Electronic Multicriticality in Bilayer Graphene

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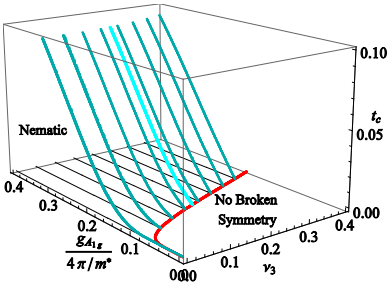
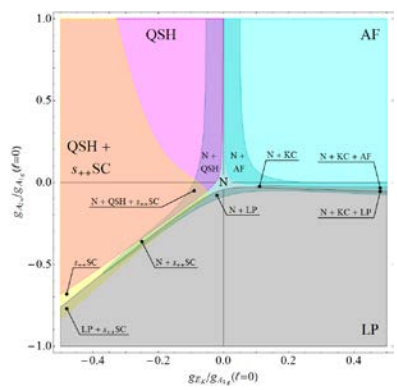
Introduction/Abstract

The low energy effective spectrum of bilayer graphene consists of a pair of Fermi points. At each, two parabolic bands touch. This makes the system susceptible to the effects of electron-electron (e-e) interaction and one expects to find an interaction driven symmetry broken state at low temperatures. In a series of earlier papers [1,2,3] we studied the problem within a zero temperature one-loop RG. Here we develop a finite temperature RG method in the weak coupling limit, demonstrating how either finite temperature or trigonal warping cut-off the RG flows. A finite bare interaction is therefore required in order to have a diverging flow, i.e., an instability toward a symmetry broken phase. We are able to solve the asymptotic behavior of the flows exactly and identify all the stable solutions which lead to a discovery of a rich phase diagram. The flows are studied numerically to determine the dependence of the symmetry breaking channel on the type of bare interaction. We find gapless nematic phase to be the leading instability in the case of forward scattering only (**Figure 1**). It is stable to addition of small finite back and/or layer imbalance scattering. The Hubbard model on bilayer graphene is studied and the results are found to be in agreement with the known exact results. The effect of perpendicular electric field on the phase boundaries is analyzed



Results and Conclusions

In this work we present the effective low energy theory for Bernal stacked bilayer graphene following symmetry analysis. The interacting problem is stated in the coherent state path-integral formalism at finite temperature. We find the flow equations for all 9 symmetry allowed couplings, as well as the flow for susceptibility toward all (relevant in the RG sense) symmetry breaking states. The transition is defined as the point where the flows diverge. These equations are analyzed at and in the vicinity of the transition point. We find all the possible stable rays for the RG flow ("target plane", **Figure 2**) and the corresponding instabilities for each ray. We consider repulsive density-density interactions and numerically determine the phase diagram (**Figure 3**) as a function of back and layer imbalance scattering (corresponding to the interaction range). The gapless nematic phase, the instability in the case of forward scattering only, is found to be stable to addition of small finite back and/or layer imbalance scattering. The increase of repulsive backscattering leads to anti-ferromagnet ground state. Other possible ground states for these, realistic, interaction parameters we find are layer polarized, Kekule current, quantum spin Hall, and s_{++}-superconducting state. We study the Hubbard model on bilayer graphene lattice and show that the SO(4) symmetry of this model is preserved at all scales. Therefore, we predict that layer polarized and s_{++}-superconducting state have the same susceptibilities in the Hubbard model (repulsive or attractive), and numerically determine these to be the instabilities in the case of attractive Hubbard model, whereas, the repulsive Hubbard interaction leads to anti-ferromagnet. Breaking the SO(4) symmetry with a small finite nearest neighbor interaction term favors either layer polarized or s_{++}-superconducting state depending on the sign of the symmetry breaking term.



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