Multiple-Collapse of a Dipolar Bose-Einstein Condensate

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In coldatomic systems, the main inter-atomic interaction is, in general, the s-wave short-range interaction, originating from the van der Waals attraction and the hard-core repulsion. In addition to this, the atoms with nonzero spin interact via the dipole-dipole interaction (DDI) which is long-range ($\propto 1/r^3$) and anisotropic. Although the DDI between alkali atoms is thousand times smaller than the s-wave interaction, recent experimental realization of Bose-Einstein condensates (BECs) of highly magnetic atoms, such as ^{52}Cr [1,2], ^{164}Dy [3], and ^{168}Er [4] (whose magnetic moments are respectively $6\mu_{\rm B}$, $10\mu_{\rm B}$, and $7\mu_{\rm B}$), have enabled us to study the nature of the DDI.

The long-range and anisotropic nature of the DDI manifests itself in the collapse dynamics as observed in the Cr experiment [2]: When the s-wave repulsion is decreased by means of the Feshbach resonance, the BEC collapses due to the attractive part of the DDI. At the onset of collapse, atoms flow inward along the polarization direction and outward in the perpendicular direction, resulting in a clover-leaf density pattern as shown in Fig. 1.

In this presentation, I show that an Er BEC exhibits different instability from that observed in the Cr BEC. Though the magnetic moments of these atoms are almost the same, they differ in the atomic masses, which means, the relative strength of the DDI to the kinetic energy becomes four times larger for Er than Cr. Thus, the DDI in an Er BEC can induce smaller spatial structures. Just before the collapse, a density wave develops in an Er condensate, and subsequently multiple-collapse occurs at each density peak. This density modulation can be explained by the dynamical instability in the phonon spectrum.

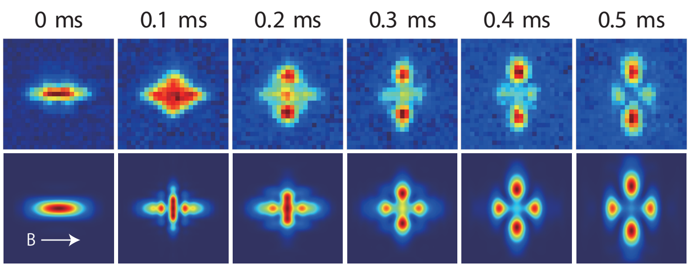

Figure 1: d-wave collapse of the ^{52}Cr BEC. (Top) Snapshos of absorption images of the collapsing condensates. (Bottom) Corresponding results of the numerical simulations. Reprinted from Ref. [2]

[1] A. Griesmaier, *et al.*, Phys. Rev. Lett., **94**, 160401 (2005).
[2] T. Lahaye, *et al.*, Phys. Rev. Lett. **101**, 080401 (2008).
[3] M. Lu, *et al.*, Phys. Rev. Lett., **107**, 190401 (2011).
[4] K. Aikawa, *et al.*, Phys. Rev. Lett. **108**, 210401 (2012).