Chapter 7

Summary

In the chapter we enumerate the findings of this thesis.

1. Exact analytical solutions for Dirac particle in cross electric and magnetic field were found using the trick of Lorentz boost.

2. Numerical computations for the cross electric and magnetic field subjected to graphene on lattice were shown to confirm the effects of Landau levels is not an artifact of continuum model.

3. The phenomenon of dielectric breakdown was discussed and predictions were made about difference of dielectric breakdown for \( n = 0 \) and \( n \neq 0 \) Landau levels. And this was verified in quantum Hall experiments by Singh and Deshmukh [18]

4. We have derived a systematic continuum approximation for the interacting lattice model for graphene. The lattice interaction terms yields a leading \( SU(4) \) terms and sub-leading part. We justified replacing the sub-leading part with the terms resulting from the nearest neighbour interaction. We have presented the interacting continuum model that we adopt in this thesis in Eq.(3.26)

5. We showed that the Landau levels for massive Dirac particle provides the same
$SU(4)$ polarization for both partially occupied $n = 0$ Landau levels and filled Dirac sea.

6. We described the number of parameters needed for the variational ground states for the Hall conductivity $\sigma_H = 0$ and $\sigma_H = -1$.

7. We developed the two point correlator for a massive Dirac particle in magnetic field.

8. With the knowledge of two point correlator for a massive Dirac particle we constructed the two point correlator and coincident correlator for Dirac particle in graphene to be used for variational mean field computations.

9. We have showed that the Coulomb interaction breaks the $SU(4)$ symmetry spontaneously for the ground states for Hall conductivity at $\sigma_H = 0$ and $\sigma_H = -1$.

10. The order parameter for spontaneous symmetry breaking is the mass of the Dirac particle which is proportional to a dimensionless $\alpha = \kappa_C / \kappa_L$, which depends on dielectric constant.

11. The order parameter is proportional to magnetic field and tends to zero as magnetic field goes to zero which indicates spontaneous symmetry breaking of $SU(4)$ symmetry by Coulomb interaction in presence of magnetic field.

12. The particle-hole gaps from symmetric model showed a square root dependence on the applied magnetic field. Our symmetric model without disorder taken into account over estimates the gaps when compared with experimental values.

13. We obtained phase diagram for the ground state for $\sigma_H = 0$ using the symmetry breaking terms of our model. The three possible phases in $U-V$ parameter space shown in Fig.6.1.

14. Phase diagram was also obtained for $\sigma_H = -1$. The two possible ground states in the $U-V$ parameter space is shown in Fig.6.2.
15. The tilted magnetic field gaps for the ground states for Hall conductivity $\sigma_H = 0$ is shown in Fig.6.3 and the charge ordered state behavior is consistent with that seen in experiments.

16. The tilted magnetic field gaps for $\sigma_H = -1$ shown in Fig.6.5 has also regions that are consistent with the experiments.

17. Fig.6.8 is our prediction for the range of values $U$ and $V$ can take for our model to explain the current quantum Hall experiments.