of spin accumulation has been finished and published[Mü1]. We were mainly focusing on the study of quantum dot systems (Objective 3.). Collaborating with the Budapest Node, we developed a Numerical Renormalization Group Code for double quantum dot systems. We found a new interesting strongly correlated state, the so-called SU(4) Kondo state, and we concluded that this type of device can be used as spin filters[Mü2](Task 3.a). With small modification, we used that code to perform calculations on a very asymmetric quantum dot-metallic grain system, in collaboration with the Basel Group[Ba1](Task 3.a). Working together with the Nodes in Karlsruhe and in Poznan, we also developed a similar code for quantum dots attached to ferromagnetic leads. We concluded that the suppression of the Kondo effect caused by the spin asymmetry of the environment can be completely recovered by applying a local magnetic field on the dot[Ka1](Task 3.a, 3.d).

Aachen: We have developed renormalization group techniques for the analysis of quantum-dot models with spin (Objective 3a.). As a first application we have published a study of interference phenomena in multi-level quantum dots [Aa1]. We found that interference phenomena can strengthen the Kondo effect and that under certain conditions the orbital Kondo resonance can be split. Working together with the Node in Karlsruhe we also developed quantum chemistry codes to study magnetic phenomena in molecular systems (Objective 4a.). As a first application to understand transport through the organic parts of molecular magnets we published new NDC-effects in tunneling transport through benzene [Aa2,Aa3,Aa4]. Furthermore we have started to generalize field theoretical renormalization group methods to study nonequilibrium transport through quantum wires coupled to spin lattices (Objective 3b.).

Basel: The project has not started

Budapest: We mainly focused on the study of quantum dot systems (Objective 3) and ferromagnetic semiconductors (Objective 1). We developed a numerical renormalization group code to study a double dot system in collaboration with the Munich Node. [Mü2] (Task 3a). We studied dephasing of the coherent spin-dynamics due to coupling to magnetic excitations [Mü3] (Task 3a). We studied the singlet-triplet transition in correlated quantum dots by numerical renormalization group methods[Bu1] (Task 3a). We analyzed the strongly correlated states that appear in triangular quantum dot systems [Bu2] (Task 3a). We derived the many-body Hamiltonian that describes magnetic semiconductors in the dilute limit [Bu3] (Task 1a). We studied spin transport through ferromagnetic magnetic multilayers and showed that for an antiparallel arrangement a spin echo appears in the spin current [Bu4]. {2b,3e}

Pisa: In the last year activity of the Pisa node concentrated mostly on objectives 4 and 2. We finished and published [Pi1] a paper on the study the effects of the mesoscopic fluctuations on the competition between exchange and pairing interactions in ultrasmall metallic dots when the mean level spacing is comparable or larger than the BCS pairing energy (Task 4b). We showed that, due to mesoscopic fluctuations, the probability to have a non-zero spin ground state may be non-vanishing and has universal features related to both level statistics and interaction. We also continued our work on counting statistics in systems in the presence of entanglement [Pi2] (Task 2c). We derived the Clauser-Horne (CH) inequality for the full electron counting statistics in a mesoscopic multiterminal conductor and we discuss its properties. In the course of this project we also produced new results, relevant for the present proposal which were not included in the milestones. We studied the Kondo effect in an ultrasmall metallic grain by calculating the susceptibility chi of the magnetic impurity [Pi3] (Task 3a). We proposed a method for measuring the degree of spin polarization of magnetic materials based on spin-dependent resonant tunneling [Pi4] (Task 1c). We also suggested how to obtain spin currents through adiabatic pumping by means of electrical gating only. This is possible by making use of the tunability of the Rashba spin-orbit coupling in semiconductor heterostructures [Ka2] (Task 1b).

Delft-th.: We have addressed the description of spin dependent transport in hybrid structures (Objective 2). Full counting statistics of spin transport between two terminal devices connected through a point contact has been achieved (task 2a). A paper presenting the results is in preparation. The techniques of counting statistics formerly developed for charge have been extended to the case of spin detection. A unified formalism accounting for several kinds of terminal structures has been derived (Tasks 2b and 2c). The formalism allows describing the counting of spin projection in different directions, and includes a quantum mechanical description of the measuring apparatuses. A proposal about the realization of spin current detectors was put forward as well.

Groningen: The project has not started

Orsay: -Decoherence in GaAs quantum wires. Determination of the phase coherence length from the harmonics content of AAS oscillations (no adjustable parameters). M. Ferrier, C. Texier, S. Guéron, G. Montambaux and H. Bouchiat
-Superconductivity in ropes of carbon nanotubes: The role of disorder. M. Ferrier, A. Kasumov, M. Kociak, R.Deblock, S. Guéron, B.Reulet and Hélène Bouchiat (PRB 2003 to be published)
<u>-Competition between Josephson and Kondo effect:</u>

-Magneto transport of magneto fullerenes (Gd atoms in C82 fullerenes) trapped between suspended tungsten nanoelectrodes. R.Deblock, A.Kasumov, S. Guéron, and H. Bouchiat
-Superconducting semiconducting superconducting nanostructures Nb/InAs. R.Deblock, A.Rowe, S.Guéron and H. Bouchiat (colaboration with F.Beltram and Pellegrini, Pisa.
-Electronic transport through DNA
DNA molecules on Pt electrodes : importance of interaction between molecule and substrate,
scaling behavior of the low temperature and low bias differential conductance. A.Yu.Kasumov, D.V. Klinov, P.E. Roche, S.Guéron, and H. Bouchiat
-Anomaous magnetism of DNA molecules. S. Nakamae, S. Guéron, H. Bouchiat.

Poznan: Analysis of spin accumulation in ferromagnetic single electron transistors has been finished and published [Po1,Po3,Ka4,Ka5,Ka9] (3d). In the case of nonmagnetic systems we also studied the role of non-equilibrium spin fluctuations in electronic transport through quantum dots with long spin relaxation time [Po4,Ka6,Ka7] (3d,3c). Working together with the nodes in Karlsruhe and Munchen, we have predicted that the Kondo correlations in quantum dots coupled to ferromagnetic leads are partially suppressed [Ka1,Ka8,Ka10](3c). We have also analyzed spin polarized transport through domain walls in quantum nanowires and point contacts, and proposed a mechanism of large negative magnetoresistance due to constrained domain walls (3b). As concerns quantum nanowires, we studied transport through carbon nanotubes attached to nonmagnetic electrodes in the limit of almost perfect transmission [Po2] and also spin polarized transport in nanotubes attached to ferromagnetic electrodes (3b).

Weizmann: Experimental effort: We have completed the analysis of the double wire cleaved edge overgrowth geometry for the purpose of studying spin charge separation in 1D. Preliminary tunneling data shows interference like structure whose analysis reveals two propagation velocities corresponding to the spin and charge degrees of freedom [weiz 1].
Theory: We have pursued our analysis of the interplay of the effects of interaction and spin in quantum dots. Important to this physics is the manifestation of such an interplay when the quantum dot(s) is (are) embedded in an interferometer. One then studies the manifestation of spin physics on Aharonov-Bohm interferometry. We are trying to focus on the strong dot-lead coupling.

Würzburg: Growth and optimization of quantum wells (QW) with a band alignment of type I (for LED applications) and two dimensional electron gases (2DEGs) were done as a first step towards spin injection into semiconductors with a narrow band gap (Objective 1). Quantum structures of $InAs/InAs_{0.9}Sb_{0.1}$ and $InAs/Ga_{0.1}In_{0.9}As$ have been grown successfully on InAs(001). Despite many efforts in the growth preparation no luminescence has been observed from the QW. We now focus on multi quantum well structures of $InAs/InAs_{0.9}Sb_{0.1}$ covered on each side by n-doped and p-doped InAs. This light emitted diode will be covered by a diluted magnetic semiconductor of (Cd,Mn)Se for a spin injection (Task 1.a, 1.c). For the 2DEG, a quantum structure of $InAs/Al_{0.2}Ga_{0.8}Sb$ with high mobility of electrons is considered for experiments on ballistic transport. To realize this structure several optimized buffer layer have been grown on a substrate of GaAs. The electrical characterizations by Hall transport measurement of the mobility of electrons are under way.

Zürich: This project is aimed at manipulating a single electron spin in a quantum dot. Within the past few months, our research has been focused on the design of guiding and resonating structures that maximize the coupling between the incident microwave energy and the quantum dot. Recently, we have been able to achieve a field amplitude of 0.2G for 400 micro Watt of continuous power at room temperature. Because the induced DC current has been predicted to occur in a typical dot for microwave fields in the range of 0.08-0.5G , the obtained value for such a remarkably low incident power is a strong motivation to continue in this direction. To that end, a new dilution fridge has been acquired and we hope to start experiments on nanostructures in the following months.

Delft-exp.: The project has not started**.**

Karlsruhe: We have developed a theory for collective spin excitations in diluted magnetic semiconductor quantum wells [Ka22,Ka33] (1a). We predicted the generation of persistent spin currents in helimagnets by applying a magnetic field [Ka31](3.f). We predicted that Kondo correlations in quantum dots attached to ferromagnetic filed is suppressed due to exchange interaction and local molecular field. We show that external magnetic field could compensate local molecular field and recover the Kondo effect. However the recover Kondo effect would have unusual properties [Ka10,Ka1] (3a). We also analyzed this system with the non-collinear leads magnetizations, where we found the interaction-driven spin precession, which can be detected by the transport measurements [Ka14] (3a). The interplay of quantum confinement and Rashba spin-orbit coupling was studied. Intriguing electronic-structure and transport properties in quantum wires, rings, and dots were discovered [Ka19,Ka23,Ka34] (3c). Generation of spin-polarized current through pumping without a magnetic field was shown to be possible [Ka2] (3c). The concept of a spin-controlled field-effect transistor was generalized to p-doped systems [Pi5] (1a). We studied the influence of strongly spin-polarized materials on the superconducting proximity effect in heterostructurs, containing superconducting and ferromagnetic parts. Singlet-triplet mixing is an intrinsic effect in such heterostructures, which leads to new effects like indirect proximity effect and indirect Josephson effect [Ka20,Ka27,Ka28] (2c).

A.2 List of Joint Publications

(too numerous to be listed in order of importance, hence listed in order of node of first author)

Legend:

Mü2] : 'Mü' are the first two letters of the first author's Node (Mü, Aa, Ba, Bu, Pi, D-th, Gr, Or, Po, We, Wü, Zü, D-exp, Ka) , 2: this digits enumerates papers from the same node

X. Ypsilon : Young researcher

[München/Budapest] : List of nodes involved in project

{3a} : Related Objective/Task (as described in Annex I, Part B, of the contract)

[**Mü1**] ***S. Kleff*** *and J. von Delft, "Nonequilibrium Excitations in Ferromagnetic Nanoparticles",* Phys. Rev. B. **65,** 214421 (2002)) (http://arxiv.org/abs/cond-mat/0110348) [Karlsruhe/München], {4b}

[**Mü2**] ***L. Borda***, *G. Zaránd, W. Hofstetter, B. I. Halperin, J. von Delft*, *"SU(4) Fermi Liquid State and Spin Filtering in a Double Quantum Dot System"*, Phys. Rev. Lett. **90**, 026602 (2003) (http://arxiv.org/abs/cond-mat/0207001) [München/Budapest], {3a}

[**Ba1**] *K. Le Hur, P. Simon,,* ***L.Borda***, *"Maximized Orbital and Spin Kondo Effects in a Single Electron Transistor"* , submitted to Phys. Rev. B. (http://arxiv.org/abs/cond-mat/0306186) [München/Basel] {3a}

[**Mü3**] *A.H. Castro Neto, E.Novais,* ***L.Borda***, *G. Zaránd, and I. Affleck*, *"Quantum Magnetic Impurities in Magnetically Ordered Systems"* , submitted to Phys. Rev. Lett. (http://arxiv.org/abs/cond-mat/0303565) [München/Budapest] {3a}

[**Mü4**] ***L.Borda***, *A. Zawadowski, and G. Zaránd, "Orbital Kondo Behavior from Dynamical Structural Defects"* , accepted for publication in Phys. Rev. B. (http://arxiv.org/abs/cond-mat/0302334) [München/Budapest] {3c}

[**Aa1**] *D. Boese, W. Hofstetter, and H. Schoeller*, *"Interference in interacting quantum dots with spin"* , Phys. Rev. B. **66,** 125315 (2002) [Aachen/Karlsruhe], {3a}

[**Aa2**] *M.H. Hettler, W. Wenzel,* ***M.R. Wegewijs***, *and H. Schoeller*, *"Current collapse in tunneling transport through benzene"* , Phys. Rev. Lett. **90,** 076805 (2003) [Aachen/Karlsruhe], {4a}

[**Aa3**] ***M.R. Wegewijs***, *M.H. Hettler, W. Wenzel, and H. Schoeller*, *"Negative Differential Conductance in a Benzene-Molecular Device"* , J. Phys. Soc. Jpn. **72,** Suppl. A 83 (2003) [Aachen/Karlsruhe], {4a}

[**Aa4**] ***M.R. Wegewijs***, *M.H. Hettler, W. Wenzel, and H. Schoeller*, *"Negative Differential Conductance in a Benzene-Molecular Device"* Physica E **18,** 241-242 (2003) [Aachen/Karlsruhe], {4a}

[**Bu1**] *W. Hofstter and G. Zaránd, "Singlet-Triplet Transition in lateral Quantum Dots: A Numerical Renormalization Group Study",* submitted to Phys. Rev. B (http://arxiv.org/abs/cond-mat/0306418) [Budapest] {3a}

[**Bu2**] *G. Zaránd, A. Brataas, and D. Goldhaber-Gordon, Using triangular quantum dots as spin filters,* Solid State Commun. **126**, 463 - 466 (2003). [Budapest] {3a}

[**Bu3**] **G.A. Fiete**, *G. Zaránd, and K. Damle*, "*Effective Hamiltonian for* $Ga_{1-x}Mn_xAs$ *in the Dilute Limit",* submitted to Phys. Rev. Lett. (http://arxiv.org/abs/cond-mat/021207) [Budapest] {1a,3f}

[**Bu4**] ***A. Brataas, G. Zaránd,*** **Y. Tsernovnyak**, ***and G.E.W. Bauer***, "*Magnetoelectronic spin echo",* submitted to Phys. Rev. Lett. (http://arxiv.org/abs/cond-mat/0306344) [Budapest] {2b,3e}

[**Pi1**] *G. Falci, R. Fazio and A. Mastellone*, *"Interplay between pairing and exchange in small metallic dots* , Phys. Rev. B. **67**, 132501 (2003) (http://arxiv.org/abs/cond-mat/0208259)

[**Pi2**] *L. Faoro, F. Taddei and R. Fazio*, *"Clauser-Horne inequality for counting statistics in mesoscopic multiterminal conductors"* (http://arxiv.org/abs/cond-mat/0306733)

[**Pi3**] *G. Franzese, R. Raimondi and R. Fazio*, *"Parity dependent Kondo effect in ultrasmall metallic grains "*, Europhys. Lett.. **62**, 264 (2003) (http://arxiv.org/abs/cond-mat/0208259)

[**Pi4**] *F. Giazotto, F. Taddei, R. Fazio and F. Beltram*, *"Ferromagnetic resonant tunneling diodes as spin polarimeters and polarizer"*, App. Phys. Lett. **82**, 2449 (2003) (http://arxiv.org/abs/cond-mat/0212242)

[**Pi5**] ***M.G. Pala, M. Governale, J. König***, *and* ***U. Zülicke***, *„Universal Rashba Spin Precession of Two-Dimensional Electrons and Holes"*, submitted to Phys. Rev. Lett. (http://arXiv.org/abs/cond-mat/0212560) [Pisa/ Karlsruhe]{1a}

[**Or1**] R. Deblock, Eugen Onac, Leonid Gurevich, Leo Kouwenhoven "Detection of Quantum Noise from an Electrically Driven Two-Level System" , Science 301, 203 (2003) [Orsay/Delft exp]

[**Po1**] *J. Barnas, J. Martinek, R. Swirkowicz, M. Wilczynski, and W. Rudzinski, „Electron tunneling through metallic particles and quantum dots connected to ferromagnetic leads"*, Czech. J. Phys. **52** (2), 329-332 (2002). [Poznan/Karlsruhe]{3a,3d}

[Po2] *S. Krompiewski, J. Martinek, J. Barnaś, Interference effects in electronic transport through metallic single-wall carbon nanotubes,* ***Phys. Rev. B 66,*** *073412 (2002)* [Poznan/Karlsruhe]{3b}

[Po3] ***I. Weymann***, *J. Barnaś, and J. Martinek, Nonequilibrium magnetic polarization abd sin currents controlled by gate voltage in ferromagnetic single electron transistor, Journal of Supercond. 16, 225 (2003)* [Poznan/Karlsruhe]{3d}

[Po4] *J. Barnaś, V. K. Dugaev, S. Krompiewski, J. Martinek, W. Rudzinski, R. Swirkowicz,* ***I. Weymann,*** *M. Wilczynski, Spin related effects in magnetic mesoscopic systems, phys. stat. Sol. (b) 236, 246 (2003)* [Poznan/Karlsruhe]{3b,3d}

[**Weiz1**] *Y. Tserkovnyak, B. I. Halperin, O. M. Auslaender, and A. Yacoby, "Finite Size Effects in Tunneling Between Parallel Quantum Wires", Phys. Rev. Lett. 89, 136805 (2002).*

[**Weiz2**] *Y. Avishai, A.Golub, and A.D. Zaikin, "Superconductor-Quantum Dot-Superconductor Junction in the Kondo Regime"*, Phys. Rev. B **67**, 041301 (R) (2003). [Weizmann/ Karlsruhe]{3a}

[**Wü1**] **P. Grabs**, G. Richter, R. Fiederling, C.R. Becker, W. Ossau, G. Schmidt, L.W. Molenkamp, W. Weigand, E. Umbach, I. V. Sedova, S. V. Ivanov *"Molecular-Beam epitaxy of (Cd,Mn)Se on InAs, a promising material system for spintronics"* Appl. Phys. Lett. **80**, 3766 (2002) (http://ojps.aip.org/journals/doc/APPLAB-ft/vol_80/iss_20/3766_1-div0.html) [Würzburg], {1a}

[**Ka1**] *J. Martinek,* ***M. Sindel, L. Borda,*** *J. Barnas, J. König, G. Schön, and J. von Delft, "NRG study of the Kondo effect in the presence of itinerant-electron ferromagnetism"*, submitted to Phys. Rev. Lett. (http://arxiv.org/abs/cond-mat/0304385) [München/Karlsruhe/Poznan] {3a,3d}

[**Ka2**] *M. Governale F.Taddei and R. Fazio "Pumping spin with electric fields"*, (http://arxiv.org/abs/cond-mat/02111211) [Pisa/Karlsruhe]

[**Ka3**] *J. Splettstoesser, M. Gover*nale and U. Zuelicke *"Persistent current in ballistic mesoscopic rings with Rashba spin-orbit coupling"*, (http://arxiv.org/abs/cond-mat/0305310) [Pisa/Karlsruhe]

[**Ka4**] *J. Martinek, J. Barnas, S. Maekawa, H. Schoeller, and G. Schön, "Spin accumulation in ferromagnetic single-electron transistors in the cotunneling regime"*, Phys. Rev. B **66**, 014402 (2002). [Karlsruhe/Poznan/ Aachen]{3d}

[**Ka5**] *J. Martinek, J. Barnas, S. Maekawa, H. Schoeller, and G. Schön, "Spin accumulation and cotunneling effects in ferromagnetic SET"*, J. Magn. Magn. Mater. **240** (1-3), 143-145 (2002). [Karlsruhe/Poznan/Aachen]{3d}

[**Ka6**] *J. Martinek, J. Barnas, S. Maekawa, and G. Schön, "Transport in magnetic nanostructures in the presence of Coulomb interaction"*, J. Appl. Phys. **93**, 8265 (2003). [Karlsruhe/Poznan]{3d,3a}

[**Ka7**] *J. Martinek, J. Barnas, G. Schön, S. Takahashi, and S. Maekawa, "Nonequilibrium spin fluctuations in non-magnetic single-electron transistors and quantum dots"*, J. of Superconductivity: Incorporating Novel Magnetism **16**, 343 (2003). [Karlsruhe/Poznan]{3d,3a}

[**Ka8**] *J. Martinek, Y. Utsumi, H. Imamura, J. Barnas, S. Maekawa, and G. Schön, "Kondo Effect in Quantum Dots Coupled to Ferromagnetic Electrodes"*, Physica E **18**, 75 (2003). [Karlsruhe/Poznan]{3a}

[**Ka9**] *J. Martinek, J. Barnas, S. Maekawa, H. Schoeller, and G. Schön, Spin Accumulation in Ferromagnetic Single-Electron Transistors*", Physica E **18**, 54 (2003). [Karlsruhe/Poznan]{3d}

[**Ka10**] *J. Martinek, Y. Utsumi, H. Imamura, J. Barnas, S. Maekawa, J. König, and G. Schön, "Kondo effect in quantum dots coupled to ferromagnetic leads"*, submitted to Phys. Rev. Lett. [Karlsruhe/Poznan] {3a}

[**Ka11**] ***J. König*** *and Y. Gefen, "Aharonov-Bohm interferometry with interacting quantum dots: spin configurations, asymmetric interference patterns, bias-voltage induced AB oscillations, and symmetries of transport coefficients"*, Phys. Rev. B **65**, 045316 (2002). [Karlsruhe/Weizmann]{3a}

[**Ka12**] ***S. Kleff*** *and J. von Delft, "Nonequilibrium excitations in ferromagnetic nanoparticles"*, Phys. Rev. B **65**, 214421 (2002). [Karlsruhe/München]{4,3d}

[**Ka13**] ***D. Boese****, W. Hofstetter, and H. Schoeller, "Interference in interacting quantum dots with spin"*, Phys. Rev. B **66**, 125315 (2002). [Karlsruhe/Aachen]{3a}

[**Ka14**] ***J. König*** *and J. Martinek, „Interaction-driven spin precession in quantum-dot spin valves",* Phys. Rev. Lett. **90**, 166602 (2003). [Karlsruhe/Poznan]{3a}

[**Ka15**] ***M. Governale*** *and* ***U. Zülicke****, "Filtering Spin with Tunnel-Coupled Hole Quantum Wires"*, J. of Superconductivity: Incorporating Novel Magnetism **16**, 257 (2003). [Karlsruhe/Pisa]{3b}

[**Ka16**] *J. Martinek, J. Barnas, G. Schön, S. Takahashi, and S. Maekawa, "Nonequilibrium spin fluctuations in single-electron transistors"*, submitted to Phys. Rev. Lett., (http://arxiv.org/abs/cond-mat/0209559) [Karlsruhe/Poznan]{3d,3a}

[**Ka17**] ***J. Splettstoesser, M. Governale,*** *and* ***U. Zülicke****, "Persistent current in ballistic mesoscopic rings with Rashba spin-orbit coupling"*, submitted to Phys. Rev. B (http://arXiv.org/abs/cond-mat/0305310) [Karlsruhe/Pisa]{3b,1a}

Without cooperation

[**Ka18**] ***U. Zülicke*** *and C. Schroll, „Interface conductance of ballistic F/2DEG hybrid systems with Rashba spin-orbit coupling"*, Phys. Rev. Lett. **88**, 029701 (2002). {1b}

[**Ka19**] ***M. Governale****, "Quantum dots with Rashba spin-orbit coupling"*, Phys. Rev. Lett. 89, 206802 (2002). {3a}

[**Ka20**] ***M. Eschrig*** *and M. R. Norman „Dispersion Anomalies in Bilayer Cuprates and the Odd Symmetry of the Magnetic Resonance"*, Phys. Rev. Lett. **89**, 277005 (2002). {2c}

[**Ka21**] ***M. Governale****, D. Boese,* ***U. Zülicke****, and C. Schroll , "Filtering spin with tunnel-coupled electron wave guides"*, Phys. Rev. B **65**, 140403(R) (2002). {3c}

[**Ka22**] *T. Jungwirth, **J. König**, J. Sinova, J. Kucera, and A.H. MacDonald, "Curie Temperature Trends in (III,Mn)V Ferromagnetic Semiconductors"*, Phys. Rev. B **66**, 012402 (2002). {1a}

[**Ka23**] ***M. Governale** and **U. Zülicke**, "Spin accumulation in quantum wires with strong Rashba spin-orbit coupling"*, Phys. Rev. B **66**, 073311 (2002). {3c}

[**Ka24**] ***J. König**, „Theory of Ferromagnetism in (III,Mn)V Semiconductors"*, Festkörperprobleme/Advances of Solid State Physics **42**, 445-456 (2002). {1a}

[**Ka25**] ***J. König**, J. Schliemann, T. Jungwirth, and A.H. MacDonald, "Collective spin fluctuations in diluted magnetic semiconductors"*, Physica E **12**, 379-382 (2002). {1a}

[**Ka26**] *D. Boese, **M. Governale**, A. Rosch, and **U. Zülicke**, "Magnetotunneling between parallel quantum wires: From coherent oscillations to spin-charge separation"*, Physica E **12**, 730 (2002). {3b}

[**Ka27**] ***M. Eschrig, J. Kopu**, J.C. Cuevas, and G. Schön, „Theory of Half-Metal/Superconductor Heterostructures"*, Phys. Rev. Lett. **90**, 137003 (2003). {2c}

[**Ka28**] *S. V. Borisenko, A. A. Kordyuk, T. K. Kim, A. Koitzsch, M. Knupfer, M. S. Golden, J. Fink, **M. Eschrig**, H. Berger, R. Follath, "Anomalous enhancement of the coupling to the magnetic resonance mode in underdoped Pb-Bi2212"*, Phys. Rev. Lett. **90**, 207001 (2003). {2c}

[**Ka29**] ***M. Eschrig** and M.R. Norman, "Effect of the magnetic resonance on the electronic spectra of high-Tc superconductors"*, Phys. Rev. B **67**, 144503 (2003). {2c}

[**Ka30**] *M. Popp, **D. Frustaglia**, K. Richter, „Spin Filter Effects in Mesoscopic Ring Structures"*, Nanotechnology **14** (2): 347-351 (2003). {3c}

[**Ka31**] ***J. Heurich, J. König**, and A. H. MacDonald, „Persistent Spin Currents in Helimagnets"* accepted for publication in Phys. Rev. B , (http://arXiv.org/abs/cond-mat/0305069) {1a}

[**Ka32**] *A. Shnirman and Yu. Makhlin, "Spin-spin correlators in Majorana representation",* (http://arxiv.org/abs/cond-mat/0305064) {3a}

[**Ka33**] ***J. König** and A.H. MacDonald, "EPR and Ferromagnetism in Diluted Magnetic Semiconductor Quantum Wells"*, submitted to Phys. Rev. Lett., (http://arXiv.org/abs/cond-mat/0306635) {3f}

[**Ka34**] *M. Popp, **D. Frustaglia**, K. Richter, "Conditions for Adiabatic Spin Transport in Disordered Systems"*, to appear in Phys. Rev. B (Rapid Communications) (http://arXiv.org/abs/cond-mat/0305076) {3c}

B.1 Research Objectives

The Objectives set forth in Annex I of the contract are still relevant and achievable.
(Exceptions:

1. In Aachen we have extended Objective 4a to the study of molecular magnets based on metalorganic compounds. This gives the possibility for the investigation of interplay between molecular and spin electronics.)

B.2 Research Method

The methods being used in order to achieve the Project Objectives have not changed during the past period of the Network Activity.
(Exceptions:

1. In München we are improving our method, namely we are currently parallelizing our NRG code to run it on a supercomputer.
2. In Aachen we are developing quantum chemistry methods to study transport through magnetic systems based on metalorganic compounds.
3. In Aachen we are developing a nonequilibrium version of field theoretical renormalization group methods to study transport through quantum wires coupled to spin chains.
4. In Karlsruhe we are improving our method, we adapted the real-time diagrammatic technique for the system of quantum dots attached to ferromagnetic leads.)

B.3 Work Plan

- **Breakdown of tasks.** There was no reason to change the number and the character of the tasks.
- **Schedule and Milestones.**
  - **München:** Although the Milestones named in the Work Plan in Annex I. of the contract have not changed, the schedule has been reorganized a bit. Milestones associated with Objective 3., which were scheduled to reach at a the later stage of the network activity, have been reached, while studies on Objective 4. have partially finished and partially been shifted to a later period of the activity. Publications associated with Objective 3: (as listed in A2): [Mü1][Mü2][Mü3][Ba1][Ka1].
  - **Aachen:** We have slightly changed our working plan concerning Objective 4a since we concentrate now on the study of molecular magnets instead of metallic nanograins. This is motivated by the increased significance and

experimental activities in molecular spin electronics. Furthermore we are presently also active in Objective 3b by studying spin transport phenomena through one-dimensional spin chains. Within Objective 3a and 4a we have already several publications (see [Aa1][Aa2][Aa3][Aa4] listed in A2).

- **Basel:** The project has not started.
- **Budapest:** The Budapest node kept the original milestones of the Work Plan but somewhat reorganized the work, and also contributed to Objectives 1b, 2b and 3e of the network [Bu3,Bu4]. Despite of the inclusion of this additional Objective, we completed all work associated with Objective 3a [Mü2,Mü3,Bu1,Bu2].
- **Pisa:** The program has not been changed as compared to the Work Plan. The milestone on the effect of spin-flip scattering on the I-V curves is still under study also because during the investigation various new results has emerged meanwhile.
- **Delft-th. :** Of the Milestones listed in the Work Plan in Annex I, one relative to Objective 2 has been reached. According to the current schedule, accomplishment of the milestones relative to Objective 2 will be the next step.
- **Groningen:** The project has not started.
- **Orsay:** We are working on two new spin-systems in reduced dimensions: Rare-earth atoms trapped in fullerene cages, between suprconducting electrodes. And DNA double helixes, which have a paramagnetic signal at low temperature, which seems to depend on the A or B phase of the DNA molecule.
- **Poznan:** The Milestones listed in the Work Plan in Annex I of the contract have not changed, although the schedule has been slightly reorganized. Milestones associated with Objective 3, which were scheduled to be reached at a the later stage of the network activity, have been already reached now, whereas studies on Objective 2 (2c) have been shifted to a later period of the activity.
- **Weizmann:** The milestones and schedules have not changed.
- **Würzburg:** Milestones reported in the Work Plan in Annex I, concerning the growth of (Cd,Mn)Se directly on InAs have been reached. Now we are exploring the best way for the vertical confinement of the InAs layer as reported in A1. Publication associated to objective 1: [Wü1]
- **Zürich:** Experiments are ongoing, no major change of the milestones.
- **Delft-exp.:** The project has not started.
- **Karlsruhe:** The Milestones listed in the Work Plan in Annex I. of the contract have not changed, however the schedule has been slightly reorganized. Milestones associated with Objective 1., which were scheduled to reach at the later stage of the network activity, have been reached. Studies on Objective 3. have been finished. In addition to the Work Plan we work on Objective 2. Publications associated with Objective 1: (as listed in A2): [Ka2,Pi5,Ka17,Ka22,Ka24,Ka25]. Publications associated with Objective 3: (as listed in A2): [Ka1,Ka11,Ka13,Ka5,Po1,Ka4,Weiz2,Ka6,Ka7,Ka8,Ka10,Ka19,Ka32], [Ka15], [Ka21,Ka23,Ka30,Ka34], [Ka4,Ka5,Po1,Ka6,Ka7,Ka9,Ka15], [Ka33]. Publications associated with Objective 2: (as listed in A2): [Ka20,Ka27,Ka28,Ka29].

- **Research effort.**

Participant	Young researchers to be financed by the contract (person-months)		Researchers to be financed from other sources (person-months)		Researchers likely to contribute to the project (number of individuals)
	According to proposal	Delivered so far	According to proposal	Delivered so far	
1. München	24	12	61	16	4
2. Aachen	36	12	34	18	5
3. Basel	24	0	66	0	7
4. Budapest	24	4	39	12	5
5. Pisa	36	0	98	25	4
6. Delft-th	24	4	64	15	4
7. Groningen	24	0	36	0	4
8. Orsay	24	0	76	24	5
9. Poznan	24	0	142	36	8
10. Weizmann	48	0	92	23	6
11. Würzburg	24	0	102	20	9
12. Zürich	24	0	57	0	4
13. Delft-exp	24	0	64	0	5
14. Karlsruhe	12	3	100	25	7

B.4. Organization and management

B.4.1 Network management: has been installed as described in Annex I, Section 4 and a homepage installed (**http://www.theorie.physik.uni-muenchen.de/~borda/RTN.html**). Relevant information, in particular job applications by postdoc candidates with interests in the network, were disseminated in network newsletters (see attached example). However, due to the much-later-than expected arrival of the first payments from Brussels, detailed in B.6, network activities were generally much more limited in the first reporting period than had been anticipated. Nevertheless, those nodes that did manage to employ a young researcher engaged in significant networking, as detailed in B.4.3, and represented the network in a substantial number of conferences, see B.5.4.

B.4.2 Network meetings: The first network meeting was held in Trieste, from August 19 to 23, 2002, parallel to a very large spintronics workshop organized by Guenterodt, Ralph and Jones. RTN-members came a day earlier, August 18, which they spent by outlining to each other their RTN-related research goals.

B.4.3 Networking: **V = Visit, P = Joint publication, S = Seminar, SCH = Summer School**

Fm/To	Mün	Aach	Basel	Budapest	Pisa	Delft-th.	Gron	Orsay	Poznan	Weizm	Würzb	Zürich	Delft-exp.	Karlsr
Mün		V	2 V	VP					P	VP			V	VP
Aach	V		V			V	V							VP
Basel	2V	V			VP			V			V			V
Bud	VP													
Pisa			VP			VP								VP
Delft-th.		V			VP									
Gron		V												
Orsay			V							VS SCH				
Pozn	P													VSP
Weiz	VP							VS SCH						
Würzb			V											
Zürich														
Delf-exp	V													
Karlsr	VP	VP	V		VP	V			VP	P	VSV		V	

Networking activity of the München Node:
München-Aachen: H. Schoeller visited München and gave a seminar talk.
München-Basel: J. von Delft visited Basel and gave seminar talks two times.
München-Budapest: A. Zawadowski visited München, L. Borda visited Budapest. Joint publications.
München-Poznan: Joint publication.
München-Weizmann: M. Sindel visited Weizmann, Y. Oreg visited München. There is a joint publication under preparation.
München-Delft-exp: L. Kouwenhoven gave a seminar talk in München.
München-Karlsruhe: M. Sindel and L. Borda visited Karlsruhe, and L.B. gave a seminar talk there. J. Martinek visited and gave a seminar talk in München. Joint publication.

Networking activity of the Aachen Node:
Aachen-München: H. Schoeller visited München and gave a seminar talk.
Aachen-Delft-th: M. Wegewijs visited Delft and gave a seminar talk.
Aachen-Groningen: M. Wegewijs visited Groningen and gave a seminar talk.
Aachen-Basel: F. Meier visited Aachen and gave a seminar talk.
Aachen-Karlsruhe: M. Wegewijs and H. Schoeller visited Karlsruhe several times. Joint publication.

Networking activity of the Basel Node: project not started

Networking activity of the Budapest Node:
Budapest-München: L. Borda visited Budapest. Joint publications. A. Zawadowski visited München.

Networking activity of the PisaNode:
Pisa-Karlsruhe: There were various exchange visits: F. Taddei in Karlsruhe, M. Governale in Pisa . Joint publication.
Pisa-Basel:F. Taddei and R. Fazio visited Basel, W. Belzig visited Pisa . A joint publication is under preparation.
Pisa-Delft: A. Romito (PhD student) visited Delft for 3 months. A joint publication is under preparation.

Networking activity of the Delft-th Node:
A. Romito from Pisa visited Delft, and gave a seminar talk.

Networking activity of the Groningen Node:

Networking activity of the Orsay Node:
Orsay-Basel: S. Guéron lectured at school organized by C. Bruder (Twannberg)
Orsay-Weizmann: Y. Gefen, H. Bouchait and S. Guéron (with G. Montambaux) are co-organizing a five-week-long summer school to take place in 2004. Y. Gefen visited Orsay, gave a seminar.

Networking activity of the Poznan Node:
Poznan- München: Joint publication.
Poznan–Karlsruhe: J. Barnas, I Weymann and S. Krompiewski visited Karlsruhe and gave seminar talks; Joint publications; J. Martinek visited Poznan.

Networking activity of the Weizmann Node:
Weizman – Munich – Visit

Networking activity of the Würzburg Node:
Würzburg-Basel: C. Gould visited Basel and gave a seminar talk.

Networking activity of the Zürich Node:

Networking activity of the Delft-exp. Node:

Networking activity of the Karlsruhe Node:
Karlsruhe– München: J. Martinek visited and gave a seminar talk in München. M. Sindel and L. Borda visited Karlsruhe, and L.B. gave a seminar talk here. Joint publication.

Karlsruhe–Basel: J. C. Cuevas visited Basel and gave a seminar talk there. W. Belzig, C. Bruder and A. Khaetskii visited Karlsruhe and gave a seminar talk there.
Karlsruhe–Aachen: Joint publications.
Karlsruhe–Pisa: M. Governale, J Koenig visited and gave a seminar talk in Pisa. Joint publication. F. Tadei and M. Pala visited and gave a seminar talk in Karlsruhe. Joint publications.
Karlsruhe–Delft-th J. Splettstößer visited and gave a seminar talk in Delft-th.
Karlsruhe–Poznan J. Martinek visited Poznan. J. Barnas, I Weymann and S. Krompiewski visited Karlsruhe and gave a seminar talk there. Joint publications.
Karlsruhe– Weizmann Y. Gefen and Y. Imry visited and gave a seminar talk in Karlsruhe. Joint publication.
Karlsruhe– Würzburg: U. Zulicke gave a seminar talk in Würzburg.
Karlsruhe– Delft-exp. M. Governale gave a seminar talk in Delft-exp.

B.5.1 Measures taken to publicise vacant positions: The most important forum to advertise vacant positions is the individual homepages of the Network nodes. Such advertisements as well as applications for job sent by young researchers appeared regularly in the Network Newsletters (which are also available on the Network homepage, in the internal part). The Weizmann node also published adds in key journals such as Science.

B.5.2 Recruitment of young researchers

Participant	*Contract deliverable of Young Researchers to be financed by the contract (person- months)*			*Young Researchers financed by the contract so far (person-months)*		
	Pre-doc(a)	*Post-doc (b)*	*Total (a+b)*	*Pre-doc (c)*	*Post-doc (d)*	*Total (c+d)*
München	*0*	*24*	*24*	*0*	*12*	*12*
Aachen	*0*	*36*	*36*	*0*	*12*	*12*
Basel	*0*	*24*	*24*	*0*	*0*	*0*
Budapest	*0*	*24*	*24*	*0*	*4*	*4*
Pisa	*0*	*36*	*36*	*0*	*0*	*0*
Delft-th.	*0*	*24*	*24*	*0*	*4*	*4*
Groningen	*0*	*24*	*24*	*0*	*0*	*0*
Orsay	*0*	*24*	*24*	*0*	*0*	*0*
Poznan	*0*	*24*	*24*	*0*	*0*	*0*
Weizmann	*0*	*66*	*66*	*0*	*0*	*0*
Würzburg	*0*	*24*	*24*	*0*	*0*	*0*
Zürich	*0*	*24*	*24*	*0*	*0*	*0*
Delft-exp.	*0*	*24*	*24*	*0*	*0*	*0*
Karlsruhe	*0*	*12*	*12*	*3*	*0*	*3*
TOTAL	-	***390***	***390***	***3***	***32***	***35***

B.5.3 Integration of young researchers into the research programme: Young researchers were regularly involved in the research activity of the Network. One particularly interesting aspect of their integration is their role in the collaboration between different nodes: in numerous cases when one or more young researchers represented the link between to Network Nodes. Young researchers have participated at international conferences many times.

B.5.4 Training of young researchers: Standard training measures, such as visits to other nodes, visits by external experts, participation in meetings, etc., are detailed in the table below. In addition, young researchers received some training in the complimentary skill of project management and reporting, in that they were asked to collect and submit much of the material contained in this report.

Participant	Visits to other Nodes	Visiting external experts	Participation in meetings	Other training
München	L. Borda visited Karlsruhe, Budapest. M. Sindel visited Weizmann, Karlsruhe.	L. Glazman, Y. Imry, W. Hofstetter, R. Bulla.	L. Borda: A, B, C . M. Sindel: A,C	L. Borda and M. Sindel visited external experts, R. Bulla and T. Pruschke in Augsburg.
Aachen	M. Wegewijs visited Delft, Groningen, Karlsruhe.	W. Wenzel	M. Wegewijs: D,E,F T. Korb: G,H C. Romeike: I	M. Wegewijs visited external expert, W. Wenzel in Karlsruhe.
Basel				
Budapest		G. Fiete, W. Hofstetter, N. Andrei.		
Pisa				
Delft-th.			A. Di Lorenzo: D, E.	
Groningen				
Orsay				
Poznan	I Weymann visited Karlsruhe	V Dugaev	I Weymann: A, B	
Weizmann				
Würzburg	C. Gould visited Basel			Idriss CHADO was trained in WÜ since 2003
Zürich				
Delft-exp.				
Karlsruhe	J. C. Cuevas visited Basel. M. Governale, J Koenig visited Pisa. J. Splettstößer visited Delft-th.U. Zulicke visited Würzburg and Weizmann. M. Governale visited Delft-exp.	Y. Imry, T. Dietl, P. Bruno, M. Sassetti, U. Merkt, W. Ruele, H. Imamura, F. Tadei, U. Roessler, A. Palevski, A. Volkov, R. Mohanty, V. Chandrasekhar, K. Tanaka, D. Eigler	U. Zulicke: A, B, K1, K2, K3, J3 M. Eschrig: I, J1, J2, D. Frustaglia: A, B, C, M. Governale: D, J. Heurich: D, E J. Konig: A, F, H, I,J. Kopu: G,	

<u>Conferences, meetings, workshops</u>

A: "Modern Aspects of Quantum Impurity Physics" Dresden March 31-April 18, 2003
B: March Meeting of the American Physical Society, Austin, Texas, 3-7 March 2003
C: "*Electrons in zero-dimensional conductors: Beyond the single-particle picture*" Dresden, 18-30 November,2002
D: "Spin Mesoscopics Workshop", University of Twente, Enschede, March 15-18, 2003.
E: "Delft-Leiden Joint Workshop in Nanophysics", Egmond an Zee, June 1-3, 2003.
G: COST P5 Workshop "Mesoscopic Electronics", Catania (I), 17.10. – 19.10.2002.
H: International Seminar on Electrons in zero-dimensional conductors: Beyond the single-particle picture, Dresden, 18.11. – 30.11.2002.
I: International Conference on "Nanoelectronics", Lancaster (GB), 4.1. – 9.1.2003.
J1: "Electronic Structure of Solids", Universität Dresden, 2.7. – 5.7.2002.
J2: Workshop "Emergent Materials and Highly Correlated Electrons", Trieste (I), 5.8. – 18.8.2002.
J3: March Meeting, Austin/Texas (USA), 3.3. – 14.3.2003.
K1: ELNANO Conference, Dresden, 4.11. – 8.11.2002.
K2: DIP Workshop, Eilat (Israel), 16.1. – 22.1.2003.
K3: Winterschule, Mauterndorf (A), 24.2. – 26.2.2003.

B.5.5 Equal Opportunities:

- Helen Bouchiat, the leader of the Orsay team, has been appointed to oversee gender-related issues in the network.
- The Groningen node has succeeded to attract a female postdoc for the next reporting period, Dr. J. Grollier.
- It is planned to arrange for babysitters to be available during the next network meetings.

B.5.5 and B.5.6: not relevant

B.6 Difficulties encountered

Although the project was expected to start in June 2002, due to administrative delays in Brussels the contract was signed only in on October 2, 2002. (Fortunately, it was nevertheless possible to set the starting date of the network starting to June 1, 2002, in order to allow young researchers in Aachen and Munich to be employed from day 1.) This delay in signing the contract, however, had a snowballing effect in causing subsequent delays for the timetable of most of the network (in particular regarding recruitment of young researchers): The first payment arrived in Munich only toward the middle of December, 2002. Regrettably, the deadline of our university administration for performing foreign transfers had already passed by then, so that these were delayed until the beginning of this year. In the case of the Orsay node, the money finally arrived only in April 2003.

In spite of all the measures taken to advertise vacant positions, it turned out that certain nodes are experiencing difficulties in attracting young researchers, in particular Poznan and Weizmann (the latter for political reasons). Poznan is now contemplating making some of its money available to another node to support a young researcher there.

Network members are not diligent enough in posting research results, such as new publications, on the network home page. This will have to be improved.