Spin-Polarized Conductance in Double Quantum Dots: Interplay of Kondo, Zeeman and Interference Effects

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Introduction

A striking example of novel physics arising from competition between strong correlations and quantum-mechanical interference has been predicted when a small quantum dot in its Kondo regime is side-coupled to external leads via a larger, weakly interacting quantum dot. The Kondo resonance (normally a single peak at the Fermi energy) splits into two peaks without any weakening of the many-body effects [1]. Here, we show theoretically that application of a magnetic field can strongly modify the system's properties. By tuning gate voltages and/or the field, experimentalists should be able to achieve complete spin polarization of the current [2].

Model

Dot j (= 1, 2) is treated as an Anderson impurity with energy ε_j and interaction (charging energy) U_j. Dot 2 has interaction $U_2 \approx 0$ and a lifetime Δ_2 due to mixing with source and drain leads, each of which has half-bandwidth $D = 1$. Dot 1 has strong interactions, an unpaired spin, and a tunneling matrix element λ with dot 2. The linear-response conductance G has been calculated within the Landauer formalism using the numerical renormalization-group method.

Results, Discussion, and Conclusions

Results shown are for $U_1 = -2\varepsilon_1 = 0.5$ and $\Delta_2 = 0.02$, varying the field B and/or gate-tuning the dot-2 energy ε_2. For $B = 0$ [**Figure 1**(a)], $G = 0$ at temperature $T = 0$ and $\varepsilon_2 = 0$ due to complete destructive interference between paths directly through dot 2 and paths that visit dot 1. Raising T (inhibiting the Kondo effect) or changing ε_2 (detuning dot 2 from the leads) reduces the destructive interference and allows current to pass. A field $B = 0.045$ [Fig. 1(b)] changes the relative phases of direct and indirect paths to yield a unitary conductance $G = 2e^2/h$ for $T = 0$, $\varepsilon_2 = 0$.

Figure 2 shows that in the presence of a field, the interference can be gate-tuned at zero temperature to achieve perfect spin polarization of the conductance: $\eta = (G_\uparrow - G_\downarrow)/(G_\uparrow + G_\downarrow) = \pm 1$. Significant polarizations survive to temperatures of order the system's Kondo scale. These findings suggest applications of the double-dot device as a highly tunable spin filter.

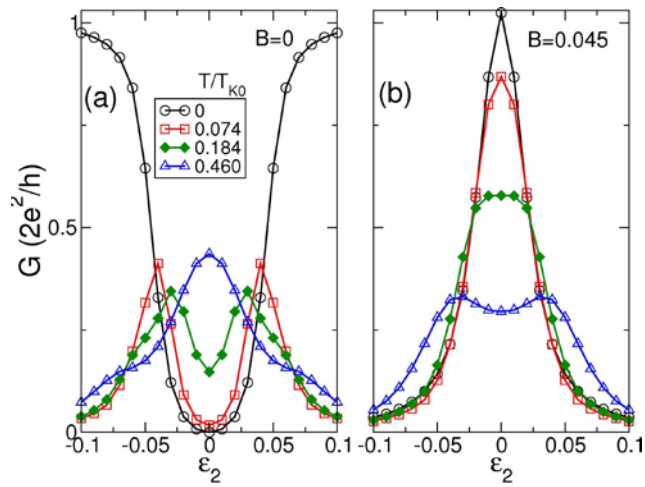

Figure 1: Linear conductance G vs dot-2 level ε_2 for (a) $B = 0$ (b) $B = 0.045$, at four temperatures T expressed as multiples of $T_{K0} = 0.021$.

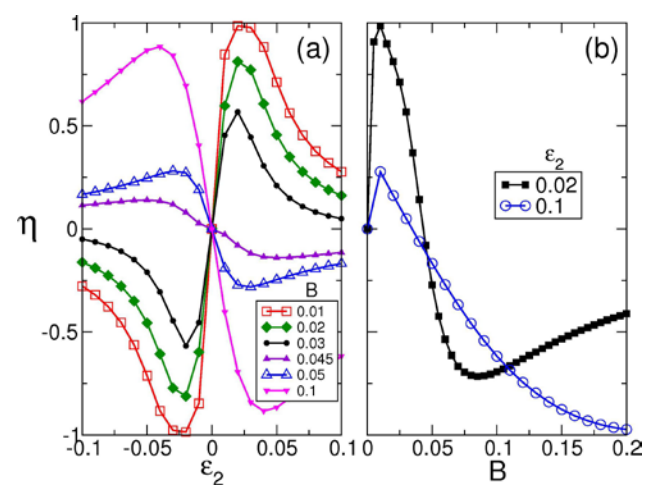

Figure 2: Conductance spin polarization η at zero temperature (a) vs dot-2 level energy ε_2 at six different fields B, and (b) vs B for two values of ε_2.

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References

[1] Dias da Silva, L.G.G.V., *et al.*, Phys. Rev. Lett. **97**, 096603 (2006).
[2] Dias da Silva, L.G.G.V., *et al.*, arXiv:1211.5289.