Textures of Spin-Orbit Coupled $F = 2$ Spinor Bose Einstein Condensates

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Motivated by recent studies of Bose Einstein condensates (BECs) under synthetic gauge fields, we study the textures of BECs with Rashba like spin-orbit coupling (SOC). Nontrivial textures due to the Rashba type SOC in pseudospin $F = 1/2$ and $F = 1$ BECs have been studied in the recent work.[1] However, it still remains an open question how textural structures can emerge in $F = 2$ spinor BECs, where the cyclic phase can be the magnetic ground state.

Here, we analytically demonstrate that the Rashba like SOC favors helical modulations of the order parameters, where the rotation in the pseudospin space propagates along its rotation axis in the real space. We also find the stable textures obtained by numerical minimization of the Gross-Pitaevskii energy functional, where the rotationally symmetric spin-spin interaction has four magnetic ground states including the cyclic phase. In the parameter region which favors the cyclic phase, we find the energetically competitive textures, which are the hexagonal lattice with the uniaxial polar core and the 1/3 vortex square lattice with the ferromagnetic core, and calculate the phase diagram of them. Finally, we show that these textures result from the two-dimensional networks of the helical modulations of the cyclic order parameters.

[1] C. Wang, C. Gao, C.-M. Jian, and H. Zhai, Phys. Rev. Lett. **105**, 160403 (2010).