NATIONAL HIGH MAGNETIC FIELD LABORATORY
2018 ANNUAL RESEARCH REPORT

Long-Distance Spin Transport Through a Graphene Quantum Hall Antiferromagnet

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Introduction

Because of their ultrafast intrinsic dynamics and robustness against stray fields, antiferromagnetic insulators are promising candidates for spintronic components. Spin currents in magnetic insulators can be carried with dissipation by magnon quasiparticles, or collectively and without dissipation by spin supercurrents in systems with easy plane magnetic order. Whereas magnon transport is less efficient in an ideal antiferromagnetic insulator (AFMI) than in a ferromagnetic insulator, superfluidity is theoretically possibility in both cases. Although the potential of antiferromagnetic materials as electrically tunable active spintronic components has been recognized, and important progress has been made, spin transport through an AFMI thicker than ~10 nm has yet to be demonstrated.

Experimental

We implement the theoretical proposal of ref. [1], using an all-electrical circuit and non-local transport to detect spin transport through an AFMI, in this case the quantum Hall state in graphene at the charge neutrality point. QH edge states at filling factors ν=-1 and -2 are employed as injectors, filters and detectors. The experiments were performed in dc fields in SCM2 and Cell 12.

Results and Discussion

We detect a large non-local voltage signal, up to 225 μV, that is transmitted ~ up to 5 μm across the AFMI. The signal disappears when the filter regions are tuned away from ν=±1 state that supplies spin-dependence (**Fig. 1**). Both the magnitude of the non-local signal and the transport distances are orders of magnitudes larger than in oxide-based AFMIs, suggesting that a fundamentally different mechanism is at play. The dependence of the signal on magnetic field, temperature, and filling factor is consistent with spin superfluidity as the spin-transport mechanism [2].

Conclusions

Our work further establishes graphene in the quantum Hall regime as a model system for fundamental studies of antiferromagnetic and ferromagnetic spintronics. The long-term goal of this research is to achieve nearly dissipationless spin-transport in practical magnetic materials for information processing and storage applications.

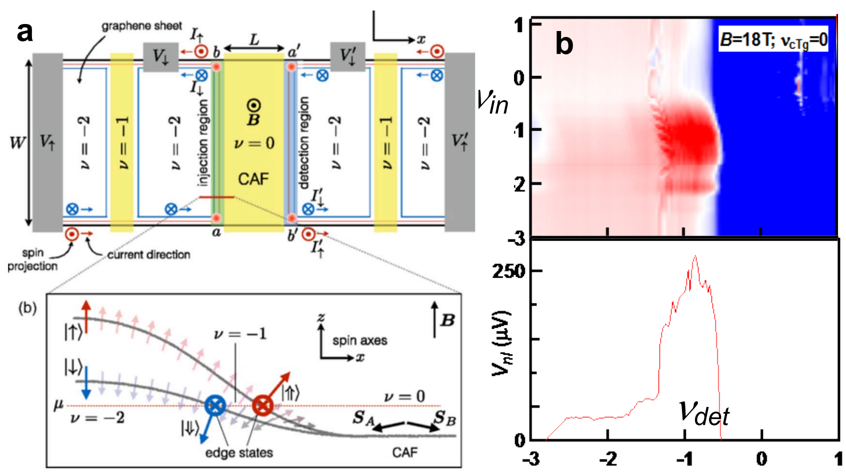

Fig. 1. (a) Proposed experimental setup. Two independently biased spin polarized edge channels serve as spin detector and injector region on the different sides of CAF state (from [1]). **(b).** Non-local signals V_{nl} as a function of filling factors in the injector and detector region when the device is configured as in (a). Note the prominent signal when both injector and detector regions are at ν=-1(from [2]).

Acknowledgements

The National High Magnetic Field Laboratory is supported by the National Science Foundation through NSF/DMR-1157490/1644779 and the State of Florida. The work is supported by SHINES, which is an Energy Frontier Research Center funded by DOE BES under Award #SC0012670. AHM acknowledges partial support by the Welch foundation under grant TBF1473. SC is supported by DOE BES under Award # ER 46940-DE-SC0010597 to study QHE in graphene. Growth of hexagonal BN crystals was supported by the Elemental Strategy Initiative conducted by the MEXT, Japan and a Grant-in-Aid for Scientific Research on Innovative Areas “Science of Atomic Layers” from JSPS.

References

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[2] Stepanov, P. et al. Long-distance spin transport through a graphene quantum Hall antiferromagnet. Nat. Phys. 14, 907-911 (2018).