Parallel Quantum Circuit in a Tunnel Junction

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Abstract: In between 2 metallic nanopads, adding identical and independent electron transfer paths in parallel increases the electronic effective coupling between the 2 nanopads through the quantum circuit defined by those paths. Measuring this increase of effective coupling using the tunneling current intensity can lead for example for 2 paths in parallel to the now standard G = G1 + G2 + 2 root(G1.G2) conductance superposition law [1]. This is only valid for the tunneling regime [2]. For large electronic coupling to the nanopads (or at resonance), G can saturate and even decay as a function of the number of parallel paths added in the quantum circuit [3]. We provide here the explanation of this phenomenon: the measurement of the effective Rabi oscillation frequency using the current intensity is constrained by the normalization principle of quantum mechanics. This limits the quantum conductance G for example to Go when there is only one channel per metallic nanopads. This effect has important consequences for the design of Boolean logic gates at the atomic scale using atomic scale or intramolecular circuits.

References:

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[2]: C. Joachim, Nature Nano.,7, 620 (2012)

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