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Strongly correlated ion plasmas in Penning traps*

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Abstract

Penning traps use static magnetic and electric fields to confine charged atomic particles. Static confinement fields enable large numbers of ions to be routinely laser-cooled to low temperatures. We have laser-cooled up to $\sim 10^6$ ions in spherically shaped plasmas to temperatures less than $\sim$10 mK. These cold plasmas provide a rigorous realization of a strongly coupled one-component plasma (OCP). After reviewing the ion crystal structures that have been observed in Penning traps and comparing them with theoretical predictions, we summarize two recent experiments. First, we describe careful measurements of the stability of the plasma rotation, which is controlled by a rotating electric field. The application of a shearing force is observed to produce sudden angular jumps or 'slips' of the crystal orientation spaced by intervals where the crystal was 'stuck' relative to the rotating field. We observed power-law distributions of the slip frequency versus slip amplitude. Similar stick–slip dynamics and power-law distributions are also seen with earthquakes, avalanches, and many other stressed systems in nature. We then discuss plasma wakes produced by the radiation pressure of a laser beam directed along the magnetic field but offset from the plasma rotation axis. This pressure excites localized plasma waves which interfere to form a stationary wake that is directly imaged through the dependence of the ion fluorescence on Doppler shifts. Theoretical calculations accurately reproduce these images. The above work has recently been discussed in detail and is not repeated below. For a detailed discussion, see Bollinger *et al* (2002 *Trapped Charged Particles and Fundamental Interactions I. Invited*

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