Adiabatic manipulations of ultrastrongly coupled superconducting systems: from virtual photons to modular computing

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I review recent scientific work performed at the University of Catania on the dynamics of superconducting architectures in the ultrastrong coupling (USC) regime.

First, I will address the problem of the detection of virtual photons from the ground-state of a USC system. This is a long-standing problem which still awaits experimental demonstration. We show that combining an unconventional design of the device, state-of-the-art superinductor technology, and advanced control techniques one may convert virtual photons to real ones, which can be detected, with nearly 100% efficiency, very large fidelity. Out protocol being resilient to a strong measurement backaction, it allows to integrate a relatively simple measurement procedure allowing to discriminate virtual from thermal photons.

Then, I will highlight new results on Quantum operations for modular computing with USC systems. Solid-state systems made of artificial atoms (AA) and cavity modes in the strong coupling (SC) regime are a well-established architecture for quantum computing leveraging the ability of manipulating individual excitations. The clock rate is fixed by the interaction strength suggesting that in the USC regime ultrafast quantum operations mau be performed. However, faster dynamics has a cost since USC breaks conservation of the number of excitations leading to a series of new fundamental effects which are unfortunately detrimental to quantum state processing.

We study strategies for suppressing the impact of such errors in a system of AAs USC-coupled to a quantized harmonic mode. We introduce a class of adiabatic protocols using the mode as a virtual quantum bus and show that substantial speedup together with high fidelity may be demonstrated for selected key operations, such as state transfer between remote units, state swapping, bi- and multi-partite entanglement generation and sharing. We derived a suitable low-energy description of the problem and found analytically a control strategy which suppresses errors down to ~10-6 for state transfer. These results were improved by optimal control numerical techniques and their robustness against parametric fluctuations and noise was shown.

References

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