Superfluidity in the Lieb lattice

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In recent works [1, 2] it has been pointed out that the critical temperature of the superconducting transition is greatly enhanced if the energy dispersion of the Bloch band, where the electron pairing occurs, has a bandwidth much smaller than the energy scale U of the effective attractive interaction. In this so-called flat-band limit, corresponding to a constant energy dispersion, the critical temperature is linearly proportional to U rather than exponentially suppressed as for a dispersive band in the weak-coupling limit. Therefore, even a modest interaction strength can drive the electron liquid into a superconducting state at much higher temperatures compared to a conventional superconductor.

Superconductivity is characterized by a non-zero superfluid weight D_s which is responsible for the defining properties of the superconductive phase, namely a dissipationless electric current and the Meissner effect [3]. An intriguing question is how the flat band affects the superfluid weight. To investigate this, we study the Lieb lattice which is the simplest two-dimensional lattice geometry with a flat band. In recent years topological, ferromagnetic and also superconductive properties of the Lieb lattice have been investigated. However, it has not been studied whether the Lieb lattice can really support finite superfluid weight. In this work we show by using the standard BCS mean field theory that in the Lieb lattice D_s can indeed be finite and large due to the flat band. Furthermore, the mean-field theory is validated by an argument showing that the BCS wavefunction is an exact ground state in the isolated flat-band limit. Our predictions can be verified in the recent realization of the Lieb lattice with ultracold gases in optical lattices [4] and may be relevant for high-T_c superconductors whose superfluid weight is known to exhibit an anomalous behavior.

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