Strong Correlation Effects in Nanostructure: Theory and Experiment

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Abstract

Nanostructures have attracted great attention for the fundamental strong correlation physics as well as nanoscale device applications due to its high and accurate tunability. In this talk, after very briefly reviewing major developments in the field, we introduce a new theoretical finding about the mixed-valence quantum phase transition and an direct experimental probe of the frozen charge at the Kondo resonance.

We first study the triad interplay of the Kondo effect, superconductivity, and ferromagnetism, any pair of which compete with and suppress each other. We find that the interplay leads to a mixed-valence quantum phase transition, which is usually a crossover rather than a true transition. The singlet side of the phase diagram is characterized by unexpected Andreev reflection in the fully spin polarized ferromagnetic lead.

We later report the direct observation of the frozen charge state at the Kondo resonance using the circuit QED architecture. We couple a quantum dot to a high finesse microwave cavity to measure with an unprecedented sensitivity the dot electronic compressibility. Because it corresponds solely to the charge response, this quantity is not equivalent to the conductance which involves in general other degrees of freedom such as spin. By performing dual conductance/compressibility measurements in the Kondo regime, we uncover directly the charge dynamics of this peculiar mechanism of electron transfer. Strikingly, the Kondo resonance, visible in transport measurements, is 'transparent' to microwave photons trapped in the high finesse cavity. This reveals that, in such a many body resonance, finite conduction is achieved from a frozen charge. This previously elusive freezing of charge dynamics is in stark contrast with the physics of a free electron gas. Our setup highlights the power of circuit QED architectures to study condensed matter problems.

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