Calanque de Sugiton - Gilbert Thomas

MINI-WORKSHOP

Frequency- and time-resolved electron transport in nano-circuits

December 7, 2009, CPT, Luminy, Marseille

PROGRAM

• 9h30–10h:	G. Stefanucci	Time-dependent transport phenomena within TDDFT and NEGF
• 10h–10h30:	H. Le Sueur	Energy Relaxation in the quantum Hall regime
Chairman: F. Michelini		
• 10h30–11h:	Coffee break	
• 11h-11h30:	P. Recher	The Josephson light-emitting diode
• 11h30–12h:	F. Hekking	Phase-charge duality in Josephson junction circuits: role of inertia and effect of microwave irradiation
Chairman: I. Safi		
• 12h–14h:	Lunch (CIRM)	
• 14h–14h30:	E.V. Sukhorukov	Theory of quantum noise detectors based on resonant tunneling
• 14h30–15h:	B. Reulet	The high frequency third cumulant of noise in a tunnel junction
• 15h–15h30:	R. Deblock	Measurement of non-symmetrized noise with a Josephson junction
Chairman: T. Martin		
• 15h30–16h:	Coffee break	
• 16h–16h30:	P. Joyez	Shot noise and dynamic Coulomb blockade in tunnel junctions
• 16h30–17h:	F. Portier	Finite frequency shot noise and photon statistics
Chairman: C. Bena		

ABSTRACTS

Time-dependent transport phenomena within TDDFT and NEGF

G. Stefanucci – Physics Department, University of Rome

We present two different propagation schemes to study time-dependent quantum transport in molecular junctions. The first method is based on open boundary TDDFT and the key quantities to propagate in time are the Kohn-Sham wave-functions. The second method is based on the time-propagation of the non-equilibrium Green's function for open systems. We discuss advantages and difficulties of both approaches. We also show recent numerical result in several one-dimensional junctions and highlight the extra information that one can extract from a time-dependent study as compared to steady-state ones.

Energy Relaxation in the quantum Hall regime

C. Altimiras, H. le Sueur, U. Gennser, A. Cavanna, D. Mailly and F. Pierre
Laboratoire de Photonique et de Nanostructures, Marcoussis

In the quantum Hall regime, charges propagate without dissipation in 1D channels along the edges of the sample. These edge channels present a similarity with light beams, which has inspired electronic analogues of quantum optics experiments, such as the Mach-Zehnder interferometer[1]. However, contrary to photons, electronic excitations interact together and with their environment, through the Coulomb interaction. This offers new opportunities, for instance to implement fast quantum logic gates, but its main consequence is to limit the quasiparticles lifetime. The question thus arises of determining the nature of inelastic mechanisms at work in the quantum Hall regime. To directly access energy transfers, we probe the energy distribution of quasiparticles f(E) in an edge channel driven out-of-equilibrium[2]. Inelastic scattering occurs on a length scale related to the excited quasiparticles lifetime. By measuring f(E) for various propagation lengths, we can explore the edge's dynamics: the inelastic mechanisms at work, and the nature of the pertinent electronic excitations. For the important case of two co-propagating ECs, we find a complete energy current equilibration, over a few micrometers. This strongly suggests that the dynamics is governed by collective edge excitations delocalized over both channels[3].

[1] Ji et al., Nature 422, 415 (2003)
[2] Altimiras et al., Nature phys., doi:10.1038/nphys1429 (2009)
[3] Degiovanni et al., arXiv:0910.2642 (2009)

The Josephson light-emitting diode

P. Recher, Yu.V. Nazarov, and L.P. Kouwenhoven
Institut für Theoretische Physik und Astrophysik, Universität Würzburg

We consider an optical quantum dot where an electron level and a hole level are coupled to respective superconducting leads. We find that electrons and holes recombine producing photons at discrete energies as well as a continuous tail. Further, the spectral lines directly probe the induced superconducting correlations on the dot. At energies close to the applied bias voltage eV, a parameter range exists, where radiation proceeds in pairwise emission of polarization correlated photons. At energies close to 2eV, emitted photons are associated with Cooper pair transfer and are reminiscent of Josephson radiation. We discuss how to probe the coherence of these photons in a SQUID geometry via single photon interference.

Phase-charge duality in Josephson junction circuits: role of inertia and effect of microwave irradiation

F. Hekking - Laboratoire de Physique et Modélisation des Milieux Condensés, Grenoble

We investigate the physics of coherent quantum phase slips in two distinct circuits containing small Josephson junctions: (i) a single junction embedded in an inductive environment and (ii) a long chain of junctions. Starting from the standard Josephson Hamiltonian, the single junction circuit can be analyzed using quasi-classical methods; we formulate the conditions under which the resulting quasi-charge dynamics is exactly dual to the usual phase dynamics associated with Josephson tunneling. For the chain we use the fact that its collective behavior can be characterized by one variable: the number m of quantum phase slips present on it. We conclude that the dynamics of the conjugate quasi-charge is again exactly dual to the standard phase dynamics of a single Josephson junction. In both cases we elucidate the role of the inductance, essential to obtain exact duality. These conclusions have profound consequences for the behavior of single junctions and chains under microwave irradiation. Since both systems are governed by a model exactly dual to the standard resistively and capacitively shunted junction model, we expect the appearance of current-Shapiro steps. We numerically calculate the corresponding current-voltage characteristics in a wide range of parameters. Our results are of interest in view of a metrological current standard.

Theory of quantum noise detectors based on resonant tunneling

E. V. Sukhorukov - Department of Theoretical Physics, University of Geneva

I will discuss the physics of noise detectors based on the phenomenon of resonant tunneling. The main idea of this type of detectors, proposed earlier by Aguado and Kouwenhoven relies on the effect of homogeneous broadening of the resonant tunneling peak induced by the emission and absorption of collective charge excitations in the measurement circuit. I return to this problem and investigate it from a different perspective. In thermal equilibrium, the signal to noise ratio of the detector as a function of the detector bandwidth (the detector function) is given by the universal hyperbolic tangent, which is the statement of the fluctuation-dissipation theorem. The universality breaks down if non-equilibrium processes take place in the measurement circuit. I propose the theory of this phenomenon and make predictions for the detector function in case when non-equilibrium noise is created by a mesoscopic conductor. I investigate measurement circuit effects and prove the universality of the classical noise detection. Finally, I evaluate the contribution of the third cumulant of current and make suggestions of how it can be measured.

The high frequency third cumulant of noise in a tunnel junction

B. Reulet - Laboratoire de Physique des Solides, Université Paris-Sud, Orsay

The third cumulant of current fluctuations at finite frequency is the simplest one that raises the problem of the link between an experimental setup and the ordering of the current operators for a simple system. We will show some experimental results and discuss their meaning: is the high frequency zero point motion of the electrons correlated with low frequency current fluctuations?

Measurement of non-symmetrized noise with a Josephson junction

R. Deblock - Laboratoire de Physique des Solides, Université Paris-Sud, Orsay

The measurement of current fluctuations is a powerful tool to probe electron dynamics in mesoscopic devices. In the quantum regime, when the frequency is of the order of or higher than the applied voltage or temperature, we show experimentally that, when a superconductor-insulator-superconductor junction is used as a high frequency detector (by measuring the quasiparticle photo-assisted current through it), the non-symmetrized noise correlator is measured. This allows us to probe the asymmetry between emission and absorption of mesoscopic devices at high frequency.

Shot noise and dynamic Coulomb blockade in tunnel junctions

P. Joyez - Quantum Group, SPEC, CEA Saclay, Gif-Sur-Yvette

For a tunnel junction embedded in an electromagnetic environment with significant impedance, the I-V characteristic is non-linear at low bias, a phenomenon known as Dynamic Coulomb Blockade (DCB), for which a well established theory exists. Extending the theory to finite frequency allows to predict all the noise and ac transport properties of this non linear system and to examine their relationship.

Finite frequency shot noise and photon statistics

F. Portier - SPEC, CEA Saclay, Gif-Sur-Yvette

What is the counting statistics of the photons emitted by a coherent quantum conductor and how does it relate to the electrons counting statistics? This question might seem artificial, unless one notices the dual representation of the current as fermionic excitations in a quantum conductor and bosonic electromagnetic modes in the external measuring circuit. This problem was addressed by Beennaker and Schomerus (PRL 86 p700 (2001) and PRL 93 p096801 (2003)), with the spectacular prediction that a QPC could emit sub-Poissonian photons. We tested Beenakker and Schomerus' prediction on the simplest and best understood mescocopic conductor, a tunnel junction. We developed an original method to measure photon statistics based on Hanburry-Brown and Twiss correlations and fast digitization. Our data show perfect agreement with theory for a wide range of frequency, voltage and temperature with no adjustable parameters. As the power fluctuations are found to be proportional to the squared emission noise power, our experiment also sheds light on the status of 'zero point' fluctuations in quantum shot noise measurements in an HBT configuration. It is also an important step toward the detection of the predicted non-classical photon noise emitted by a quantum point contact.

LIST OF PARTICIPANTS

1. Juan-Manuel AGUIAR — Strasbourg – aguiar@ipcms.u-strasbg.fr
2. Selma AMARA — Marseille – selma.amara@etu.univ-provence.fr
3. Julien BASSET — Orsay – basset@lps.u-psud.fr
4. Cristina BENA — Orsay – bena@lps.u-psud.fr
5. Marc BESCOND — Marseille – marc.bescond@im2np.fr
6. Denis CHEVALLIER — Marseille – denis.chevallier@cpt.univ-mrs.fr
7. Adeline CRÉPIEUX — Marseille – adeline.crepieux@cpt.univ-mrs.fr
8. Anne-Marie DARÉ — Marseille – anne-marie.dare@univ-provence.fr
9. Richard DEBLOCK — Orsay – deblock@lps.u-psud.fr
10. Benoît DOUÇOT — Paris – doucot@lpthe.jussieu.fr
11. Pierre DEVILLARD — Marseille – pierre.devillard@cpt.univ-mrs.fr
12. Gabriel ELIAS — Marseille – gabriel.elias@im2np.fr
13. Julien GABELLI — Orsay – gabelli@lps.u-psud.fr
14. Marine GUIGOU — Bordeaux – marine.guigou@u-bordeaux1.fr
15. Géraldine HAACK — Genève – geraldine.haack@unige.ch
16. Roland HAYN — Marseille – roland.hayn@im2np.fr
17. Frank HEKKING — Grenoble – frank.hekking@grenoble.cnrs.fr
18. Thibaut JONCKHEERE — Marseille – thibaut.jonckheere@cpt.univ-mrs.fr
19. Philippe JOYEZ — Saclay – philippe.joyez@cea.fr
20. Hélène LE SUEUR — Marcoussis – helene.le-sueur@lpn.cnrs.fr
21. Thierry MARTIN — Marseille – thierry.martin@cpt.univ-mrs.fr
22. Fabienne MICHELINI — Marseille – fabienne.michelini@univ-provence.fr
23. Michael POLIANSKI — Orsay – polian@lps.u-pud.fr
24. Fabien PORTIER — Saclay – fabien.portier@cea.fr
25. Gianluca RASTELLI — Grenoble – gianluca.rastelli@grenoble.cnrs.fr
26. Jérome RECH — Marseille – jerome.rech@cpt.univ-mrs.fr
27. Patrik RECHER — Würzburg – precher@physik.uni-wuerzburg.de
28. Bertrand REULET — Orsay – reulet@lps.u-psud.fr
29. Inès SAFI — Orsay – safi@lps.u-psud.fr
30. Andrès SAUL — Marseille – saul@cinam.univ-mrs.fr
31. Gianluca STEFANUCCI — Rome – gianluca.stefanucci@roma2.infn.it
32. Eugene SUKHORUKOV — Genève – eugene.sukhorukov@physics.unige.ch
33. Tineke VANDENBERG — Marseille – tineke.vandenberg@im2np.fr
34. Alberto VERGA — Marseille – alberto.verga@im2np.fr
35. Valentin ZAGREBNOV — Marseille – valentin.zagrebno@cpt.univ-mrs.fr

ORGANIZERS

- Cristina BENA — Laboratoire de Physique des Solides
- Adeline CRÉPIEUX — Centre de Physique Théorique
- Fabienne MICHELINI — Institut Matériaux Microélectronique Nanosciences de Provence
- Inès SAFI — Laboratoire de Physique des Solides