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Geometric energy transport in time-dependently driven quantum dots – by Juliette Monsel

We study energy pumping in a single-level quantum dot weakly coupled to two electronic reservoirs when a pair of the setup's parameters are slowly driven. We consider a finite local electron-electron interaction in the quantum dot and analyze both a repulsive, i.e. the usual Coulomb interaction, as well as an attractive interaction.
We compute analytically the first non-adiabatic correction to the energy current using a geometric approach [1]. We classify the different mechanisms leading to energy pumping and compare them to the case of particle pumping [2].
Interestingly, we find that energy pumping does not require the quantum dot to be in resonance with the Fermi level of one reservoir, in stark contrast to the case of charge pumping. Even more, charge and energy pumping can be complementary, in the sense that for the same pair of driving parameters, they occur in separated areas of the parameter space.
Furthermore, this first non-adiabatic correction to the currents plays an important role in slowly-driven quantum thermal machines [3, 4].

[1] J. Monsel, T. Baquet, J. Schulenborg, M. R. Wegewijs, and J. Splettstoesser, in preparation
[2] B. A. Placke, T. Pluecker, J. Splettstoesser, and M. R. Wegewijs, Phys. Rev. B 98, 085307 (2018)
[3] B. Bhandari, P. T. Alonso, F. Taddei, F. von Oppen, R. Fazio, L. Arrachea: Phys. Rev. B 102, 155407 (2020)
[4] H. J. D. Miller, M. H. Mohammady, M. Perarnau-Llobet and G. Guarnieri, Phys. Rev. Lett. 126, 210603 (2021)

Readout of quantum screening effects using a time-dependent probe – by Matteo Acciai

In voltage- and temperature-biased coherent conductors, quantum screening effects play a relevant role if the conductor's transmission is energy-dependent [1,2]. These effects, however, manifest appear as nonlinear corrections to the charge and heat current responses and are therefore difficult to isolate from other nonlinearities that may be present in the system. In this work [3], we show that an additional ac-driven terminal can act as a probe for a direct readout of such effects, hitherto largely unexplored.

We find that screening of charges induced by the static biases impacts already the standard linear thermoelectric response coefficients, due to nonlinear effects arising from the frequency of the time-dependent driving. These effects should be observable under realistic experimental conditions and can literally be switched on and off with the ac-driving.

[1] T. Christen and M. Büttiker, Eur. Phys. Lett. **35**, 523–528 (1996).
[2] D. Sánchez and R. López, Phys. Rev. Lett. **110**, 026804 (2013).
[3] N. Dashti, M. Acciai, S. Kheradsoud, M. Misiorny, P. Samuelsson, and J. Splettstoesser, arXiv:2107.04667

Time-scales of a driven interacting quantum dot with superconducting proximity – by Lara Ortmanns

We analyze the time-evolution of a quantum dot with strong onsite Coulomb interaction in contact with a large-gap superconductor, which is weakly probed by a wide-band normal electrode and driven out of equilibrium by a switch in the applied gate voltage. Whereas basic arguments lead one to expect two time scales that depend nontrivially on the pairing amplitude and Coulomb interaction, we show that only a single time scale associated with quasiparticles is sensitive to the interplay of the proximity effect and electron-electron interaction [1]. Instead, the time scale associated with the change in parity of the quantum dot charge is equal to the overall tunneling constant; it is hence a mere interface property. We map out the full time-dependent decay of the quantum dot controlled by a quench of the gate voltage as reflected by measurable transient charge and heat flows. Here, we make use of a dissipative symmetry for fermionic systems [2], a so-called fermionic duality relation, to identify the amplitudes of transient charge and heat currents. These amplitudes can be conveniently understood in terms of stationary quantities of the real model system and of a corresponding dual system, which is related to the real system by an inversion of energy parameters.

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[2] J. Schulenborg, R. B. Saptsov, F. Haupt, J. Splettstoesser, and M. R. Wegewijs, "Fermion-parity duality and energy relaxation in interacting open systems," Phys. Rev. B 93, 081411 (2016).

Quantum confinement in topological insulator nano-devices – by Xavier Palermo

According to theory, a single-electron transistor made with a topological insulator (TI) could be used to define a new standard for defining the Ampere. One way to do it is to create a quantum dot in a TI nanowire using constrictions as barriers, which is challenging since TIs are delicate materials.

In this work, we present methods to pattern constricted nanowires in Bi-doped Sb_2Te_3 films and as-grown Bi_2Se_3 nanobelts by electron-beam lithography and argon ion milling. By using cured PMMA or metallic layers such as Al_2O_3 as etching mask, we could pattern constrictions down to a few 10 nm in width. Preliminary electrical measurements at 300 mK indicated a switch from ohmic to tunneling behavior for constrictions of approx. 50 nm in width in Bi_2Se_3 nanowires.

It suggests that further reducing the dimensions may enhance this effect, and possibly lead to the formation of a quantum dot.

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Efficiency of Hot-Carrier Photovoltaics – by Ludovico Tesser

When a photon is absorbed by a solar cell, it produces an electron-hole pair. By separating these oppositely charged carriers, the solar cell generates power. If the absorbed photon has energy greater than the band gap, one speaks of "hot" carriers. Their excess energy is simply lost, when these hot carriers relax to the lattice temperature. However, this energy could be exploited to improve the performance of solar cells! This is what so-called hot-carrier solar cells aim at, by employing energy filters to extract the hot carriers and harvest their excess energy.
Here, I will present a study on hot-carrier photovoltaics, where the combination of the thermoelectric and the photovoltaic effect plays a central role in the performance of the device. We find the transmission of the energy filters that maximizes the efficiency of the device for a given power output. We thereby show that the hot carrier solar cell converts energy into power more efficiently than both the standard Carnot efficiency of a thermoelectric heat engine and the regular solar cell, while keeping the second law of thermodynamics satisfied. These results are obtained when the carriers are thermally distributed, but we also study the effects of a non-equilibrium carrier distribution, determined by the competition between the generation of hot carriers and the carrier relaxation to the lattice temperature.