Contribution ID: **22** Type: **Poster**

Heating Effects for Wigner Ion Crystals and Experimental Realization of Multi-ion Sympathetic Cooling

Monday, 25 September 2023 19:30 (2 hours)

Trapped ions are one of the leading platforms in quantum information science. And a trapped-ion Wigner crystal is a suitable platform for a controlled study of the solid-liquid phase transition with its unprecedented resolution of individual atomic ions. We study the melting dynamics of a linear chain of 174Yb+ ions, which is initially cooled to the Doppler temperature and is then periodically heated and detected by a focused laser beam. We achieve controlled melting of the ion chain and observe nontrivial effects over the chain under localized heating. These explorations have deepened our understanding of the solid-liquid phase transition in ion crystals and insights into energy transport problems in low-dimensional systems. Additionally, it provides guidelines for extending the lifetime of large ion crystals and conducting large-scale sympathetic cooling. Here, we also report experimental realization of multi-ion sympathetic cooling on a long ion chain using a narrow cooling beam focused on two adjacent ions, and optimize the choice of the cooling ions according to the collective oscillation modes of the chain. By cooling a small fraction of ions, cooling effects close to the global Doppler cooling limit can be achieved. This experiment therefore demonstrates an important enabling step for quantum information processing with large ion crystals.

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Session Classification: Monday Poster