Non-equilibrium statistics and thermodynamic machines with trapped ions

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Ions confined in a Paul trap arrange in linear crystals and allow for a unique control and analysis. Also, control parameters may be tailored such that a structural phase transition from a linear to a zigzag configuration of the crystal is crossed [1]. Trapped ions serve here as a clean model system to investigate universal laws of defect formation when such transition is crossed fast and causally separated regions form [2]. The amount of defects is predicted by the Kibble-Zurek mechanism [3]. We have experimentally determined the universal scaling exponent for defect formation and confirm the scaling law for the inhomogeneous Kibble-Zurek effect accurately at the percent level [4]. In a second part of the talk we highlight thermodynamic machines scaled down to a single ion [5]. We propose driving the trapped ion in an Otto cycle, oscillating in a specially designed linear Paul trap and coupled to engineered laser reservoirs. We present detailed Monte Carlo simulations and the calculation of the efficiency of such single ion heat engine, exceeding the standard Carnot limit when employing a squeezed thermal reservoir [6].

Figure: Linear ion crystals, zigzag structures with and without defects, as observed after the structural phase transition.