Spin-orbit coupled ultracold atoms in bilayer structures

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Currently there is a great deal of activities in studying the spin-orbit coupling (SOC) for ultracold atoms. One of the challenges is to experimentally produce a two-dimensional (2D) SOC of the Rashba type, as well as a 3D Weyl SOC for the center of mass motion of ultracold atoms [1]. It was proposed that the 2D and 3D SOC can be generated by laser coupling atomic internal states [1] or using a periodic sequence of magnetic gradient pulses [2,3]. Here we shall consider another way of creating the SOC for ultracold atoms by confining them in a laser assisted bilayer structure. An interplay between the inter-layer tunneling, intra-layer Raman coupling and intra-layer atom-atom interaction gives rise to an effective 2D SOC providing diverse ground-state configurations for bilayer Bose-Einstein condensates (BEC) [4] and degenerate Fermi gases [5]. We shall also discuss a possibility of formation of a robust Fulde-Ferrell-Larkin-Ovchinikov (FFLO) state exhibiting a spontaneous density-modulation of the order parameter for a two-component Fermi gas in a bilayer system without the lossy intralayer Raman-induced spin-flip transitions involved [6]. In that case the atomic states localized in different layers play a role of the quasi-spin states, and the laser assisted interlayer tunneling provides effectively the SOC between the layer states. Since the atoms with opposite momenta are located mainly in different layers and the atomic attraction dominates in the same layer, the FFLO state is robust in a wide parameter range.

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