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1st São Paulo School of Advanced Science:
Spintronics and Quantum Computation

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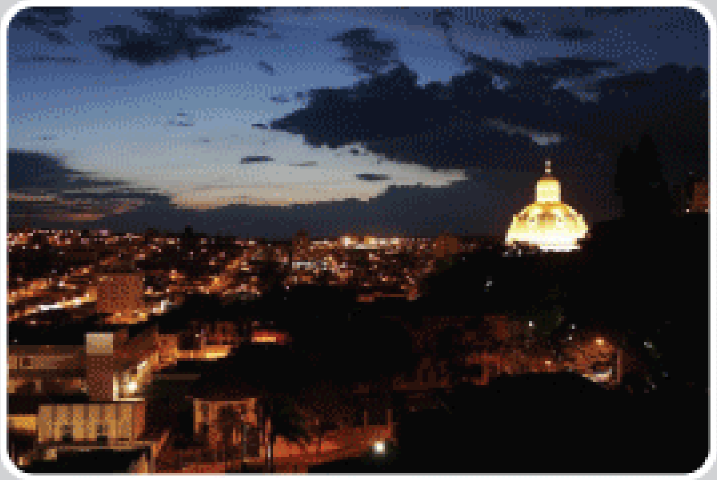

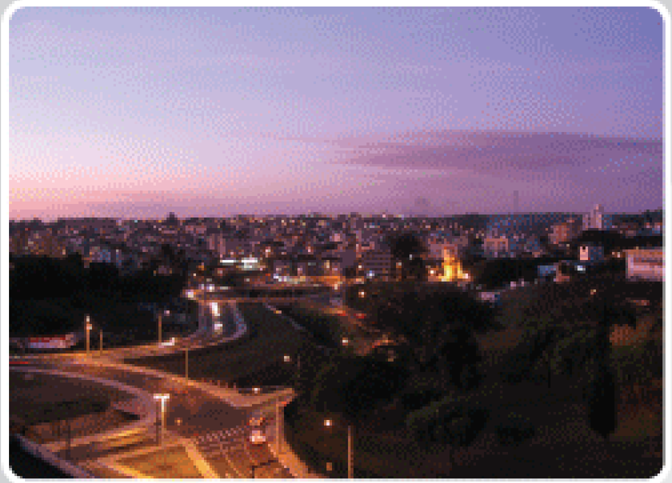

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1st São Paulo School of Advanced Science: Spintronics and Quantum Computation

November 1 - 5, 2010
São Carlos, SP, Brazil

Spin-related phenomena and quantum computation are two fascinating interconnected fields of research, which have attracted a great deal of attention worldwide in the last couple of years. Quite uniquely, these two fields encompass a vast number of frontier-type problems all of which concern fundamental aspects of quantum physics.

In this context, the 1st São Paulo School of Advanced Science: Spintronics and Quantum Computation in São Carlos aims at bringing together graduate students and young postdoctoral researchers - from Brazil and other countries (50/50) - with interests in these fields, thus (i) providing an ideal forum for fruitful and productive interactions among them, local researchers and leading scientific figures and (ii) fostering future scientific exchange and international collaborations in advanced topics in science.

This School is an initiative of FAPESP - "Fundação de Apoio à Pesquisa do Estado de São Paulo" our state funding agency. There are in fact seven Advanced Schools taking place in the São Paulo state within the first batch of approved proposals in many fields of research.

Overview and scope

Many exciting problems within the theme "Spintronics and Quantum Computation" are currently under investigation by many groups across the globe. Some of these are:

1. Spin entanglement: production, detection & manipulation
2. Spin injection and spin transport
3. Spin-field effect transistors
4. (Quantum) Spin Hall effect
5. Coherent spin dynamics, spin relaxation & dephasing in nanostructures
6. Spin-based quantum computing (NMR and quantum dots)
7. Domain wall motion in magnetic systems (metals and semiconductors)
8. Novel spintronic systems (e.g., graphene, carbon nanotubes)
9. Quantum computing with quantum optics
10. Novel materials for spintronics (graphene, carbon nanotubes, etc)

The above topics are particularly interesting and suitable for an advanced School aimed at senior undergraduate students, graduate students and young postdoctoral researchers. That is, many of the topics involve Quantum Mechanics, Solid State Physics, Quantum Optics, Electromagnetism, Statistical Physics etc. as applied to relevant state-of-the-art problems in the literature. Moreover, many of these problems are still open and hence should be a source of motivation for talented young graduate students and postdocs.

School Organizers

School chair
J. Carlos Egues (University of São Paulo, USP - São Carlos)

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Adilson J. A. de Oliveira (UFSCar)
Guilherme M. Sipahi (IFSC/USP)
Yara G. Gobato (UFSCar)
Esmerindo Bernardes (IFSC/USP)

Student Organizers
Beat Röthlisberger (Unibas)
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Invited Speakers

Peter Grünberg
Jülich, Nobel 2007

Daniel Loss
Basel

Guido Burkard
Konstanz

Ivan C. da Cunha Lima
Rio de Janeiro

John Schliemann
Regensburg

Antônio Azevedo
Recife

Luiz Davidovich
Rio de Janeiro

Michael Flatté
Iowa

Paul M. Koenraad
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Peter Zoller
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São Paulo

Seigo Tarucha
Tokyo

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São Carlos

Yaroslav Tserkovnyak
Los Angeles

Maria José S.P. Brasil
Campinas

Social Program

Welcome reception
Hotel Anacã
Sunday, October 31, 19:30

Churrasco
BBQ-"Brazilian style"
Wednesday, November 3, 12:30

Special Events

Workshop: Meet the Editors

Wednesday, November 3, 10:30 – 12:00

FAPESP: Funding opportunities & International cooperation programs

Thursday, November 4, 16:15 – 17:15

Round Table: Grünberg, Loss, Flatté, Zoller

Friday, November 5, 14:00 – 15:00

Meet the Editors

Wednesday, November 03, 10:30 - 12:00

Talk by Peter Adams
The Physical Review: A Brief History
How to Deal with the Publication Process AND Feel Good About It

The Physical Review was created in 1893 and has grown considerably in size and sophistication since then. This talk will focus on the last $\tilde{4}0$ years of Phys Rev B in particular. It will discuss the history of the journal and explain how decisions regarding acceptance or otherwise of submitted articles are made. The ethics of performing research and the preparation of subsequent submissions to journals will be debated. The essential role played by referees in maintaining the standards of journals will be presented.

Tutorial for authors and Referees

Dr. Peter Adams, Editor of Physical Review B, and Dr. Yonko Millev, Senior Assistant Editor of Physical Review Letters, will present a tutorial for authors and referees. The Editors will provide useful information and tips for referees and authors. The information presented will be relevant to anyone who is looking to submit or review manuscript for any of the APS journals, or to anyone who would like to add to their knowledge and experience of the authoring and refereeing processes.

Talk by Yonko Millev
Physical Review Letters: What is in a name? What is in a Letter?

Physical Review Letters emerged in 1958 as the first letter-format journal covering all of physics when Sam Goudsmith embarked on the experiment of collecting the Letters to the Editor of Physical Review in a standalone APS publication. The idea has excelled, and the journal has become a leader in scientific publication through vigorous interaction with the community and critical self-assessment. This talk will build on the timeline of significant events and milestones in PRLs history in order to offer an insight into what the latest developments in the editorial process are and what plans the journal has for the foreseeable future.

FAPESP Funding & International cooperation

Thursday, November 4, 16:15 – 17:15

Prof. Osvaldo Novais de Oliveira Jr. representing FAPESP - The São Paulo Research Foundation - will present the funding opportunities within the state of São Paulo, the agreements and exchange programs between FAPESP and other funding agencies abroad and International cooperation programs. This should be particularly interesting for foreign participants by acquainting them with the many funding opportunities and possibilities for them to come to Brazil to carry out research as, e.g., as a postdoctoral associate, funded by FAPESP. Moreover, Brazilian students shall also benefit from this presentation by finding out about new possibilities for developing joint projects in collaboration with major research institutions abroad, with which FAPESP has exchange programs.

Minicourses

Check the full program on the back cover 1

MIN 1:
Quantum Information in Solid State Systems,
Daniel Loss 1
MIN 2:
Semiconductor Spintronics and Quantum Coherence,
M. E. Flatté 1
MIN 3:
Quantum Information with Quantum Optical Systems,
Peter Zoller 2
MIN 4:
The Spin on Electronics!,
Stuart Parkin 3

Plenary talks 5

PLE 1: Monday, 16:15 – 17:15
From Giant Magnetoresistance to World Energy Problems,
Peter A. Grünberg 5
PLE 2: Tuesday, 9:00 – 10:00
The EPR paradox: has the problem now been solved?,
Peter A. Grünberg 5
PLE 3: Wednesday, 9:00 – 10:00
Entanglement and decoherence: from Einstein and Schrödinger to quantum optics experiments,
Luiz Davidovich 6
PLE 4: Thursday, 9:00 – 10:00
Single and two-qubit gates for manipulating and detecting electron spin in quantum dots,
Seigo Tarucha 7

Invited Talks 8

INV 1: Thursday, 10:30 – 11:10
Multicolor entanglement,
Paulo Nussenzveig 8
INV 2: Thursday, 11:10 – 11:50
Mysteries of the intricate magnetic and transport properties of GaMnAs: lyrics by "The Mobility Edge", music by "The Impurity Band",
Ivan C. da Cunha Lima 9
INV 3: Thursday, 11:50 – 12:30
Charge separation by spin pumping in magnetic interfaces,
Antonio Azevedo 9
INV 4: Thursday, 14:00 – 14:40
Finite size superfluid: turbulence and granulation as a possible decoherence mechanism,
Vanderlei S. Bagnato 10
INV 5: Thursday, 14:40 – 15:20
Spin qubits in semiconductor and graphene quantum dots,
Guido Burkard 11
INV 6: Thursday, 15:20 – 16:00
Geometric Spin Hydrodynamics and Caloritronics,
Yaroslav Tserkovnyak 11
INV 7: Friday, 10:30 – 11:10
Spin Polarization of Carriers on Resonant Tunneling Diodes,
Maria José S. P. Brasil 12
INV 8: Friday, 11:10 – 11:50
The Interacting Semiconductor Hole Gas,
John Schliemann 13
INV 9: Friday, 11:50 – 12:30
Manipulation and analysis of a single magnetic impurity in semiconductors by STM,
Paul Koenraad 13

Tuesday Poster Session

Nov 2, 17:15 – 19:15 15

TUE 1:
Compensation domain walls in $Gd_{1-x}Co_x$ films,
A. Hrabec, S. Pizzini, L. Ranno 15

TUE 2:
Spin Multistability in a Semiconductor Microcavity,
T. K. Paraïso, M. Wouters, Y. Léger, F. Morier-Genoud, B. Deveaud-Plédran 15

TUE 3:
Using magnetotransport to determine the g-factor in graphite,
J. M. Schneider, L. Smrcka, P. Vasek, M. Potemski, M. Orlita, Z. Vyborny, N. A. Goncharuk, D. K. Maude, P. Svoboda 16

TUE 4:
Improving Electromagnetically Induced Transparency in Si:GaAs by Selective Pumping of Nuclear Spins,
A.R. Onur, M. Sladkov, A.U. Chaubal, C.H. van der Wal 17

TUE 5:
Electromagnetically Induced Transparency in a Semiconductor,
Alok U. Chaubal, Alexander R. Onur, Maksym Sladkov, Caspar H. van der Wal, Morten P. Bakker, Andreas D. Wieck, Dirk Reuter 18

TUE 6:
Low-Bias Negative Differential Resistance in Graphene Nanoribbon Superlattices,
Gerson J. Ferreira, Michael N. Leuenberger, Daniel Loss, J. Carlos Egues 18

TUE 7:
Many-body effects on the ρ_{xx} ringlike structures in two-subband wells,
Gerson J. Ferreira, Henrique J. P. Freire, J. Carlos Egues 19

TUE 8:
Ultrafast preparation and detection of arbitrary coherent dark states with donor-bound electrons in GaAs,
Sergii Z. Denega, Maksym Sladkov, Dirk Reuter, Andreas D. Wieck, Caspar H. van der Wal 20
TUE 9:
Time-resolved Magneto Luminescence from a resonant tunneling diode,
Helder Vinicius Avanco Galeti, Yara Galvão Gobato, Maria Jose S. P. Brasil, Mohamed Henini, G. Hill 20
TUE 10:
Strong correspondence principle for joint measurement of conjugate observables,
A. Di Lorenzo 21
TUE 11:
Spin-assisted Optical Transitions in Zincblende Quantum Wells with Two Subbands,
Thiago Schiavo Mosqueiro, Esmerindo Bernardes, J. Carlos Egues 21
TUE 12:
Spin susceptibility of interacting two-dimensional electrons in the presence of Rashba spin-orbit coupling [1],
Robert Andrzej Żak, Dmitrii Maslov, Daniel Loss . 22
TUE 13:
Spin Relaxation in Silicon Based Quantum Dots,
Martin Raith, Peter Stano, Jaroslav Fabian 23
TUE 14:
Entanglement dynamics of two strongly driven qubits interacting with a cavity,
Marcin Dukalski, Ya. M. Blanter 23
TUE 15:
Analytical approach for the dipolar switching field distribution broadening and shearing of the hysteresis loop in bistable magnetic particle assemblies,
J. M. Martínez Huerta, J. de La Torre Medina, L. Piraux, A. Encinas 24
TUE 16:
A Theoretical Model of Single Photon Source at Room Temperature ,
Ahmed Elhalawany, Michael N. Leuenberger 24

TUE 17:
Spin-active Scattering in Superconductor-Ferromagnet Hybrid Devices, Roland Grein, Matthias Eschrig, Tomas Löfwander, Georgo Metalidis, Gerd Schön 25

TUE 18:
Anholonomic spin manipulation in drift transport in semiconductors, Ben J. Moehlmann, Michael E. Flatté 26

TUE 19:
Energy Spectra of Electrons in Spin-Orbit Wires, Vanita Srinivasa, Jeremy Levy 26

TUE 20:
Hybrid entangled stated in a parabolic quantum dot with spin-orbit and Magnetic field., Carlos Ochoa and Fernando Rojas 27

TUE 21:
A spin polarizing device through decoherence, Luis A. González-Árraga, Ernesto Medina 27

TUE 22:
Effects of scattering area shape on spin conductance in a four-terminal spin-Hall setup, Gunnar Thorgilsson, Sigurdur I. Erlingsson 28

TUE 23:
Analysis of the environment influence on the measurement process in two level quantum systems using the Lindblad equation, Carlos Alexandre Brasil and Reginaldo de Jesus Napolitano 28

TUE 24:
Polarized resolved Photoluminescence studies in self assembled Quantum Dots, J. A. Nobrega, Y. Galvão Gobato, G. E. Marques, D. Taylor, M. Henini 29

TUE 25:
Polarized Resolved Photoluminescence in n-type Resonant Tunneling Diodes with a Si Delta-Doping Layer in the Quantum Well, L. Herval, Y. Galvão Gobato, D. Taylor, M. Henini, G. E. Marques 30

TUE 26:
Fabrication and Magnetic Response of Cobalt Nanowires with Reduced Diameter, P. Schio, , F. Vidal, Y. Zheng, D. Demaille, A. J. A. de Oliveira, V. H. Etgens 30

TUE 27:
High Speed Single Dopant Spin Manipulation with a Single Electrical Gate, Victoria Povilus and Michael Flatté, ... 31

TUE 28:
Equilibrium spin currents in mesoscopic rings with spin-orbit interactions coupled to an electron reservoir, Michael E. Ellner, Luis A. González-Árraga, Ernesto Medina 32

TUE 29:
EXAFS and XANES of Ca2MnReO6 under pressure up to 1.2 GPa, Danilo O. Souza, H. P. S. Correa, M. T. D. Orlando 32

TUE 30:
New materials with perpendicular anisotropy for spin-torque experiments, M. Gottwald, S. Girod, G. Lengaigne, F. Montaigne, M. Hehn, S. Andrieu, S. Mangin, B. J. Krishnatreya, J-M. L. Beaujour, A. D. Kent, N. Vernier, D. Ravelosona 33

TUE 31:
Counting statistics of transport through chaotic cavities, Marcel Novaes 34

TUE 32:
Resonances states in atomic and quantum dot models, Federico M. Pont, Omar Osenda, Pablo Serra . . . 34

TUE 33:
Casimir effect revisited and vacuum fluctuations, Rommel R. Oliveira 35

TUE 34:
Kondo effect and transport properties in quantum dot system: a study via Numerical renormalization group, Gisele Iorio Luiz, Edson Vernek, E.V.Anda, K. Ingersent 35

TUE 35:
Polarization Resolved Electroluminescence Investigations of p-i-n GaAs/AlAs Resonant Tunneling Diodes ,
I. Taj Awan, H. V. Avanço Galeti, Y Galvão Gobato, G. E. Marques, G. Hill, M. Henini 36

TUE 36:
Spin-polarized currents in nano-structures: Study of the role of electron-electron interactions,
Enrique Montes, Thereza Paiva 37

TUE 37:
Coherent excitation dynamics in the photocurrent signal,
Marcelo Z. Maialle, Marcos H. Degani 37

TUE 38:
Spin-Orbit Interaction in Inversion-Symmetric Semiconductors,
Cuneyt Sahin, Michael E. Flatté, Giovanni Vignale 38

TUE 39:
Quantum Correlations in Spin Chains at Finite Temperatures and Quantum Phase Transitions,
T. Werlang, C. Trippe, G. A. P. Ribeiro, Gustavo Rigolin 38

TUE 40:
Numerical Investigation of Shape, Doping, and Width Influence on Rasbha Spin-Orbit Coupling in AlInSb Quantum Wells,
Joseph Pingenot, Kieran Mullen 39

TUE 41:
Classical-to-Quantum transition of a cavity field interacting with atoms,
Daniel Zini Rossatto, Thiago Werlang, Eduardo Inácio Duzzioni, Celso Jorge Villas-Bôas 41

TUE 42:
Entangling remote nuclear spins linked by a chromophore,
M. Schaffry, V. Filidou, S. D. Karlen, E. M. Gauger, S. C. Benjamin, H. L. Anderson, A. Ardavan, G. A. D. Briggs, K. Maeda, K. B. Henbest, F. Giustino, J. J. L. Morton, B. W. Lovett 42

TUE 43:
Spin-dependent transport through a Dirac delta potential coupled to a harmonic coordinate,
F. C. Penha, Beat Röthlisberger, Daniel Loss, J. Carlos Egues 42
TUE 44:
Spin orbit mediated entanglement in graphene,
Alexander Lopez and John Schliemann 43
TUE 45:
Microwave Detection in a Magnetic Single-Electron Transistor ,
Scott Bender, Arne Brataas, Yaroslav Tserkovnyak 44
TUE 46:
Dielectric properties and magnetization of gapped graphene,
Andreas Scholz, John Schliemann 44
TUE 47:
Low temperature transport study of InAs/InP core/shell quantum dot devices,
Eduardo J. H. Lee, Georgios Katsaros, Xiaocheng Jiang, Charles M. Lieber, Silvano De Franceschi . . 45
TUE 48:
Transport and local magnetism in zigzag graphene nanoribbons,
R.M. Guzmán Arellano, Gonzalo Usaj 46
TUE 49:
Near Field Photon Emission and Revival in Quantum Dots Embedded in Dielectric Microcavities,
Sergio Tafur and Michael N. Leuenberger 46

Thursday Poster Session

Nov 4, 17:15 – 19:15 47

THU 1:
Single-qubit lasing in the strong-coupling regime, Stephan André, Pei-Qing Jin, Valentina Brosco, Jared H. Cole, Alessandro Romito, Gerd Schön . . 47

THU 2:
The guidance of vortex-antivortex pairs by in-plane magnetic dipoles in a superconducting finite-size film, A. V. Kapra, V. R. Misko, D. Y. Vodolazov, F. M. Peeters 48

THU 3:
Different types of integrability and their relation to decoherence in central spin models, B. Erbe, J. Schliemann 49

THU 4:
Spin-Polarized Scanning Tunneling Microscopy, E.P. Smakman, R. van Voornveld, J.G. Keizer, J.K Garleff, P.M. Koenraad 49

THU 5:
Hyperfine interaction in electron spin qubits in quantum dots coupled via an optical cavity, Julia Hildmann, Guido Burkard 50

THU 6:
Angular Dependence of Magnetoelectric effect with electrical polarization direction in $(1-x)Pb(Mg_{1/3}Nb_{2/3})-xPbTiO_3/NiFe_2O_4$ composite, Alexandre Jose Gualdi, Fabio Zabotto, Ducinei Garcia, Adilson Jesus Aparecido de Oliveira 50

THU 7:
Emergence of the persistent spin helix in semiconductor quantum wells, Jake Koralek, Joe Orenstein, Luyi Yang, Chris Weber, David Awschalom, Shawn Mack, Mike Lilly . 51

THU 8:
Studies on the ensemble of Wishart-Tsallis random matrices, Felippe Otavio Souza de Almeida, Andre Mauricio C. de Souza 51

THU 9:
Spin polarized electrons generated in core-shell nanowires,
V.V. Ravi Kishore, B. Partoens, F.M. Peeters . . . 52

THU 10:
***Zitterbewegung*-induced Spin Resonance in Quantum Wires**,
Marco O. Hachiya, Gonzalo Usaj, J. Carlos Egues 52

THU 11:
Ferromagnetic Instabilities in Cylindrical Quantum Wires,
Udson C. Mendes, Salviano A. Leão, Gerson J. Ferreira, J. Carlos Egues 53

THU 12:
Exchange driven ferromagnetic instabilities at high magnetic fields in quantum wires via DFT,
Filipe Sammarco, Gerson J. Ferreira, J. Carlos Egues 54

THU 13:
Quantum critical behavior and magnetism of antiferromagnetic Cr-Ti alloys,
A. L. S. Varella, A. J. A. de Oliveira 55

THU 14:
Generalization of superconducting qubit and qudit architecture,
Krzysztof Pomorski, Przemyslaw Prokopow 55

THU 15:
Tunneling induced transparency in coupled semiconductor quantum dots,
Halyne S. Borges, Augusto M. Alcalde, Liliana Sanz 56

THU 16:
Strong Light-Mater Coupling in Quantum Dot-Nanocavity System,
J. M. Villas-Bôas, A. Laucht, M. Kaniber, J. J. Finley 56

THU 17:
Spin relaxation of electrons in InGaAs/GaAs quantum wells with d-(Mn) doped barriers,
Miguel A.G. Balanta, Rossano Lang, M.J.S.P. Brasil, F. Iikawa, Yu. A. Danilov, M.V. Dorokhin, O.V. Vikhrova, B.N. Zvonkov 57

THU 18:
Ion-induced epitaxy in Fe^+ implanted SiO_2/Si: synthesis and optical characterization of $FeSi_2$ nanoparticles,
Rossano L. Carvalho, Livio Amaral, Eliermes A. Meneses, Fernando Iikawa 58
THU 19:
Phase dependent spin manipulation in quantum dot,
Ted S. Santana, José M. Villas-Bôas 59
THU 20:
Quantum simulation of a two-Component Bose-Einstein Condensate using a NMR quadrupolar system,
R. Auccaise, E. R. de Azevedo, T. J. Bonagamba, M. H. Y. Moussa 59
THU 21:
Study of Electronic Properties of Quantum Rings,
Vivaldo Lopes, Victor Lopez-Richard 60
THU 22:
Non-Abelian formulation for Rashba and Dresselhaus coupling and the spin currents,
Alexander López, Ernesto Medina Dagger, Nelson Bolívar, Bertrand Berche 61
THU 23:
Growth and characterization of MnGa epilayers on GaAs,
Alexandre Werner Arins, Dante Homero Mosca . . 61
THU 24:
Spin Coherence in Graphene Nanoribbons,
Matthias Droth and Guido Burkard 62
THU 25:
Effects of the interfaces in the anisotropic magnetoresistance in Ta/NiFe/Ta trilayers,
T. J. A. Mori, L. S. Dorneles, L. F. Schelp 63
THU 26:
Simulations and Magnetoelasticity of Mnas epilayers on GaAs,
V.Z.C.Paes, J. Varalda, V. H. Etgens, D.H. Mosca 64
THU 27:
State protection application in Deutsch's algorithm,
M. M. Santos, E. I. Duzzioni 64

THU 28:
Self-correcting quantum memory in a thermal environment,
Beat Röthlisberger, Stefano Chesi, Daniel Loss . . 65

THU 29:
Electronic Transport Properties of Superconductor/Semiconductor-Nanowire/Superconductor Hybrid Devices,
H. Y. Günel, I. E. Batov, H. Hardtdegen, K. Sladek, A. Penz, R. Calarco, G. Panaitov, D. Grützmacher, Th. Schäpers 66

THU 30:
Local quantum control of Heisenberg spin chains,
Vladimir M. Stojanovic, R. Heule, C. Bruder, D. Burgarth 67

THU 31:
Method for Cooling Nanostructures to Microkelvin Temperatures,
L. Casparis, D.M. Zumbuhl, A.C. Clark, T. Bandi, D. Maradan, K.K. Schwarzwaelder 67

THU 32:
Nuclear Spin Relaxation in an All-Electrical Lateral Spin Transport Device,
D. Koelbl, S. F. Alvarado, A. Fuhrer, D. Salis, D. M. Zumbuhl 68

THU 33:
Nonadiabatic Quantum Computation by Dynamic Invariants,
R. M. Serra, E. I. Duzzioni, M. S. Sarandy 68

THU 34:
Tripartite entanglement and disentanglement for finite losses,
A. S. Coelho, F. A. S. Barbosa, K. N. Cassemiro, A. S. Villar, M. Martinelli, P. Nussenzveig 69

THU 35:
Laser noise correlations induced by cold atoms in Hanle /EIT conditions,
Hans Marin Florez, Laercio Benedito, Marcelo Martinelli, Paulo Nussenzveig 70

THU 36:
Spin Injection from Ferromagnetic Contacts into Semiconductor Nanowires,
S. Heedt, K. Weis, C. Morgan, Th. Jansen, R. Schreiber, D. Bürgler, T.-Y. Yang, B. Beschoten, R. Calarco, D. Grützmacher, Th. Schäpers 70
THU 37:
Disentanglement for Partial Losses in Bipartite Systems,
F. A. S. Barbosa, A. S. Coelho, A. J. de Faria, K. N. Cassemiro, A. S. Villar, P. Nussenzveig, M. Martinelli 71
THU 38:
Spin-orbit and strain effect on graphene and graphene nanoribbons,
M. R. Guassi, Fanyao Qu 72
THU 39:
Electrical control of spin-ordering in few-electron lateral quantum dot molecules,
Damaso R. Santos Jr., Victor Lopez-Richard, Qu Fanyao, Gilmar E Marques 72
THU 40:
Dynamic Properties of Carbon Nanotubes Based Quantum Hybrid Circuits,
M. R. Delbecq, T. Kontos 73
THU 41:
Reactivity of interface Mn/GaAs,
Marlon Vinícius Soares, Dante Homero Mosca . . . 73
THU 42:
Quantifying decoherence in spin channels through Loschmidt Echo,
P.R. Zangara, A.D. Dente, P.R. Levstein, H.M. Pastawski 74
THU 43:
Electronic Transport through Synchronized Systems ,
Axel D. Dente, Horacio M. Pastawski 74
THU 44:
Transport through a magnetic domain wall in the presence of Decoherence,
Lucas J. Fernández, Horacio M. Pastawski 75
THU 45:
Photon Assisted Spin-polarized Current,
Fabricio M. Souza 76

THU 46:
Spin asymmetric interactions and Landau-Fermi liquid instabilities,
P. Rodríguez Ponte, D.C. Cabra, N. Grandi 76

THU 47:
Spin-orbit coupling in InAs-based wurtzite quantum well,
J. Y. Fu, Poliana H. Penteado, J. Carlos Egues . . 77

THU 48:
Transfer of two Q-bit states using fiber optical coupled cavities with one or two coletive modes,
J. C. Gonzalez, J. A. Roversi 77

THU 49:
Ferromagnetic STM tip operating as a Spin-diode,
Poliana H. Penteado, Fabrício M. Souza, Antônio C. Seridonio, Renato M. Coutinho, Edson Vernek, J. Carlos Egues 78

THU 50:
1D cold photoassociative ionization of Na inside a storage ring,
R.R. Paiva, R. Muhammad, R. Shiozaki, A. L. de Oliveira, K. M. F. Magalhães, O. Morizot, V. S. Bagnato 79

THU 51:
Brazilian Atomic Fountain: Current Status and Future Developments,
Felipe Arduini Otoboni, Aida Bebeachibuli, Renato Ferracini Alves, Stella Torres Müller, Vanderlei Salvador Bagnato, Daniel Varela Magalhães 80

THU 52:
Spin-resolved STM for a Kondo adatom in a ferromagnetic island,
A. C. Seridonio, F. S. Orahcio, M. S. Figueira . . . 80

THU 53:
Dissipative dynamics in coupled quantum dots: Protection of states,
Augusto Alcalde, Halyne Silva Borges, Liliana Sanz 81

THU 54:
Equation of State of a Harmonically Trapped ^{87}Rb gas: BEC Transition and zero-Temperature Pressure analyses,
R. F. Shiozaki, E. A. L. Henn, M. A. Caracanhas, J. A. Seman, K. M. F. Magalhães, V.S. Bagnato, G. Roati, V. Romero-Rochin 82
THU 55:
New system for production of quantum fluids to study mesoscopic quantum effects,
J. A. Seman, F. J. Poveda-Cuevas, P. C. Castilho, R. Benevides, C. E. Máximo, K. M. F. Magalhães, S. R. Muniz, V. S. Bagnato 82
THU 56:
Cooperative Two-photon Absorption by Colliding Sodium Atoms in a Magneto Optical Trap,
E.E. Pedrozo, R.R. Paiva, V.S. Bagnato, K.M.F. Magalhães 83
THU 57:
Tunability of *p-d* exchange interaction in single-Mn doped double quantum dots: Electrical and intense laser field effects,
Fanyao Qu, L. Villegas-Lelovsky, Fabrízio M. Alves 84
THU 58:
Phenomenological study of field induced Josephson junctions,
Krzysztof Pomorski, Przemyslaw Prokopow 85

Minicourses

Check the full program on the back cover

MIN 1:

Quantum Information in Solid State Systems

Daniel Loss

University of Basel

I introduce and review the basic concepts for spin qubits in quantum dots and scalable quantum computers in solid-state systems [1]. I start with the standard model of quantum computing and the basic criteria for its realization. Other alternative formulations such as measurement-based and adiabatic quantum computing are discussed. I then focus on spin qubits in single and double GaAs electron quantum dots and discuss initialization, coherent manipulation and readout of the spin states. I address the problem of decoherence in this system, mainly due to spin orbit and hyperfine interaction, with particular emphasis on its theoretical treatment and possible ways to overcome it. I discuss the experimental status of the field. The concept of a quantum memory is introduced and its representation in terms of an extended toric code model.

[1] See review: R. Żak, B. Röthlisberger, S. Chesi, and D. Loss, Rivista del Nuovo Cimento **033**, 345 (2010), arXiv:0906.4045.

MIN 2:

Semiconductor Spintronics and Quantum Coherence

M. E. Flatté

Optical Science and Technology Center and Department of Physics and Astronomy, University of Iowa, Iowa City, Iowa, 52242, USA

Spin dynamical systems in semiconductors span a range of materials and regimes from clean to dirty, ferromagnetic to paramagnetic, large spin ensemble to single spin realization, and low temperature to high temperature. The spins involved can be electrons, holes, ions, or nuclei. Semiconductors themselves are among the most flexible material systems, for they can exhibit metallic or insulating behavior, they can strongly couple to light, and their properties can be substantially tuned with moderate external fields. This series of four lectures will span the range of physical and material phenomena exhibited by semiconductors that are associated with spin dynamics.

The first lecture will emphasize the electronic properties of nonmagnetic semiconductors, including traditional models for describing their electronic structure including spin-orbit interactions, especially based on envelope-function (k.p) models and tight-binding models. The resulting effective spin-orbit Hamiltonians will be described, along with their effect on spin coherence times and spin transport (especially the spin Hall effect and current-induced spin polarization). Modifications of these spin-orbit Hamiltonians when semiconductor heterostructures and nanostructures are considered will be described, including the physical mechanisms behind electric field control of spin precession axes. The state of the art for numerically evaluating spin dynamical properties, such as g factors, spin Hall conductivities, spin drag, and spin coherence times, will be outlined.

The second lecture will describe the building blocks for ferromagnetism in semiconductors, starting from the properties of individual magnetic impurities and developing from them the theoretical models currently under consideration for dilute magnetic semiconductors. Similarities and differences between such ferromagnetic semiconductors and both ferromagnetic metals and ferromagnetic insulators will be emphasized, along with recent experimental probes of the electronic structure of magnetic semiconductors. The effects of external perturbations on the ferromagnetic state, including electric field and strain, will be described, especially the effects on magnetic anisotropy and spin precession. Differences based on host semiconductor type and magnetic dopant type will be described, as well as some of the challenges of distinguishing a true dilute magnetic semiconductor material from a phase-separated matrix.

The third lecture will explore the coupling between semiconductor spin systems and optical fields, from the single-spin/single-photon limit to the interaction of coherent light fields with large ensembles of spin-polarized carriers in semiconductors. Optical selection rules, and their corresponding consequences will be enumerated, including coherent generation of spin currents using optical interference. Methods of coherently rotating spins using the shift in electronic energy levels caused by intense optical fields will also be described.

The final lecture will outline some of the device proposals that have emerged from the above unique properties of semiconductor spin systems, including high-speed, low-power spin-based transistors, hybrid logic devices and spin-based teleportation schemes. Comparison with other approaches, and ideal limits for device functionality will be discussed.

MIN 3:

Quantum Information with Quantum Optical Systems

Peter Zoller

Institute for Theoretical Physics, University of Innsbruck, and Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, Innsbruck, Austria

Quantum optical systems allow control on the single quantum level in the laboratory, and thus are ideal systems to implement various quantum information protocols. The purpose of the present lectures is to provide an introduction to quantum computing and quantum simulation with quantum optical systems including trapped ions and atoms in optical lattices, and describe some of the recent developments.

Lectures 1, 2 and 3: Trapped ions and atoms in optical lattices - an introduction: We develop theoretical models for quantum computing with trapped ions, in particular we describe the physics behind quantum gates, as well as quantum simulation of Hubbard models with bosonic and fermionic atoms in optical lattices. In addition, we summarize some of the basic techniques of theoretical quantum optics including coherent control and modelling open quantum systems.

Lecture 4: Advanced Topics: In the last lecture we will focus on some recent developments. This includes an open system quantum simulator, and quantum interfaces between atomic and solid state systems.

MIN 4:

The Spin on Electronics!

Stuart Parkin, IBM Fellow

IBM Almaden Research Center, San Jose, California

Today, nearly all microelectronic devices are based on storing or flowing the electrons charge. The electron also possesses the quantum mechanical property of “spin that gives rise to magnetism. Electrical current is comprised of “spin-up and “spin-down electrons, which behave as largely independent spin currents. The flow of these spin currents can be controlled in thin-film structures composed of atomically thin layers of conducting magnetic materials separated by non-magnetic conducting or insulating layers. The resistance of such devices, so-called spin-valves and magnetic tunneling junctions, respectively, can be varied by controlling the relative magnetic orientation of the magnetic layers, giving rise to magnetoresistance tailored for different applications. In the first part of my lectures I will introduce the basic concepts underlying spin transport in metals and metallic heterostructures and of spin dependent tunnelling in magnetic tunnel junction devices. I will discuss three terminal devices using tunnel spin injectors and show how these can be used to explore the physics of the spin dependent scattering of “hot electrons in metals. I will also show how tunnel spin injectors allow for the injection of highly spin polarized electron currents into semimetal and semi-conducting materials.

The ability to generate, manipulate and detect spin-polarized electrons and electrical current make possible new classes of spin based sensor, memory and logic devices, generally referred to as the field of spintronics. The most important application, to date, of spintronics has been the development of highly sensitive detectors of small magnetic fields for use in recording read heads of magnetic disk drive. Our invention and development of such sensors which we called spin-valves- enabled a 1,000-fold increase in the storage capacity of disk drives in the decade following their introduction by IBM in late 1997 [1]. I will discuss the fundamentals of “spin engineering that made such sensors possible. Since 1997 the basic magnetic structure of such sensing devices has remained the same but the physics has changed from that of spin diffusive transport in metallic magnetic multi-layered structures to that of spin dependent tunnelling across ultra-thin tunnel barriers separating thin magnetic electrodes. The latter give rise to much larger magnetoresistance effects than is possible in devices based on spin diffusive transport. I will discuss the physics of spin dependent tunnelling and how the degree of spin polarization of the tunnelling current can be directly measured by replacing one magnetic electrode with a superconducting layer. The latter, in the presence of large magnetic fields, acts as an almost perfect spin detector. In the last part of my lectures I will discuss another important spintronic concept, namely that of manipulating magnetic moments by the flow of currents of spin polarized electrons through or into magnetic regions. Since the current carries spin angular momentum the delivery of such angular momentum can cause the rotation and eventual reversal of direction of magnetic regions. This has important potential application in magnetic memory and logic devices.

The storing of data in the magnetic states of magnetic tunnel junction has the potential to realize a novel, high performance random access solid state memory which maintains its memory in the absence of electrical power. Such a memory would have high performance and high reliability but would also, like all conventional solid state memories, have a much higher cost per bit than that of magnetic disk drive storage devices. In the last part of my lectures I will discuss a novel three dimensional technology- the Racetrack Memory - which uses nanosecond long pulses of spin-polarized current to move a series of magnetic domain walls along magnetic nanowires [2]. I will discuss the physics of the field and current induced dynamics of magnetic domain walls in magnetic racetracks.

[1] Stuart Parkin *et al.*, *Magnetically engineered spintronic sensors and memory*. Proc. IEEE **91**, 661-680 (2003).

[2] S.S.P. Parkin *et al.*, Science **320**, 190 (2008).

Plenary talks

PLE 1: Monday, 16:15 – 17:15

From Giant Magnetoresistance to World Energy Problems

Peter A. Grünberg

Research Center Jülich, IFF, 52428 Jülich, Germany

I want to start the lecture by discussing global energy consumption comparing computers and air traffic, which are alternatives for global communication. When oil resources will be exhausted the importance of video conferences and skyping via computer will increase. Therefore it is also of interest to discuss the energy consumption of computers. I shall do that by focusing on the evolution of recording heads for magnetic storage. Inductive writing and reading will be compared to sensors based on various magnetoresistance effects (XMR). Of particular importance here is also the development of non-volatile magnetic random access memories (MRAMs). Current Dynamic Random Access Memories (DRAMs) are volatile and therefore have high power consumption. Further developments, also interesting from the viewpoint of low energy consumption, are "current induced magnetic switching" and "spin currents".

PLE 2: Tuesday, 9:00 – 10:00

The EPR paradox: has the problem now been solved?

Peter A. Grünberg

Research Center Jülich, IFF, 52428 Jülich, Germany

Einsten, Podolsky, and Rosen have proposed a paradox questioning the Heisenberg uncertainty principle. However, experiments with entangled photons seem to prove the principle.

PLE 3: Wednesday, 9:00 – 10:00

Entanglement and decoherence: from Einstein and Schrödinger to quantum optics experiments

Luiz Davidovich

Instituto de Física, Universidade Federal do Rio de Janeiro, 21941-972 Rio de Janeiro, Brazil

The dynamical behavior of entanglement, for a multi-partite system interacting with individual and independent environments, can be quite different from the typical time dependence expected for the constituents of the system. Even when each part of the system decays asymptotically in time, due to the action of its own environment, entanglement may vanish at a finite time. The robustness of entanglement, and specially its behavior under size scaling, has practical implications, related to the viability of quantum computers, as well as fundamental ones, concerning the classical limit of quantum mechanics, which are directly related to conceptual problems raised by Einstein and Schrödinger. Entangled photon beams have allowed the experimental investigation of this dynamics in a controllable way [1, 2, 3]. This talk will discuss recent experimental [1, 2, 3] and theoretical [4, 5, 6, 7, 8] progress on this question, involving the study of the detailed dynamics and the robustness of several kinds of multiparticle entangled states.

[1] M. P. Almeida, F. de Melo, M. Hor-Meyll, A. Salles, S. P. Walborn, P. H. Souto Ribeiro, and L. Davidovich. *Environment-induced sudden death of entanglement.* Science **316**, 579 (2007).

[2] A. Salles, F. de Melo, M. P. Almeida, M. Hor-Meyll, S. P. Walborn, P. H. Souto Ribeiro, and L. Davidovich. *Experimental investigation of the dynamics of entanglement: Sudden death, complementarity, and continuous monitoring of the environment*, Phys. Rev. A, **78**, 022322 (2008).

[3] O. Jimenez Farias, C. Lombard Latune, S. P. Walborn, L. Davidovich, and P. H. Souto Ribeiro, *Determining the Dynamics of Entanglement.* Science **324**, 1414 (2009).

[4] M. França Santos, P. Milman, L. Davidovich, and N. Zagury, *Direct measurement of finite-time disentanglement.* Phys. Rev. A **73**, 040305, Rapid Communication (2006).

[5] L. Aolita, R. Chaves, D. Cavalcanti, A.Acín, and L. Davidovich. *Scaling laws for the decay of multiqubit entanglement.* Phys. Rev. Lett. **100**, 080501 (2008).

[6] Daniel Cavalcanti, Rafael Chaves, Leandro Aolita, Luiz Davidovich, and Antonio Acín, *Open-system dynamics of graph-state entanglement.* Phys. Rev. Lett. **103**, 030502 (2009).

[7] L. Aolita, D. Cavalcanti, R. Chaves, C. Dhara, L. Davidovich, and A. Acín. *Noisy evolution of graph-state entanglement.* Phys. Rev. A **82**, 032317 (2010).

PLE 4: Thursday, 9:00 – 10:00

Single and two-qubit gates for manipulating and detecting electron spin in quantum dots

Seigo Tarucha

Department of Applied Physics, The University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-8656, Japan

To date various kinds of techniques of implementing spin-based quantum computing with quantum dots have been developed. Among them single qubit and two-qubit gates are fundamental building blocks to prepare a universal set of logical operations. In this talk I will review the current status of spin qubit technologies with an emphasis on our recent work: micro-magnet technique for double quantum dots in realizing scalable spin qubits, two-qubit gates, and non-destructive spin readout.

Electron spin resonance is the fundamental concept of spin qubits, in which two Zeeman states are defined by a static magnetic field and superposed by an ac magnetic field normal to the static field. One of the ways to manipulate individual electron spin in quantum dots in a scalable manner is to make both magnetic fields local to each quantum dot. We have developed a combined technique of a micro-magnet and ac electric field (or microwave field) to meet this requirement. A micro-magnet placed on top of quantum dots imposes two static stray fields: an out-of plane field gradient and an in-plane field both local to each quantum dot. Oscillation of an electron inside the dot driven by a microwave field can generate an a.c. magnetic field local to the dot. The in-plane field and external field are added up to generate a total in-plane field or Zeeman field local to the dot. We apply this technique for a double quantum to make two spin qubits, and then a two-qubit gate including SWAP and spin rotation. This two-qubit gate operates on a non-entangled state to control and selectively detect the weight of a spin singlet state, typical spin entangled state, included in the output state.

We also use the micro-magnet technique to readout the spin state in a non-destructive manner. Because the Zeeman field is different between the two dots, as described above, the inter-dot photon (or microwave) assisted resonant tunneling occurs at different microwave frequencies between up-spin electrons and down-spin electrons. This inter-dot tunneling tends to delocalize an electron between the dots, resulting in a change of the averaged charge distribution. This change in the charge state can be detected using a charge sensing technique. Finally, I will discuss a dephasing problem due to fluctuating hyperfine field.

Invited Talks

INV 1: Thursday, 10:30 – 11:10

Multicolor entanglement

Paulo Nussenzveig

Instituto de Física, Universidade de São Paulo

Entangled beams of light hold promise of efficient communication of quantum and classical information [1]. At present, no single quantum hardware is known to possess all the necessary properties in order to build scalable quantum technologies, especially for quantum computing [2]. It is thus appealing to devise ways of communicating information among different physical systems, which interact with light at different frequencies. Multicolor entangled light beams enable such quantum communication. In this talk, I will discuss the generation of bright three-color entanglement [3-6]. Furthermore, we also address the issue of communication losses and the possibility of complete disentanglement for partial losses [7], an effect reminiscent of entanglement sudden death [8].

[1] T. C. Ralph and P. K. Lam, *A bright future for quantum communications*, Nature Photonics **3**, 671 (2009).

[2] T. D. Ladd, F. Jelezko, R. Laflamme, Y. Nakamura, C. Monroe and J. L. O'Brien, *Quantum Computers*, Nature **464**, 45 (2010).

[3] A. S. Villar, L. S. Cruz, K. N. Cassemiro, M. Martinelli and P. Nussenzveig, *Generation of Bright Two-Color Continuous Variable Entanglement*, Phys. Rev. Lett. **95**, 243603 (2005)

[4] A. S. Villar, M. Martinelli, C. Fabre and P. Nussenzveig, *Direct Production of Tripartite Pump-Signal-Idler Entanglement in the Above-Threshold Optical Parametric Oscillator*, Phys. Rev. Lett. **97**, 140504 (2006).

[5] A. S. Villar, K. N. Cassemiro, K. Dechoum, A. Z. Khoury, M. Martinelli, and Paulo Nussenzveig, *Entanglement in the above-threshold OPO*, J. Opt. Soc. Am. B **24**, 249 (2007).

[6] A. S. Coelho, F. A. S. Barbosa, K. N. Cassemiro, A. S. Villar, M. Martinelli and P. Nussenzveig, *Three-color entanglement*, Science **326**, 823 (2009).

[7] F. A. S. Barbosa, A. S. Coelho, A. J. de Faria, K. N. Cassemiro, A. S. Villar, P. Nussenzveig and M. Martinelli, *Robustness of bipartite Gaussian entangled beams propagating in lossy channels*, Nature Photonics, Advance Online Publication, DOI: 10.1038/NPHOTON.2010.222 (Published Online 17 October 2010).

[8] T. Yu and J. H. Eberly, *Sudden Death of Entanglement*, Science **323**, 598 (2009).

INV 2: Thursday, 11:10 – 11:50

Mysteries of the intricate magnetic and transport properties of GaMnAs: lyrics by "The Mobility Edge", music by "The Impurity Band"

Ivan C. da Cunha Lima

State University of Rio de Janeiro - Brazil

We discuss the intriguing inter-related magnetic and transport properties in GaMnAs since the non-metal-to-metal (and *vice versa*) transitions were observed on the very first samples obtained, in association to the existence of ferromagnetic phases. We introduce the concept of an impurity band, the difficulties concerning the mobility edge, and the nature of states as extended or localized. Observations of optical and transport behavior point to the origin of this results as caused by an impurity band. We will present our recent theoretical results leading to the definition of a figure of merit for the metallic behavior of a particular sample, explain the possible origin of the transitions, and show how the existence of an impurity band would appear in the curve resistance versus temperature in a layered structure.

INV 3: Thursday, 11:50 – 12:30

Charge separation by spin pumping in magnetic interfaces

Antonio Azevedo

Departamento de Física, Universidade Federal de Pernambuco, 50670-901, Recife PE Brazil

In the last few years it has been realized that a complete control of spins in metallic and semiconductors materials could lead to the development of novel data processing schemes and to the discovery of remarkable new effects. Since the discovery of transport and generation of dc spin-polarized current, the development of devices based on the spin-valve effect brought the spin electronics to the daily life. Due to the static nature of the giant magnetoresistance (GMR) effect, most of the development in this area has been concentrated in dc spin transport. Recently, the discovery of current-driven magnetization dynamics [1] increased the interest for spin-polarized ac transport. In this work we will explore the dynamic effect known as spin pumping, which occurs when the precessing magnetization vector of a ferromagnet injects a pure spin current into an adjacent non-magnetic metal. While in spin-polarized current there a net transfer of charge, in a pure spin current there is only transport of angular moment. By using the spin pumping effect we were able to investigate the generation of an in-plane dc voltage in ferromagnetic/non-magnetic (FM/NM) bilayers, under ferromagnetic resonance excitation [2, 3]. The dc voltage results from the phenomenon known

as inverse spin Hall effect where a dc charge current is generated perpendicularly to a pure spin current. In this work different ferromagnetic metals (Permalloy) and insulators (YIG) were used to inject pure spin current into an adjacent metal of Pt. By attaching Cu electrodes on the Pt surface we directly measured the in-plane dependence of the dc voltage as a function of the FM and NM layer thicknesses as well the as microwave power. The line shape of the dc voltage has an angular dependence that is well explained by two different effects: (i) dc voltage due to anisotropic magnetoresistance (AMR) (caused by the presence of an induced current flowing through the FM layer), (ii) dc voltage due to injection of the pure spin current in the NM material (caused by the inverse spin Hall effect).

[1] S. M. Rezende, F. M. de Aguiar, and A. Azevedo, *Spin-Wave Theory for the Dynamics Induced by Direct Currents in Magnetic Multilayers*, Phys. Rev. Lett. **94**, 037202 (2005).

[2] A. Azevedo, L. H. Vilela Leão, R. L. Rodriguez-Suarez, A. B. Oliveira, and S. M. Rezende, *dc effect in ferromagnetic resonance: Evidence of the spin-pumping effect?*, J. Appl. Phys. **97**, 10C715 (2005).

[3] A. Azevedo, L. H. Vilela-Leão, R. L. Rodriguez-Suarez, A.F. Lacerda Santos, and S. M. Rezende, *Spin pumping dc voltage: Theory and Experiment*, (Submitted to Phys. Rev. Lett.)

INV 4: Thursday, 14:00 – 14:40

Finite size superfluid: turbulence and granulation as a possible decoherence mechanism

Vanderlei S. Bagnato

Instituto de Física de São Carlos, Univeristy of São Paulo, São Carlos, SP, Brazil

In this work we review our technique to generate turbulence in a BEC, where an oscillating field generated by a set of coils is superimposed to the trapping field creating displacement, rotation and deformation of the trap potential. The generation of quantized vortices is investigated as a function of the amplitude of oscillation as well as time of excitation. Results are collected in a diagram showing zones of behavior. For severe oscillatory excitation, we have observed a granulation of the quantum atomic fluid, which will be discussed in this presentation. We discuss the hydrodynamic properties and the granulation as a mechanism for decoherence of the condensate. *(The topic of atomic superfluid and turbulence has collaboration of E. Henn, J. Seman, P. Castilho, G. Roati, K. Magalhaes, R. Shiozaki, E. Ramos, M. Caracanhas, C. Castelo-Branco, P.Tavares , F. Poveda, G. Telles, and the participation of external collaborators: A. Fetter, V. Yukalov , V.Romero-Rochin and M. Tsubota).* Financial support from FAPESP and CNPq Brazilian agencies.

INV 5: Thursday, 14:40 – 15:20

Spin qubits in semiconductor and graphene quantum dots

Guido Burkard

University of Konstanz, Germany

Both semiconductors and carbon each have their own advantages and problems as host materials for spin qubits, and both are currently being studied experimentally and theoretically. In the first part of my talk, I will concentrate on spin qubits in III-V semiconductors, where the hyperfine coupling to a large ensemble of nuclear spins brings up new and interesting questions. Among them is the possibility to use pulsed-gate techniques in a two-electron double quantum dot system to prepare a large number of nuclear spins [1], as well as to coherently manipulate a singlet-triplet T+ qubit [2]. Both processes can be described theoretically based on Landau-Zener-Stückelberg transitions. The second part of the talk will be on spin qubits in carbon-based quantum dots. Carbon has recently emerged as an interesting alternative material for spin qubits, due to the low concentration of nuclear spins and relatively weak spin-orbit coupling. I will discuss the formation of quantum dots in extended graphene, being a non-trivial issue due to the absence of a band gap and the effect of Klein tunneling [3]. Further topics include the role of the valley degeneracy for spin qubits, hyperfine interactions with 13C nuclear spins and their manifestation the spin-valley blockade [4], as well as spin-orbit induced spin relaxation for spin qubits in graphene [5].

[1] H. Ribeiro and G. Burkard, Phys. Rev. Lett. **102**, 216802 (2009).

[2] H. Ribeiro, J. R. Petta, and G. Burkard, Phys. Rev. B **82**, 115445 (2010).

[3] B. Trauzettel, D. Bulaev, D. Loss, and G. Burkard, Nature Phys. **3**, 192 (2007).

[4] A. Pályi and G. Burkard, Phys. Rev. B **80**, 201404 (2009); Phys. Rev. B **82**, 155424 (2010).

[5] P. R. Struck and G. Burkard, Phys. Rev. B **82**, 125401 (2010)

INV 6: Thursday, 15:20 – 16:00

Geometric Spin Hydrodynamics and Caloritronics

Yaroslav Tserkovnyak

University of California, Los Angeles

I will discuss an intricate interplay between magnetic domain-wall motion, electrical power generation, and mechanical rotation in magnetic nanowires. The domain wall can be viewed as a piston whose motion responds to external magnetic field, applied current, temperature gradient, mechanical rotation and, by reciprocity, can generate electrical power in an external coil as well as induce voltage, heat flow, and mechanical motion in the nanowire itself. Strong couplings between the thermoelectric, magnetic, and elastic subsystems is provided by the interplay of various torques: spin torques between itinerant electrons and the collective magnetization as well as spin-orbit interaction that couples both electronic subsystems to the lattice. I will discuss general theory for these related phenomena, drawing heavily on thermodynamic reciprocities and recent developments in magnetoelectronics. As an example, I will demonstrate hypothetical domain-wall utilization for cooling, heat pumping, and power generation, and construct the magnetocaloritronic “ZT”-like figure of merit.

INV 7: Friday, 10:30 – 11:10

Spin Polarization of Carriers on Resonant Tunneling Diodes

Maria José S. P. Brasil

UNICAMP, Instituto de Física “Gleb Wataghin”, 13083-970 Campinas-SP, Brazil

We present our results concerning the spin polarization of carriers on Resonant Tunneling Diodes (RTDs). The double-barrier structure has been proposed as an alternative system to manipulate the spin of carriers, including hybrid structures with semi-magnetic layers and standard non-magnetic structures. In recent years, we demonstrated that the spin of carriers injected in the quantum well of a non-magnetic RTD structure under an external magnetic field parallel to the tunnel current can be controlled by the RTD bias voltage [1-5]. We investigated a series of structures, including p-i-p, n-i-n and p-i-n devices using magneto-optical measurements. The degree of spin polarization of the injected carrier is analyzed by measuring the left-and right-circularly polarized emission intensities from the quantum well and the contact layers when the structure is illuminated with a linearly polarized laser tuned below the quantum well absorption edge. We observed large variations of the polarization degree from the optical emissions as a function of the bias voltage, including inversions of the polarization signal. The effect is mainly due to the strong variations of charge distribution along the structure with applied bias. We also explored the dynamics of the spin polarization of the carriers as they tunnel through the double barrier by measuring the time-resolved photoluminescence emission [6]. Under an applied bias, majority carriers introduced by doping attain a quasi-stationary distribution along the structure, while photogenerated minority carriers are solely created at the contact layers during the pulsed excitation. Subsequently, the photocreated carriers may tunnel into and recombine at the well. Therefore, the polarized-resolved photoluminescence transient gives direct information on the dynamics of the spin of carriers tunneling through the structure and it revealed a complex behavior of the polarization as a function of time, excitation intensity and bias voltage.

[1] H. B. Carvalho, M. J. S. P. Brasil, V. Lopez-Richard, Y. G. Gobato, G. E. Marques, I. Camps, L. C. O. Dacal, M. Henini, L. Eaves, G. Hill, Phys. Rev. B **74**(4), 041305 (2006).

[2] H. B. Carvalho, I. Camps, Y. G. Gobato, M. J. S. P. Brasil, V. Lopez-Richard, G. E. Marques, M. Henini, L. Eaves, G. Hill, Phys. Rev. B **73**(15), 155317 (2006).

[3] H. B. Carvalho, M. J. S. P. Brasil, Y. G. Gobato, G. E. Marques, H. V. A. Galeti, M. Henini, G. Hill, Appl. Phys. Lett. **90**, 062120 (2007).

[4] L. F. Santos, Y. G. Gobato, G. E. Marques, M. J. S. P. Brasil, M. Henini, R. Airey, Appl. Phys. Lett. **91**, 073520 (2007).

[5] L. F. Santos, Y. G. Gobato, V. Lopez-Richard, G. E. Marques, M. J. S. P. Brasil, M Henini, R. J. Airey, Appl. Phys. Lett. **92**, 143505 (2008).

[6] H. V. A. Galeti, H. B. de Carvalho, M. J. S. P. Brasil, Y. G. Gobato, V. Lopez-Richard, G. E. Marques, M. Henini, G. Hill, Phys. Rev. B **78**, 165309 (2008).

INV 8: Friday, 11:10 – 11:50

The Interacting Semiconductor Hole Gas

John Schliemann

Institute for Theoretical Physics, University of Regensburg, D-93040 Regensburg, Germany

I will discuss the homogeneous interacting hole gas in p-doped bulk III-V semiconductors. The structure of the valence band is modelled by Luttinger Hamiltonian in the spherical approximation, giving rise to heavy and light hole dispersion branches, and the Coulomb repulsion is taken into account via a self-consistent Hartree-Fock treatment. As a nontrivial feature of the model, the self-consistent solutions of the Hartree-Fock equations can be found in an almost purely analytical fashion, which is not the case for other types of effective spin-orbit coupling terms. In particular, the Coulomb interaction renormalizes the Fermi wave numbers for heavy and light holes. As a consequence, the ground state energy found in the self-consistent Hartree-Fock approach and the result from lowest-order perturbation theory do not agree. Moreover, I will report on a recent study of the dielectric function of the homogeneous hole gas in p-doped zinc-blende III-V bulk semiconductors within random phase approximation. In the static limit we find a beating of Friedel oscillations between the two Fermi momenta for heavy and light holes, while at large frequencies dramatic corrections to the plasmon dispersion occur.

[1] John Schliemann, *Theoretical study of interacting hole gas in p-doped bulk III-V semiconductors*, Phys. Rev. B **74**, 045214 (2006).

[2] John Schliemann, *The dielectric function of the semiconductor hole gas*, to appear in Europhys. Lett., preprint: arXiv:1003.4820.

INV 9: Friday, 11:50 – 12:30

Manipulation and analysis of a single magnetic impurity in semiconductors by STM

Paul Koenraad

COBRA, Eindhoven University of Technology, P.O.Box 513, 5600 MB, The Netherlands

We have shown that one can ionize single impurities [1, 2] and spatially resolve the shape of the wavefunction of a single hole or electron bound to an impurity atom by using Cross-sectional Scanning Tunneling Microscopy (X-STM) [3, 4]. Such information about the wavefunction is very valuable as it allows a direct identification of the character of the electronic state and its interaction with the environment which, for instance, can be strained or

involve magnetic fields. The X-STM topographic and spectroscopic measurements were performed at room temperature and low (4.2K) temperature in UHV at the cleaved (110) surface of III/V semiconductor nanostructure materials. In this presentation we will review our results on wavefunction imaging of single impurities [5], strained impurities [6, 7], impurities in self-assembled InAs quantum dots [8] and magnetic impurities in a strong magnetic field. There will be strong emphasis on the analysis of magnetic Mn impurities that are key for the development of magnetic semiconductor structures. The measurements will be compared with the results obtained by either envelope function effective mass model (EFM) and tight binding model (TBM) calculations.

[1] K. Teichmann *et al.* PRL **101**, 076103 (2008).

[2] I. Wijnheijmer *et al.* PRL **102**, 166101 (2009).

[3] A. Yakunin *et al.* PRL **92**, 216806 (2004).

[4] A. Yakunin *et al.* PRL **95**, 256402 (2005).

[5] J. Garleff *et al.* PRB **78**, 075313 (2008).

[6] A. Yakunin *et al.* Nature Materials **6**, 513 (2007).

[7] C. Celebi *et al.* PRL **104**, 086404 (2010).

[8] M. Bozkurt*et al.*, APL **96**, 042108 (2009).

Tuesday Poster Session

Nov 2, 17:15 – 19:15

TUE 1:

Compensation domain walls in $Gd_{1-x}Co_x$ films

A. Hrabec, S. Pizzini, L. Ranno

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Achieving reproducible spin-torque induced domain wall (DW) movements with low current densities and high DW velocities is one of the main challenges in spintronics. Reducing the magnetization while keeping the spin polarization constant should lead to enhancement of the spin-torque effect. We report here on our results about $Gd_{1-x}Co_x$ ferrimagnetic alloy with compensation temperature close to 300K. Using magnetron sputtering technique, we have obtained films with a controlled lateral composition gradient 0.9 at%/mm. Polar Kerr microscopy mainly sensitive to Co magnetization allows to image the Gd rich, Co rich and the compensation (M_{tot}=0) zones. We have studied the field-induced magnetization process (imaging H_c) in patterned stripes. Joule effect is used to measure the thermal properties and the heating impact on the magnetization process, including the displacement of the magnetization compensation surface and also of the angular momentum compensation surface. This work is supported by the French ANR-07-NANO-034 Dynawall project and by Fondation Nanosciences.

TUE 2:

Spin Multistability in a Semiconductor Microcavity

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A central issue in spintronics is to realize coherent manipulation of spin ensembles in the solid-state. In this scope, spin multistability will definitely lead to innovative schemes of logic gating and data storage. A recent theory

showed that the anisotropy of polariton spinor interactions allows for multi-valued spin switch in semiconductor microcavities [1]. This prediction has been followed by important proposals for the design of localized spin memories [2] and spin logic gates [3]. However, the implementation of such devices still required the existence of spin multistability to be demonstrated in the solid-state.

We report on the first experimental realization of spin multistability in the solid-state, in a semiconductor microcavity with patterned traps for polaritons. We first investigate spinor-bistability in our system. Because of strong spinor-interactions that we precisely characterize, we evidence unusual bistability regimes, with decoupled thresholds for spin-up and spin-down polaritons. This allows us to demonstrate state-of-the art power-dependent spin-switching operations.

At constant excitation power, the switch in polariton spin-polarization is controlled by the excitation polarization degree ρ_{p}. We evidence strong polarization hysteresis and determine the appropriate conditions to achieve spin multistability. For a given set of excitation conditions, three stable spin states (-1, 0 ,+1) coexist for the system and reversible switch between them can be monitored by tuning ρ_{p} [4].

We characterize the complete polariton spin state and evidence macroscopic spin coherence during the whole process. Using additional, femtosecond excitation sources, we are able to trigger ultrafast switching between the stable spin states (-1, 0, +1) and we evidence long lived spin-memory.

We develop a model in the framework of the spinor Gross-Pitaesvskii equation with which we reproduce our experimental observations with very good qualitative agreement.

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TUE 3:

Using magnetotransport to determine the g-factor in graphite

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In magnetic field the properties of graphite are remarkably well described by the Slonczewski, Weiss and McClure (SWM) band structure calculations [1, 2]. While orbital effects have been extensively used to map the Fermi surface, the more subtle spin effects have received less attention. This is perhaps because the well documented movement of the Fermi energy in a magnetic field seriously complicates the extraction of the g-factor from the magnetotransport data. Recent advances in experimental techniques, in particular the vastly increased desktop computing power available for diagonalizing the SWM Hamiltonian, makes it timely to revisit this problem.

The oscillatory component of the longitudinal resistance ΔR_{xx} as a function of the magnetic field from $B = 0 - 28$ T for various orientations between

$\theta = 0°$ and $\theta = 90°$ reveals quantum oscillations due to the majority electron and hole cross sections of the Fermi surface. For increasing tilt angles the quantum oscillations shift as $1/\cos(\theta)$ to higher magnetic field demonstrating the quasi two-dimensional nature of graphite. The experimentally observed splitting $\Delta B = B_\downarrow - B_\uparrow$, where $B_\downarrow$ and $B_\uparrow$ are the magnetic field positions of the spin up and spin down features, as a function of the mean total magnetic field position $B_m = (B_\downarrow + B_\uparrow)/2$ for the $n = 1$ electron and hole features fails to follow a simple quadratic behavior. This is an experimental signature that the movement of the Fermi energy must be taken into account when extracting the g-factor [3].

To extract the g-factor, we use the SWM model. The effect of the in-plane magnetic field can be incorporated into the SWM model through an effective spin gap $\Delta_s = g_{\text{eff}}\mu_B B_\perp$ where the real g-factor is $g_s = g_{\text{eff}}\cos(\theta)$. In graphite, E_f moves with the applied perpendicular magnetic field as carriers are transferred between the electron and hole pockets. The Fermi level has to be calculated selfconsistently assuming the sum of the electron and hole concentrations is constant. At each angle, the effective spin gap is found for which the SWM model gives the correct magnetic field position for the crossing of the spin up and spin down Landau bands with the Fermi energy. The spin gap Δ_s extracted from the SWM calculations as a function of the total magnetic field for the $n = 1$ hole and the $n = 1 \ldots 4$ electron Landau bands increases linearly with magnetic field and a linear fit to $\Delta_s = g_s \mu_B B_m$ (solid line) for both electron and hole Landau bands gives $g_s = 2.5\Omega \pm 0.1$. The enhancement compared to the electron spin resonance value can be attributed to electron-electron interactions.

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TUE 4:

Improving Electromagnetically Induced Transparency in Si:GaAs by Selective Pumping of Nuclear Spins

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We recently observed Electromagnetically Induced Transparency (EIT) with an ensemble of donor-bound electrons in GaAs. EIT is a quantum optical effect that relies on destructive quantum interference in a resonant Raman scheme and gives access to strong coherent field-matter interactions. High quality EIT requires a long electron-spin dephasing time, which is in this system limited by hyperfine coupling between each electron spin and 10^5 fluctuating nuclear spins. We study how dynamical nuclear polarization that results from the EIT control scheme itself can pump away these nuclear spin fluctuations, and thus turn EIT into a self-improving effect.

TUE 5:

Electromagnetically Induced Transparency in a Semiconductor

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We report the observation of Electromagnetically Induced Transparency (EIT) in GaAs. EIT is the phenomenon that an absorbing optical transition becomes transparent because destructive quantum interference with another driven transition prohibits populating the optically excited state. This yields strong field-matter interactions, and EIT lies at the heart of various quantum information schemes. EIT can occur with three-level systems with two low-energy spin states that have a long coherence time. We used an ensemble of donor-bound electrons in GaAs, which can be operated as hydrogen-like atoms. Our implementation in a semiconductor gives access to very compact quantum optical devices with high optical density, and a new approach to controlling and probing spin coherence in a semiconductor.

TUE 6:

Low-Bias Negative Differential Resistance in Graphene Nanoribbon Superlattices

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Due to the high mobility of its charge carriers, graphene based devices are expected to outperform their semiconductor counterparts. Here we theoretically investigate negative differential resistance (NDR) for ballistic transport in semiconducting armchair graphene nanoribbon superlattices (5 to 20 barriers) at low bias voltages V_{SD} and room temperature [1]. We combine the modulated graphene-Dirac hamiltonian with the Landauer formalism to calculate the current ISD through the system. This description is expected to be valid at low biases and for narrow samples. We find three distinct transport regimes in which NDR occurs: (i) a "classical regime" in which the transport across the crossings of barrier and valley bandgaps is suppressed, thus leading to alternating regions of nearly unity and zero transmission probabilities as a function of V_{SD}; (ii) a quantum regime dominated by superlattice miniband conduction, with current suppression arising from the misalignment of miniband states with increasing V_{SD}; (iii) a Wannier-Stark ladder regime with current peaks occurring at the crossings of Wannier-Stark rungs from distinct ladders. We emphasize that all the above mechanisms show NDR at voltages lower than 500 mV. Interestingly, within the miniband transport regime the NDR occurs at biases as low as 10 mV, i.e., comparable to the miniband width. We note that these NDR bias ranges can be engineered by adjusting the number of layers and their spacings, barrier and valley heights, nanoribbon widths, and the zero-bias chemical potential. This work was supported by FAPESP, CNPq, NSF/USA, DARPA/MTO, AFOSR, Swiss NSF, and NCCR Nanoscience.

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TUE 7:

Many-body effects on the ρ_{xx} ringlike structures in two-subband wells

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The longitudinal resistivity ρ_{xx} of two-dimensional electron gases formed in wells with two subbands displays ringlike structures when plotted in a density–magnetic-field diagram, due to the crossings of spin-split Landau levels (LLs) from distinct subbands. Using spin density functional theory and linear response, we investigate the shape and spin polarization of these structures as a function of temperature and magnetic-field tilt angle [1]. We find that (i) some of the rings "break" at sufficiently low temperatures due to a quantum Hall ferromagnetic phase transition, thus exhibiting a high degree of spin polarization ($\sim 50\%$) within, consistent with the NMR data of Ref. [2], and (ii) for increasing tilting angles the interplay between the anticrossings due to inter-LL couplings and the exchange-correlation (XC) effects leads to a collapse of the rings at some critical angle θ_c, in agreement with the data of Ref. [3].

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TUE 8:

Ultrafast preparation and detection of arbitrary coherent dark states with donor-bound electrons in GaAs

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We report an optical pump-probe study of spin coherence of donor-bound electrons in GaAs. We find that single pump pulses prepare the spins in a coherent dark state via an ultrafast stimulated Raman process. Two orthogonal polarization components in the pump pulses each address one leg of the Raman system. The phase and amplitude difference between these components govern which spin state is prepared, and we can prepare any superposition of spin states. This preparation occurs 1000 times faster than the system's spontaneous emission and decoherence time, and probably relies on rapid pulse-induced decoherence that is unique for solid-state systems.

TUE 9:

Time-resolved Magneto Luminescence from a resonant tunneling diode

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Spin dynamics of carriers in semiconductor devices is a fundamental issue for spintronic applications. In this work, we investigated the spin dynamics in a p-i-p GaAs/AlAs Resonant Tunneling Device (RTD) by measuring time-resolved polarized photoluminescence under magnetic elds parallel to the tunnel current. Under an applied bias, holes introduced by doping attain a quasi-stationary distribution along the structure, while photogenerated electrons are only created at the top GaAs layer during the pulse excitation by a ps - Ti:Sa laser tuned below the quantum well (QW) absorption edge. Subsequently, the electrons may tunnel into and recombine with holes at the QW. Therefore, the QW transient gives direct information on the spin dynamics of electrons tunneling through the structure. For bias around the resonance of the fundamental QW electron-level, we observed a very large polarization ($\sim 60\%$ for 15T) that is mainly constant during the whole transient and cannot be explained by the small Zeeman-splitting energy. The RTD structure thus seems to act as a spin-filter where electrons injected into the well acquire a preferential spin that is at least partially retained when they recombine. For other biases, the polarization shows a much complex dynamics, including sign

inversions along the time-evolution of a given transient. Our results reveal that the structure provides different spin-polarization mechanisms with different characteristic times that may result in distinct spin polarizations of the carriers depending on the applied bias.

TUE 10:

Strong correspondence principle for joint measurement of conjugate observables

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A rich correspondence between classical and quantum mechanics is demonstrated: not only do the average values of an observable obey the classical equations of motion, as established by Ehrenfest's theorem, but the full joint probability of the outcomes has the same expression in the classical as in the quantum case in terms of the initial probability distributions of the dynamical variables of system and detectors, provided that one substitutes the classical joint probabilities with Wigner quasi-probabilities. Due to the uncertainty relations, the Wigner quasi-probabilities come in such combinations that they give rise to a positive probability distribution. A fecund concept is also introduced, that of quasi-characteristic function, in terms of which the characteristic function of the joint outcomes has a remarkably simple expression. From this, one can conclude that detectors contribute with an additive term to the cumulants of all orders. The strong correspondence between the classical and the quantum case is shown to hold also for the determination of the conditional state of the system after the measurement.

TUE 11:

Spin-assisted Optical Transitions in Zincblende Quantum Wells with Two Subbands

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A recently proposed intersubband spin-orbit coupling, present even in symmetric zincblende quantum wells with two subbands, can give rise to novel and interesting physical effects [Bernardes *et al.*, Phys.Rev.Lett. **99**,076603; Calsaverini *et al.*, Phys.Rev.B **78**,155313; Lee *et al.*, Phys.Rev.B **80**,155314]. Here we investigate optically-induced intersubband transitions in the presence of spin-orbit couplings. By performing the substitution $p \mapsto \mathbf{P} - e/c\,\mathbf{A}$, we find that different effective sources of the* *electron-photon interaction arises: the usual coupling ($\mathbf{P} \cdot \mathbf{A}$), a $k \cdot p$ based coupling ($\mathbf{k} \cdot \mathbf{A}$) and a spin-assisted coupling ($\sigma \times \nabla V(Z) \cdot \mathbf{A}$). The spin-assisted contribution depends on the quantum well structural potential and the electronic interaction. We use the symmetry properties of the 8×8 Kane model to derive optically-induced transition rates. Our preliminary results show that these transition rates strongly depend on the intersubband coupling; this offers a possibility for extraction of this coupling via optical means.

TUE 12:

Spin susceptibility of interacting two-dimensional electrons in the presence of Rashba spin-orbit coupling [1]

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A long-range interaction via virtual particle-hole pairs between Fermi-liquid quasi-particles leads to a nonanalytic behavior of the spin susceptibility as a function of the temperature (T) [2,3], magnetic field ($|\mathbf{B}|$) [4], and momentum ($|\mathbf{q}|$) [2,5,6]. We study the effect of the Rashba spin-orbit (SO) coupling on the nonanalytic behavior of the spin susceptibility of a two-dimensional electron liquid. We show that, although the SO coupling breaks $SU(2)$ symmetry, it does not eliminate nonanalyticity but rather makes it anisotropic: while the linear scaling of χ_{zz} with T and $|\mathbf{B}|$ saturates at the energy scale set by the SO coupling, that of χ_{xx} ($= \chi_{yy}$) continues through this energy scale. We also discuss the renormalization of the backscattering amplitude in the Cooper channel derived both perturbatively and within the renormalization group theory framework.

Our result has immediate consequensces for the nuclear ferromagnetism. The recent study of the RKKY interaction between localized moments, e.g., nuclear spins of Ga and As atoms in a GaAs heterostructure, mediated by two-dimenstional electrons, has shown a possibility of polarizing nuclear spins at currently accessible temperatures [7,8]. This ferromagnetic transition is related to a nonanalyticity in momentum dependence of the spin susceptibility and in the absence of the SO coupling the ferromagnetic state is of a Heisenberg-type. Although we have not studied here the $|\mathbf{q}|$-dependence of χ in the presence of the SO coupling, this dependence is likely to mirror the dependence on the temperature. Therefore, we can reasonably expect that the linear scaling with $|\mathbf{q}|$ survives in χ_{xx} but not in χ_{zz} for $v_F|\mathbf{q}| < |\alpha|k_F$. This suggests that the nuclear-spin ferromagnetic state is of the XY type.

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TUE 13:

Spin Relaxation in Silicon Based Quantum Dots

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Recent progress in manufacturing top-gated quantum dots based on Si/SiGe or Si/SiO2 systems emphasized the importance of silicon as a possible host material for the creation of spin qubit arrays and the associated idea proposed by Loss and DiVincenzo [1] for the realization of a quantum computer. Silicon is of special interest because of its small spin-orbit coupling and the availability of isotopes with zero nuclear spin. Therefore silicon based quantum dots imply long spin lifetimes and yield promising candidates for quantum information processing. We provide quantitative results of the characteristic energies in the presence of spin-orbit coupling and phonon-induced spin relaxation times for realistic silicon based single and double dot systems using analytical models and numerical methods.
This work is supported by the DFG SPP 1285.

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TUE 14:

Entanglement dynamics of two strongly driven qubits interacting with a cavity

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Entanglement is essential for quantum information processing, however it is difficult to create and control entanglement in realistic quantum systems. We theoretically study the dynamics of two strongly driven qubits in a dissipative cavity. The qubits do not interact directly and are individually off-resonantly coupled to a single mode of quantized radiation.

The evolution of the entanglement of this system shows a novel effect of initial atomic entanglement decay followed by its periodic in time revival leading to a complete asymptotic entanglement recovery. Despite the qubits never entangling as they interact through a cavity, we can entangle them by a post-selective measurement with a 50 per cent certainty.

TUE 15:

Analytical approach for the dipolar switching field distribution broadening and shearing of the hysteresis loop in bistable magnetic particle assemblies

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Based on an analytical mean field expression for the configuration dependent dipolar interaction field, it is shown that the corresponding broadening of the intrinsic switching field distribution ($iSFD$) can be estimated along with the hysteresis loop shearing. This has been shown for the case of low density arrays of magnetic nanowires that both the broadening of the SFD as well as the shearing of the hysteresis loop can be corrected by removal of the configuration dependent dipolar interaction, leading to the determination of the $iSFD$ without the necessity to suppose or guess the functional form of the SFD. Furthermore, these expression allows correcting the remanence curves, and thus the Henkel and ΔM plots have been calculated showing that once the dipolar interaction field is removed, the resulting plots show a good a very good correspondence with those of a non-interacting array of particles. By exploring the use of higher order terms in the mean field approximation, the results suggest that taking into account the fluctuations of the interaction field, the results can be improved. A generalized expression for the configuration dependent dipolar interaction field has been derived, and used to express the effective demagnetization factor and the change in slope observed in the hysteresis loop responsible for its shearing. These results provide support for concluding that the dipolar interaction field acts as a bias field thus shifting the hysteresis loop of the individual particles. The expression for the configuration dependent interaction field is physically clear and can be both calculated and measured for any array of particles, it can potentially be of great interest in areas such as perpendicular magnetic recording, cellular automatas, and other coupled systems such as those considered in supermagnetism. This method also opens the perspective of finding mode explicit and reliable methods to include or measure ferromagnetic type interactions.

TUE 16:

A Theoretical Model of Single Photon Source at Room Temperature

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In this work we present a theoretical model for an electrically injected single photon source at room temperature. The source is made of three regions. The region containing the source is n-doped, the middle region is an intrinsic semiconductor heterostructure. The region containing the drain is

p-doped. The configuration of the intrinsic region is designed to trap a single pair of electron and hole; this is due to Pauli Exclusion Principle and Coulomb blockage. This is achieved by applying a reverse voltage to neutralize the intrinsic electric field between the n- and p-doped regions. Based on the calculated tunneling time of the electron/hole, the reverse voltage will be switched off. For the kinetics at the room temperature operation is calculated by means of the Master equations. For this we use an effective Hamiltonian in the tight-binding approximation. The results show that a single electron and a single hole are trapped simultaneously for an adequate period of time until they recombine.

TUE 17:

Spin-active Scattering in Superconductor-Ferromagnet Hybrid Devices

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We study the impact of spin-active scattering on Andreev reflection and the proximity effect in superconductor(SC)/ferromagnet(FM) hybrid structures where (SC) is a singlet, s-wave superconductor and FM a strongly spin-polarized ferromagnet. We discuss both the conductance spectra of SC/FM point contacts [1] and the long-range triplet Josephson current in SC/FM/SC heterostructures [2] which was subject to intense experimental studies recently [3,4,5]. In both scenarios, spin-active scattering at the layer interfaces plays a pivotal role, as it provides a mechanism for the creation of triplet pairing amplitudes in proximity to the interface. The physical consequences of such scattering events are numerous. In point contact spectroscopy, the most prominent effect is the emergence of Andreev bound states due to the spin-mixing effect. For the Josephson setup, the mere presence of a supercurrent is related to the creation of equal spin pairing correlations at the interface. Further effects are a temperature anomaly of the critical current and a possible, spin-dependent modification of the current-phase relation which leads to the prediction of a pure spin-supercurrent in a SC/FM bilayer.

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TUE 18:

Anholonomic spin manipulation in drift transport in semiconductors

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We find that the electronic spin rotation induced by drift transport around a closed path in a wide variety of nonmagnetic semiconductors at zero magnetic field depends solely on the physical path taken. Physical paths that produce any possible spin rotation due to transport around a closed path are constructed for electrons experiencing strain or electric fields in (001), (110), or (111)-grown zincblende semiconductor quantum wells. Spin decoherence due to travel along the path is negligible compared to the background spin decoherence rate. The small size of the designed paths ($<$ 100 nm scale in GaAs) may lead to applications in nanoscale spintronic circuits.

TUE 19:

Energy Spectra of Electrons in Spin-Orbit Wires

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We calculate the energy spectra of electrons in quantum wires with spatially uniform and modulated spin-orbit coupling. The effects of Rashba spin-orbit coupling arising from asymmetric confinement in perpendicular and lateral directions with respect to the plane containing the wire are considered. We investigate the resulting interplay of strong lateral confinement, a periodic one-dimensional superlattice potential, and spin-orbit coupling in two orthogonal directions. The implications for the spin-dependent properties of electrons confined within these quantum wires are discussed. A potential realization of such systems within narrow nanowires at the interface of $LaAlO_3/SrTiO_3$ heterostructures is also described.

This work is supported by NDSEG, an Andrew Mellon Fellowship, and the National Science Foundation (DMR-0704022).

TUE 20:

Hybrid entangled stated in a parabolic quantum dot with spin-orbit and Magnetic field.

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We study the dynamics of an electron in a two dimensional Quantum Dot (QD) with parabolic confinement with Rashba Spin-Orbit Coupling and a Magnetic Field. The study of hybrid spin orbit (charge) entanglement for pure states is studied through the time evolution of Schmidt coefficients. We evaluate the effect of the magnetic field, parameter of confinement and the spin-orbit amplitude on such coefficient. We observe that there are conditions of resonance in the system, where the degrees of freedom of the spin and orbit are maximally correlated, i.e., entangled, refereed as hybrid entanglement. We find that there is resonance between an eigenmode frequency of the system and the one induced by the magnetic field. Under this condition and considering as a initial condition two arbitrary contiguous states, we find that system can generate hybrid Bell states between the occupation states and the spin in the QD. We can determine the probability occupations and how they vary with the magnetic field and observe how it changes the conditions of resonance.

We also consider the dynamics of a QD interacting with a bosonic bath in thermal equilibrium, taking account the state transition rate between system and environment. The dynamics of the system-environment is described with a Born-Markov Master Equation for the density operator, with this operator we can compute the degree of entanglement as function of time and also the intrinsic magnetization of the electron inside the QD. We compute the transitions between states inside the QD to find several occupation probabilities dependents of the initial state of the system and the parameter of our model.

TUE 21:

A spin polarizing device through decoherence

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A pair of maximally entangled electrons collides with a beamsplitter and enters into two perpendicular branches of length L, composed of spin-orbit active materials of the Rashba and Dresselhaus spin-orbit type (gate confined 2D electron gas). One of the branches is connected to an electron reservoir that acts as a voltage probe and thus acts as a source of decoherence. The collision with the electron reservoir is described by a scattering matrix approach valid for $E_f \gg k_B T$. At the end of the branches two detectors are placed. We calculate the concurrence and the spin polarization of the outgoing electrons as a function of the coupling to the electron reservoir, the reservoir temperature and position. We find that changing the entropy of the incoming state we are able to polarize the outgoing state, so decoherence serves as a spin polarizer in this setup without requiring a postselection. We also inject unpolarized electrons in a mixed state in the same device described above revealing up down spin scattering assymetries. Finally the electrons are

introduced in a Mach Zehnder interferometer crossed by a magnetic field perpendicular to its plane. In this case, spin-polarization effects are cause by both the presence of the reservoir and the combination of the gauge field and spin-orbit interaction

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TUE 22:

Effects of scattering area shape on spin conductance in a four-terminal spin-Hall setup

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We study spin conductance in a ballistic and quasi-ballistic two dimensional electron system with Rasbha spin-orbit coupling. The system has a four-terminal geometry with round corners at the connection to the leads. It is found that by going from sharp corners to more round corners in the ballistic system the energy depended spin conductance goes from being relatively flat to a curve showing a series of minima and maxima. It is also found that when changing the size of the terminal area by modifying the roundness of the terminal corners the maxima and minima in the transverse spin conductance are shifted in energy. This shift is due increased (decreased) energy for smaller (larger) terminal area. These results were also found to be reasonably stable in quasi-ballistic systems.

TUE 23:

Analysis of the environment influence on the measurement process in two level quantum systems using the Lindblad equation

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The aim of this work is to explore a model for finite time steps based on the Lindblad equation [1] with analysis of a system consisting of a single spin (2 levels) coupled to a thermal reservoir. The component of spin to be measured can commute or not with the system component. The analytical solution for the Lindblad equation in the absence of environment / reservoir is relatively simple to be obtained [2, 3]. However, the inclusion of the environment necessitates the use of techniques for supress it (partial trace) involving the use of operators projection of Nakajima-Zwanzig [3, 4], and super-operators relating to various terms of the Liouvillian (system, reservoir and interaction between them) and lindbladiano. Analytical calculations are underway. Besides representing a fundamental problem importance in quantum mechanics, potential applications will include computing irreversible quantum [5], that depends intrinsically of measures.

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TUE 24:

Polarized resolved Photoluminescence studies in self assembled Quantum Dots

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We have studied the spin polarization of carriers in a n-type GaAs/GaAlAs resonant tunnelling diode which incorporates a layer of InAs self-assembled quantum dots (QDs) in the center of the GaAs quantum well. Our device was grown by Molecular Beam Epitaxy on (3 1 1)B-oriented GaAs substrate. The spin-dependent carrier transport in the structure was investigated by measuring the left- and right-circularly polarized photoluminescence (PL) intensities from InAs QDs and GaAs contact layers as a function of the applied voltage, laser intensity and magnetic field up to 15 T. Under low bias voltage, we have observed a good correlation between the current-voltage characteristics curve (I(V)) and the QD PL intensity for both circular polarizations. In this bias range, the circular polarization degree is bias and light intensitydependent and presents a maximum value near the resonant tunnelling condition of photogenerated holes. At higher voltages, the PL intensity is no more correlated to the I(V) curve and the polarization degree tends to saturate. Our results are explained in terms of the tunneling of minority carriers into the QW, carrier capture by InAs QDs, bias-controlled density of holes and its partial thermalization in the QW. The observed control of spin polarization in QDs by light and bias voltage may be explored to design new devices for spintronic applications.

TUE 25:

Polarized Resolved Photoluminescence in n-type Resonant Tunneling Diodes with a Si Delta-Doping Layer in the Quantum Well

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In this work, we have studied GaAs/AlGaAs resonant tunneling diodes with a Si delta-doped layer placed at the center of the quantum well (QW). We have studied magneto-transport and polarized resolved photoluminescence from GaAs QW and contact layer as a function of applied voltage and magnetic field parallel to the tunnel current. Two resonant peaks are observed in the current-voltage characteristics I(V) curve and are associated to the donor-assisted resonant tunneling and to the electron resonant tunneling through the first confined state in the QW. We have observed that the polarization degree is light and voltage dependent. High values of polarization degree (up to 85

TUE 26:

Fabrication and Magnetic Response of Cobalt Nanowires with Reduced Diameter

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Magnetic nanowires (MNW) have been widely studied in recent years because of their potential applications in magnetic data storage and also of their academic interest. Fundamental research interest lies principally in the study of the magnetization reversal mechanism of these elongated magnetic entities. We have recently evidenced the self-assembly of Co magnetic nanowires embed- ded in a cerium oxide epilayer grown by pulsed laser sequential deposition [1]. This result, already intriguing in itself, is even more surprising when considering the reduced diameter of the nanowires (below 5 nm). Such dimensions lie in the limit that could be envisaged using electrochemical deposition in porous template, which is the most explored method in the literature to fabricate this kind of system. In these reduced diameter nanowires, the magnetization reversal mechanism is domi- nated by localized reversal. The temperature dependence of the coercivity has been interpreted by thermally activated reversal mechanism over an energy barrier. At very small diameter, the energy barrier depends on T. This could be explained by a competition between shape and magnetocrys- talline anisotropy; this competition depending on orientation and size distribution of grains inside the MNW.

[1] Vidal F , et al Appl. Phys. Lett. 95, 152510 (2009)

TUE 27:

High Speed Single Dopant Spin Manipulation with a Single Electrical Gate

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With the possible application to spintronics there has been increased interest in spin manipulation. Spin-1 objects are of interest due to several unanswered questions including; how g-tensor modulations works, the achievable visibilities of Rabi oscillations and the limits on spin manipulation frequency. Manipulation schemes using electrical fields are of particular interest due to their relatively accessible scalability. In this vein calculations demonstrating the feasibility of electrical manipulation of a spin-1 object, manganese in gallium arsenide, have been carried out [Phys. Rev. Lett. **97**, 106803 (2006)].

We have examined the same system, a spin-1 Mn+hole complex in GaAs, with a static electric and magnetic field in addition to a driving electric field. The addition of the magnetic field serves the purpose of allowing both electric fields to be in the same direction promoting greater scalability. With the static electric, static magnetic and oscillating electric fields parallel in the [113] direction and relatively low field strengths, 0.5 kV/cm, 0.1 Tesla and 0.05-0.55 kV/cm respectively, we predict Rabi oscillations with periods between 2-40 ns with visibilities not below 0.950.

In an effort to increase Rabi frequency and by specific choice of the field direction and using increased field strengths, in this case the direction is [20 20 21] which is an experimentally inconvenient direction but one that clearly demonstrates the results, the energy splitting between the ground and first excited state is fixed at 5 GHz. The splitting between the ground and second excited state is driven up in energy effectively isolating the ground and first excited state allowing for higher Rabi frequencies while maintaining acceptable visibilities.

In addition to single Mn calculations we have also explored the averaged spin dynamics of several Mn in GaAs. Each Mn is modeled in a random electric field which begins to give us an idea of how robust the single spin calculations are. Calculations have been done including the random field, static magnetic field and bias electric field. The random field blurs the resonance signal as expected and the non-linearity in the resonance lines is evidence of g-factor tuning. While the random signal blurs the resonance signal it is not significant enough to eradicate the g-factor tuning. This points to the conclusion that the single spin manipulation calculations are moderately robust.

TUE 28:

Equilibrium spin currents in mesoscopic rings with spin-orbit interactions coupled to an electron reservoir

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In previous works, Büttiker[1] studied how persistent currents are degraded in a metal loop coupled to an electron reservoir using a scattering matrix approach. A recent study by Berche[2] et al. found analytical solutions for the full spectrum and equilibrium spin currents of electrons on a mesoscopic ring subject to Rashba and Dresselhaus spin-orbit interactions. We investigate the effect of coupling a reservoir, that acts as a voltage probe, to a single channel of the ring described above. We present preliminary results on the decoherence of equilibrium spin currents.

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2. B. Berche, C. Chatelain, E. Medina, Eur. J. Phys. 31 (2010) 1267-1286.

TUE 29:

EXAFS and XANES of Ca2MnReO6 under pressure up to 1.2 GPa

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Double perovskyte materials have been attracted renewest interest in early years because the of large low-field room-temperature magnetoresistance in these compounds (mainly in half-metallic Sr2FeMoO6, described by Kobayashi in 1998) stimulated interest in the study of the properties of ordered double perovskites, in the context of their potential application in the field of spin electronics. This type of compound exhibits magnetic and electronic properties related to the strong interplay between structure, charge and spin ordering, which is the subject of nano-spintronic studies. This work was proposed by taking into account a scenario which the magnetic and electronics properties of the Ca2MnReO6 double perovskite present a strong correlation with structural order. The main goal was to investigate the synthesis and crystal structure of the monophasic compound Ca2MnReO6. EAXFS measurements at ambient pressure were performed in order to determine the ReO6 and MnO6 octahedral coordination in the Ca2MnReO6 double perovskyte. The valence of Mn and Re was determined taken into account the MnO, MnO2, ReO2 and ReO3 calibrators. EXAFS pattern behavior of ReO6 and MnO6 octahedral was also investigated under hydrostatic pressure up to 1.2 GPa. A CuBe pressure cell with B4C anvils was used to applied pressure in situ. Our conclusions are that the both octahedral present a tilt under pressure without change its Re-O and Mn-O coordination distances.

TUE 30:

New materials with perpendicular anisotropy for spin-torque experiments

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The transfer of angular momentum by a spin polarized current to a magnetic system in order to manipulate its magnetization is a topic of high research interest nowadays [1]. Two effects related to angular momentum transfer should be studied: Spin transfer torque switching [2] and current induced domain-wall motion [3]. Systems with perpendicular magnetic anisotropy (PMA) seem to be suitable for applications since critical current densities can be decreased [4]. The effects of anisotropy, magnetization, exchange stiffness etc. on angular momentum transfer are discussed by several theoretical papers e.g. [2,5,6]. Two model systems should be discussed, allowing checking existing models of angular momentum transfer.

The first system is epitaxial [Co/Ni](111) superlattices grown by molecular beam epitaxy. High energy electron diffraction (RHEED) proofs the good crystalline structure and allows controlling the thicknesses in the ML with sub-monolayer precision. PMA was found over a large range of layer thicknesses and its origin was shown to be due to the Co/Ni interfaces. We could show that we can control the PMA, the magnetization, the damping parameter α and the polarization by varying the layer-thicknesses [7 and 8]. The damping parameter α was found to be quite small (0.01) which makes the system a promising candidate for high spin-torque efficiency. Furthermore by using Au as a non-magnetic spacer layer, fully epitaxial spin-valves can be grown. Nano-pillars and Nano-wires were patterned by E-beam lithography. The propagation of single domain-walls under field in the wires was proven by Kerr-microscopy. The control of the domain-wall position by artificial pinning centers is studied.

The second system consists of Co_xTb_{1-x} alloys long for a long time for possessing PMA over a large range of compositions [9]. Furthermore PMA and magnetization can be easily tuned by changing the sample composition and/or the temperature, also shown by [9]. As Co_xTb_{1-x} alloys are ferromagnetic, it is possible to find a concentration as a function of temperature where the net-magnetization vanishes, called the compensation point $x_C(T)$. The polarization was shown to be dependent on the orientation of the Co-sublattice and thus to switch when crossing the compensation point. As for the [Co/Ni] samples Nano-pillars and Nano-wires were patterned by E-beam lithography.

[Ni/Co](111) super-lattices as well as Co_xTb_{1-x} alloys, are model magnetic systems to study angular momentum transfer by a spin polarized current. Our measurements show that we precisely control magnetization M_S and PMA of these systems. Transport measurements showed that magneto-resistive effects can be used to analyze the magnetic state of the samples. First observations of single domain-wall propagation under a magnetic field in nano-wires of [Co/Ni] super-lattices were successful. Transport measurements on Nano-wires as well as on Nano-pillars in order to observe spin-torque are following.

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[3] A. Mougin et al. - EPL, 78 (2007) 57007
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[8] M. Gottwald et al. IOP Conf. Series: Mat. Sci. and Eng. 12 (2010) 012018
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TUE 31:

Counting statistics of transport through chaotic cavities

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Quantum transport through ballistic quantum dots has universal statistical properties as long as the shape of the dot induces chaotic particle dynamics. Quantities like conductance, shot-noise and other statistics are used to characterize these devices. These quantities have universal sample-to-sample fluctuations that are well described by the theory of random matrices. I will present calculations based on the semiclassical approximation that are able to reproduce the universal results. The main ingredient is the construction of families of correlated scattering trajectories.

TUE 32:

Resonances states in atomic and quantum dot models

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In quantum few-body systems a resonance state is a localized metastable state. The main difference with bound states is that they have a finite lifetime after which the system delocalizes. In this work we studied resonance states of a one-electron atomic model and two-electron quantum dot (QD). Both systems were studied using complex scaling techniques and variational expansions with real-basis functions. In the real-basis approach, we estimated the resonance Energy and Lifetime using the density of states(DOS) from known stabilization methods. For the one-electron model we improved the stabilization method in order to obtain numerical convergence with increasing basis-set size. The resonance energy for the two-electron QD was calculated using DOS and a Fidelity based quantity. Thinking towards a possible use of

resonances in QD for quantum computation, we proposed a definition of the von Neumann entropy (an entanglement witness) for a resonance state. The entropy was calculated using real-basis sets and complex-scaled quantities. Both techniques showed excellent agreement for the real part of the entropy.

TUE 33:

Casimir effect revisited and vacuum fluctuations

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The concept of vacuum always intrigued the human mind. Today our common sense tell us that it's the absense of everything, however it was not always like this. For many centuries the Aristotle's idea, that matter was continuous and that vacuum was something impossible, ruled the common knowledge. This persisted untill some experiments, as the mercury barometer from Torricelli, showed the possibility of absense of matter. The quantum concept of vacuum differs from our intuition today because, even in the absense of everything and at absolute zero, we still have left the vacuum fluctuations. From the quantization of the electromagnetic field we get that it can be represented as a collection of harmonic oscilators. However, even in the ground state, a quantum harmonic oscilator doesn't have zero energy. So, even in the absense of everything, and at absolute zero, the vacuum still have some energy. The energy of a quantum harmonic oscilator is $E_n = (n + 1/2)\hbar\omega$, where n, for the electromagnetic field, is the number of photons. That is, even with no photons, vacuum has a ground state energy. It's from that vacuum fluctuations that the Casimir effect arises. In his original paper, Casimir predicted that between two parallel non-charged conducting plates there would be a atracting force. This simple example show us that even vacuum can disturb a system, wich is a bad thing if we are talking about a quantum computer for instance. Here we revisited Casimir's original paper and the quantization of the harmonic oscilator. Finally we have a brief and more qualitative discussion on the quantum vacuum and vacuum fluctuations.

TUE 34:

Kondo effect and transport properties in quantum dot system: a study via Numerical renormalization group

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The rapid advance of experimental techniques has allowed the observation of singular behavior of electrons in low dimensional systems, such as the formation of electronic states of large spins, due to an increase in correlations of electronic systems, resulting in the modification in the magnetic and transport properties of the system. In the context of the development of new devices and electronic circuits, it is extremely important to understanding the

behavior of such systems in contact with their neighboring external environments. Of particular interest are interacting quantum dot (QD) structures in contact with external electronic reservoirs, with which they can share electrons. These reservoirs can act as electronic sources and drains, allowing the electrons to flow across the structure, injected by bias voltage.

In this work we present a study of transport properties in a system of strongly interacting QD in the low temperatures regime. In this regime, depending on to the total localized electron spin in the QD and the coupling between them and the conduction electrons the well known "Kondo effect" emerges. In particular, we study a system of a two orbital QD connected to two conduction bands, such that we can control the number of electrons inside the quantum dots through local gate potentials. We also consider the interaction between the localized electrons and optical phonons in the system. To theoretically tackle the underlying Kondo physics of the system we employ a numerical renormalization group[1] (NRG) which allows for the calculation of the relevant thermodynamics as well as the dynamics of the system. Our preliminary results show that the electron-phonon interaction produce a dramatic modification in the ground state of the system, leading to unpredicted new features of the Kondo effect in the system.

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TUE 35:

Polarization Resolved Electroluminescence Investigations of p-i-n GaAs/AlAs Resonant Tunneling Diodes

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Resonant tunneling diodes are interesting systems for spin- based devices because the spin character of carriers can be voltage selected. In this work, we have studied polarization resolved electroluminescence (EL) of a p-i-n GaAs/AlAs resonant tunneling diode (RTD). Under applied bias, electrons and holes tunnel through the double-barrier structure, generating current and also optical emission from the various layers of the structure. The spin-dependent tunneling of the carriers was studied by analyzing the current-voltage characteristics (I(V)) and the right and left circular polarized electroluminescence from the contact layers and the quantum well (QW) as function of the applied bias under magnetic field parallel to the tunneling current. Three resonant peaks were observed in the I(V) characteristics curve. These peaks are associated to the resonant tunneling of carriers through: the first light hole level (LH1), the first electron level (E1) and through the second heavy hole level (HH2). We have observed two QW emission lines which correspond to the recombination of holes in the two lowest energy valence sub bands (E1-LH1 and E1-HH1). Population inversion of holes in the HH1 and LH1 sub bands is observed over a wide range of applied bias. We have observed that polarization degree from both LH1-E1 and HH1-E1 emissions is voltage dependent. The QW polarization degree also presents an abrupt sign inversion after the LH1 resonant peak. The origin of the voltage dependence of spin polarization degree of the carriers along the structure is discussed considering effects of carrier tunneling and carrier charge densities. Finally, our experimental results are probably interesting for the developing of new voltage- controlled spintronics devices.

TUE 36:

Spin-polarized currents in nano-structures: Study of the role of electron-electron interactions

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After the development of electronics in past decades, we have now entered a new phase where, in addition to the electron charge, it is also possible and desirable to manipulate the electron spin. The need to develop devices in increasingly smaller sizes has lead to the materials in the nanoscopic scale. In this limit of small system sizes and low dimensionality, electron-electron interactions become more relevant and have to be considered carefully. The Hubbard model is a fundamental model to study how the interactions between electrons in a solid give rise to properties like magnetism and metal-insulator transitions. Here we use Quantum Monte Carlo methods to study the Hubbard model in the presence of a Zeeman field in a two-dimensional square lattice for different values of the strength of the repulsive interaction at half filling. We study the magnetic properties of the system analyzing how the magnetic structure factors $S(\mathbf{q})$ evolve as a function of inverse temperature β for different system sizes and magnetic field strengths, at $\mathbf{q} = (\pi, \pi)$ (antiferromagnetic order) and $\mathbf{q} = (\mathbf{0}, \mathbf{0})$ (ferromagnetic order). We also compute the spin-spin correlation functions and the local moment as a function of the magnetic field. In addition to that, we analyze how the transport properties are affected by the magnetic field and the temperature. This is done through the calculation of the density of states, the conductivity and Drude's weight. Finally we obtain a phase diagram in the Coulomb interaction and the Zeeman magnetic field plane, finding a saturation field where the system undergoes a transition to a Ferromagnetic-saturated phase in an insulator state.

TUE 37:

Coherent excitation dynamics in the photocurrent signal

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We present results from numerical simulations of the photocurrent for intersubband optical transitions in a double quantum well coupled to a continuum of states. The photocurrent spectra are obtained from the time-dependent Schrödinger equation solved in the coherent regime, without perturbative approximations nor basis set expansions and truncations. This is

one of the first attempt of studying a realistic representation of a three-level system in the lambda configuration. Resonance between the exciting fields and the quantum states leads to coherent effects such as Rabi oscillations and population trapping, which are investigated in terms of the photocurrent spectral changes. A novel excitation scheme is proposed to produce the population-trapping effects using only one exciting field.

TUE 38:

Spin-Orbit Interaction in Inversion-Symmetric Semiconductors

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Low-energy effective spin-orbit Hamiltonians have proved effective at describing the effect of spin-orbit interactions on populations of polarized carriers in direct-gap semiconductors such as gallium arsenide. No similar low-energy Hamiltonians are available for materials with inversion asymmetry, such as group-IV semiconductors or cubic oxides. In order to construct such low-energy Hamiltonians we have calculated the electronic band structures of several group-IV semiconductors, including germanium, silicon, and diamond, using a tight-binding electronic structure with atomic spin-orbit interactions. We have also calculated the electronic structure of strontium titanate, a perovskite material which has recently been used to make high-density two-dimensional electron gases. An expression for the effective spin-orbit interaction in the conduction band of these materials has been derived, and calculated for these materials. The symmetry properties of this effective spin-orbit interaction tensor will also be discussed.

TUE 39:

Quantum Correlations in Spin Chains at Finite Temperatures and Quantum Phase Transitions

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We compute the quantum correlation (quantum discord (QD)) and the entanglement (EoF) between nearest neighbor qubits (spin-1/2) in an infinite chain described by the Heisenberg model (XXZ Hamiltonian) at finite temperatures. The chain is in the thermodynamic limit and thermalized with a reservoir at temperature T (canonical ensemble). We show that QD, in contrast to EoF and other Thermodynamic quantities, spotlight the critical points associated to quantum phase transitions (QPT) for this model even

at finite T. This remarkable property of QD may have important implications for experimental characterization of QPTs when one is unable to reach temperatures below which a QPT can be seen.

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TUE 40:

Numerical Investigation of Shape, Doping, and Width Influence on Rasbha Spin-Orbit Coupling in AlInSb Quantum Wells

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The electron spin is coupled to electric fields through the spin-orbit interaction. One type of spin-orbit interaction, the Rashba spin-orbit interaction, originates in the inversion asymmetry of the carrier's host nanostructure. This is in contrast to the Dresselhaus spin-orbit interaction which originates from the *bulk* inversion asymmetry of a crystal. The lack of inversion symmetry in the nanostructure may be due to an external applied electric field, an internal potential between the carriers in the well and the donor layer, or the valence band structure.

The Rashba spin-orbit interaction may be calculated by means of a projection operator formalism, in which the influence of the valence states is included in the conduction band states as a first- or second-order perturbation term. From an effective-mass calculation, then, the effective Rashba coupling can be calculated. The Rasbha interaction then splits into interface and electric field terms, which come from the inversion asymmetry of the nanostructure valence bands and the external applied electric field, respectively:[1,2]

$$\alpha_{efield} = \frac{\hbar^2 E_p}{6m_0} \int_{-\infty}^{\infty} \left(\frac{1}{\left(E_F - E_{\Gamma_7}(z) - \phi(z)\right)^2} - \frac{1}{\left(E_F - E_{\Gamma_8}(z) - \phi(z)\right)^2} \right) \frac{d\phi(z)}{dz} \left|\psi(z)\right|^2 \mathrm{d}x$$

$$\alpha_{interface} = \frac{\hbar^2 E_p}{12m_0} \sum_{i=0}^{N_i} \left(\frac{E^+_{\Gamma_7}(z_i) - E^-_{\Gamma_7}(z_i)}{\left(E_F - E_{\Gamma_7}(z_i) - \phi(z_i)\right)^2} - \frac{E^+_{\Gamma_8}(z_i) - E^-_{\Gamma_8}(z_i)}{\left(E_F - E_{\Gamma_8}(z_i) - \phi(z_i)\right)^2} \right) \left|\psi(z_i)\right|^2$$

Where E_F is the Fermi energy, $E_{\Gamma_i}(z)$ is the energy of the edge of the Γ_i valence band (a plus or minus indicates that it is to the $+z$ or $-z$ side of an interface), $\phi(z)$ is the electrostatic potential (either internal or external), E_p is the conduction band–valence-band coupling parameter, N_i is the number of interfaces in the nanostructure, and $\psi(z)$ is the effective-mass wavefunction.

Using self-consistent solutions of the Poisson and effective mass Schrödinger equations at zero applied electric field, we have calculated the Rashba spin-orbit interaction strength for a variety of $Al_{x(z)}In_{1-x(z)}Sb/\ Al_{0.1}In_{0.9}Sb$ quantum wells. The wells were of different types (square, triangular, half-parabolic, and half-quadratic; each being symmetric or having an abrupt interface at the minimum Al concentration) and in a variety of orientations (i.e. with the abrupt interface on the side of the well toward or away from the dopant layer). In addition to the well types and orientations, the doping was varied between $.625 \times 10^{11} cm^{-2}$ and $1.875 \times 10^{11} cm^{-2}$ (located 20nm away from the nearest well edge) and the well widths were varied between 10nm and 20nm.

We find that the quantum wells in which the slope is toward the dopant layer have a lower α value, owing to the fact that the interface and electric field terms are of opposite sign. As a function of doping, however, the Rashba couplings of these wells, when narrow, change sign, allowing perhaps the sign to be changed as a function of applied gate voltage. The small magnitude of the Rasbha spin-orbit interaction of these wells, however, (8.2×10^{-14}eV m makes this a very small spin splitting relative to the other wells.

The Rashba coupling of wider wells shows a greater sensitivity to dopant concentration than that of the narrower wells, owing to the greater ability of the wavefunction to distort within the well, i.e. increase the asymmetry of the electron probability density at the interfaces. This likely also indicates a greater ability to tune the wavefunction with an external electric field.

The parabolic well with the abrupt interface away from the dopant layer provides the greatest-magnitude Rashba coupling at low dopings ($.625 \times 10^{11} cm^{-2}$ with $\alpha = 1.7 \times 10^{-12} eVm$ and $1.25 \times 10^{11} cm^{-2}$ with $\alpha = 2.6 \times 10^{-12} eVm$) but is surpassed by the square well at the high doping ($1.875 \times 10^{11} cm^{-2}$ with $\alpha = 3.2 \times 10^{-12} eVm$).

A number of wells show a saturation of the Rasbha coupling as a function of well width. Because of this and also due to growth considerations, it is possible that larger Rashba couplings might be achieved at wider well widths than were investigated here, based upon the trends we have found. In particular, the symmetric parabolic well indicates that it could surpass the square well at reasonable well widths (80-100nm).

We have studied the zero-applied-field Rashba spin-orbit interaction of a large number of $Al_{x(z)}In_{1-x(z)}Sb/\ Al_{0.1}In_{0.9}Sb$ wells of varying structures, dopings, and widths. We find that which structure's Rasbha coupling is the largest depends on well width and doping. A narrow half-parabolic well in which the abrupt interface is away from the dopant layer is optimal at low doping, whereas a square well is optimal at narrow widths and higher dopings or a symmetric parabolic well at higher dopings and larger well widths. In addition, the direction of the well asymmetry relative to the dopant layer is critical to the overall Rashba coupling. The sign change may provide greater tunability of these wells, but at low coupling magnitude.

1 Lange, J. *Quantentransport in Halbleiter-Heterostrukturen* (RTWH Aachen, 1996).

2 Schäpers, T. *et al.* "Effect of the heterointerface on the spin splitting in modulation doped $In_xGa_{1-x}As/InP$ quantum wells for $B \to 0$." *Journal of Applied Physics* **83**, 4324 (1998).

TUE 41:

Classical-to-Quantum transition of a cavity field interacting with atoms

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In this work we studied the quantum-to-classical transition of an optical cavity mode based on measurement of the correlations between two atoms which do not interact with each other, but interact with the cavity mode.

Varying the system parameters, such as the cavity decay rate, the strength of the pumping classical (external) field and the coupling strength between the atoms and the cavity mode, we show when the cavity mode has a classical or quantum behavior.

The use of the correlations between two atoms is employed to describe such a transition because it is known that a cavity mode is not able to generate any kind of quantum correlation between the atoms when the cavity mode behaves classically. These quantum correlations are quantified by quantum discord and entanglement of formation. Then, when the cavity mode behaves classically, all the quantum correlations must be null. On the other hand, the quantum correlations can be non-zero only when the cavity mode has a quantum behavior. In this way, the presence of quantum correlations works out as a signature of the non-classical behavior of the cavity field.

Firstly, we note that there is a time window where the mode has a classical behavior, such that the time window depends on the cavity decay rate, the coupling strength between the atoms and the cavity mode and the number of atoms.

When there are only two atoms inside the cavity, we note that the entanglement between them disappears in the asymptotic limit, but the quantum discord has a non-zero value in this limit, even when we have many photons inside the cavity. Therefore, it reveals that the cavity mode, which is quantum by construction, always preserves its quantum behavior in the asymptotic limit even with many photons inside the cavity. Thus we note that the quantum discord is more efficient than the entanglement to observe the non-classical behavior of the cavity mode.

TUE 42:

Entangling remote nuclear spins linked by a chromophore

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(3) *Centre for Quantum Technologies, NUS, Singapore 117543*
(4) *CAESR, The Clarendon Laboratory, University of Oxford, OX1 3PU, UK*
(5) *CAESR, ICL, Department of Chemistry, University of Oxford, OX1 3QR, UK*

Molecular nanostructures may constitute the fabric of future quantum technologies, if their degrees of freedom can be fully harnessed. Ideally one might use nuclear spins as low decoherence qubits and optical excitations for fast controllable interactions. Here we present a joint experimental and theoretical investigation of the prospects for an optically controlled gate between molecular spin qubits. Specifically, we consider a structure involving two nuclear spins, without any direct interaction, and an optically excited electron spin mediator. The interaction between the mediator and the nuclear spins leads to an effective coupling of the two remote spins. The strength of this coupling differs by several orders of magnitude according to the mediator state. Strong coupling can entangle a wide variety of product states of the remote spins, while weak coupling preserves this entanglement.

Crucial for this scheme to create and preserve entanglement is that certain parameters like the lifetime of the excitation, and the coupling strength of the excitation to the nuclear spins fulfill some conditions. Hence we present experimental results and DFT modeling on functionalized fullerenes in the second part of the poster. Here we used time resolved EPR and ENDOR to investigate both the interaction between the triplet spin of photo-excited fullerene and the nuclear spin of functional groups attached to the fullerene cage and the relevant relaxation times. These results show great promise for the implementation of our entangling scheme and will help identify other candidate molecular systems.

TUE 43:

Spin-dependent transport through a Dirac delta potential coupled to a harmonic coordinate

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Spin-dependent transport refers to the scenario in which the spin polarization of the electron affects its motion. This can, for example, be achieved in semiconductor heterostructures containing a magnetic layer, such as ZnSe/

$Zn_{1-x}Mn_xSe/ZnSe$. In these systems, the s-d interaction between the conduction electrons and those in the $3d^5$ orbital of the magnetic impurities [1,2] gives rise to effective spin-dependent electron potentials. Here, we consider the limit of a thin magnetic layer in the heterostructure, and describe the system as a spin-dependent Dirac delta potential, additionally allowing spin-flips in the transmission and reflection processes. Moreover, we include the electron-phonon interaction by considering a harmonic oscillator coupled to the delta potential [3,4].

Using the Green's function method, we investigate the spin-dependent transmission probability through the n-th harmonic mode as a function of the energy of the impinging electrons. For a repulsive potential, we find kinks around energies $n\hbar\omega$ ($n = 1, 2, ...$), whereas for an attractive potential, we identify Fano resonances [5]. Furthermore, we show that by enhancing spin-flip processes, Fano resonances may also be present for the repulsive potential.

This work was supported by the Swiss NSF, the NCCR Nanoscience, DARPA, FAPESP, CAPES, CNPq and Pró-reitoria de Graduação da Universidade de São Paulo.

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[2] J. C. Egues and J. W. Wilkins, Phys. Rev. B **58**, R16 012 (1998).
[3] B. Y. Gelfand, S. Schmitt-Rink and F. J. Levi, Phys. Rev. Lett. **62**, 1683 (1989).
[4] W. Cai et al., Phys. Rev. B **41**, 3513 (1990).
[5] U. Fano, Phys. Rev. **124**, 1866 (1961).

TUE 44:

Spin orbit mediated entanglement in graphene

Alexander Lopez [1,2] and John Schliemann [2]

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(2) *Institute for Theoretical Physics, University of Regensburg, Regensburg, Germany*

We discuss the interplay of spin orbit coupling (SOC) and nonmagnetic impurities on the generation of two and three qubit entanglement on graphene. We consider both extrinsic and extrinsic SOC contributions, and analyze the robustness of the generated electron-hole entanglement against scattering off static impurities. Thermal effects are also presented, and possible experimental implementations are discussed as well.

TUE 45:

Microwave Detection in a Magnetic Single-Electron Transistor

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(2) *Norwegian University of Science and Technology*

Magnetic aspects of single-electron transistors (SET's) have been the focus of much recent interest. We consider an SET in the form of a ferromagnetic dot in contact with normal-metal and pinned ferromagnetic leads. Microwave-driven precession by the dot induces a pumped electric current. In open circuits, this pumping produces a measurable reverse bias voltage, which can be enhanced and made highly nonlinear by Coulomb blockade in the dot. The dependence of this bias on the power and spectrum of microwave irradiation may be utilized to develop nanoscale microwave detectors analogous to single-electron transistor-based electrostatic sensors and nanoelectromechanical devices.

TUE 46:

Dielectric properties and magnetization of gapped graphene

Andreas Scholz, John Schliemann

Department of Physics, University of Regensburg, Germany

Graphene, which was first isolated in 2004, soon began to attract enormous interest in condensed matter physics because of its remarkable electronic properties and possible applications, e.g. in the field of Spintronics. Graphene differs, compared to most two-dimensional systems, by its relativistic energy-momentum relation and its non-trivial spinor structure, originating from the two-atomic Wigner-Seitz cell. We have studied the systems response to an electromagnetic potential, described by the current-current and density-density correlation functions, for arbitrary frequency, wavevector, doping and bandgap. The static limit was used in order to find the Landau (orbital) and Pauli magnetization as well as the Lindhard correction which describes Friedel and RKKY oscillations. While graphene without bandgap is quite different compared to the 2DEG, we found that gapped graphene shows features of both the 2DEG and the gapless case. Furthermore, we have studied the influence of an increasing mass term, whereat we found that increasing the bandgap makes gapped graphene behave more and more like the 2DEG. In the *nonrelativistic limit*, i.e. if the bandgap is compareable to the chemical potential, the plasmon dispersion, the Lindhard function and the Pauli susceptibility reproduce the results of the 2DEG while the peculiar band structure of gapped graphene yields to a pseudospin paramagnetism and thus to a special form of the orbital magnetization.

TUE 47:

Low temperature transport study of InAs/InP core/shell quantum dot devices

Eduardo J. H. Lee[1], Georgios Katsaros[1], Xiaocheng Jiang[2], Charles M. Lieber[2], Silvano De Franceschi[1]

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Semiconductor nanowires are a fascinating class of materials, due to the high degree of control achieved in their growth, and to the versatility of their physical properties. In particular, considerable interest has been devoted to InAs nanowires, largely due to their high electron mobility, low effective mass, and low contact resistance, which may lead to electronic devices of improved performance. Additionally, it is envisioned that the strong spin-orbit interaction of InAs could be exploited for the realization of spintronic devices. Recently, some of us developed a technique for growing nanowires comprised of an InAs core covered by a uniform InP shell of 2-3 nm. This configuration leads to the confinement of a one-dimensional gas of increased mobility in the InAs core, thus making it an attractive system for transport studies. In spite of their small diameter ($\sim$ 30 nm), room temperature measurements on InAs/InP core/shell devices revealed two-probe on-resistances as low as a few $k\Omega$. In this work, we report a low-temperature transport study on quantum dot devices made from Al-contacted InAs/InP core/shell nanowires. Different transport regimes are achieved depending on whether the contacts are in a normal or a superconducting state and on whether their coupling to the nanowire quantum dot is weak or strong. The superconductivity of the contacts can be turned on and off by finely tuning a magnetic field across the superconducting critical field. The tunnel coupling strength is found to vary with the voltage applied to a back gate. By taking advantage of this tunability, we have explored different aspects associated with the spin degree of freedom of the confined electrons. In particular we shall report on the intriguing competition between Kondo-type and superconducting correlations in strongly coupled spin-1/2 quantum dots. Using the magnetic field to tune the superconducting gap, Δ(B), we observe a narrowing and gradual suppression of the zero-bias Kondo resonance with the ratio $\Delta(\mathrm{B})/k_B T_K$, where T_K ($\sim$ 0.9 K) is the Kondo temperature measured in the absence of superconductivity, i.e. just above the critical field. This suppression is accompanied by the emergence of Kondo-enhanced Andreev-reflection structures at $eV = \pm\Delta(\mathrm{B})$ in line with earlier experiments. In addition, current-biased measurements reveal that the conductance peak at zero bias coexists with a proximity supercurrent of the order of a few hundred pA. Under relatively large magnetic fields, well-above the superconducting critical field of the contacts, the Kondo resonance is split by the Zeeman effect. In this regime, we have carried out some first studies of the electron g-factor. By varying the field angle with respect to the nanowire axis we find strongly anisotropic g-factors with values ranging between $\sim$ 0.9 and $\sim$ 24 and $g_{//}/g_{\perp}$ as high as $\sim$ 17.

TUE 48:

Transport and local magnetism in zigzag graphene nanoribbons

R.M. Guzmán Arellano, Gonzalo Usaj

Centro Atómico Bariloche, CNEA, Instituto Balseiro, CNEA-UNCuyo, and CONICET.

In this work, we study the effect of magnetic order on the transport properties of zigzag graphene nanoribbons (ZGNR). The mangnetism in ZGNR originates from the presence of eigenstates that are localized at the edges of the nanoribbon ('edge states'). In this work, we use a tight binding Hubbard model in the mean field approximation to describe the graphene electronic structure and to study the different magnetic phases that appear as the electronic doping is changed (which is controlled by an external electrostatic potentials). Once the magnetism of the system was characterized, we study the electrons transport across a potential well within the Landauer's formalism. We show that the coexistence of the potential well and the magnetism creates regions with different magnetic order between the nanoribbons edges, which in turns leads to the appearance of non-trivial interference effects on transport. Namely, the conductance shows narrow dips due to the interference between two conducting channels (Fano resonances). These two channels are related to the presence of two types of states within the potential well: the extended ones that are strongly coupled to the leads, thus providing the continuous transport channel, and the others which are localized in the transverse direction, and thus weakly coupled to the leads, that provides the discrete transport channel. In addition, we analyse the stability of the magnetic order as a function of the applied bias.

TUE 49:

Near Field Photon Emission and Revival in Quantum Dots Embedded in Dielectric Micro-cavities

Sergio Tafur[1,2] and Michael N. Leuenberger[1,2]

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Modeling the spontaneous emission of photons coupled to the electronic states of quantum dots is important for understanding quantum interactions in dielectric media as applied to proposed solid-state quantum computers, single photon emitters, and single photon detectors. A quantum dot in an excited state can be experimentally observed to decay to its ground state and the observed homodyne tomography of the emitted photon can yield information about the qubit state of the emitter. The characteristic lifetime of photon emission is traditionally modeled in the Weisskopf-Wigner approximation. In this study we seek to model the fully quantized spontaneous emission, including near field effects, of a photon from the excited state of a quantum dot beyond the Weisskopf-Wigner approximation. We propose the use of discretized central-difference approximations of space and time partial derivatives, similar to finite-difference time domain models, to describe single photon states via single photon operators. Additionally, within the future scope of this model, we seek results in the Purcell and Rabi regimes for spontaneous emission events from quantum dots embedded in micro-cavities.

Thursday Poster Session

Nov 4, 17:15 – 19:15

THU 1:

Single-qubit lasing in the strong-coupling regime

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Motivated by recent "circuit QED" experiments we study the lasing transition and spectral properties of single-qubit lasers. In the strong coupling, low-temperature regime quantum fluctuations dominate over thermal noise and strongly influence the linewidth of the laser. When the qubit and the resonator are detuned, amplitude and phase fluctuations of the radiation field are coupled, and the phase diffusion model, commonly used to describe conventional lasers, fails.

We predict pronounced effects near the lasing transition, with an enhanced linewidth and non-exponential decay of the correlation functions. We cover a wide range of parameters by using two complementary approaches, one based on the Liouville equation in a Fock state basis, covering arbitrarily strong coupling but limited to low photon numbers, the other based on the coherent-state representation, covering large photon numbers but restricted to weak or intermediate coupling.

THU 2:

The guidance of vortex-antivortex pairs by in-plane magnetic dipoles in a superconducting finite-size film

A. V. Kapra[1], V. R. Misko[1], D. Y. Vodolazov[1,2], F. M. Peeters[1]

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(2) *Institute for Physics of Microstructures, RAS, 603950 Nizhny Novgorod, Russia*

Hybrid superconducting nanostructures have recently attracted considerable attention due to possibility of manipulating vortex matter by using various artificial pinning arrays. In particular, a bias magnetic field (induced by pinning arrays of magnetic dots) suppresses the superconducting order parameter (OP) and produces vortices (antivortices). The OP in the hybrid structure is calculated numerically on the basis of the time-dependent Ginzburg-Landau (TDGL) equation. We study the vortex-antivortex dynamics in a hybrid structure consisting of a finite-size superconductor with magnetic dipoles on top which generate vortex-antivortex pairs in the presence of an external current. The v-av dynamics is analyzed for different arrangements and magnetic moments of the dipoles, as a function of angle α between the direction of the magnetic dipole and that of the Lorentz force produced by the applied current. The interplay of the attractive interaction between a v-av pair and the Lorentz force leads either to the separation of (anti)vortices and their motion in opposite directions or to their annihilation. The calculation of the IV-curve shows that the critical current of the hybrid structure is highly sensitive to this. We found a critical angle α_c, below which vortices and antivortices are repelled, while for larger angles they annihilate. In case of a single (few) magnetic dipole(s), this magnetic-dipole-induced v-av guidance is influenced by the self-interaction of the antivortex pair with their images in a finite-size sample, while for a periodic array of dipoles the guidance is determined by the interaction of a v-av pair with other dipoles and v-av pairs created by them. This effect is tunable through the external current and the magnetization and size of the magnetic dipoles. The manipulating vortex matter by using various artificial pinning arrays (dots, holes, impurities) is of significant importance for possible applications in fluxonics nano- and micro-devices.

Acknowledgements: This work was supported by the “Odysseus” program of the Flemish Government and the Flemish Science Foundation (FWO-Vl), the Interuniversity Attraction Poles (IAP) Programme — Belgian State — Belgian Science Policy, and the FWO-Vl.

THU 3:

Different types of integrability and their relation to decoherence in central spin models

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In a large variety of nanostructures spins couple to a bath of other spin degrees of freedom. Important examples are given by semiconductor and carbon nanotube quantum dots, phosphorus donors in silicon, nitrogen vacancy centers in diamond and molecular magnets. Commonly such systems are described by so-called central spin models [1,2].

We present recent results on the relation between integrability and decoherence in central spin models with more than one central spin. We show that there is a transition between integrability ensured by Bethe ansatz and integrability ensured by complete sets of commuting operators. This has a significant impact on the decoherence properties of the system, suggesting that it is not necessarily integrability or non-integrability which is related to decoherence, but rather its type or a change from integrability to non-integrability [3].

[1] J. Schliemann, A. Khaetskii, and D. Loss , J. Phys.: Condens. Mat. **15**, R1809 (2003).
[2] W. A. Coish and J. Baugh, phys. stat. sol. B **246**, 2203 (2009).
[3] B. Erbe and J. Schliemann, to appear in Phys. Rev. Lett., preprint: arXiv:1006.4983.

THU 4:

Spin-Polarized Scanning Tunneling Microscopy

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Eindhoven University of Technology

Our goal in this project is to use spin-polarized scanning tunneling microscopy (SP-STM) to study nano-magnetic structures in semiconductors. As a proof of concept, we present measurements on a metal which has been studied previously [Phys. Rev. Lett. 84, 5212 (2000)]: a W(110) crystal covered with 1.5 ML Fe. The crystal has step edges and plateaus of roughly 7 nm wide. A plateau is divided in a mono layer wire and a double layer wire of Fe, because of the step flow growth method. By also coating the W tip in situ with several ML Fe, the tip is made spin sensitive. By means of a lock-in amplifier, differential conductivity data is obtained from the surface, which contains both electronic and magnetic information. The mono and double layer wires of Fe on the surface show a different contrast in the data. Additionally, nearby mono layer wires are shown to be antiferromagnetically ordered, which is a sign that our tip is sensitive for in-plane magnetization of the surface. As a next step, we are planning to perform luminescence (STL) measurements on the same sample. It is possible that the optical data also contains magnetic information in the form of polarized light.

THU 5:

Hyperfine interaction in electron spin qubits in quantum dots coupled via an optical cavity

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Electron spin states in semiconductor structures represent good candidates for implementing quantum bits (qubits) [1]. Logical gates between distant qubits can be realized using a high finesse cavity and an adjustable laser field (see Fig. 1) [2]. Virtual Raman transitions between an electron in the conduction band and a heavy hole in the valence band provide a controllable mechanism for single and two qubit operations. However there are several processes in semiconductor quantum dots leading to decoherence. In the time scale for the optical control of the qubit states the main source of the decoherence is due to Fermi contact hyperfine interaction with the surrounding nuclear spins (e. g. Knight shift of the Zeeman frequency) [3]. Here we calculate the fidelities of the two qubit operations in the presence of the nuclear spins.

[1] D. Loss and D. P. DiVincenzo, Phys Rev. A **57**, 120 (1998).
[2] A. Imamoglu *et al.*, Phys. Rev. Lett. **83**, 4204 (1999).
[3] W. A. Coish and J. Baugh, Phys. Stat. Solidi (b) **149**, 1443 (2009).

THU 6:

Angular Dependence of Magnetoelectric effect with electrical polarization direction in $(1-x)Pb(Mg_{1/3}Nb_{2/3})-xPbTiO_3/NiFe_2O_4$ composite

Alexandre Jose Gualdi[1], Fabio Zabotto[2], Ducinei Garcia[2], Adilson Jesus Aparecido de Oliveira[1]

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Multiferroic materials with coexistence of ferroelectric and ferromagnetic orders are of great interest because of simultaneous control of ferroic phases due to applications in multifunctional devices. In these materials, the coupling interaction between the different order parameter could produce new effects, such as magnetoeletric effect. In this work we present the magnetoelectric and magnetostrictive characterization of multiferroic composites based on $(1-x)Pb(Mg_{1/3}Nb_{2/3})-xPbTiO_3(PMN-PT)$, as ferroelectric matrix, and $NiFe_2O_4$, as ferromagnetic phase. The samples were synthesized by hot forging process at 1050^oC during 30 min and 6MPa. After the synthesis, the sample was submitted to electrical polarization up to 2 kV/cm.

The magnetoelectric (ME) and magnetostriction (MS) measurements were performed at room temperature as a function of angle between the applied D.C. magnetic field and the electrical polarization direction, using a home−made experimental setup. The results shows an angular dependence of the ME coefficient in respect of D.C. magnetic field direction showing maximum when the field is parallel with the electrical polarization. The same behavior was observed in MS measurements. These results are indication that the ME effects observed in the samples is a directly associated to mechanic coupling between ferromangetic and ferroelectric phase due to magnetostrictive and piezoelectric coefficients.

THU 7:

Emergence of the persistent spin helix in semiconductor quantum wells

Jake Koralek[1], Joe Orenstein[1], Luyi Yang[1], Chris Weber[1], David Awschalom[2], Shawn Mack[2], Mike Lilly[3]

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(3) *Sandia National Lab*

The persistent spin helix is a collective spin excitation of 2D electron systems that emerges as a new conserved quantity when the spin-orbit interaction is tuned to recover SU(2) symmetry in the spin Hamiltonian. The spin helix has great potential for application to spintronics, where it would allow rapid gate control of the spin lifetime over several orders of magnitude in devices with both high electron density and high mobility. We observe the persistent spin helix in semiconductor quantum wells using transient grating spectroscopy. This technique uses femtosecond pulses of light to generate spatially non-uniform spin (or charge) patterns in the sample. Studying the decay of spin patterns of varying periodicity allows quantitative characterization of the diffusion properties of the material. Additionally, we have developed a phase-resolved version of the transient grating technique which enables us to observe the spin helix moving in an electric field with 1 nm spatial resolution. Using this technique we have uncovered a qualitatively new picture of spin transport in the spin-orbit coupled Fermi gas. Supported by DMSE office of BES-DOE, NSF, MARCO, ASEE and CNID.

THU 8:

Studies on the ensemble of Wishart-Tsallis random matrices

Felippe Otavio Souza de Almeida, Andre Mauricio C. de Souza

Universidade Federal de Sergipe

Wishart random matrices, composed of independent and real elements that follow the distribution of Tsallis, is studied. In particular, the eigenvalues and spacing distributions of levels. For entropic index $1 < q < \frac{5}{3}$, using a variable transformation, it is possible to show that such matrices fall in the same class of Wishart gaussian set. For entropic index $\frac{5}{3} < q < 2$, each value of q presents a different universality class.

THU 9:

Spin polarized electrons generated in core-shell nanowires

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Generation of spin-polarized electrons is an essential part of spintronics research. It has been shown that spin-polarized electrons can be generated optically in semiconducting materials such as GaAs. Here the heavy hole → conduction band transition results in the generation of spin polarized electrons. We found that spin polarization is further enhanced in nanowires due to the quantum confinement effect. In GaAs/$Al_xGa_{1-x}As$ core-shell nanowires grown in the [001] direction, the degree of spin polarization is influenced by the Al concentration (x) and also the size of the core. Thus by varying both the Al concentration (x) and the core radius (R_c) we can generate spin polarized electrons for different incident photon energies. Our results show how the valence band ground state around the Γ point influences the absorption intensity and hence the generation of spin polarized electrons. Our methodology is based on the **k.p** method with the 6×6 Kohn-Luttinger Hamiltonian, and we took into account the spin-orbit interaction in all our calculations.

THU 10:

Zitterbewegung-induced Spin Resonance in Quantum Wires

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Recently, the *Zitterbewegung* in quantum wires was proposed theoretically by Schliemann *et al.* [1]. This effect is characterized by an oscillatory motion in the position and spin components of an electron wave packet injected along the quantum wire with spin-orbit coupling. We investigate the *Zitterbewegung* evaluating time dependent expectation value for the spin operators. Here we consider the *Zitterbewegung* in a multi-band quantum wire with both the Rashba and Dresselhaus spin-orbit interactions. We find that an external magnetic field perpendicular to the quantum wire can be used to tune the probability of spin flip, i.e., the resonance condition. Interestingly, the comparison between the harmonic and square confinements shows distinctive physical features. The square confinement exhibits several resonance conditions in contrast to the harmonic confinement which displays only one resonance. A possible experimental scenario to observe this effect is proposed using injection via a quantum point contact [2]. Similarities between the *Zitterbewegung*-induced spin resonance and the experimentally observed "ballistic spin resonance" [3] are also discussed. This work is supported by the CIAM program (NSERC-CNPq-CONICET) and FAPESP.

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THU 11:

Ferromagnetic Instabilities in Cylindrical Quantum Wires

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Ferromagnetic instabilities on two-dimensional electron gases (2DEGs) and quasi-1D quantum wires, both at high magnetic fields, arise from the interplay of the Coulomb and thermal energy scales near opposite spin level crossings. At low enough temperatures, a spin-polarized ferromagnetic phase lowers the Coulomb energy as the Pauli exclusion principle keeps the electrons apart. Additionally, at zero magnetic field, split-gate quantum wires show an anomalous conductance plateau, i.e.: the 0.7 anomaly, possibly related to an spontaneous spin polarization induced by the Coulomb interaction.

Motivated by our quantitative results on 2DEGs on the quantum Hall regime, we use a similar model to study the ferromagnetic instabilities on the conductance of cylindrical core-shell quantum wires. Here we use the spin density functional theory via the Kohn-Sham self-consistent scheme within the local spin density approximation to calculate the quantum wire electronic structure and the Landauer-Buttiker formalism to obtain the conductance G in the linear response regime. The conducting electrons of the wire are coupled to the reservoirs via the saddle-point model for the transmission function.

Differently from split-gate quantum wires, the symmetry of cylindrical core-shell quantum wires retains the orbital angular momentum as a conserved quantum number. Therefore, these may provide an interesting system to investigate the interplay of spin and orbital angular momentum properties. Our results show that the zero magnetic field spontaneous spin-polarization of the usual 0.7 anomaly of split-gate wires only appears at modes with orbital angular momentum different from zero. This result suggests a connection between the usual 0.7 anomaly and the symmetry of the electronic distribution.

THU 12:

Exchange driven ferromagnetic instabilities at high magnetic fields in quantum wires via DFT

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Ferromagnetic instabilities [1] on two-dimensional electron gases (2DEGs) and quasi-1D quantum wires, both at high magnetic fields, arise from the interplay of the Coulomb and thermal energy scales near opposite spin level crossings. At low enough temperatures, a spin-polarized ferromagnetic phase lowers the Coulomb energy as the Pauli exclusion principle keeps the electrons apart.

Motivated by our quantitative results on 2DEGs on the quantum Hall regime [2,3], we use a similar model to study the ferromagnetic instabilities on the conductance of split-gate quantum wires [4]. We use the spin density functional theory (SDFT) via the Kohn-Sham self-consistent scheme within the local spin density approximation (LSDA) to calculate the quantum wire electronic structure and the Landauer formalism to obtain the conductance G in the linear response regime.

The characteristic quantized plateaus of the quantum wire magnetoconductance $G = ne^2/h$ shows up as spikes on transconductance dG/dV_{SG}, where V_{SG} is the split-gate voltage used to control the number n of occupied transverse modes. In split-gate quantum wires at high in-plane magnetic fields, the instabilities occurs at opposite spin crossings of transverse modes. The transconductance measurements [4] shows discontinuous structures near these crossings, referred to as “0.7 analogs” due to similarities with the puzzling zero-magnetic-field 0.7 anomaly of quantum point contacts. First, we show [5] that an exchange-induced abrupt rearrangement of the energy levels near the crossings leads to the discontinuous behavior of the transconductance. Second, modeling the wire-reservoir coupling via the saddle-point model for the transmission function, we show that the broadening due to the coupling is required to obtain the transconductance signal near the crossings.

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THU 13:

Quantum critical behavior and magnetism of antiferromagnetic Cr-Ti alloys

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Along the last decades, Cr and its alloys with small impurity quantities have been very studied because of its peculiar antiferromagnetic state, described by spin-density waves (SDW) incommensurate with reciprocal lattice. The particular shape of the Fermi surface of Cr is the responsible for the SDW state. Doping Cr with transition metals, changes its electronic structure and the shape of Fermi surface, resulting in a change of incommensurability parameter and consequently in dramatic effects on its physical properties, such as the Néel temperature (TN). The interest on studies of Cr and its alloys has been renewed by some works that reports a quantum phase transition in Cr-V, Cr-Ru-V and Cr-Ti systems. In these cases, they observed a presence of a zero temperature paramagnetic to antiferromagnetic phase transition on decreasing the doping concentration. For Cr-Ti alloys, we observed in previous work that TN vanishes around 1.3at.%Ti, instead of occurring at 1.9at.%Ti, such suggest the band rigid model. Around the same concentration, we observed the change of regime curves of resistivity ratio measurements and an abrupt jump in the Hall coefficient, suggesting the existence of a quantum critical point. In this work we present the results of X-ray structural characterization, resistivity ratio, magnetic susceptibility and Hall number measurements for SDW antiferromagnetic Cr-Ti alloys. The low temperature measurements as a function of Ti concentration indicates that exists a quantum critical point at 1.3at.%Ti.

THU 14:

Generalization of superconducting qubit and qudit architecture

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We introduce the new implementation scheme of superconducting qudit, which is the system of two Josephson junctions made of 2 different high temperature superconductors with d-wave order parameter. In the literature and in the conducted research around the globe most attention is focused mainly on implementation of qubit in various physical systems, particularly in superconductor (superconducting qubit) in one of three architectures: flux qubit, charge qubit and phase qubit. We propose the generalization of superconducting qubit architecture, so it is possible to obtain double qubit, which is the superposition of single qubits in the phase-charge architecture (phase-charge qudit), charge-flux architecture (charge-flux qudit), flux-phase architecture (flux-phase qudit), double phase architecture (phase-phase qudit), double charge architecture (charge-charge qudit), double flux architecture (flux-flux qudit). We show formalisms suitable for the description of the system.

THU 15:

Tunneling induced transparency in coupled semiconductor quantum dots

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Semiconductor quantum dots coherently driven by pulse laser are physical systems which allow studying the dynamical properties of confined quantum states. These systems are good candidates for a solid-state qubit, opening the possibility for several investigations in quantum information processing. In this work, we study the optical properties of an asymmetric double quantum dot coupled by tunneling. By solving the Liouville-Von Neumman-Lindblad equation, considering the Markovian approximation, we calculate the optical susceptibility considering the spontaneous exciton decay as the main decoherence channel. In the limit of low optical excitation, we demonstrate that the tunneling coupling establishes an efficient destructive quantum interference path, which creates a sharp transmission region in the absorption spectra. This effect is analogous to the electromagnetic induced transparency observed in atomic systems, where the role of the optical pump field is replaced by a strong tunneling coupling parameter between quantum dots. As we increase the tunneling coupling, given a fixed value of the optical coupling intensity, the absorption spectra exhibits a behavior similar to Autler-Townes doublets. Numerical calculations allow us determine a wide and precise regime of parameters where the tunneling induced transparency effect can be experimentally observed. We consider physical parameters as tunneling coupling, external electric field detuning and laser intensity rigorously compatible with current experiments in III-V coupled quantum dots spectroscopy. In this framework, we calculate the refraction index and group velocity of the radiation pulse and suggest a possibility of slow light effects produced by tunneling and externally controlled by an electric field which modifies the level detuning.

THU 16:

Strong Light-Mater Coupling in Quantum Dot-Nanocavity System

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We present detailed theoretical and experimental investigations of electrically tunable single quantum dot (QD) - photonic crystal (PhC) nanocavity systems operating in the strong coupling regime of the light matter interaction. Unlike previous studies, where the exciton-cavity spectral detuning was varied by changing the lattice temperature, or by the adsorption of inert gases at low temperatures, we employ the quantum confined Stark-effect to electro-optically control the exciton-cavity detuning. Our devices enable us to systematically probe the emission spectrum of the strongly coupled system as a function of external control parameters, as for example the incoherent excitation power density or the lattice temperature. Those studies reveal for the first time insights in dephasing mechanisms of 0D exciton polaritons

[1]. Furthermore, the different size and strain profiles of different individual self-assembled QDs enable us to tune two spatially separated QDs in resonance with each other and the cavity mode simultaneously. We study such a system experimentally and theoretically [2] and observe a triple peak during resonance. This is a clear signature of a coherently coupled system of three quantum states.

For a single strongly coupled QD cavity system, we observe a clear anticrossing between exciton and mode emission (vacuum Rabi splitting $\Omega_{\mathrm{vrs}} \approx 120\ \mu$eV), when tuning them into resonance. When increasing the power of the incoherent optical excitation or the lattice temperature, the vacuum Rabi-splitting remains constant at first and then decreases until only a single broadened peak can be observed in the spectrum. From comparison with theory we could extract the pumping, decay and dephasing rates. For high pump powers or elevated temperatures dephasing leads to a reduction of the vacuum Rabi splitting. However, the system stays in the strong coupling regime although the double peak cannot be spectrally resolved [1]. In a second experiment, we experimentally and theoretically investigate a system of two QDs coupled to a nanocavity. The triple peak in resonance is a clear signature of the three coupled quantum states. Theory enables us to calculate the contributions of each quantum state to the eigenstates of the coupled system and, therefore, the coupling between the individual states [2].

We acknowledge financial support of the DFG via SFB 631 B3, and the German Excellence Initiative via NIM. JMVB acknowledges the support of the Alexander von Humboldt Foundation, CAPES, CNPQ and FAPEMIG.

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THU 17:

Spin relaxation of electrons in InGaAs/GaAs quantum wells with d-(Mn) doped barriers

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The interaction between magnetic ions and carriers on semimagnetic-semiconductor structures is a fundamental point for spintronic applications. We investigated the effects of Mn ions on the spin relaxation time of electrons. Our structure consists of an InGaAs/GaAs quantum well (QW) with a Mn-planar layer at the GaAs barrier separated by 3 nm from the QW interface. An additional C planar-doped layer is included in the opposite barrier to increase the 2DHG density in the well. We studied a series of samples with different Mn concentrations, including a reference sample with no Mn atoms. The hole densities were determined by Shubnikov-de-Haas oscillations and are consistent with the Stokes-shift energies obtained by optical measurements. We have performed continuous-wave (CW-PL) and time-resolved

(TR-PL) photoluminescence measurements with circularly polarized excitation and detection and variable excitation energy. We determined the electron lifetime, t and its spin relaxation time, ts, using both the Hanle effect and the time-evolution of the polarization degree directly obtained from TR-PL measurements. The results from the two techniques were rather consistent and revealed a threshold of Mn concentration at which both, tand ts, show a strong and abrupt fall. Surprisingly, this fall does not affect the CW effective polarization degree, since the ratio t/ts that determines this result remains basically constant for all samples.

THU 18:

Ion-induced epitaxy in Fe^+ implanted SiO_2/Si: synthesis and optical characterization of $FeSi_2$ nanoparticles

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Semiconductor silicides are of great interest for silicon-based optoelectronics, optical interconnects and optical communications technologies. Among the transition-metal silicides, $FeSi_2$ is the unique that owns a semiconductor phase (β) and two distinct metallic phases (α and γ). The semiconductor β-$FeSi_2$ is a promising material for photodetectors, light emitters and solar cells devices, due to its energy gap which is in the near-infrared region at about 1.55 μm. In particular, the metastable magnetic γ-$FeSi_2$ phase is a promising candidate for application in metal nanocrystal memory devices which employ discrete charge traps as storage element due to its high density of d states at the Fermi level. Although this material presents interesting properties few works have been reported on them.

We have synthesized and investigated the optical properties of $FeSi_2$ nanoparticles produced by ion-beam-induced epitaxial crystallization (IBIEC) in SiO_2/Si(100) n-type substrates. For this, Fe^+ ions were implanted at cryogenic temperature ($\approx$ 90 K) in two steps: i) 70 keV at the fluence of 5×10^{15} cm^{-2} and ii) 40 keV at the fluence of 3×10^{15} cm^{-2}. This implantation process produces an amorphous silicon layer of $\approx$ 115 nm thickness that was subsequently recrystallized by high energy irradiation with Si^+ ions at 600 keV with the target at 350 °C.

By Micro-Raman Scattering Spectroscopy (μRSS) we have identified the vibrational properties and thermal stability of the distinct $FeSi_2$ phases. Moreover, we show that annealing at T = 700 °C/1h (in a gas atmosphere 95% N_2 - 5% H_2) leads to complete phase transition from the metastable γ to the β phase. Our Transmission Electron Microscopy (TEM) results corroborate the μRSS characterization. Photoluminescence (PL) spectra of these samples measured at 2 K show a broad band at $\approx$ 0.79 eV which is attributed to intrinsic emission from β-$FeSi_2$. This emission band is only observed for samples annealed at 700 °C, as described above, dominated by β-phase.

THU 19:

Phase dependent spin manipulation in quantum dot

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Researches on spin qubits in semiconductor quantum dots (QD) have attracted a lot of attention since the seminal work of Loss and DiVincenzo [1]. Controlling a single electron spin in a QD is a key ingredient for implementing this in a solid-state device. Using ultra fast optical control is very attractive due to the possibility to achieve a spin rotation in a picosecond timescale, much shorter than the spin coherence time in such system [2]. Here, we use two lasers pulses with different frequency, polarization and relative phase to coherent manipulate a single electron spin in QD with a magnetic field applied in the Voigt geometry [3]. We have numerically solved the Schrödinger equation, and for lasers with large detuning to the trion (two electrons and one hole in the QD) transition we were also able to adiabatically eliminate the trion states, obtaining an effective Hamiltonian which couples the two electron spin states. The effective coupling is strongly dependent on the relative phase between the pulses, making it possible to complete switching it *on* and *off* by a simple adjust of the phase. We gratefully acknowledge financial support of the CAPES, CNPq and FAPEMIG.

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THU 20:

Quantum simulation of a two-Component Bose-Einstein Condensate using a NMR quadrupolar system

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The study of quantum properties as superconductivity, superfluidity, condensation showed new frontiers of knowledge and an evident technological advance. Mainly, the experimental implementation of the Bose-Einstein Condensation (BEC) stablish the new regime of macroscopic colective behaviour of cold atoms. Other quantum signatures were verified, where the most recent of them is the concept of turbulence [1]. In this kind of developments we can say affirmatively that the complexity of the experimental setup is the main obstacle to achieve other ideas, for example the storage of spin squeezing [2]. The study of squeezed spin state in BEC was discussed by many authors [2-6] and there is not an experimental implementation because its difficult setup.

In this sense, it would be more suitable if we can afford another quantum system with similar characteristics of a BEC that we could use to test

these new ideas. This physical context envolves the concept of Quantum Simulation discussed by R. Feynman [7], and few years after, experimental implementations were reported using Nuclear Magnetic Resonance (NMR) technique [8-11]. Our purpouse in this work is to show that NMR quadrupolar systems are capable to reproduce theoretical results developed to study storage of spin squeezing in a two-component BEC [2].

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THU 21:

Study of Electronic Properties of Quantum Rings

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This work aims at studying electronic and optical properties of nanosystems with ring topology, or quantum rings (QRs). This type of system has attracted the scientific community interest due to its rotational symmetry and the possibility to check quantum phenomena, as trapping of magnetic flux in its interior and effects related to Aharonov-Bohm interference [1,2]. The QRs studied in this work are formed by quantum dots (QDs) that collapse. For the QRs synthesis, some factors, such as temperature, amount of material deposited and annealing time, are important. The samples of InGaAs QDs were grown using Molecular Beam Epitaxy (MBE) and form the QRs. Analytical calculations of electronic structure were performed for the cases of an electron confined in a one-dimensional and three-dimensional quantum ring. These calculations will be complemented with simulation of the electronic structure of holes at the valence band using the k.p method, which is the main objective. This will allow the simulation of the photoluminescence and the effects of external fields.

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THU 22:

Non-Abelian formulation for Rashba and Dresselhaus coupling and the spin currents

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A gauge theory interpretation for the Rashba and Dressehaus Hamiltonians is briefly discussed. It is draw the fact that Pauli Hamiltonian and the non Abelian gauge formulation of Rashba and Dresselhaus spin orbit interactions cannot be written correctly in a general gauge invariant form. We argue that the correct formulation demands a gauge symmetry breaking term that allows for locally gauge invariant matter spin current. The explicit form of the radiative spin current is written in the seek for a physical interpretation.

THU 23:

Growth and characterization of MnGa epilayers on GaAs

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Hybrid heterostructures consisting of MnGa epilayers grown by molecular beam epitaxy on GaAs substrates have been studied in our group. The aim of the research is stabilized the MnGa-based heterostructures on GaAs surfaces in view their potential for applications to develop spintronics devices. Crystalline structure of MnGa epilayers will be characterized in situ by using Reflection High Energy Electron Diffraction (RHEED). During growth of the MnGa epilayers it will be possible to determine the surface stoichiometry by carrying out X-ray photoelectron spectroscopy (XPS) analyses using a ESCA VG 3000 spectrometer equipped with unmonochromatized Mg X-ray source and hemispherical analyzer with overall energy resolution of 0.8 eV through ultra-high vaccum transfer between XPS chamber in tanden with MBE system. Complementary, the samples will be characterized ex situ by using standard x-ray diffraction measurements and electron diffraction with an electronic microscope JEOL JEM 1200EX-II operating at 120 kV. MnAs compounds have a tetragonal structure exhibiting a ferromagnetic behavior with a Curie temperature above room temperature and strong uniaxial magnetic anisotropy. Such magnetic properties together with a chemical compatibility as well as a favorable lattice-matching between MnGa on GaAs lead to MnGa as a strong candidate for applications in magnetic recording devices. Epitaxial relationships between MnAs and GaAs can also mimic the complex behavior of MnAs epilayers on GaAs in terms of a magnetostructural transition with phase coexistence. The thickness dependences of the Curie temperature and magnetic anisotropy and their interplay with residual stress due to lattice mismatching will be investigated by magnetic measurements performed with a vibrating sample magnetometer (Cryogenic model Q7180b).

THU 24:

Spin Coherence in Graphene Nanoribbons

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Quantum computing requires long coherence times. A spintronics approach is considered promising due to the readily available expertise in solid state physics and possibly long coherence times [1]. We investigate a qubit implementation as real electron spin in graphene nanoribbon (GNR) quantum dots (QD). This system is particularly interesting because it allows for non-local QD coupling and a high threshold for fault-tolerant quantum computing [2]. QD electron spin coherence is determined by the coupling to nuclear spins and the lattice. Due to the vanishing nuclear spin of ^{12}C, the latter is particularly important in carbon based materials.

In a magnetic field, spin states $|\uparrow\rangle$ and $|\downarrow\rangle$ are split by the Zeeman energy $g\mu_B B$, which needs to be absorbed by the lattice. This requires an effective spin-phonon coupling, which we assume to occur via spin-orbit and electron-phonon interaction as previously proposed [3]. For magnetic fields perpendicular to the GNR plane only Rashba-type spin-orbit coupling contributes in lowest order. Starting from a continuum model, we derive a full phonon field theory for acoustical ribbon modes at the center of the Brillouin zone. Due to open boundary conditions at the edges of the quasi-one-dimensional GNR, the usual q^2-dependence for out-of-plane modes in bulk is cut off at the zone center, where we find a linear dispersion. The transverse and longitudinal sound velocities of the in-plane modes match well with literature values for comparable systems [4]. As expected, all modes approach bulk behavior for wavelengths much smaller than the ribbon width. In lowest order, only in-plane modes locally dilate or compress the GNR, thereby contributing to the electron-phonon coupling deformation potential which we express in terms of ribbon phonon creators and annihilators.

All couplings are treated completely analytically and we find Van Vleck cancellation, as expected for this time-reversal symmetry conserving system. To calculate the relaxation rate Γ_1 via Fermi's Golden Rule a quasi-continuous spectrum of final states is required. This is ensured by the vanishing dependence of the rate on the ribbon length, thus allowing for a continuous phonon spectrum. For conventional magnetic fields and ribbon widths ($B \sim 1$ T, $W \sim 30$ nm), Γ_1 goes with B^5 and W^{-1} and relaxation times T_1 range from 180 μs to 43×10^3 s. These rather long times are caused by (i) a vanishing coupling to every second QD state, (ii) Van Vleck cancellation, (iii) the assumption of phononic vacuum and (iv) a low density of states of the contributing modes.

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THU 25:

Effects of the interfaces in the anisotropic magnetoresistance in Ta/NiFe/Ta trilayers

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Anisotropic magnetoresistance (AMR) is the phenomenon observed in ferromagnetic metals consisting in the change of resistivity when the angle between the sensing current and the magnetization is varied. Devices based on AMR provide excellent sensors to measure both position and displacement within the earth's magnetic field. NiFe films used in AMR sensors have a structure of Ta/NiFe/Ta and the thickness of the NiFe layer is only 20nm or less so as to reduce the demagnetization field. However, in the photolithographic process of patterning, NiFe films are often exposed to temperatures above 500K, and this probably changes the characteristics of interface and stress and then reduces the percentual AMR. As recently reported, the AMR value $\Delta R/R$ and magnetic field sensitivity S_v of NiFe films can be remarkably enhanced by insertion of a nano-oxide layer on the interfaces and thus S_v is comparable to that of a spin valve [1-4]. The enhancement is mainly attributed to the large specular reflection at the flatter NiFe interfaces in the trilayered magnetic structure with a nanometer-thick oxide layer. We have fabricated by sputtering structures of Ta(5nm)/NiFe(t)/Ta(5nm) with t varying from 10 to 40nm, where oxygen was deliberately admitted into the chamber atmosphere after the deposition of some of the individual layers in order to form a nano-oxide layer. Magnetic characterization was made using both vibrating sample and alternating gradient force magnetometers. Electric characterization was made using a four-probe resistometer. In this work, we have investigated the influence of the nano-oxide layer in anisotropic magnetoresistance in that samples as-deposited and after submit to annealing at different temperatures. Results show that the partial oxidation of the thin film surface prevents intermixing at the interfaces, allowing the oxygen reduction on the magnetic surface by the formation of TaO_x, what enhances the AMR. Measurements like angle and external field sweeps ($RxAngle$ and RxH, respectively) are presented and discussed in terms of annealing temperature and characteristics of interfaces.

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Key-words: Anisotropic Magnetoresistance; NiFe/Ta Interface; AMR Sensors; Nano-Oxide Layer.

THU 26:

Simulations and Magnetoelasticity of Mnas epilayers on GaAs

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MnAs/GaAs epilayers are promissing materials for applications in spintronics. So for a deep understanding of its magnetic properties and anisotropies contributions, a mathematical model is required. We investigated the following systems with thickness of 70nm: MnAs/GaAs(111) and MnAs/GaAs(111), performing magnetic measurements and obtained the respectives hysteretic curves. We developed with basis in the literature a general model -which of course must be rewritten in each because of a different epitaxy relation- in order to simulate both systems, so a free energy density is needed and we must investigate the main anisotropic contributions to these system . Were taken into account the well-known anisotropies sources as: zeeman interaction, demagnetizing energy, magneto-crystalline anisotropy and, because of the existence of a deformation of our films relative to the bulk, we added a magneto-elastic and magneto-strictive energy. Our results show that is possible to simulate both systems if we take into account a non-negligible magneto-elastic energy. Our findings are in excellent agreement with the findings of other groups before the phase transition, but the magneto-elastic coefficients do increase in the phase transition, as reported by other groups and has a physical meaning if we look at the measurement of stress-induced field at the phase transition performed by other researchers. Finally, non-linear terms added to the free density energy can be explained as a contribution of the magnetostriction to the magnetoelasticty, since they are indeed one order smaller than the first order coefficients of magneto-coupling.

THU 27:

State protection application in Deutsch's algorithm

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Quantum dots are among the physical systems best suited to form the basis for the hardware of a future quantum computer. Several proposals to make quantum computing have already been made considering such a system. However, the decoherence generated by the interaction of a physical system with the environment is a limiting factor for the control over the dynamics of the system states. This limitation can be overcome by the existence of a decoherence-free subspace or by performing a reservoir engineering, enabling the protection of one or more states against decoherence. The physical system used consists of two quantum dots coupled by tunneling. A laser is used to excite an electron in a quantum dot taking the system from state $|0\rangle$ to state $|1\rangle$. The excited electron can then migrate to the other quantum dot by tunneling leading the system to the state $|2\rangle$. The decay of the states $|1\rangle$ and $|2\rangle$ to the state $|0\rangle$ are the decoherence channels considered. The study

of the system dynamics reveals that the system achieves, asymptotically, a state protected from decoherence formed by a superposition of the states $|0\rangle$ and $|2\rangle$ whose relative phase is the laser phase. Here, the implementation of Deutsch's algorithm, i.e., to decide if a function is constant or balanced with one measurement only, may be understood as the task of discovery of the laser phase, which is assumed to be unknown and can have 0 or π values. The superposition state measurement can be made through the recording of the temporal pattern of the laser absorption by the system after a modification in the laser coupling value, enabling the complete implementation of Deutsch's algorithm.

THU 28:

Self-correcting quantum memory in a thermal environment

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The ability to store information is of fundamental importance to any computer, be it classical or quantum. To identify systems for quantum memories, which rely, analogously to classical memories, on passive error protection ("self-correction"), is of greatest interest in quantum information science. While systems with topological ground states have been considered to be promising candidates, a large class of them was recently proven unstable against thermal fluctuations. Here, we propose two-dimensional (2D) spin models unaffected by this result. Specifically, we introduce repulsive long-range interactions in the toric code and establish a memory lifetime polynomially increasing with the system size. This remarkable stability is shown to originate directly from the repulsive long-range nature of the interactions. We study the time dynamics of the quantum memory in terms of diffusing anyons and support our analytical results with extensive numerical simulations. Our findings demonstrate that self-correcting quantum memories can exist in 2D at finite temperatures.

THU 29:

Electronic Transport Properties of Superconductor/Semiconductor-Nanowire/Superconductor Hybrid Devices

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When a superconductor interrupted by a non-superconducting material, which is called Josephson junction, many new physical phenomena can be observed such as Andreev reflection and quantum interference. In this work, we will present the experimental results of Nb/Nanowire/Nb Josephson Junctions. In such devices we have investigated the Andreev reflection in both zero and nonzero magnetic fields.

Superconductor/nanowire hybrid structures are one of the motivations of the future quantum electronics devices that attracted more attention in recent years. More specifically, in the superconductor semiconductor interface besides of normal reflection, electron (hole) can enter the superconducting part and reflect a hole (electron) back into the semiconductor part. The process is called *Andreev reflection*.

To observe Josephson junctions we have used doped InAs and undoped InN nanowires. InAs nanowires were grown by Metal Organic Vapor Phase Epitaxy (MOVPE) while InN nanowires were grown by Molecular Beam Epitaxy (MBE). We mechanically removed nanowires from the growth substrate to 200nm SiO_2 covered degenerately doped Si wafer with pre-defined e-beam markers. The superconducting contacts were defined by electron beam lithography and subsequently Nb deposition was done by means of magnetron sputtering. The resulting devices have contact distance varied between 80nm and 200nm. Low temperature measurements have been done in ^3He (T=300K) and dilution refrigerator (30mK). In this work, we have particularly focused on magnetic field dependence of differential conductance. We used a conventional lock-in technique to measure differential conductance of Nb/Nanowire/Nb junctions. At zero magnetic fields the differential conductance revealed features characteristic for Andreev reflection. In detailed measurement of differential conductance as a function of magnetic field, we have observed a periodic dependence of magnetic field. Furthermore, in the dc measurements we have observed kinks in the current voltage characteristics which are attributed to multiple Andreev reflections (MAR). The details of measurement results will be presented.

THU 30:

Local quantum control of Heisenberg spin chains

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With the aim of exploring local quantum control in arrays of interacting qubits, we investigate XXZ Heisenberg spin-1/2 chains with control fields acting on one of the end spins. In this work, which hinges on a recent Lie-algebraic result pertaining to local controllability of spin chains with always-on interactions, we find piecewise-constant control pulses corresponding to optimal fidelities for selected quantum gates. To make contact with imperfections in anticipated realizations of interacting qubit arrays, we analyse the sensitivity of the obtained results to random variations in the control-field amplitudes. We find that more rapid switching between piecewise-constant controls renders the system effectively less sensitive to these variations, a behaviour that bears close resemblance to the motional narrowing in NMR experiments. To account for realistic constraints on the frequency spectra of control fields, we also discuss how spectral filtering of these fields affects the resulting gate fidelities. Finally, we discuss the implications of our study for superconducting qubit arrays.

THU 31:

Method for Cooling Nanostructures to Microkelvin Temperatures

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We propose a new scheme aimed at cooling nanostructures to microkelvin temperatures, based on the well established technique of adiabatic nuclear demagnetization: we attach each device measurement lead to an individual nuclear refrigerator, allowing efficient thermal contact to a microkelvin bath. On a prototype consisting of a parallel network of nuclear refrigerators, temperatures of 1 mK simultaneously on ten measurement leads have been reached upon demagnetization, thus completing the first steps toward ultracold nanostructures.

THU 32:

Nuclear Spin Relaxation in an All-Electrical Lateral Spin Transport Device

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Interaction of electron spins with the nuclear magnetic environment has been identified to be important for future developments in spintronics and spin-based quantum information processing. In the Quantum Coherence Lab at the university of Basel we are investigating according effects in semiconductors of variing dimensionality at low temperatures.

Using all-electrical Fe/GaAs lateral spin-injection devices operated in a non-local geometry, we study nuclear spin relaxation in a one micron thick n-doped GaAs epilayer as a function of temperature in a dilution refrigerator, investigating unprecedented temperatures well below 1 K.

We create a dynamic nuclear spin polarization via the hyperfine coupling using spin polarized electrons injected from surface Fe bars. Nuclear spin signatures in non-local electron transport include a depolarization peak centered around zero magnetic field when the field is applied along the Fe injector bars. Further, Hanle satellite peaks appear away from zero field when a magnetic field perpendicular to the sample surface and Fe injectors is applied using a home-built vector magnet system. Using these signatures, we investigate the nuclear spin relaxation time as a function of temperature and compare it with the Korringa law which is known to be applicable in metals. We especially focus on temperatures well below 4.2 Kelvin, where no detailled study of the nuclear relaxation in doped GaAs has been carried out before. We find a clearly sublinear temperature dependence of the nuclear relaxation rate for temperatures below 20K, where phonon contributions to relaxation are suppressed.

THU 33:

Nonadiabatic Quantum Computation by Dynamic Invariants

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We introduce an approach for quantum computing based on the theory of dynamic invariants. This approach generalizes adiabatic quantum computation to a nonadiabatic regime, recovering it as a particular case. We show that the relaxation of adiabaticity can be achieved by processing information in the eigenlevels of a time dependent observable, namely, the dynamic invariant oper- ator. Moreover, we derive the conditions for which the computation can be implemented by time independent as well as by adiabatically varying Hamiltonians. We illustrate our results by providing the implementation of both Deutsch-Jozsa and Grover algorithms via dynamic invariants. An open question in our approach is how to implement the protocol using two-body interactions only.

THU 34:

Tripartite entanglement and disentanglement for finite losses

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Entanglement is a key resource to implement tasks in quantum computing and quantum information, such as distribution of cryptographic keys and teleportation of quantum states. In a broader context, it is expected that the generation of entanglement among different physical systems will allow performing tasks which would be impossible using classical physics. In this scenario, the quantum information would be generated, processed and stored in physical systems and the exchange would be performed through quantum channels that use entanglement as a fundamental resource. Due to the weak interaction with the environment and the high-speed, light is a strong candidate for transmitting information. In our laboratory, we demonstrated the generation of entanglement among three beams of intense light produced by an Optical Parametric Oscillator (OPO), all with different wavelengths (532,251 nm, 1062,102 nm and 1066,915 nm). The entanglement between the fields is attested through measurements of the amplitude and phase quadratures, carried out with the aid of empty optical cavities. To show the inseparability of the three fields, we use a necessary and sufficient criterion for Gaussian modes, the positivity under partial transposition (PPT). Under specific operation conditions of our system, we investigate the fragility of entanglement when we introduce losses into the beams paths, simulating a realistic quantum channel. We observe the occurrence of disentanglement for finite losses in the context of continuous variables, a phenomenon analogous to entanglement sudden death described in the context of discrete variables.

THU 35:

Laser noise correlations induced by cold atoms in Hanle /EIT conditions

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Noise intensity correlation and anti-correlation between two independent lasers in EIT configuration has been observed before, after propagation through a rubidium vapor cell. Now we wanted to observe the same degree of intensity correlation but using two beams with opposite circular polarization coming from one laser, in a Hanle/EIT configuration interacting with cold atoms in a MOT. We explore the dependence of the atomic response on the intensity for different analisis frequency. The results shows a similar behavior with the vapor cell case, and it can be describe by the theoritical model developed in the group.

THU 36:

Spin Injection from Ferromagnetic Contacts into Semiconductor Nanowires

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InN nanowires, grown by plasma-enhanced molecular beam epitaxy (MBE) were contacted depositing cobalt micro magnets via MBE for the purpose of injecting spin-polarized currents into the nanowire. To this end the introduction of an appropriate narrow tunnel barrier is crucial. These barriers were made from MgO and Al_2O_3 respectively by molecular beam epitaxy with a thickness between 8 and 20 Å.

Controlling spin injection from ferromagnetic sources into a semiconductor material is highly desirable as hitherto ferromagnetic metals are still indispensable tools for room temperature spintronic devices. A spin polarized current in a semiconductor is only possible if different voltages drop over both spin-channels of spin up and spin down electrons, respectively. For the ideal ohmic junction the effectiveness of spin-injection depends on the ratio of the spin-dependent conductivities of the ferromagnet and the semiconductor nanowire. To overcome this fundamental problem, the so called "conductivity mismatch", a tunnel barrier is introduced. This way the transport is expected to be governed by the respective density of state of the two materials forming the junction. In this case almost the entire voltage drops across the thin oxide layer and a considerable difference in the electrochemical potentials for spin up and spin down electrons is supported under the essential condition of slow spin relaxation.

InN is a particularly interesting material for semiconductor nanowires, as surface states give rise to a pinning of the Fermi energy in the conduction band, forming a two-dimensional electron gas (2DEG) on the nanowire surface. The nanowire diameter is between 35 and 120 nm, depending on the growth parameters. The native oxide is being removed in-situ before depositing the thin oxide film and a cobalt micro magnet of 60 nm thickness. To avoid excessive bending of the ferromagnetic metal strips near the point of contact to the nanowire, the structure is planarized using HSQ (Hydrogen Silsesquioxane) resist. This way the ideal case of a single domain magnetic structure at the interface is expected to be easier to achieve, which is investigated using magnetic force microscopy. Magnetoresistance measurements have been carried out successfully using a local and a non-local measurement geometry.
The switching behavior as a result of the shape anisotropy is further going to be investigated more deeply harnessing the local Hall effect due to the stray fields of the cobalt strips and comparing this to simulation results.

THU 37:

Disentanglement for Partial Losses in Bipartite Systems

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We experimentally analyzed the robustness of continuous-variable bipartite states possessing Gaussian statistics. We used an above threshold optical parametric oscillator (OPO) to generate entangled twin beams. Such states are fully characterized by the covariance matrix of the phase space operators. In our case, the action of the environment is limited to dissipation only, which is implemented by losses in a beam-splitter. In this context, we call robust those states that maintain their entanglement until total loss. We observed regions of robust and non-robust states and we can pass from one to another by varying the phase noise. This is done by increasing the pump power. We also theoretically studied the robustness of entanglement in continuous-variable two-mode bipartite system. We derived, from the PPT criterion, a sufficient condition that attests the robustness, which becomes also necessary for Gaussian states. It is an optimized form of the Duan criterion, which gives it an operational meaning connected with transmission losses. As a consequence, we showed that it is possible to transit between robust and non-robust states by local squeezing. Consequently, the robustness is independent of the amount of entanglement, since it is invariant by local squeezing.

THU 38:

Spin-orbit and strain effect on graphene and graphene nanoribbons

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The electronic struture of graphene and nanoribbons (armchair and zigzag boundaries) have been studied throught the tight-binding method. We have considered only the first-neighbours interactions. We showed that conduction band and valence band make contact with each other at the Dirac point energy in six points inside the Brillouin zone of graphene with an hexagonal distribution and two inequivalents ones, the K and K' points. The energy gap between these bands strongly depends of the nanoribbon type, armchair or zigzag and also the width of nanoribbon. We also demonstrated that strain could be used to manipulate the graphene properties. To study sistematicaly the strain effects, we have applied uniaxial and biaxial strain, respectively. We realized that graphene electronic strutures can be modified by changing the direction and magnitude of strain. Finally, we have considered the Rashba spin-orbit interaction, which magnitude can be controlled by an external electric field applied in the normal direction of the graphene plane. As an important result we have found Rashba spin-orbit interaction plays an important role in graphene electronic struture.

THU 39:

Electrical control of spin-ordering in few-electron lateral quantum dot molecules

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Electrical control of individual spins through g-factor is highly desirable for implementation of quantum gate operations. We investigate theoretically the tunability of effective electron g-factor in tunable lateral double quantum dots (DQDs), subjected to spin-orbit interaction (SOI), vertical electrical and magnetic fields, using exact diagonalization method. To avoid numerical artifacts in the single-electron energy spectrum and circumvent the cumbersome calculation,we adopt the modified Gaussian functions as basis functions and divide the full Hilbert space into orthogonal sub-spaces. We find that sweeping interdot barrier voltage or changing interdot distance leads to a switch of electronic states from atomic-like to molecular-like and then atomic-like again in nature. We address the theoretical prediction of in-plane local gate-voltage induced a largely tunable effective electron g-factor and its dependence on spin-orbital interaction strength. We also point out a pathway to electrical control over the spin-states of a DQD.

THU 40:

Dynamic Properties of Carbon Nanotubes Based Quantum Hybrid Circuits

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Carbon nanotubes are quantum conductors in which various transport regimes can be observed, ranging from Coulomb blockade or Fabry-Pérot electronic interferometer physics to Kondo physics. To a great extent, they behave as tunable artificial atoms at low temperature and can be used to implement various thought experiments of quantum transport. Our project is to probe the behaviour of such artificial atoms in the GHz range in order to measure directly their charge dynamics, especially in the Kondo regime. The main idea is the use of a non-contact method to probe the quantum capacitance of the carbon nanotube which is similar to the electric dipole coupling used in atomic physics. The quantum capacitance is expected to be very sensitive to electron-electron interactions and therefore is expected to give interesting insights in the Kondo regime. In the near future, we plan to extend our setup to perform cavity quantum electrodynamics type measurements with carbon nanotube based quantum dots.

THU 41:

Reactivity of interface Mn/GaAs

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This master's project will be developed with the laboratories of Film Group and Magnetic Nanostructures UFPR: Laboratory of Nanostructures for Sensors (Lansen) and Laboratory of Surfaces and Interfaces (LSI). We have goals for both the production of thin films and heterostructures made from manganese (Mn) on substrates of gallium arsenide (GaAs), as the production of intermediate compounds from the thermal reaction at the interface Mn / GaAs in an environment of ultra- high vacuum. The system will be used for growth by molecular beam epitaxy (Molecular Beam Epitaxy - MBE) installed on the LSI, which allows in situ analysis with the techniques of RHEED (Reflection High Energy Electron Diffraction) and XPS (X-ray Photoelectron Spectroscopy). The ex situ characterization of structural-morphological properties, micro-chemical as well as electronic and magnetic films and heterostructures will also be implemented during the dissertation process. An axis of group activities and this dissertation is spintronics, a major theme in both magnetism and nanotechnology. The results of scientific activities to be performed are of interest to both basic science and applications of nanostructured materials in devices.

THU 42:

Quantifying decoherence in spin channels through Loschmidt Echo

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The implementation of nano-devices capable for quantum information processing demands high efficiency control on quantum dynamics. Particularly, experiments with interacting spin lattices in NMR [1], and ultra cold bosonic gases [2], show that many body interactions conspire against quantum control. The coherence in a quantum channel (spins $\frac{1}{2}$ chain with XY interaction) is lost when it interacts with a non-controlled chain (the "environment"). This can be evaluated by means of the attenuation of the recurrences (mesoscopic echoes) that arise from the channel finite size [3a]. Here, equivalent coherence times are obtained evaluating the reversibility of the dynamics in the controlled channel, when it is coupled to the environment. For that purpose, we take advantage of the quantum paralelism [3b], by means of an algorithm that reduces drastically the computational resources needed. Meanwhile, we compare the reversibility of a local observable (Polarization Echo) with the many-body state of the system (Loschmidt Echo), verifying that, for short times, spins behave, in some approximation, statically independent.

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THU 43:

Electronic Transport through Synchronized Systems

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Synchronization phenomena appears in many fields of physics. Usually it is taken as an emergence phenomenon in complex systems. The oldest example of Huygens's sympathy of clocks [1](two pendulum clocks with different frequencies and phases placed over a table oscillates in unison) is an example of "few body" synchronization. By taken advantage of quantum-classical analogies we construct systems which have "quantum synchronization". In this work we will show the study of the quantum sync phenomena in thigh binding model and the electronic transport through small "synchronized systems". Also, we will show the connection between the Fano [2] resonances and the synchronization phenomena in the electronic transport. The dynamical behavior and the transport properties are analyzed by using the Green functions formalism. Previous works [3] where used to complement the analytical results. The understanding of the sync phenomena may be useful for improve the efficiency of quantum computation.

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THU 44:

Transport through a magnetic domain wall in the presence of Decoherence

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We address the electric resistance caused by a magnetic domain wall in nanowires. It is known that domain walls are well described by functional forms of Falicov-Cabrera. When electrons pass through the domain wall, magnetic interaction produces a rotation of the spin of the incident particle orienting it with the magnetic field at x position. This situation is treated within a discrete version of the Bogoliubov-DeGennes equations, which describe the coupling between the spin components at each position. This is a problem of dispersion in steady state. With collaboration of our group, this has been treated successfully within a Green function formalism in the local representation [GWJS04]. However, in a dynamical description, this problem could also be seen as a variant of Landau-Zener problem. The degree of adiabaticity could be controlled by the group velocity of the wave packet, the strength of the Zeeman interaction and the dispersion of the domain wall. In this problem, the presence of decoherence opens possibilities for new physics that has only recently begun to be explored with approximate methods [FJWS06]. Our work: 1) establishes an unambiguous correspondence with the Landau-Zener problem, 2) Develops a strategy to describe transport in the presence of local decoherence by introducing a variation of D'Amato-Pastawski model [DP90] valid for this particular problem.

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THU 45:

Photon Assisted Spin-polarized Current

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Spin coherent dynamics and transport in quantum dots has attracted a lot of attention due to its relevance to the potential new generation of spintronic devices (e.g., Datta-Das transistor[1]) and quantum computation, where quantum coherence of the electron spins plays a crucial role. Recent experiments demonstrate the possibility to coherently manipulate quantum states of single and double electron spins in quantum dot systems[2]. Such control can be achieved, for instance, via fast bias/gate voltage pulses, electron spin resonance (ESR) fields and coherent optical fields. Those experiments indicate the feasibility of using a single electron in quantum dot system as a quantum bit and reveal encouraging spin coherence lifetimes for quantum processing. Recently, spin lifetime of 6 s has been reported[3].

Here we investigate time-dependent transport in a quantum dot coupled to two leads in the presence of intra-dot Coulomb interaction. We consider a gate terminal that oscillates in time. Using nonequilibrium Green function technique we show that a photon-assisted spin-current arises in the Coulomb blockade regime for particular values of the gate frequency. This contrasts to the static limit (constant gate voltage) where no current can flow in this regime. This polarization of the photon-mediated current can happen when the dot is magnetized. The current polarization can be tunned via the modulation amplitude and the gate frequency. A source-drain bias voltage is kept constant in time. We also look at the effects of the photon-assisted spin-current on the tunnel magnetoresistance (TMR), thus proposing possible experimental ways to measure the present effect. In addition to this, we will show quantum coherent beats of the TMR due to a fast switch-on of the bias voltage, and spikes of polarized current in the case of a fast switch-off of the bias voltage.

This work was supported by CNPq and FAPEMIG.

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THU 46:

Spin asymmetric interactions and Landau-Fermi liquid instabilities

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We study the effects of asymmetric spin interactions on the stability of the Landau-Fermi liquid description. In particular we focus on the type of interactions proposed by Varma *et al* to describe the hidden order transition in URu_2Si_2. In the presence of a magnetic field this type of interactions produce an enhanced region of instabilities of the Pomeranchuk type. The relevance to different possible experimental observations is discussed.

THU 47:

Spin-orbit coupling in InAs-based wurtzite quantum well

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We investigate the spin-orbit coupling for electrons in wurtzite quantum wells. By folding down the 8x8 Kane model, taking into account the relevant s-pz orbital mixing absent in zincblende structures, we derive an effective 2x2 Hamiltonian for the conduction electrons. In this derivation, we account for the renormalization of the spinor component of the conduction band wave function, which is crucial to properly obtain the corresponding spin-orbit couplings. In addition to the Dresselhaus- and Rashba-type terms, both arising from the bulk inversion asymmetry of the wurtzite lattice, [1-3] we obtain the usual linear in momentum Rashba term induced by the structural inversion asymmetry of the well. Interestingly, we also find a new Rashba-like contribution, proportional to the well profile only and not its derivative, entirely arising from the s-pz mixing. In contrast to zincblende semiconductor wells,[4,5] here this term is non-zero even in symmetric structures with one subband. We self-consistently calculate the spin-orbit coupling parameters for realistic InAs-based single and double wells in the wurtzite phase with two subbands. By gating the structures, which breaks the structural symmetry of the wells, we find that the new Rashba term shows a distinctive voltage dependence as compared to that of the usual Rashba coupling. Finally, for the double-well case, we find that both the intersubband spin-orbit coupling and the Dresselhaus term for each subband show a resonant behavior for the symmetric configuration of the well. This work was supported by FAPESP and CNPq. One of the authors (J.Y.F) thanks Gerson J. Ferreira, Marco O. Hachiya and E. Bernardes for valuable discussions.

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THU 48:

Transfer of two Q-bit states using fiber optical coupled cavities with one or two coletive modes

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Studies of the transfer of quantum states of one and two q-bits using coupled cavities, via evanescent waves or optical fiber, has been of great importance in the discussion of the coherence losses in quantum processing.

Many works deal with the study of systems with two coupled cavities via optical fiber and with one trapped ion in each one, adopting various medium of transmission between the states of one q-bit of the ions.A common occurrence among these different studies is that they work with only one cavity collective mode for convey information.In our study using an optical fiber for transmission medium, rather than to transmit two q-bits, the electronic and vibrational bits, we was able to consider analytically the second collective mode and discuss its effects on the fidelity of transmission as well their influence on different parameters of the system.

THU 49:

Ferromagnetic STM tip operating as a Spin-diode

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A promising approach to nanoscopic systems consists of manipulating and controlling the spin of the carriers aiming at the development of new devices and possibly the discovery of new physical effects. The Scanning Tunnelling Microscope (STM) has allowed huge advances in condensed matter physics. In the exciting field of spintronics [1], STM was recently used to manipulate individual cobalt atoms and their spins [2]. It has been also applied to study both the interactions between Mn acceptors and the influence of the surface on the impurity properties in diluted magnetic semiconductors, e.g. Mn-doped GaAs [3,4]. Here we study spin-dependent transport in a system composed of a ferromagnetic STM tip coupled to an adsorbed atom (adatom) and to a host metallic (non-magnetic) surface. Electrons can tunnel directly from the tip to the surface or through the adatom. We apply the nonequilibrium Green function technique (Keldysh formalism) [5] to calculate the current through the tip. By performing a self-consistent calculation we determine the adatom spin occupation and its magnetization as a function of the tip position. We find that the adatom becomes magnetized when the tip approaches it; this magnetization switches sign as the voltage changes from forward to reverse bias. If the tip is nearby the adatom, we obtain a spin-diode effect [6] - i. e., unpolarized current for positive bias and polarized current for reverse bias - when the adatom is singly occupied. When the tip moves away from the adatom the spin-diode effect vanishes and the current becomes polarized for both bias. We also observe Friedel oscillations in the current as the tip-adatom distance increases. This work was supported by the funding agencies CNPq, CAPES, FAPEMIG and FAPESP.

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THU 50:

1D cold photoassociative ionization of Na inside a storage ring

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Motivated by recent interest in low dimensional arrays of atoms, we experimentally investigated the way cold collisional processes are affected by the geometry of the considered atomic sample. More specifically, we studied the case of photoassociative ionization (PAI) both in a unidimensional and a tridimensional system. First, creating a ring shaped trap (atomotron) we investigated two-color PAI dependence with intensity and polarization of a probing laser. The intensity dependence of the PAI rate was also measured in a magneto-optical trap presenting equivalent temperature and density conditions. Indeed, the results show that in the ring trap, the value of the PAI rate constant is much lower and does not saturate, unlike in the case of the 3D-MOT. Control of cold atomic collisions inside almost 1D system constitutes a whole new field of investigation.

THU 51:

Brazilian Atomic Fountain: Current Status and Future Developments

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This work reports the current status of the atomic fountain experiment developed in our laboratory. Since this is a system intended to be used as an atomic standard of frequency and time, the up-to-date characterization of stability and frequency shifts affecting the clock transition will be presented. A new apparatus for the symmetrical feed of the microwave signal that interrogates the atomic sample will be shown. In addition, the high quality of such an experiment can be used as an essay environment for new tests. More specifically, some tests involving a proposal of the use of different frequencies in the Ramseys interrogation method are in course of realization [D. Seidel and J. G. Muga, Phys. Rev. A, 75, 023811(2007)]. The core idea of this proposition is to reduce the linewidth of the clock transition resonance, in order to increase the capability of frequency standards. On the other hand, the implications of such method in practical devices should be analyzed, so defining ways of its implementation.

THU 52:

Spin-resolved STM for a Kondo adatom in a ferromagnetic island

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In this work we investigate the spin-resolved local density of states (LDOS) of a ferromagnetic (FM) island in the presence of a Kondo adatom. The description of the FM host is performed with a modified single impurity Anderson model (SIAM), which allows to study the differential conductance of a scanning tunneling microscope (STM). As the conductance is well described by the LDOS in the Kondo regime, we derive based on a Green's function (GF) formalism, a spin-resolved conductance formula expressed in terms of the phase shifts due to the Kondo scattering and Fano interference. In which concerns on the adsortion state of the impurity on the host surface, we consider a non local coupling. And for a sake of simplicity, a spin-polarized free density of states with a lorentzian line shape for the energy dependence is adopted to mimic this kind of hybridization. Applying the atomic approach

on the SIAM in the limit of infinity Coulomb energy, spin-polarized profiles for the Fano factor and Friedel oscillations emerge, additionally with a Kondo peak splitting in the adatom spectral density. The understanding of such features are important for an adequate operation of spintronics devices.

THU 53:

Dissipative dynamics in coupled quantum dots: Protection of states

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Universidade Federal de Uberlandia

Semiconductor quantum dots coherently driven by pulse laser are fundamental physical systems which allow studying the dynamical properties of confined quantum states. These systems are attractive candidates for a solid-state qubit, which open the possibility for several investigations in quantum information processing. In this context, we study the dissipative dynamics of excitonic states in an asymmetric double-quantum-dot coupled via tunneling. We applied a three-level-model to describe this system. The states $|0\rangle$, $|1\rangle$, $|2\rangle$ correspond to vacuum, direct exciton (the electron and the hole in the same dot) and indirect exciton (the electron and hole are in different quantum dots), respectively. We also consider, the effects of decoherence through exciton recombination rates. To obtain a full description of the dynamical evolution, we solved the Liouville-Von Neumman-Lindblad equation. We calculate occupation probability of the states through diagonal elements of the density matrix obtained from the master equation of the system. We identify three regimes for population dynamic: Rabi oscillations, dynamical localization and collapse and revival; these regimes are easily accessible by an appropriate choice of external parameters compatible with well-known experimental setups. We also showed that the indirect exciton state is robust against decoherence allowing potential applications in quantum memories and quantum gate architectures.

THU 54:

Equation of State of a Harmonically Trapped ^{87}Rb gas: BEC Transition and zero-Temperature Pressure analyses

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An interesting aspect of atomic superfluids still not well explored is the generalization of pressure and volume for the trapped gas. Atoms are conventionally confined by non-homogeneous fields resulting in a non uniform spatial distribution of atoms, where the concepts of volume and pressure are not directly equivalent to those employed for a rigid wall confinement. Following a theoretical analysis [1], it is possible to define equivalent variables and determine an equation of state. We have measured the equivalent isochoric curves of this equation of state for a broad range of temperatures. Observing the critical temperature for each curve, we have been able to determine the critical line of the BEC transition. The extrapolation of each curve to zero provides the zero-temperature pressure whose dependence with the density and the scattering length was analyzed. We found a good agreement between the measurements and the theoretical prediction. We also discuss other studies that can be realized with this type of experiment.

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THU 55:

New system for production of quantum fluids to study mesoscopic quantum effects

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We present the progresses towards the construction of a new system for the production of a Bose-Einstein condensate (BEC) of ^{87}Rb atoms. The BEC will be produced in a harmonic potential and in this system we will have the possibility of having to different kinds of trap: an optical dipole trap and a magnetic trap. This makes our system very versatile and will allow us to perform several experiments for measuring mesoscopical effects of this system.

Initially, we intend to perform two experiments. The first one has the goal of understanding some thermodynamic properties of this quantum system. In the second experiment we want to explore the magnetic structure of the condensate.

Thermodynamics of cold atoms. Little attention has been given to the thermodynamics of ultracold trapped gases. Due to the anisotropic character of the confining potential, in these systems the volume and the pressure are not well defined global variables. Instead, they are local variables that depend on the position. Therefore, understanding the thermodynamic properties of these trapped system is a non trivial task. However, in a recent publication * it is shown that in a gas confined in a harmonic potential the pressure and volume can be formally replaced by new global variables. These are known, respectively as, harmonic pressure and harmonic volume. The harmonic volume is obtained in terms of the parameters of the potential and can be shown that it is an extensive quantity. The harmonic pressure is obtained as the conjugate variable of the harmonic volume and turns out to be intensive. Using these definitions it is possible to construct a PV diagram from which all thermodynamic quantities are obtained. Specifically, we are interested in measuring the order of the quantum phase transition. Up to now, this transition has been assumed to be a second order transition but there are no experiments confirming this.

Magnetism of ultracold atoms. We present an experimental proposal for studying magnetic properties of a spin-polarized sample of ultracold ^{87}Rb atoms. Since this system has a total magnetization, it must produce an inducted current as it passes through an external conducting closed loop. For doing so, we will rapidly push a sample trapped in an optical trap through a superconducting coil. We expect to observe different behaviors in the induction signal depending on if the cloud is quantum degenerated or not. We believe that it will be possible to detect the quantum phase transition by analyzing the induction signal of the atoms. Additionally, this experiment should reveal new aspects of the global magnetic properties of the system.

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THU 56:

Cooperative Two-photon Absorption by Colliding Sodium Atoms in a Magneto Optical Trap

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The two-photon absorption is an important spectroscopy technique, which can reveal states not seen with the one photon spectroscopy. This technique is commonly studied in solids, where has been widely explored several decades ago. We are using this technique for studying the collisions between atoms of sodium in a cold gas, in the low temperature regime, giving a possibility of studying this phenomenon in an alternative fashion. In our experimental setup sodium atoms coming from the oven are slowed down by passing a Zeeman slower (with a spin-flip configuration) and interacting with a counter-propagating laser beam. With this method we can obtain a sample of cold atoms in a magneto-optical trap. With that sample we want to produce atom pairs of which one atom will be in the $P_{1/2}$ and the other one in the $P_{3/2}$ state

$$Na(3S) + Na(3S) + 2\hbar\omega \rightarrow Na(3P_{1/2}) + Na(3P_{3/2}) \tag{1}$$

Starting from atoms in the ground state $3S_{1/2}$ a two-photon excitation promoted by a probe laser beam at a frequency between the transitions $S \rightarrow$

$P_{1/2}$ and $S \rightarrow P_{3/2}$ will create the atom pair. The identification of the formed pair will be performed by selective photoionization using a wavelength of about 407 nm. Then, the existence of cooperative two-photon transition in the sample can be demonstrated with this experiment.

THU 57:

Tunability of *p*-*d* exchange interaction in single-Mn doped double quantum dots: Electrical and intense laser field effects

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The successful fabrication of quantum dots (QDs) doped with a single Mn atom has stimulated extensive studies about exchange interaction between carrier spins and single Mn atom. Depending on the charge status in QDs, the spin properties of the ground state change. In negatively charged QDs, for instance, the Mn spin M (=5/2) and the conduction-band electron couples ferromagnetically, yielding a septuplet with total spin $S_T = 3$. In the case of positively charged QDs, however, the ground state of the system in the regime of strong confinement is doublet corresponds to the Mn spin maximally polarized against the heavy-hole spin. Since the charge-status of QDs is controlled with extremely high fidelity through an *n*-type field effect structure, *sp*-*d* exchange interaction can be tuned electrically.

Since interdot tunnel-coupling (TC) in vertically coupled double quantum dots (DQDs), responsible for the formation of molecular bounding and anti-bounding states, depends strongly on both interdot distance and interdot barrier height, the orbital wave functions are continuously tunable from atomic to molecular in nature. Vertical electrical field induces detuning between upper and lower quantum dots, driving the carriers move from one dot to another. Hence, it results in charge-spatial redistribution as well as that variation of *p*-*d* exchange interaction in DQDs.

In this work, we have studied *p*-*d* exchange interaction in asymmetric InAs DQDs, based on k.p formalism in the frame of linear combination of molecular orbitals (LCMO). The detuning of a DQD affects strongly the *p*-*d* exchange interaction and spin-splitting. The possibility for on/off key switching of the *p*-*d* exchange interaction can be controlled by applied electrical field, by Mn-ion position and interdot distance. The resonant maximum values of the exchange interaction observed for the Mn-ion located inside the interdot barrier region opens up a great opportunity to realize electrical fast operation of individual spin states.

As well known, the application of either an electrostatic (Franz-Keldysh and quantum confined Stark effects) or a magnetic field changes the electronic states of carriers confined in nanostructures. While the high-power tunable laser field induces dynamical Franz-Keldysh effect, which changes the density of states of carriers in semiconductor nanostructures. In this work, we also demonstrate the optical control of *p*-*d* exchange interaction and point out the optimization condition for laser frequency and intensity to realize spin-manipulation in QDs.

THU 58:

Phenomenological study of field induced Josephson junctions

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We formulate the new class of Josephson junction and Josephson junction arrays as field induced Josephson junction made by putting the ferromagnetic or multiferroic strip on the top of superconductor strip. We obtain the continuous transition from the tunneling Josephson junction to the weak link as the function of the thickness of superconducting strip, the magnitude of magnetization and temperature. We formulate the scheme of description in Ginzburg–Landau and Usadel formalism.

Index

Alcalde, A., 81
Alcalde, A. M., 56
Alexander, L., 43
Alvarado, S. F., 68
Alves, F. M., 84
Alves, R. F., 80
Amaral, L., 58
Anda, E. V., 35
Anderson, H. L., 42
André, S., 47
Andrieu, S., 33
Ardavan, A., 42
Arellano, R. M. G., 46
Arins, A. W., 61
Auccaise, R., 59
Awan, I. T., 36
Awschalom, D., 51
Azevedo, A., 9

Bürgler, D., 70
Bagnato, V. S., 10, 79, 80, 82, 83
Bakker, M. P., 18
Balanta, M. A. G., 57
Bandi, T., 67
Barbosa, F. A. S., 69, 71
Batov, I. E., 66
Beaujour, J-M. L., 33
Bebeachibuli, A., 80
Bender, S., 44
Benedito, L., 70
Benevides, R., 82
Benjamin, S. C., 42
Berche, B., 61
Bernardes, E., 21
Beschoten, B., 70
Blanter, Ya. M., 23
Bolívar, N., 61
Bonagamba, T. J., 59
Borges, H. S., 56, 81
Brasil, C. A., 28
Brasil, M. J. S. P., 12, 20, 57
Brataas, A., 44
Briggs, G. A. D., 42
Brosco, V., 47
Bruder, C., 67
Burgarth, D., 67
Burkard, G., 11, 50
Burkard, M. D. a. G., 62

Cabra, D. C., 76
Calarco, R., 66, 70
Caracanhas, M. A., 82
Carvalho, R. L., 58
Casparis, L., 67
Cassemiro, K. N., 69, 71
Castilho, P. C., 82
Chaubal, A. U., 17, 18
Chesi, S., 65
Clark, A. C., 67
Coelho, A. S., 69, 71
Cole, J. H., 47
Correa, H. P. S., 32
Coutinho, R. M., 78

Dagger, E. M., 61
Danilov, Y. A., 57
Davidovich, L., 6
de Almeida, F. O. S., 51
de Azevedo, E. R., 59
de Faria, A. J., 71
de Oliveira, A. J. A., 30, 50, 55
de Souza, A. M. C., 51
Degani, M. H., 37
Delbecq, M. R., 73
Demaille, D., 30
Denega, S. Z., 20
Dente, A. D., 74
Deveaud-Plédran, B., 15
Di Lorenzo, A., 21
Dorneles, L. S., 63
Dorokhin, M. V., 57
Dukalski, M., 23
Duzzioni, E. I., 41, 64, 68

Egues, J. C., 18, 19, 21, 42, 52–54, 77, 78
Elhalawany, A., 24
Ellner, M. E., 32
Encinas, A., 24
Erbe, B., 49

Erlingsson, S. I., 28
Eschrig, M., 25
Etgens, V. H., 30, 64

Fabian, J., 23
Fernández, L. J., 75
Ferreira, G. J., 18, 19, 53, 54
Figueira, M. S., 80
Filidou, V., 42
Finley, J. J., 56
Flatté, M., 31
Flatté, M. E., 1, 26, 38
Florez, H. M., 70
Franceschi, S. D., 45
Freire, H. J. P., 19
Fu, J. Y., 77
Fuhrer, A., 68

Günel, H. Y., 66
Galeti, H. V. A., 20, 36
Garcia, D., 50
Garleff, J. K., 49
Gauger, E. M., 42
Girod, S., 33
Giustino, F., 42
Gobato, Y. G., 20, 29, 30, 36
Goncharuk, N. A., 16
González-Árraga, L. A., 27, 32
Gonzalez, J. C., 77
Gottwald, M., 33
Grünberg, P. A., 5
Grützmacher, D., 66, 70
Grandi, N., 76
Grein, R., 25
Gualdi, A. J., 50
Guassi, M. R., 72

Hachiya, M. O., 52
Hardtdegen, H., 66
Heedt, S., 70
Hehn, M., 33
Henbest, K. B., 42
Henini, M., 20, 29, 30, 36
Henn, E. A. L., 82
Herval, L., 30
Heule, R., 67
Hildmann, J., 50
Hill, G., 20, 36
Hrabec, A., 15
Huerta, J. M. M., 24

Iikawa, F., 57, 58
Ingersent, K., 35

Jansen, Th., 70
Jiang, X., 45
Jin, P., 47

Kaniber, M., 56
Kapra, A. V., 48
Karlen, S. D., 42
Katsaros, G., 45
Keizer, J. G., 49
Kent, A. D., 33
Kishore, V. V. R., 52
Koelbl, D., 68
Koenraad, P., 13
Koenraad, P. M., 49
Kontos, T., 73
Koralek, J., 51
Krishnatreya, B. J., 33

Löfwander, T., 25
Léger, Y., 15
López, A., 61
Lang, R., 57
Laucht, A., 56
Leão, S. A., 53
Lee, E. J. H., 45
Lengaigne, G., 33
Leuenberger, M. N., 18, 24, 46
Levstein, P. R., 74
Levy, J., 26
Lieber, C. M., 45
Lilly, M., 51
Lima, I. C. C., 9
Lopes, V., 60
Lopez-Richard, V., 60, 72
Loss, D., 1, 18, 22, 42, 65
Lovett, B. W., 42
Luiz, G. I., 35

Müller, S. T., 80
Máximo, C. E., 82
Mack, S., 51
Maeda, K., 42
Magalhães, K. M. F., 82
Magalhães, D. V., 80
Magalhães, K. M. F., 79, 83
Maialle, M. Z., 37
Mangin, S., 33
Maradan, D., 67
Marques, G. E., 29, 30, 36, 72
Martinelli, M., 69–71
Maslov, D., 22
Maude, D. K., 16
Medina, E., 27, 32
Medina, J. de La T., 24
Mendes, U. C., 53
Meneses, E. A., 58
Metalidis, G., 25
Misko, V. R., 48

Moehlmann, B. J., 26
Montaigne, F., 33
Montes, E., 37
Morgan, C., 70
Mori, T. J. A., 63
Morier-Genoud, F., 15
Morizot, O., 79
Morton, J. J. L., 42
Mosca, D. H., 61, 64, 73
Mosqueiro, T. S., 21
Moussa, M. H. Y., 59
Muhammad, R., 79
Mullen, K., 39
Muniz, S. R., 82

Napolitano, R. de J., 28
Nobrega, J. A., 29
Novaes, M., 34
Nussenzveig, P., 8, 69–71

Oliveira, A. L. d., 79
Oliveira, R. R., 35
Onur, A. R., 17, 18
Orahcio, F. S., 80
Orenstein, J., 51
Orlando, M. T. D., 32
Orlita, M., 16
Osenda, O., 34
Otoboni, F. A., 80

Paes, V. Z. C., 64
Paiva, R. R., 79, 83
Paiva, T., 37
Panaitov, G., 66
Paraïso, T. K., 15
Partoens, B., 52
Pastawski, H. M., 74, 75
Pedrozo, E. E., 83
Peeters, F. M., 48, 52
Penha, F. C., 42
Penteado, P. H., 77, 78
Penz, A., 66
Pingenot, J., 39
Piraux, L., 24
Pizzini, S., 15
Pomorski, K., 55, 85
Pont, F. M., 34
Ponte, P. R., 76
Potemski, M., 16
Poveda-Cuevas, F. J., 82
Povilus, V., 31
Prokopow, P., 55, 85

Qu, F., 72, 84

Röthlisberger, B., 65
Röthlisberger, B., 42
Raith, M., 23
Ranno, L., 15
Ravelosona, D., 33
Reuter, D., 18, 20
Ribeiro, G. A. P., 38
Rigolin, G., 38
Roati, G., 82
Rojas, C. O. a. F., 27
Romero-Rochin, V., 82
Romito, A., 47
Rossatto, D. Z., 41
Roversi, J. A., 77

Sahin, C., 38
Salis, D., 68
Sammarco, F., 54
Santana, T. S., 59
Santos Jr, D. R. S., 72
Santos, M. M., 64
Sanz, L., 56, 81
Sarandy, M. S., 68
Schäpers, T., 70
Schäpers, Th., 66
Schön, G., 25
Schön, G., 47
Schaffry, M., 42
Schelp, L. F., 63
Schio, P., 30
Schliemann, J., 13, 43, 44, 49
Schneider, J. M., 16
Scholz, A., 44
Schreiber, R., 70
Schwarzwaelder, K. K., 67
Seman, J. A., 82
Seridonio, A. C., 78, 80
Serra, P., 34
Serra, R. M., 68
Shiozaki, R., 79
Shiozaki, R. F., 82
Sladek, K., 66
Sladkov, M., 17, 18, 20
Smakman, E. P., 49
Smrcka, L., 16
Soares, M. V., 73
Souza, D. O., 32
Souza, F. M., 76, 78
Srinivasa, V., 26
Stano, P., 23
Stojanovic, V. M., 67
Stuart, P., 3
Svoboda, P., 16

Tafur, S., 46
Tarucha, S., 7
Taylor, D., 29, 30

Thorgilsson, G., 28
Trippe, C., 38
Tserkovnyak, Y., 11, 44

Usaj, G., 46, 52

van der Wal, C. H., 17, 18, 20
van Voornveld, R., 49
Varalda, J., 64
Varella, A. L. S., 55
Vasek, P., 16
Vernek, E., 35, 78
Vernier, N., 33
Vidal, F., 30
Vignale, G., 38
Vikhrova, O. V., 57
Villar, A. S., 69, 71
Villas-Bôas, J. M., 56
Villas-Bôas, C. J., 41
Villas-Bôas, J. M., 59
Villegas-Lelovsky, L., 84
Vodolazov, D. Y., 48
Vyborny, Z., 16

Weber, C., 51
Weis, K., 70
Werlang, T., 38, 41
Wieck, A. D., 18, 20
Wouters, M., 15

Yang, L., 51
Yang, T.-Y., 70

Zabotto, F., 50
Zak, R. A. ; 22
Zangara, P. R., 74
Zheng, Y., 30
Zoller, P., 2
Zumbuhl, D. M., 67, 68
Zvonkov, B. N., 57