CHRISTOPHER BUERLE
CNRS-CRTBT

Decoherence in metallic quantum wires and quantum networks

Probably the most fundamental property of a particle in any quantum system is the time over which the phase coherence is maintained in its wave function. Coupling the quantum system to an environment can lead to decoherence and subsequently to a reduction of the phase coherence time. In a solid state system, the main decoherence mechanisms are due to electron-electron, electron-phonon and magnetic impurity interactions. In the first part of the talk we will focus on the influence of magnetic impurities on the phase coherence time. In particular, we will show that the magnetic contribution to the dephasing rate per impurity is described by a single, universal curve when plotted as a function of T/TK. In addition, we show that the dephasing rate is remarkably well described by recent numerical results for spin S=1/2 impurities T ¿ 0.1 TK [1, 2]. We will also present new measurements of the phase coherence time in extremely clean metallic quantum wires and comment on the recent debate on intrinsic decoherence in mesoscopic systems in the light of scattering from magnetic impurities. In the second part of the talk we will present quantum interference measurements in metallic quantum networks. We will show that the environment, in this case simply the geometry of the system, strongly influences the phase coherence time [3].

[1] C. Buerle, F. Mallet, F. Schopfer, D. Mailly, G. Eska, L. Saminadayar, Phys. Rev. Lett. 95, 266805 (2005).

[2] F. Mallet, J. Ericsson, D. Mailly, S. nlbayir, D. Reuter, A. Melnikov, A.D. Wieck, T. Micklitz, A. Rosch, T.A. Costi, L. Saminadayar, and C. Buerle, cond-mat/0607154, submitted to PRL

[3] F. Mallet, F. Schopfer, D. Mailly, G. Montambaux, C. Texier, L. Saminadayar, C. Buerle, submitted to PRL

AASHISH CLERK
McGill University

Quantum-Limited Detection With Strongly Correlated Detectors

Quantum mechanics places constraints on the back-action of detectors; in the case of a weakly-coupled, linear QND qubit detector, this constraint means that the back-action dephasing rate cannot be any slower than the rate at which the measurement provides information. I will discuss recent theoretical which demonstrates that mesoscopic electron detectors with strong correlations (i.e. a quantum point contact in a Luttinger liquid, or a DC SQUID amplifier) are able to achieve a ”quantum-limited” back-action. I will also discuss how this result connects to the broader connection between the quantum limit and information (PRL 96, 056801, 2006).

W. A. COISH
University of Basel

Hyperfine interaction in quantum dots: non-Markovian evolution and the quantum/classical distinction

The decoherence of electron spins confined to GaAs quantum dots is dominated by the hyperfine interaction with nuclei in the surrounding lattice. In the presence of a strong applied magnetic field it is possible to control this decoherence to some extent with spin-echo pulses or by preparing the nuclear-spin environment through polarization or measurement (”state narrowing”). The residual electron spin dynamics are difficult to calculate since they are manifestly non-Markovian–the correlation time of the ”environment” (nuclear spins) is much longer than the correlation time of the ”system” (electron spin(s)). Furthermore, a replacement of the nuclear field operator by a classical field followed by an ensemble average is questionable for a finite nuclear spin system in a single isolated quantum dot. The residual quantum dynamics can, however, be evaluted using an appropriate perturbative treatment in the presence of an applied magnetic field or polarized nuclear spin system.

This talk will give an overview of the hyperfine decoherence problem for spins in single and double quantum dots, some ways of eliminating this decoherence, and the intriguing dynamics that ensue.

Co-author: Daniel Loss

IVAN DEUTSCH
University of New Mexico

Quantum State Estimation via Continuous Measurement

We present a new procedure for quantum state reconstruction based on weak continuous measurement of an ensemble average. By applying controlled evolution to the initial state, new information is continually mapped onto the measured observable. A Bayesian filter is then used to update the state estimate in accordance with the measurement record. This generalizes the standard paradigm for quantum tomography based on strong, destructive measurements on separate ensembles. This approach to state estimation induces minimal perturbation of the measured system, giving information about observables whose evolution cannot be described classically in real time and opening the door to new types of quantum feedback control.

FABRICE GERBIER
ENS Paris

Phase (de)coherence in ultracold quantum gases

Long-range phase coherence is perhaps the most fundamental signature of Bose-Einstein condendates. Such systems are characterized by a macroscopic wavefunction with a well-defined phase, with important consequences for applications in precision interferometric measurements. In the field of atomic quantum gases, this enables a whole class of interferometry experiments with coherent matter waves, with a potential for applications in precision measurements. However, phase coherence is by no means an obvious properties of ultracold boson systems. I will discuss two distinct experimentally relevant situations where this property is degraded or even entirely lost, namely low-dimensional gases and interacting gases in periodic potentials (optical lattices). Finally, if time allows, I will discuss prospects to achieve matter-wave interferometry at the Heisenberg limit with Bose-Einstein condensates.

SHOHINI GHOSE
Wilfrid Laurier University

Dynamics of Open Quantum Chaotic Systems

The predictions of quantum and classical theory can be markedly different for systems that exhibit chaos in the classical limit. We present studies of the behavior of open quantum systems that are classically chaotic. We analyze entanglement in a system undergoing continuous measurement as it approaches the classical limit, and show that classical dynamics can be concomitant with highly non-classical entangled states. We also analyze a system of cold atoms which can be used to realize a standard chaotic system, namely the quantum kicked top. Our detailed model allows us to examine decoherence due to photon scattering in regular versus chaotic regimes.

SALMAN HABIB
Los Alamos National Laboratory

Decoherence and the Quantum-Classical Transition

Open quantum dynamical systems display a wide variety of behaviors, including an effectively classical subset. How this classical subset arises has been a matter of continuing debate. In this talk, I will discuss a framework in which some of the underlying questions can be studied in a simple way and answered unambiguously. Of particular interest are cases where "standard" decoherence arguments do not lead to a quantum-classical transition.

BRIAN KING
McMaster University

Trapped atomic ions as a decoherence "micro laboratory"

Trapped atomic ions offer an unparallelled "micro laboratory" for controlling and studying quantum behaviour. In particular, by controlling their interactions with laser beams, it is possible to engineering various interaction Hamiltonians. One can, for example, introduce decoherence into the internal or external degrees of freedom of the ions in a controllable fashion. In this talk, I'll review ion trapping technology and the interaction between a trapped ion and laser fields, and discuss a few experiments which have allowed control of decoherence properties.

ROGER KOCH
IBM Research

Experimental Demonstration of an Oscillator Stabilized Josephson Flux Qubit

In this talk, I will review the basic types of Josephson qubits, discuss the IBM Josephson flux qubit extensively, and review the some of the systems issues in making a quantum computer using Josephson technology.

Our qubit consists of three Josephson junctions and three loops coupled to a fixed-length superconducting transmission line. The bare qubit has two control parameters, the flux and the control flux. This allows the qubit to have a tunable difference frequency between the ground and first excited states and at the same time to be biased at a degenerate point with respect to the flux parameter. This condition can be met for a wide range of junction critical currents. This flexibility of our structure is a very desirable property for a scalable qubit. To stabilize the operation of our qubit and increase its coherence time, we couple the bare qubit to the lowest mode of a superconducting transmission line, which we model as a harmonic oscillator. Using harmonic oscillator stabilization and pulsed dc operation, we have observed Larmor oscillations with a single shot visibility of 90 percent and a coherence time of 100 ns. In another qubit the visibility was 60 percent and there was no measurable visibility reduction after 35 ns.

Our system has several unique features that offer good prospects for scalability, compared with other Josephson qubits: The transmission line frequency, depending only on one geometric parameter, the length, can be fixed with very high precision. Its insensitivity to the magnetic flux environment when biased at the oscillator stabilized operating point will greatly diminish the degree of unintended couplings between qubits. The gradiometric design of the qubit can be exploited to further reduce crosstalk during gate operations, when the qubit is moved off the oscillator stabilized operating point. These issues of scalability are the most important ones to be explored in the next round of experiments on this qubit system.

GERSHON KURIZKI
Weizmann Institute of Science

Preventing Multipartite Disentanglement by Local Modulations

An entangled multipartite system coupled to a zero-temperature bath undergoes rapid disentanglement in many realistic scenarios, due to local, symmetry-breaking, differences in the particle-bath couplings. We show that locally controlled perturbations, addressing each particle individually, can impose a symmetry, and thus allow the existence of decoherence-free multipartite entangled systems in zero-temperature environments.

JAN KYCIA
University of Waterloo

1/f Noise in Josephson Junctions

Critical current fluctuations can be a major source of intrinsic decoherence of qubits based on Josephson junctions. We have measured the 1/f noise due to critical current fluctuations in several macroscopic Josephson junctions. In this talk, I will describe how we make these measurements and present our progress in understanding and reducing this noise.

DANIEL LIDAR
University of Southern California

Adiabaticity in open quantum systems

The adiabatic approximation is an 80+ year old pillar of quantum mechanics, which has found rich applications in a variety of physics and chemistry problems. However, in its original formulation the adiabatic theorem was derived in the context of closed quantum systems, described by unitary dynamics. We have recently introduced a generalization of the the adiabatic theorem to open quantum systems described by convolutionless master equations [1]. This version of the adiabatic theorem is naturally suited to problems in quantum information theory, and we describe applications to the adiabatic quantum computing paradigm [2], and to the problem of geometric phases (both Abelian and non-Abelian) in open quantum systems undergoing cyclic adiabatic evolution [3]. One our main findings is that, in general, adiabaticity in an open quantum system depends on two competing timescales: the speed of the driving field and the decoherence due to the interaction with the environment. These timescales generically determine a finite interval for adiabaticity. This has implications for both adiabatic quantum computing and the robustness of geometric phases to decoherence.

References: [1] Adiabatic Approximation in Open Quantum Systems, M.S. Sarandy and D.A. Lidar, Phys. Rev. A 71, 012331 (2005). [2] Adiabatic Quantum Computation

in Open Systems, M.S. Sarandy and D.A. Lidar, Phys. Rev. Lett. 95, 250503 (2005). [3] Abelian and Non-Abelian Geometric Phases in Adiabatic Open Quantum Systems, M.S. Sarandy and D.A. Lidar, Phys. Rev. A 73, 062101 (2006).

RAJ MOHANTY
Boston University

QUANTUM NANOMECHANICS: Quantized Motion and Stochastic Resonance

Observation of quantum mechanical motion in macroscopic mechanical oscillators has been an outstanding goal in a number of fields. Enabled by recent technological advances, it is now possible to create nanomechanical oscillators at resonance frequencies in the gigahertz range. If cooled to millikelvin temperatures, these nanomechanical structures enter the quantum regime of mechanical motion. I will describe recent experiments in my group, which demonstrate mechanical motion in the quantum regime, marked by their discrete response to applied drive. I will also discuss the prospect of classical nanomechanical computation with memory elements created by nanomechanical silicon beams, and their control by stochastic resonance.

LORENZA VIOLA
Dartmouth College

Coherence preservation via randomized dynamical control

Preserving coherence in complex quantum evolutions is a key challenge for both coherent control and quantum information processing. A variety of dynamical decoupling schemes have been introduced to meet this challenge. I will focus here on describing the basic principles underlying recently introduced randomized decoupling methods [1] and on illustrating physically relevant scenarios where the advantages of randomization become evident compared to deterministic design [2,3]. For systems which are either time-varying or require decoupling cycles involving a large number of control operations, we show how simple randomized protocols can achieve superior convergence and stability than standard periodic counterparts. In addition, we show how randomization allows to outperform deterministic schemes at long times, including efficient combinatorial and concatenated methods. General criteria for interpolating between deterministic and stochastic design are proposed and tested in explicit closed- and open-system decoupling settings relevant to robust quantum information storage.

[1] L. Viola and E. Knill, "Random decoupling schemes for quantum dynamical control and error suppression", Phys. Rev. Lett. 94, 060502 (2005). [2] L.F. Santos and L. Viola, "Enhanced Convergence and Robust Performance of Randomized Dynamical Decoupling", quant-ph/0602168. [3] L. Viola and L.F. Santos, Randomized Dynamical Decoupling Techniques for Coherent Quantum Control", quant-ph/0602175.

ANDREW WHITE
University of Queensland

Optical entangling gates

Entangling gates lie at the heart of quantum information. We discuss our recent efforts building, applying and characterising optical entangling gates in quantum computing, control, and metrology protocols. In particular, we look at the surprisingly deleterious effect of independent input photons on entangling gates; and a simple method for achieving phase super resolution.

FRANK WILHELM
University of Waterloo

Loss of visibility and the sensitivity to initial conditions in spin-Boson type models

With the growing precision in qubit experiments, more and more details of decoherence processes at low temperatures can be resolved. We analyze the paradigmatic spin Boson model for a variety of environmental spectra. We show, that for nonequilibrium initial conditions including the standard factorized stade, the Markovian T2 decay is joined by short-term losses leading to reduced visibility. These can be large even if T2 is long, in particular if the environment is engineered to have a gapped. We generalize these results away from pure dephasing using a novel approximation scheme for gapped environments. Time pertmitting, I will touch upon optimizing coherence in two-qubit gates for generic models which are neither collective nor local.

HOWARD M. WISEMAN
Griffith Universiy

The Preferred Ensemble Fact, with Applications to Quantum Feedback Control

The preferred ensemble fallacy [1] is that a mixed quantum state should be represented by one particular ensemble of pure states, rather than any one of the infinitude of other ensembles satisfying this. We do not deny that this is a fallacy. However, for open quantum systems for which the decoherence can be described by a master equation with a unique steady state, there is a preferred ensemble *fact* [2]. This is that only some ensembles are physically realizable. That is, it is only some ensembles for which i) an observer could, by monitoring the environment, know at all times which pure state the system is in; and ii) the proportion of time the system spends in each pure state is equal to its weight in the ensemble. This fact has applications in quantum feedback control of LQG (linear quadratic gaussian) systems [3].

[1] P. Kok and S.L. Braunstein, Phys. Rev. A 61, 042304 (2000). [2] H.M. Wiseman and J.A. Vaccaro, Phys. Rev. Lett. 87, 240402 (2001). [3] H. M. Wiseman, and A. C. Doherty, Phys. Rev. Lett. 94, 070405 (2005).

ANDREI D. ZAIKIN
Institute for Nanotechnology

Quantum decoherence in quantum dots: Effect of electron-electron interactions

I will present our recent theory describing weak localization and interaction-induced decoherence of electrons in various structures composed of metallic quantum dots. I will address a fundamental problem of low temperature saturation of the electron decoherence time in disordered conductors and demonstrate that this saturation is an intrinsic effect and in different types of conductors it is caused by the same physical mechanism: Electron-electron interactions.