Probing ultrastrong coupling by coherent amplification of population transfer

Giuseppe Falci, Alessandro Ridolfo, Pietro G. Di Stefano, and Elisabetta Paladino

DFA University of Catania & CNR-IMM UOS Catania (Università), Via Santa Sofia 64, Catania, Italy

The ability of manipulating multilevel coherence in solid-state architectures of artificial atoms would be a key issue for several achievements both in fundamental and in applied physics. Fabrication techniques have recently allowed to enter the regime of ultra-strong coupling (USC) between light and matter where unexplored non-perturbative phenomena emerge [1]. While experiments so far provided spectroscopic evidence of USC, we propose the detection of a dynamical signature of USC in atom- cavity systems [2,3]. Indeed a new channel opens for photon-pair creation, whose detection is a smoking gun for the existence in Nature of this new ultra-strong regime of coherent coupling with the electromagnetic field [4]. We show how to coherently amplify this channel by inducing coherent population transfer via advanced control similar to STIRAP in atomic physics [5], which yields $\sim$100% detection efficiency. To this end we propose to operate a three level system where a selected transition is coupled in the USC regime to a cavity [2]. We then address implementation of the protocol in state of the art quantum hardware, and show that unambiguous detection of USC poses strong design constraints to the device. We found that requirements are met by persistent current qubits, already fabricated within present technology, driven in the Vee configuration. Alternatively systems of many artificial atoms strongly coupled to a cavity could be used [3]. Besides its fundamental importance, the proposed dynamical detection of the USC channel in state of the art superconducting architectures would be a benchmark for quantum control in distributed networks, in view of new ideas of using adiabatic protocols in this coupling regime [2,3].

[1] T. Niemczyk, F. Deppe, et al., Nat. Phys. 6, 772 (2010).

[2] G. Falci, P.G. Di Stefano, A. Ridolfo, A. D'Arrigo, G.S. Paraoanu and E. Paladino, Fort. Phys. online 18 NOV 2016; DOI: 10.1002/prop.201600077, arxiv:1704.00581.

[3] G. Falci, A.A. Ridolfo, P.G. Di Stefano and E. Paladino, preprint (2017).

[4] R. Stassi, A. Ridolfo, O. Di Stefano, M.J. Hartmann, and S. Savasta, Phys. Rev. Lett. 110, 243601 (2013).

[5] N.V. Vitanov, A.A. Rangelov, B.W. Shore, and K. Bergmann, Rev. Mod. Phys. 89, 015006 (2017).