Cooling of Hot-Carriers with Landau Levels in Graphene

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Introduction

One important triumph of graphene research was the demonstration of the quantum Hall effect with unusual filling factor ±2, ±6, ±8 ··· by Geim's and Kim's groups separately in 2005. The experiments established the massless Dirac fermion properties of electrons in graphene. Later, the availability of even higher quality graphene samples enabled the demonstration of the fractional quantum hall effect. Fractional quantum hall states imply strong electron-electron interactions in graphene at high magnetic fields. Many-body electronic interactions also manifest themselves in bilayer graphene, where the interaction between ground states leads to a finite bandgap in zero magnetic field. Recently, broken-symmetry quantum Hall states have been discovered in trilayer graphene and also indicate strong interactions between electrons. However, there have been very limited efforts to directly probe the dynamics of carriers in quantum Hall regime. Such understanding will provide insights of many-body electronic states and their interactions, in harmony with the existing electrical transport achievements.

Experimental

Our experiment focuses on the investigation of the hot-carrier dynamics in quantum hall regime by ultrafast pump-probe photocurrent/photoconductivity spectroscopy. The advantage of this technique is that it probes the electronic properties of graphene while utilizing the features of nano-optical spectroscopy, including ultrafast time resolution (~ 100 femto second), and electronic structure and polarization sensitivity.

We used the17.5 T superconducting magnet (SCM 3) in the DC field facility. Staff scientist Zhiqiang Li provided tremendous help. During our two trips to the Magnet Lab in 2012, we indentified the biggest problem of the system was how to locate the sample (100 μm^2) with the incident laser beam in the magnet bore. Working with Zhiqiang Li, a new sample mount has been designed and fabricated to allow precise positioning of the sample in the middle of the magnet bore. To image the sample and reduce the laser spot size, we also designed and fabricated a lens mount, which is inserted into the magnet bore. This allows us to position a small focal length lens very close to the sample in order to reduce the laser spot size. The setup at this time has a spot size of order 10 micrometers with room for improvements still.

Results and Discussion

The new imaging system and lens mount have been fabricated and tested in the Magnet Lab at low temperature. **Figure 1** shows a typical device and laser spot as seen with this system. We are able to clearly see where important photoactive regions are in the device and can reposition the laser spot to be incident on those areas. This will greatly improve the ease and ability to perform the ultrafast pump-probe experiment with high magnetic field.

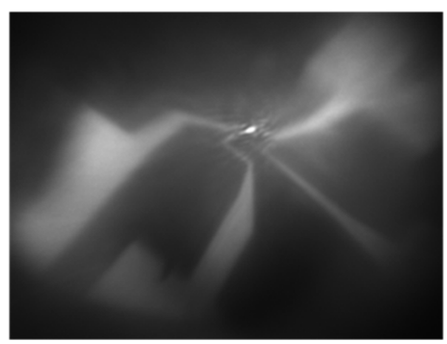

Figure 1: Image of typical device and laser spot with the new system.

Conclusions

The highly improved optical spectroscopy system will enable us to investigate hot-carrier cooling pathways with Landau levels in graphene.

Acknowledgements

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