Quantum dynamics of Coulomb crystals at structural instabilities

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In the first part of the talk we discuss the stability and dynamics of an ion chain confined inside a high-finesse optical resonator. When the dipolar transition of the ions strongly couples to one cavity mode, the mechanical effects of light modify the chain properties close to a structural transition. We focus on the linear chain close to the zigzag instability and show that linear and zigzag arrays are bistable for certain strengths of the laser pumping the cavity. For these regimes the chain is cooled into one of the configurations by cavity-enhanced photon scattering. The excitations of these structures mix photonic and vibrational fluctuations, which can be entangled at steady state. These features are signaled by Fano-like resonances in the spectrum of light at the cavity output.

In the second part of the talk we discuss a procedure for creating coherent superpositions of motional states of ion strings. The motional states are across the structural transition linear-zigzag, and their coherent superposition is achieved by means of spin-dependent forces, such that a coherent superposition of the electronic states of one ion evolves into an entangled state between the chain's internal and external degrees of freedom. It is shown that the creation of such an entangled state can be revealed by performing Ramsey interferometry with one ion of the chain. Sufficiently close to the linear-zigzag instability the visibility decays very fast, but exhibits revivals at the period of oscillation of the mode that drives the structural instability. These revivals have a periodicity that is independent of the crystal size, and they signal the creation of entanglement by the quantum quench.