The Abdus Salam International Centre for Theoretical Physics

Conference on Frontiers of Nanoscience
24 August - 1 September 2015, Trieste, Italy

Adiabatic Manipulation of Architectures of Multilevel Artificial Atoms

G. FALCI,
E. Paladino, A. D'Arrigo, P. Di Stefano
and A. Ridolfo

Dipartimento di Fisica e Astronomia, Università di Catania
& CNR-IMM-MATIS, Catania & CSFNSM, Catania

Abstract:

The ability of manipulating multilevel coherence in solid-state "artificial atoms" architectures would be a key issue for several achievements both in fundamental and in applied physics. With respect to their quantum optical counterparts, such systems allow design flexibility, a large degree of integration of strongly coupled individual units and control with external fields with new characteristics, which may compensates drawbacks coming from a stronger interaction with the environment, leading to decoherence [1]. This new field may lead both to proof of principle of new fundamental phenomena and to applications to quantum information, as quantum gates or routers for quantum networks, to microwave quantum photonics and to the possibility to build emulators of artificial nanostructures for certain functional tasks, as efficient light harvesting.
In this contribution we address the implementation of a Lambda scheme in superconducting N>2 "artificial atoms" which is a fundamental building block of such architectures, and study coherent population transfer (CPT) as a benchmark process for quantum control. Despite many theoretical

proposals this problem is still experimentally unsettled. We have shown [2] that implementing an efficient Lambda system in a "qutrit" depends on the tradeoff between non-Markovian (low-frequency *1/f* [1]) components of noise, and efficient coupling prevented by selection rules, both issues crucially depending on the (tunable) symmetry of the Hamiltonian. We propose two strategies, namely optimization of symmetry breaking and selective dynamical decoupling, to achieve large efficiencies in artificial atoms [3].

We next introduce two new protocols to implement quantum state engineering by population transfer in solid-state Circuit-QED or nanoelectromechanichal architectures. The first is a 2+1-photon scheme allowing for a Lambda configuration at the symmetry point [4], which minimizes noise, despite of selection rules, and can be applied to present technology high-quality superconducting qubits [5]. The second is a protocol where CPT is obtained with the constraint of an always on field, mimicking an unswitchable hardware coupling [6] .

We finally address the problem of detecting signature of the ultrastrong coupling in atom-cavity systems. We show that a new channel for CPT is opened, whose detection is a "smoking gun" for the existence in Nature of this new ultrastrong regime of coherent coupling with the electromagnetic field. We show how a ~100% efficiency of detection can be achieved in systems of many artificial atoms strongly coupled to a cavity [7], fabricable within present technology.

[1] E. Paladino, Y. Galperin, G. Falci, B. Altshuler, "1/f noise: implications for quantum information", Rev. Mod. Phys. **86**, 361 (2014).

[2] G. Falci et al., "Design of a Lambda system for population transfer in superconducting nanocircuits", Phys. Rev. B **87**, 214515 (2013).

[3] P.G. Di Stefano et al. Rom. Jour. Phys. Volume 60, Number 5-6 (2015); arXiv:cond-mat 1502.05924

[4] G. Falci et al., PHYSICA SCRIPTA T151, 014020 (2012).

[5] P.G. Di Stefano et al., in preparation

[6] P.G. Di Stefano et al., to be published in Phys. Rev. B: arXiv:cond-mat 1505.

[7] A. Ridolfo et al., in preparation