Condensate Phase Microscopy

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We show that the phase of a Bose-Einstein condensate wave-function of ultra-cold atoms in an optical lattice potential in two-dimensions can be detected [1]. The time-of-flight images, obtained in a free expansion of initially trapped atoms, are related to the initial distribution of atomic momenta but the information on the phase is lost. However, the initial atomic cloud is bounded and this information, in addition to the time-of-flight images, is sufficient in order to employ the phase retrieval algorithms. We analyze the phase retrieval methods for model wave-functions in a case of a Bose-Einstein condensate in a triangular optical lattice in the presence of artificial gauge fields.

In crystallography, electron microscopy and astronomical imaging, computationally retrieving the phase of diffraction patterns is remarkably successful [2]. The examples range from the biological cells imaging to the evaluation of the aberrations in the Hubble space telescope. In the cold atoms problems, it is not an external wave that diffracts on a measured object and is subsequently detected, but the matter wave itself is the *object* to be reconstructed.

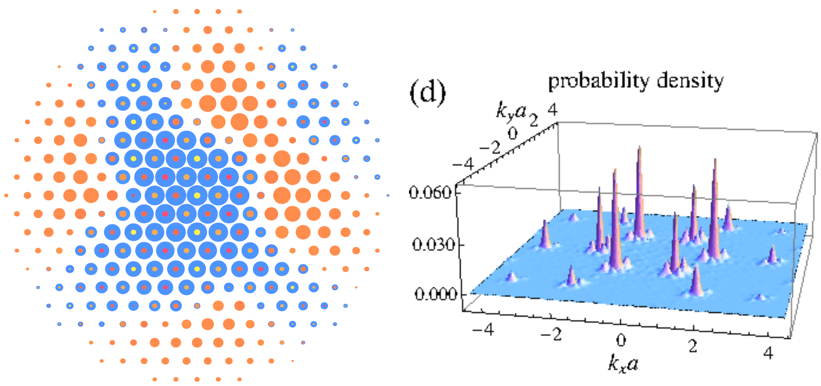

Figure 1: *Left panel shows domain structures formed by cold atoms in the presence of a triangular optical lattice with negative tunneling amplitudes. The domains are obtained from the retrieved wave-function corresponding to the time-of-flight image presented in the right panel [1].*

References

[1] A. Kosior and K. Sacha, Phys. Rev. Lett. **112**, 045302 (2014).

[2] S. Marchesini, Rev. Sci. Instrum. **78**, 011301 (2007).