Investigating Electrons on Helium with RF Reflectometry

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Surface electrons (SEs) floating above liquid helium show promise as a quantum computing candidate due to the long relaxation time of the spin state and relatively small size [1, 2]. To take advantage of the spin state coherence time, we propose to create a hybrid qubit by coupling the hydrogen-like Rydberg state to the spin state [2]. Quantum information is held in the spin state, which is read out through the Rydberg state. It then needs to be possible to measure the Rydberg state of a single electron.

In our experimental approach, we couple a lumped element LC circuit (resonant frequency = 121 MHz, loaded Q-factor = 298) with the Rydberg state of approximately 10^7 SEs on superfluid helium, which we detect using RF reflectometry [3]. The LC circuit is formed by two parallel sets of disk electrodes acting as a capacitor, with SEs held between them, and a superconducting micro-inductor. To excite the Rydberg state, we apply a continuous microwave with a frequency resonant with the Rydberg transition; this results in a change in the capacitance of the LC circuit and consequently altering the reflected signal.

Furthermore, we explore the coupling of the collective motion modes of many electrons, known as plasmons [4], with the LC circuit, achieving a strong coupling regime. We also discuss how these experimental advancements could pave the way for quantum information applications.

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