New Experiments with Ultracold Plasmas

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Photoionizing laser-cooled atoms near the ionization threshold produces ultracold neutral plasmas with initial temperatures of 1-1000 K and densities as high as $10^{10}$ cm$^{-3}$. Over the last several years experiments have probed the methods and conditions for forming the plasma[1], excitation and detection of plasma oscillations[2], dynamics of the plasma expansion[2], and collisional recombination into Rydberg atomic states[3]. Related work has examined the spontaneous evolution of a dense, cold cloud of Rydberg atoms into a plasma [4].

Several theory papers [5–10] recently examined the electron and ion temperatures in these plasmas because of the possibility of forming neutral, two-component plasmas near the strongly coupled regime. Charged particles in a plasma are strongly coupled when their thermal energy is less than the Coulomb interaction energy between nearest neighbors. The calculations also addressed three body recombination and collisional cascade of Rydberg atoms to more tightly bound levels.

In my talk, I will review these results and then describe the status of new experiments that are studying ultracold plasmas formed from laser-cooled alkaline-earth atoms such as strontium. Alkaline-earth systems allow fundamentally different experiments than were possible with the alkali and metastable noble gas atoms that have been used previously.

The ability to directly image the ion density profile through light scattering or absorption imaging would allow simple monitoring of the plasma density as a function of time. If one could resolve variations in the local density, it would be possible to study structural features such as ion acoustic waves or ion-ion spatial correlations.

The plasma is optically thick during much of its evolution, which means that optical imaging is straightforward in principle. Such imaging was impossible in previous studies because the ions used had principal electronic transitions in the deep ultraviolet - outside the regime of simple lasers and imaging systems. Strontium ions, however, have strong electric dipole transition at 422 nm - a wavelength for which lasers and standard CCD cameras are available.

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