SYPS 1 Symposium: Plasmas in unusual situations, Part I: Ultracold plasmas

Zeit: Montag 10:45–12:45 Raum: HU Audimax

Hauptvortrag SYPS 1.1 Mo 10:45 HU Audimax

Ultracold Neutral Plasmas — •Thomas Killian — Department of Physics and Astronomy, Rice University, Houston, Texas, USA

Ultracold neutral plasmas [1], formed by photoionizing laser-cooled atoms near the ionization threshold, stretch the boundaries of traditional neutral plasma physics. The electron temperature in these plasmas is from 1-1000K and the ion temperature is around 1 K. The density can be as high as 10^{10} cm^{-3}. Fundamental interest stems from the possibility of creating strongly-coupled plasmas, but recombination, collective modes, and thermalization in these systems have also been studied.

The ultracold plasma group at Rice University recently demonstrated optical absorption imaging of a strontium plasma [2] using the Sr^+ $^2S_{1/2} \rightarrow {}^2P_{1/2}$ transition at 422 nm. Images depict the density profile of the plasma and probe kinetics on a 50 ns time-scale. The Doppler-broadened ion absorption spectrum measures the ion velocity distribution, which gives an accurate measure of the ion dynamics in the first few hundred nanoseconds after photoionization.

Current work focuses on kinetic energy oscillations during plasma equilibration and developing the tools to laser cool and trap the plasma. This work is supported by the Department of Energy, National Science Foundation, Alfred P. Sloan Foundation, Research Corporation, and David and Lucille Packard Foundation.

[1] T. C. Killian, S. Kulin, S. D. Bergeson, L. A. Orozco, C. Orzel, and S. L. Rolston, Phys. Rev. Lett. **83**, 4776 (1999). [2] C. E. Simien, Y.C. Chen, P. Gupta, S. Laha, Y. N. Martinez, P. G. Mickelson, S. B. Nagel, T. C. Killian, Phys. Rev. Lett. **92**, 143001 (2004).

Hauptvortrag SYPS 1.2 Mo 11:15 HU Audimax

Strong coupling effects in expanding ultracold neutral plasmas — •Thomas Pohl — Max-Planck-Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, D-01187 Dresden

In a number of recent experiments ultracold neutral plasmas have been produced by photoionizing laser-cooled atomic ensembles. The very low initial temperatures suggest that these plasmas have been produced deep within the strongly coupled regime. Furthermore, the relaxation timescales realized in these plasmas indicate that Bogoliubov's functional hypothesis, frequently used in plasma kinetic theory, is violated in the present case, giving rise to an unusual relaxation behavior.

Based on a recently developed hybrid-molecular-dynamics approach [1], we discuss the expansion dynamics of ultracold plasmas with special emphasis on the strongly coupled ion dynamics. We demonstrate that the present method yields an accurate description of recent measurements [2,3] and allows to address important questions beyond present experimental capabilities.

Furthermore, we show that additional laser cooling during the plasma evolution drastically modifies the expansion dynamics, so that crystallization of the ion component can occur in this nonequilibrium system [4].

[1] T. Pohl, T. Pattard and J.M. Rost, Phys. Rev. A **70**, 033416 (2004)
[2] C.E. Simien et al., Phys. Rev. Lett. **92**, 143001 (2004)
[3] J.L. Roberts et al., Phys. Rev. Lett. **92**, 253003 (2004)
[4] T. Pohl, T. Pattard and J.M. Rost, Phys. Rev. Lett. **92**, 155003 (2004)

Hauptvortrag SYPS 1.3 Mo 11:45 HU Audimax

Theory of strongly correlated charged particles in traps — •Michael Bonitz and Alexei Filinov — Institute for Theoretical Physics and Astrophysics, Christian-Albrechts-University Kiel, Leibnizstr. 15, 24098 Kiel

Charged particles which are spatially confined by trapping potentials constitute a peculiar type of plasmas which are *non-neutral*. Such plasmas can exist for very long times and may be manipulated in broad parameter ranges. Of special interest is the possibility to create and analyze in detail strong correlation phenomena, including the formation of bound states or of liquid-like and crystal-like collective behavior. Examples are ultracold ions in Paul traps, electron or positron plasmas in Penning traps, dusty plasmas, electrons and holes in quantum confined semiconductor structures or valence electrons of metal clusters.

In this talk we present theoretical results for classical two-dimensional and three-dimensional mesoscopic Coulomb crystals in parabolic spherical traps. After this, quantum Coulomb systems in traps are discussed. In particular, we present results for excitonic bound states in semiconductor quantum wells, including the influence of disorder (well width fluctuations), and for quantum Wigner crystals in quantum dots. Finally, a quantum kinetic theory for the short-time behavior of trapped correlated particles is outlined. Of particular interest is the dynamics of Coulomb correlations and the possibility of correlation induced cooling which was predicted a few years ago [1] and for which meanwhile a few interesting schemes have been proposed.

[1] D. Semkat, D. Kremp, and M. Bonitz, Phys. Rev. E **59**, 1557 (1999)

Hauptvortrag SYPS 1.4 Mo 12:15 HU Audimax

Recent experiments with laser-cooled ion plasmas in a Penning trap — •M.J. Jensen[1], J.J. Bollinger[1], T. Hasegawa[2], and D.H.E. Dubin[3] — [1]NIST, Boulder, CO 80305, USA — [2]Univ. of Hyogo, Hyogo 678-1297, Japan — [3]UCSD, La Jolla, CA 92093, USA

Up to $\sim 10^6$ $^9Be^+$ ions are trapped in a 4.5 Tesla Penning trap and laser-cooled to ∼1 mK where the ions form a crystal with an interparticle spacing of $\sim 20\ \mu$m. This system is a realization of a strongly coupled one-component plasma. Through Bragg scattering and direct imaging we have observed 3-dimensional periodic crystals in this plasma. Recently, we have measured the temperature of the plasma when not laser-cooled. A slow heating rate of <100 mK/s, observed for the first 100-200 ms after turning off the laser-cooling, is followed by a sudden, rapid heating to 1-2 K in 100 ms as the plasma undergoes the solid-liquid phase transition at $T = 10$ mK ($\Gamma \sim 170$). We will present evidence that this rapid heating is due to a sudden release of energy from weakly cooled degrees of freedom involving the cyclotron motion of trapped impurity ions. A method to suppress this rapid heating will be presented, and the prospects for observing the latent heat associated with the phase transition will be discussed.