physikalisches Kolloquium

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Carbon nanotubes: spectral and transport properties in magnetic fields

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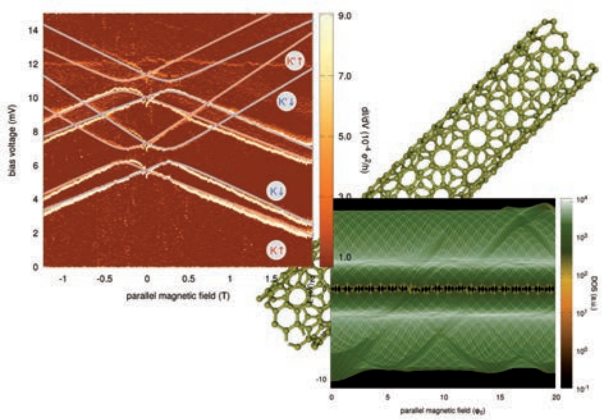
Since the discovery of carbon nanotubes and, more recently, graphene, carbon materials have become a hope for the basis of new electronics. There are already schemes of how to make use not only of the electrons' charge, but also of their spin; graphene and carbon nanotubes offer an additional quantum number to manipulate, the so-called valley. In nanotubes these two latter degrees of freedom are coupled by the spin-orbit interaction.

The physics of nanotubes is however much richer - their ends can support very localized electronic states, or, in double-wall tubes, the coupling between the two shells affects the transport of an electron along such a tube. All these phenomena - the spin-valley interplay, the localization of electrons at the tube ends, the specific properties of the intershell coupling - can be explored and understood by subjecting the nanotube to a magnetic field. Its influence perturbs the spectrum in a continuous way and permits us to disentangle the various effects - for instance, it shows that in one class of nanotubes the fundamental property of a state is not the valley, but the equivalent of parity, or that only specific many-body transitions contribute to the Kondo effect in carbon nanotubes.

Finally, the application of the magnetic field modifies also the nature of electronic transport in nanotubes: metallic nanotubes can be turned into semiconducting and vice versa; extended states can become localized; electrons travelling along one shell of double-wall nanotube can spread over both shells.



Above: The evolution of valley and spin energy levels of a carbon nanotube quantum dot in magnetic field.
Background: measurement results, foreground: theoretical fit.
Right: The density of states of a double-walled carbon nanotube in parallel magnetic field.

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