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Ultracold gas coupled to a nanomechanical resonator via Zeeman interaction

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A strong need for computational power as well as limits of classical computers has led to the development of quantum information science. One of the critical problems in realizing quantum computing is manipulating quantum bits while maintaining coherence. One of the possible solutions is to use a hybrid system that combines the long coherence times available in microscopic quantum systems with the strong interactions and integration available in solid state systems. Studying such systems can help to investigate ways to reduce decoherence and apply the results for quantum information processing.

In our lab we are building a system to study coupling of nanomechanical resonator to a cloud of ultracold Rb atoms in a Bose-Einstein condensate (BEC). Condensed state is achieved by means of laser and evaporative cooling. Condensate will be placed in an optical trap above the tip of a cantilever-type resonator. The tip carries a single-domain ferromagnet which creates a dipole-like magnetic field. The tip oscillations create an oscillatory component of the magnetic field, which provides coupling to the atomic spin via the Zeeman interaction. When the frequency of the resonator mode matches the Larmor frequency corresponding to the hyperfine structure of Rb, the coupling induces spin flips. This can be detected by observing the loss of atoms from the trap. This technique allows one to probe thermal motion of the cantilever at room temperature. At low resonator temperatures the spin back action determines the resonator motional state analogously to cavity quantum electrodynamics. In this regime BEC can be used to actuate the resonator motion or to provide entanglement with another resonator.

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