Optomechanical self-structuring in cold atoms

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Optomechanics has attracted a lot of interest recently due to the combined control of light and mechanical modes. Spontaneous optomechnical self-organization was observed in a variety of non-linear systems such as atomic ensembles in a cavity [1].

We are looking in a single mirror scheme where a single pump beam and a mirror placed after the atomic cloud induce spontaneous self-organization observed on a plane transverse to the beam propagation. Previous investigations that showed continuous symmetry breaking on both translation and rotation relied on spatial modulation on the internal states of the atoms. Recently it was predicted that dipole forces alone could induce the same kind of transverse self-organization based on the atomic density without intrinsic optical non-linearities [2].

We report on the observation of spontaneous self-structuring in cold atoms released from a magneto-optical trap [3]. The trap was initially loaded with 6×10^{10} atoms of ^{87}Rb. The structures emerge in blue-detuned pump light as hexagons (blue in the Fig. 1, online) and in the atomic density as honeycombs (red in the Fig. 1, online) - the atoms are expelled from the intensity maximums. The set-up relies on the conversion from phase to amplitude modulation by diffraction (Talbot effect) and the length-scale of these structures is continuously tuned with the mirror distance. Two mechanisms come into play in these experiments: the already known internal states non-linearity and the new optomechanical nonlinearity. We identified regimes where each mechanism is dominant as well as the mixed case by comparing the structures in both the pump and in a probe beam sent a few tens of microseconds after pump extinction. In the optomechanical dominant regime, we observed in the probe the dynamical growth and decay of atomic structures in the order of magnitude comparable to the atomic motion at ultracold atoms temperatures.

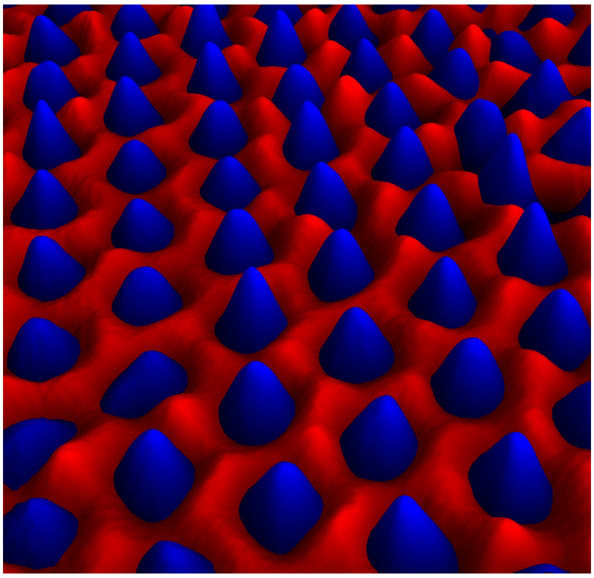

Figure 1: *(Color online) Complementary honeycomb self-structuring of the atomic density imaged on the red-detuned probe beam (red) and hexagonal light patterns in the transmitted blue-detuned pump beam (blue).*

We also present analysis on the structures contrast and wave-vector dependence on detuning and intensity.

References

[1] H. Ritsch *et al.* Rev. Mod. Phys. **85**, 553–601 (2013)
[2] E. Tesio *et al.* Phys. Rev. A **86** 031801(R) (2012)
[3] G. Labeyrie *et al.* Nature Photon. **8** 321–325 (2014)