Phase transition of soft-core bosons in disordered optical lattice

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Synopsis The mean-field phase diagram of two-dimensional soft-core extended Bose-Hubbard model in the presence of spatial disorder is determined.

The interplay between disorder and interactions in ultracold atoms has been a topic of intense theoretical investigations in the past years. In the presence of disorder, ultracold atoms in deep optical lattice are described by the Bose-Hubbard(BH) model and its extensions with disorder. It was found that disorder in BH model generates a novel Bose-glass(BG) phase, which always intervenes between the Mott-insulator(MI) and the Superfluid(SF) states. For the extended BH model, there may be possible a supersolid state, which also intervenes between the incompressible solid and SF states in the parameter space. The introduction of disorder into the extended BH model leads to the competition between the BG and SS phases, which may influence the existence of the SS phase. For hard-core bosons in square lattice, external spatial disorder always destroys the long rang density wave order and makes it no chance to become a SS state[1]. QMC and disordered mean field theory studies demonstrate that the SS are stable against weak spatial disorder on the simple cubic lattice.[2]. To our knowledge, the phase digram of soft-core bosons with nearest-neighbor interactions and disorder in two-dimensional(2D) optical lattice has not been studied, and the fate of the SS state in such system is still unknown.

We use inhomogeneous mean-field theory[3] to study the effects of spatial disorder in the soft-core Bose-Hubbard model on a 2D square lattice. The mian results are summarized in Figure 1, rendering a rich phase diagram. We find five distinct phases: MI, Checkerboard(CB) solid, Disorder Solid(DS), SS and SF. In contrast to hard-core bosons in square lattice, we find that the solid and SS phases are stable against the spatial disorder. And the spatial disorder yields a sequence of DS phases which intervene between the incompressible lobes. Especially, it is remarkable that the regions of DS and SS phases can be tuned by varying the disorder strength. For weak nearest-neighbor interactions, the disorder induces the solid and SS phase shrinking to smaller hopping regions. However, for strong nearest-neighbor repulsions, the competition between nearest-neighbor interactions and disorder stabilizes the SS phase and makes it extending to large hopping region. Therefore, our results suggest that the prospect of observing the SS phase is much higher when loading dipolar Bose gases into disordered optical lattices.

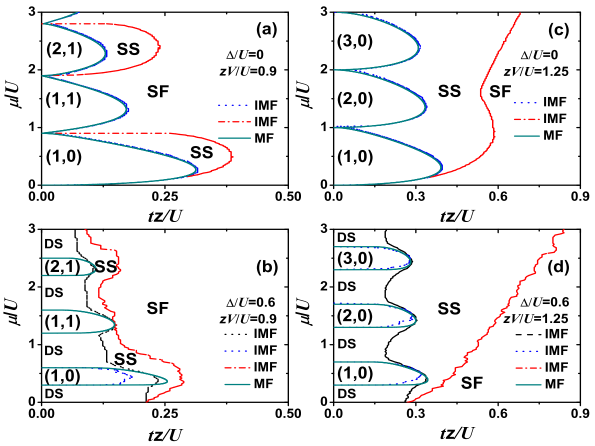

Figure 1. (Color online) The ground-state phase diagrams as a function of the chemical potential μ/U and hopping tz/U.

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References

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