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Ultracold Neutral Plasma Density Waves[1]

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Ultracold neutral plasmas, which are created by photoionizing laser cooled atoms near the ionization threshold, have been extensively studied in order to probe strong Coulomb coupling effects, low-energy atomic processes, equilibration, and collective phenomena [1]. The experimental study of collective modes, however, has previously been limited to phenomena involving electrons. By spatially modulating the intensity pattern of the photoionizing laser, we are now able to create controlled density perturbations on the plasma, which enables study of ion collective behavior. Periodic modulation excites ion acoustic waves [2]. We have also created two distinct plasmas that stream into each other. In the hydrodynamic regime, the central gap between the two plasmas splits into two density "holes" that propagate away from the plasma center at the ion acoustic velocity. At lower densities and higher particle velocities, plasmas are less collisional, and we observe kinetic effects such as plasma streams penetrating each other, with a penetration depth that reflects the ion stopping power. This general technique for sculpting the density opens many new possibilities, such as investigation of non-linear phenomena, instabilities, and shock waves in the ultracold regime, and determination of the effects of strong coupling on dispersion relations. The low temperature, small size, plasma expansion, and strongly coupled nature of ultracold plasmas make these studies fundamentally interesting. They may also shed light on similar phenomena in high energy density, laser-produced plasmas that can be near the strongly coupled regime.

[1] T. C. Killian, T. Pattard, Thomas Pohl, and J. M. Rost, Phys. Rep., 449, 77 (2007).
[2] J. Castro, P. McQuillen, and T. C. Killian, Phys. Rev. Lett. 105, 065004 (2010).

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