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Coupling-assisted Landau-Majorana-Stuckelberg-Zener transitions in two-interacting-qubit systems

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Abstract

We analyse a system of two interacting spin-qubits subjected to a Landau-Majorana-Stuckelberg-Zener (LMSZ) ramp. We show that LMSZ transitions of the two spin-qubits are possible without an external transverse static field thanks to the coupling between the spin-qubits. We show how such a physical effect could be exploited to estimate the strength of the interaction and to generate entangled states of the spins by appropriately setting the slope of the ramp. Moreover, effects of the coupling parameters on the time-behaviour of the Entanglement as well as effects stemming from the presence of a classical noise are analysed.

We considered [1] a physical system of two interacting spin-1/2's whose coupling consists in the anisotropic exchange interaction. Moreover, each of them is subjected to a local field linearly varying over time. The C_2-symmetry (with respect to the quantization axis $\hat{z}$) possessed by the Hamiltonian allowed us to identify two independent single spin-1/2 sub-problems nested in the quantum dynamics of the two spin-qubits [2]. This fact gave us the possibility of decomposing the dynamical problem of the two spin-1/2's into two independent problems of single spin-1/2. In this way, our two-spin-qubit system may be regarded as a four-level system presenting an avoided crossing for each pair of instantaneous eigenenergies related to the two dynamically invariant subspaces. This aspect turned out to be the key to solve easily and exactly the dynamical problem, bringing to light several physically relevant aspects.

We showed that, although the absence of a transverse constant field, LMSZ transitions of the two spins are still possible. Such transitions occur thanks to the presence of the coupling between the spins which plays as effective static transverse field in each subdynamics.

Considering the STM (Scanning Tunneling Microscopy) scenario [3], that is when one local field is applied on just one spin, we showed the possibility of 1) a non-local control, that is to manipulate the dynamics of one spin by applying the field on the other one and 2) a state exchange/transfer between the two spins. We brought to light how such effects are two different replies of the system depending on the isotropy properties of the exchange interaction.

It is worth the fact that each subdynamics is characterized by different combinations of the coupling parameters. Indeed, this aspect has relevant physical consequences since by studying the transition probability in the two subspaces, it is possible to estimate the strength of the interaction terms ruling the dynamics of the two-spin system. We brought to light how such an estimation could be of relevant interest since, through this knowledge, it is possible to set the slope of variation of the LMSZ ramp as to generate asymptotically entangled states of the two spin-1/2's. Moreover, we analysed the exact time-behaviour of the Entanglement for different initial conditions and how the coupling parameters can determine different Entanglement regimes and asymptotic values.

Finally, we emphasized how our symmetry-based analysis results useful also to get exact results when a classical random field component or non-Hermitian terms are considered to take into account the presence of a surrounding environment interacting with the system. In this cases, the dynamics decomposition is unaffected by the presence of the noise or the dephasing terms and then we may apply the results previously reported for a two-level system [4] and reread them in terms of the two spin-1/2's.

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