Singlet-triplet transition in a single-electron transistor at zero magnetic field

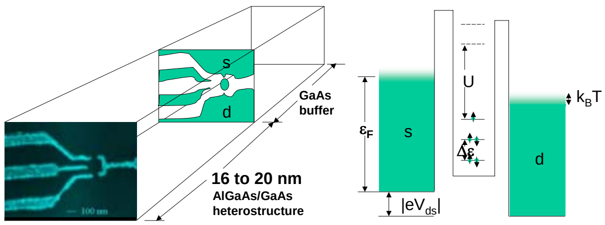
M.A. Kastner

A. Kogan, G. Granger, D. Goldhaber-Gordon, H. Shtrikman

Abstract

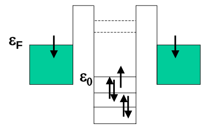
We report sharp peaks in the differential conductance of a single-electron transistor (SET) at low temperature, for gate voltages at which charge fluctuations are suppressed. For odd numbers of electrons we observe the expected Kondo peak at zero bias. For even numbers of electrons we generally observe Kondo-like features corresponding to excited states. For the latter, the excitation energy often decreases with gate voltage until a new zero-bias Kondo peak results. We ascribe this behavior to a singlet-triplet transition in zero magnetic field driven by the change of shape of the potential that confines the electrons in the SET.

Sample Geometry and Energy Scales



Experimentally:

ε_F ~ 25 meV
U ~ 2 meV
$\Delta\varepsilon$ ~ 0.5 meV
Γ ~ 0.2 - 0.5 meV

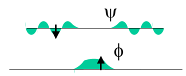


Kondo temperature:

$$T_K = \frac{\sqrt{\Gamma U}}{2} \exp\left(\frac{\pi\varepsilon_0(\varepsilon_0+U)}{\Gamma U}\right)$$

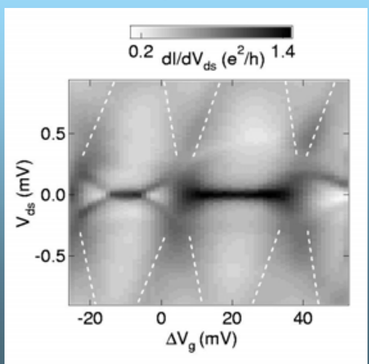
Experimentally:
T_K is from 50 mK to 3 K

Hybridization

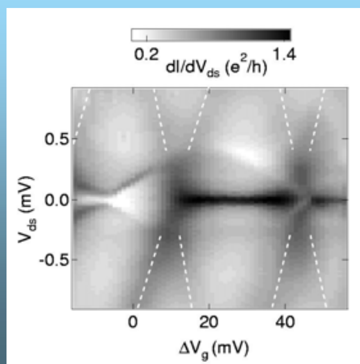


Differential Conductance Data

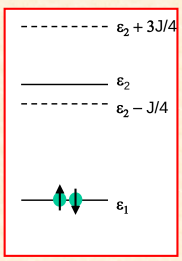
Singlet-Triplet Transition



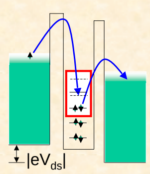
Avoided Crossing



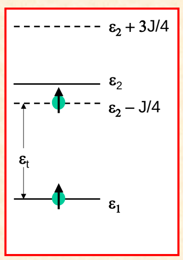
Mechanism and Two-Level Model



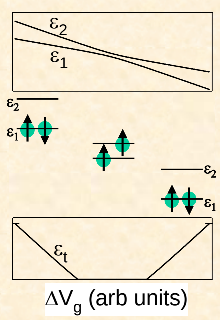
Ground state

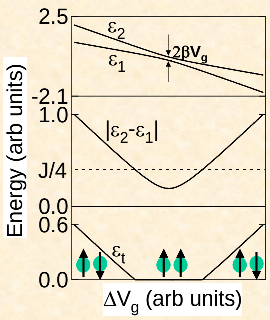


Inelastic cotunneling



Excited state





$$H_{st} = \begin{pmatrix} \varepsilon_1^0 - \gamma_1 \Delta V_g & \beta\Delta V_g \\ \beta\Delta V_g & \varepsilon_2^0 - \gamma_2\Delta V_g \end{pmatrix}$$

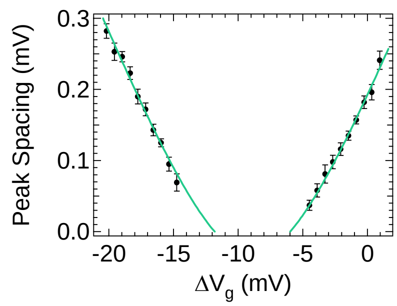
$$|\varepsilon_2 - \varepsilon_1| = \sqrt{(\gamma_{12}\Delta V_g + \varepsilon_{21}^0)^2 + 4\beta^2\Delta V_g}$$

where $\gamma_{12} \equiv \gamma_1 - \gamma_2$
and $\varepsilon_{21}^0 \equiv \varepsilon_2^0 - \varepsilon_1^0$

$$\varepsilon_t = |\varepsilon_2 - \varepsilon_1| - J/4$$

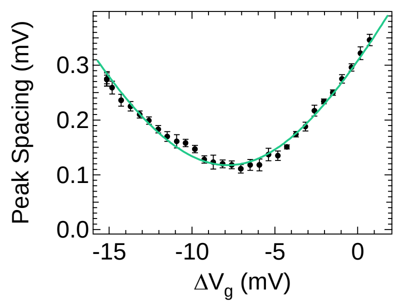
Analysis

Singlet-triplet Transition



γ_{12} = (0.0195 ± 0.0009) e
ε_{21}^0 = (0.25 ± 0.08) meV
β = (0.006 ± 0.003) e
J = (0.6 ± 0.3) meV

Avoided Crossing



γ_{12} = (0.021 ± 0.001) e
ε_{21}^0 = (0.4 ± 0.2) meV
β = (0.013 ± 0.006) e
J = (1.0 ± 0.8) meV

Conclusion

- We observed singlet-triplet transitions by deforming the potential near the electron droplet.
- The energy of the triplet excited state and its dependence on gate voltage were measured with high precision because the inelastic cotunneling threshold and the concomitant Kondo peaks are much sharper than the Coulomb charging peaks.
- Future plans: studying the singlet-triplet transition vs. B, T, V_g, and V_{ds}.

Acknowledgments

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