TT 7: Transport: Quantum Coherence and Quantum Information Systems – Theory (jointly with HL, MA)

Time: Monday 9:30–13:00 Location: H 3005

TT 7.1 Mon 9:30 H 3005

Collective modes in the fluxonium qubit — •Gianluigi Catelani[1] and Giovanni Viola[2] — [1]Forschungszentrum Jülich, PGI-2 — [2]RWTH Aachen, IQI

In the fluxonium qubit, an array comprising a large number of identical Josephson junctions form a so-called superinductance. The superinductance is connected to a junction – the phase slip element – with a smaller Josephson energy and a different charging energy. We investigate the effects of unavoidable capacitive couplings to ground as well as non-linearities of the superinductance: they both introduce interactions between the low-energy qubit degree of freedom and higher-energy collective modes of the circuit. We also consider the role of the additional capacitances that are used to couple the qubit to a resonator for driving and read-out. We show that the interactions with the collective modes can affect not only the spectrum of the qubit but also its coherence.

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TT 7.2 Mon 9:45 H 3005

Optimal Control of Quantum Measurement — Daniel Egger and •Frank Wilhelm — Theoretical Physics, Saarland University, 66123 Saarbrücken, Germany

Pulses to steer the time evolution of quantum systems can be designed with optimal control theory. In most cases it is the coherent processes that can be controlled and one optimizes the time evolution towards a target unitary process, sometimes also in the presence of non-controllable incoherent processes. Here we show how to extend the GRAPE algorithm in the case where the incoherent processes are controllable and the target time evolution is a non-unitary quantum channel. We perform a gradient search on a fidelity measure based on Choi matrices. We illustrate our algorithm by optimizing a measurement pulse for superconducting phase qubits. We show how this technique can lead to large measurement contrast close to 99%. We also show, within the validity of our model, that this algorithm can produce short 1.4 ns pulses with 98.2% contrast.

TT 7.3 Mon 10:00 H 3005

Optimal control of single flux quantum pulses — •Per Liebermann, Daniel Egger, and Frank Wilhelm — Universität des Saarlandes, Saarbrücken

Rapid single flux quantum pulses are a natural candidate for on-chip control of superconducting qubits [1]. We apply trains of single flux quantum pulses to perform single qubit gates. Under the constraint of constant amplitudes and gate times we use genetic algorithms for optimising the pulse sequence to decrease the gate error by two orders of magnitude. We consider leakage transitions into a third energy level as well as timing jitter of the pulses, exploring the robustness of our optimized sequence. This takes us one step further to on-chip qubit controls.

[1] R. McDermott and M.G. Vavilov, Phys. Rev. Applied 2, 014007 (2014)

TT 7.4 Mon 10:15 H 3005

Adaptive characterization of coherent states — •Markku P. V. Stenberg, Kevin Pack, and Frank K. Wilhelm — Theoretical Physics, Saarland University, 66123 Saarbrücken, Germany

We present a method for efficient characterization of an optical coherent state $|\alpha\rangle$. We choose measurement setups adaptively based on the data while it is collected. Our algorithm divides the estimation in three different steps with different measurement strategies: (i) searching a crude estimate, (ii) rapidly improving the accuracy, and (iii) the phase where the improvement of the accuracy slows down due to the quantum nature of the coherent state. Our algorithm significantly outperforms nonadaptive schemes. While our standard strategy is robust against measurement errors we also present strategies optimized for the presence of such errors.

TT 7.5 Mon 10:30 H 3005

Qubit dephasing due to Quasiparticle Tunneling — •Sebastian Zanker, Michael Marthaler, and Gerd Schön — Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology, D-76128 Karlsruhe, Germany

We study dephasing of a superconducting qubit due to quasiparticle tunneling through a Josephson junction. While qubit decay due to tunneling processes is well understood within a golden rule approximation, pure dephasing due to BCS quasiparticles gives rise to a divergent golden rule rate. We calculate qubit dephasing due to quasiparticle tunneling beyond lowest order approximation in coupling between qubit and quasiparticles. Summing up a certain class of diagrams we show that qubit dephasing due to purely longitudinal coupling to quasiparticles leads to dephasing $\sim \exp(-x(t))$ where $x(t) \propto t^{3/2}$ for short time scales and $x(t) \propto t \log(t)$ for long time scales.

TT 7.6 Mon 10:45 H 3005

Detecting nonlocal Cooper pair entanglement by optical Bell inequality violation — Simon E. Nigg, Rakesh P. Tiwari, Stefan Walter, and •Thomas L. Schmidt — Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland

Based on the Bardeen Cooper Schrieffer (BCS) theory of superconductivity, the coherent splitting of Cooper pairs from a superconductor to two spatially separated quantum dots has been predicted to generate nonlocal pairs of entangled electrons. In order to test this hypothesis, we propose a scheme to transfer the spin state of a split Cooper pair onto the polarization state of a pair of optical photons. We show that the produced photon pairs can be used to violate a Bell inequality, unambiguously demonstrating the entanglement of the split Cooper pairs.

[1] Nigg et al., arXiv:1411.3945 [cond-mat.mes-hall]

TT 7.7 Mon 11:00 H 3005

Detection of non-local spin-entanglement by light emission from a superconducting pn-junction — •Alexander Schroer and Patrik Recher — Institut für Mathematische Physik, Technische Universität Braunschweig, D-38106 Braunschweig, Germany

We model a superconducting pn-junction in which the n- and the p-site are contacted through two optical quantum dots, each embedded into a photonic nanocavity. Whenever a Cooper pair is transported from the n-site to the p-site, two photons are emitted. When the two electrons of a Cooper pair are transported through different quantum dots, polarization entangled photons are created, provided that the Cooper pairs retain their spin-singlet character although being spatially separated on the two quantum dots. We show that a CHSH Bell-type measurement is able to detect the entanglement of the photons over a broad range of microscopic parameters, even in the presence of parasitic processes and imperfections. Observing this signature is a direct proof of crossed Andreev reflection, or, equivalently, Cooper pair splitting, retaining the spin-singlet wave function.

15 min. break.

TT 7.8 Mon 11:30 H 3005

Scattering of two photons from two distant qubits: exact solution — Matti Laakso and •Mikhail Pletyukhov — Institute for Theory of Statistical Physics, RWTH Aachen, 52056 Aachen

We consider the inelastic scattering of two photons from two qubits separated by an arbitrary distance and coupled to a one-dimensional transmission line. We present an exact, analytical solution to the problem, and use it to explore a particular configuration of qubits which is transparent to single-photon scattering, thus highlighting non-Markovian effects of inelastic two-photon scattering: Strong two-photon interference and momentum dependent photon (anti)bunching. This latter effect can be seen as an inelastic generalization of the Hong-Ou-Mandel effect.

TT 7.9 Mon 11:45 H 3005

Robust entanglement under multipartite correlated dephasing — •Edoardo Carnio[1,2], Manuel Gessner[2], and Andreas Buchleitner[2,3] — [1]Department of Physics, University of Warwick, Coventry, CV4 7AL, United Kingdom — [2]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [3]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität Freiburg, Albertstraße 19, 79104 Freiburg, Germany

We derive an analytical description for the dephasing process undergone by a system on non-interacting atomic qubits, immersed in a uniform, fluctuating magnetic field. The dephasing process is correlated, as the noise source is common to all the particles and induces an effective atom-atom interaction on them. This correlated nature allows to specify field orientations that preserve any degree of atomic entanglement for all times, and families of states with entanglement properties that are time-invariant for arbitrary field orientations. Our formalism applies to arbitrary spectral distributions of the fluctuations.

TT 7.10 Mon 12:00 H 3005

Bell inequalities and waiting times — •Christina Pöltl and Michele Governale — School of Chemical and Physical Sciences and MacDiarmid Institute for Advanced Materials and Nanotechnology, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand

We propose a Bell test based on waiting time distributions for spin entangled electron pairs, which are generated and split in mesoscopic Coulomb blockade structures, denoted as entanglers. These systems have the advantage that quantum point contacts enable a time resolved observation of the electrons occupying the system, which gives access to quantities such as full counting statistics and waiting time distributions. We use the partial waiting times to define a CHSH-Bell test, which is a purely electronic analogue of the test used in quantum optics. After the introduction of the Bell inequality we discuss the findings on the two examples of a double quantum dot and a triple quantum dot. This Bell test allows the exclusion of irrelevant tunnel processes from the statistics normally used for the Bell correlations. This can improve the parameter range for which a violation of the Bell inequality can be measured significantly.

TT 7.11 Mon 12:15 H 3005

Quantum dynamics of a strongly driven Josephson Junction — •Jennifer Gosner, Björn Kubala, and Joachim Ankerhold — Institute for Complex Quantum Systems, University of Ulm, Germany

A Josephson Junction embedded in a dissipative circuit can be driven to exhibit non-linear oscillations.

Classically the non-linear oscillator shows under sufficient strong driving and weak damping dynamical bifurcations and a bistable region similar to the conventional Duffing-oscillator. These features depend sensitively on initial conditions and parameters. The sensitivity of this circuit, called Josephson Bifurcation Amplifier, can be used to amplify an incoming signal, to form a sensing device or even for measuring a quantum system.

The *quantum* dynamics can be described by a dissipative Lindblad master equation. Signatures of the classical bifurcation phenomena appear in the Wigner representation, used to characterize and visualize the resulting behaviour. In order to compare this quantum dynamics to that of the conventional Duffing-oscillator, the complete cosine-nonlinearity of the Josephson Junction is kept for the quantum description while going into a rotating frame.

TT 7.12 Mon 12:30 H 3005

Dissipation-induced first order decoherence phase transition in a non-interacting fermionic system — •Mihailo Cubrovic — Institute for Theoretical Physics, Universität zu Köln, Zülpicher Str. 77, D-50937, Köln, Germany

We consider a dissipative tight-binding fermionic chain as a model for a nanowire with current leakage due to imperfect isolation. The dissipation manifests as tunneling into/out of the chain from/to the environment. The evolution of the system is described by the Lindblad equation, generalized to incorporate the memory effects in the bath. Already infinitesimally small dissipation along the chain induces a quantum phase transition (QPT). This is a decoherence QPT: the reduced density matrix of a subsystem (far from the ends of the chain) can be represented as the tensor product of single-site density matrices. We analyze the QPT in the thermodynamic limit by looking at the entropy and the response function in the bulk, and compare in detail the results with and without memory in the bath. To gain a better intuitive understanding we also contruct the analogous classical model (a correlated random walk process) and compare its behavior to the QPT of the quantum chain.

TT 7.13 Mon 12:45 H 3005

Spin dynamics using the Majorana representation: validity, path integral and higher correlators — •Pablo Schad[1], Boris N. Narozhny[1,2], Gerd Schön[3], Yuriy Makhlin[4,5], and Alexander Shnirman[1] — [1]Institut für Theorie der Kondensierten Materie, Karlsruhe Institute of Technology, D-76131 Karlsruhe, Germany — [2]National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Kashirskoe shosse 31, 115409 Moscow, Russia — [3]Institut für Theoretische Festkörperphysik und Institut für Nanotechnologie, Karlsruhe Institute of Technology, D-76131 Karlsruhe, Germany — [4]Landau Institute for Theoretical Physics, acad. Semyonov av., 1a, 142432, Chernogolovka, Russia — [5]Moscow Institute of Physics and Technology, 141700, Dolgoprudny, Russia

We present a method to calculate higher spin correlators via the Majorana fermion representation of spin operators. We show explicitly that the Majorana representation does not require any projection procedure. Previously found identities [1,2] between spin and Majorana fermion correlation functions are extended. As an example we consider a spin-1/2 coupled to an isotropic, ohmic bath. We formulate a path-integral approach, which is valid at B=0 in contrast to perturbation theory, find the saddle-point solution and discuss fluctuations. We demonstrate that spin correlators in the high-temperature regime can be obtained using saddle-point Green's functions.

[1] A. Shnirman and Y. Makhlin,
Phys. Rev. Lett. 91, 207204 (2003).
[2] W. Mao, P. Coleman, C. Hooley, and D. Langreth,
Phys. Rev. Lett. 91, 207203 (2003).