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Exploring Hybrid Quantum Systems using Superconducting Circuits

Using modern micro and nano-fabrication techniques combined with superconducting materials we create, store, and coherently manipulate individual microwave photons in quantum electronic circuits. Using coplanar wave guide resonators with small mode volume, which create electromagnetic fields of sizable strength even at the level of individual microwave photons, we can create strong electromagnetic interactions between photons and a variety of different quantum systems. With superconducting quantum two-level systems (qubits) we have probed fundamental quantum effects of microwave radiation such as the Hong-Ou-Mandel effect [1] and developed circuits demonstrating all basic features of a quantum information processor by implementing a teleportation protocol [2] in an approach known as circuit quantum electrodynamics (QED). In this presentation, I will discuss two recent experiments in the context of semiconductor and atomic physics in which we make use of the exquisite quantum control and measurement technology developed for circuit QED. In a first experiment, we have explored the dipole coupling of a semiconductor double quantum dot to microwave photons stored in a coplanar wave guide resonator [3]. In a second experiment, we have investigated the interaction of Rydberg atoms with microwave frequency radiation emanating form a transmission line in a cryogenic environment [4]. Both experiments are expected to provide new experimental techniques and new scientific perspectives for exploring the physics of quantum systems at the interface between condensed matter and atomic physics.

[1] C. Lang et al., Nat. Phys. 9, 345–348 (2013) [2] L. Steffen et al., Nature, in print, arXiv:1302.5621 (2013) [3] T. Frey et al., Phys. Rev. Lett. 108, 046807 (2012) [4] S. Hogan et al., Phys. Rev. Lett. 108, 063004 (2012)

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