Electron coherence in mesoscopic quantum wires in the presence of magnetic impurities

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The understanding of the ground state of an electron gas at zero temperature is one of the major challenges in Solid State Physics. For a long time it has been known that such a ground state is well described by Landau's theory of Fermi liquids [1]. In this description, the lifetime of quasiparticles is infinite at zero temperature, as the coupling to the environment tends to zero.

Alternatively, in mesoscopic physics, one key physical concept is the phase coherence time, *i.e.* the time an electron can travel in a solid before it looses its phase coherence and thus its quantum, wave like behaviour. Such a decoherence is due to inelastic processes, like electron-phonon, electron-electron or electron-photon collisions. It has been shown by Altshuler and coworkers [2] that the phase coherence time diverges at zero temperature as electron-phonon, electron-electron and electron-photon interactions all go to zero at zero temperature.

However, recent experiments on metallic as well as semiconductor wires suggest that the phase coherence time saturates at very low temperature [3]. Following this work, it has been argued that the observed saturation is indeed universal and intrinsic, and due to electron-electron interactions in the ground state of the Fermi liquid [4], which has sparked a relativly heavy debate in the mesoscopic community.

In this context, other interpretations have been proposed and argue that this saturation is extrinsic and due to the coupling to other degrees of freedom, like two level systems [5]. On the other hand, some experimental results suggest that the dephasing depends on the dimensions of the samples [6], whereas another group argues that some of their experimental results agree with standard theory [7], at least down to 50 mK.

One should also emphasize, that the problem of relaxation at zero temperature is not subject of debate in the mesoscopic community only. Recent experiments in spin polarized helium, a textbook example of a Fermi liquid, show a saturation of the transverse spin-diffusion coefficient at zero temperature [8]. This equally raises key questions about the applicability of conventional Fermi liquid theory.

More recent experiments invoke the coupling to magnetic impurities as a possible source of the frequently observed low temperature saturation of the phase coherence time [9, 10, 11]. It is well known that in metals the interaction of conduction electrons with magnetic impurities gives rise to the Kondo effect [12]. Concerning transport properties of metals, the best known feature of this effect is the existence of a minimum and a subsequent logarithmic increase of the resistivity with decreasing temperature below the Kondo temperature T_K. The influence of Kondo impurities on the dephasing rate, on the other hand, is by far more subtle.

In addition, it is well known that above a certain amount of impurities, and below a certain temperature, RKKY interactions between magnetic moments lead to the formation of a spin glass [13]. This regime has basically not been explored so far and may contain a great deal of new physical phenomena.

All this physics related to magnetic impurities leads to new energy scales: the Kondo temperature T_K and the spin glass transition temperature T_g. Both energy scales have to be considered when dealing with the "zero" temperature limit, and have also to be introduced in the theoretical description of dephasing in mesoscopic wires.

In this talk we will review shortly recent experimental progress on the dephasing issue. In particular we will concentrate on the influence of magnetic impurities on the phase coherence time in mesoscopic quantum wires. We will show that the interactions between the magnetic impurities even in very dilute systems lead to a saturation of the phase coherence time at low temperatures and are hence important for the issue of electron coherence in metallic conductors.

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