Plasma dynamics and recombination in a high-magnetic-field atom and plasma trap

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Developments in cooling and trapping of atoms and ions have given birth to the emerging area of cold, ionized, strongly magnetized matter (magnetized plasmas). We report on the creation of such plasmas in a particle trap that has the unique capability to simultaneously laser-cool and trap neutral atoms [1] as well as to confine plasmas [2] and low-magnetic-field-seeking Rydberg atoms [3] in magnetic fields of about three Tesla. The atom trap is a high-field Ioffe-Pritchard laser trap, while the plasma trap is a nested Ioffe-Penning trap that traps electrons and ions in separated wells that are close to each other. The observed plasma dynamics is characterized by a breathing-mode oscillation of the positive (ionic) plasma component, which feeds back on the behavior of the negative (electron) component of the plasma [2]. At higher densities, the observed oscillations become nonlinear. The electron component has been found to undergo significant cooling. We further report on the recombination of magnetized plasmas into Rydberg atoms in transient traps and quasi-steady-state traps. In transient traps (plasma lifetime of order 30 microseconds), large numbers of recombined Rydberg atoms in high-lying states are observed. In quasi-steady-state traps, the measured numbers of recombined atoms are much lower, and binding energies are higher. Results are compared with theory.

Left: Trapping potential (blue curve) along the magnetic-field axis. Electrons are trapped at the center, while ions are trapped in the wider double-well structure. The trap can be distorted (red curve) to extract and measure the electron component of the plasma. Right: Measured electron shake-off signal caused by coupled space-charge oscillations of the electron and ion components of the trapped plasma. The shake-off maxima (A-D) occur at the ion breathing-mode frequency. At 450 μs an electron extraction ramp is applied. The extracted electron signal at t > 450 μs is used to determine the electron temperature.