Charge Kondo impurity simulator operating in the fractional quantum Hall regime

A.V. Parafilo[1]

[1]*Center for Theoretical Physics of Complex Systems, Institute for Basic Science (IBS), 55 Expo-ro, Yuseong-gu, Daejeon, 34126, Republic of Korea*
e-mail: aparafil@ibs.re.kr

A single-electron transistor (SET) provides an ideal platform for simulating various quantum-impurity models, which refer to a class of systems defined by a finite number of local degrees of freedom that are coupled to one or more bath continua. This analogy is possible due to the Coulomb blockade phenomenon, which is the source of charge quantization in a quantum dot (QD).

Recently, the charge implementation of the multi-channel Kondo problem has been achieved in breakthrough series of experiments [1, 2]. An experimental device in [1, 2] has been designed as a hybrid metal-semiconductor SET formed in a two-dimensional electron gas, where the QD is connected to several reservoirs via nearly open single-mode quantum point contacts. The experiment has been performed in a strong external magnetic field, thus achieving the integer quantum Hall regime. While the original Kondo problem is attributed to the spin degree of freedom, the quantum pseudo-spin in the charge implementation of the Kondo problem is represented by the QD's two degenerate macroscopic charge states [3, 4]. The high tunability of the conducting channels entering the QD provides access to the study of multi-channel Kondo physics [1, 2].

In this work, I address the question of how the low-temperature transport properties change when the SET-based devices studied in [1, 2] operate in the fractional quantum Hall (FQH) regime with the filling factor $\nu = 1/m$, where m is odd integer. In case of two-terminal SET, when the problem is mapped onto the two-channel charge Kondo problem, it is predicted that the power of leading temperature correction to the conductance is determined by the fractional filling factor, $G_0/2 - G(T) \propto T^{\nu}$. In case of the multi-terminal setup, the SET device can be treated as the simulator of the Luttinger-liquid with an impurity, whose effective interaction parameter $K = \nu N/(N+1)$ is determined by the filling factor ν and the number of open ballistic channels N. The conductance scaling in the weak and strong tunnel regimes is used to discuss the low temperature transport behavior of the multi-channel single- and two-charge Kondo circuits. A well-known correspondence between a one-dimensional edge excitation in the FQH effect and the Luttinger-liquid is utilized to study the influence of electron-electron interaction on quantum-impurity physics in various charge Kondo devices.

[1] Z. Iftikhar, S. Jezouin, A. Anthore, U. Gennser, F. D. Parmentier, A. Cavanna, and F. Pierre, Nature 526, 233 (2015).
[2] Z. Iftikhar, A. Anthore, A. K. Mitchell, F. D. Parmentier, U. Gennser, A. Ouerghi, A. Cavanna, C. Mora, P. Simon, and F. Pierre, Science 360, 1315 (2018).
[3] K. A. Matveev, Sov. Phys. JETP 72, 892 (1991).
[4] K. A. Matveev, Phys. Rev. B 51, 1743 (1995).