Quantum Droplets and Supersolidity in a Dipolar Quantum Gas

Tilman Pfau[1*]

[1] 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology (IQST), Universität Stuttgart, Germany
E-mail: t.pfau@physik.uni-stuttgart.de

Dipolar interactions are fundamentally different from the usual van der Waals forces in real gases. Besides the anisotropy the dipolar interaction is nonlocal and as such allows for self organized structure formation. In 2005 the first dipolar effects in a quantum gas were observed in an ultracold Chromium gas. By the use of a Feshbach resonance a purely dipolar quantum gas was observed three years after [1]. Recently it became possible to study degenerate gases of lanthanide atoms among which one finds the most magnetic atoms. Similar to the Rosensweig instability in classical magnetic ferrofluids self-organized structure formation was expected. In our experiments with quantum gases of Dysprosium atoms we could observe the formation of a droplet crystal [2]. In contrast to theoretical mean field based predictions the super-fluid droplets did not collapse. We find that this unexpected stability is due to beyond meanfield quantum corrections of the Lee-Huang-Yang type [3,4]. We observe and study self-bound droplets [5] which can interfere with each other. We also observe self-organized stripes in a confined geometry [6] and collective scissors mode oscillations of dipolar droplets [7]. Very recently in the striped phase also phase coherence was observed in Dysprosium and Erbium experiments, which is evidence for a supersolid state of matter [8]. This transition to a supersolid is a beautiful example for the appearance of a Goldstone mode even in a finite system, which we have observed recently.

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* website: www.pi5.uni-stuttgart.de