Manipulating spin-dependent photocurrent in topological insulator/magnetic insulator heterostructures with light polarization and magnetic fields

T. Pillsbury[1], Y. Pan[1], Y. Luo[2], J. Kally[1], H. Wang[1], A. Richardella[1], T. Liu[3], M. Wu[3], R. Kawakami[3], N. Samarth[1]

[1] *Physics Department, Penn State University, University Park, PA 16803*

[2] *Physics Department, Ohio State University, Columbus, OH 43210*

[3] *Department of Physics, Colorado State University, Fort Collins, CO 80523*

The use of light to induce an electrical signal in topological insulators (TIs) has important applications towards using these materials in spintronics. Previous studies have shown that the photocurrent (PC) measured is dependent on the polarization of the applied light [1]. We have expanded on previous results in the literature to establish a more complete explanation of how these spin-polarized PC are created in the TI surface states [2]. The next crucial step towards achieving practical 'topological spintronics' is to interface the helical Dirac surface states of TIs with magnetism. Heterostructures that combine TIs with insulating magnetic materials are particularly relevant within this context. Recent studies have shown that such heterostructures result in TIs with proximity induced magnetism [3,4]. Here, we describe the discovery of a spin-dependent PC in heterostructures of the ferimagnetic insulator yttrium iron garnet (YIG) and the 3D TI $(Bi_xSb_{1-x})_2Te_3$. We have explored how these created photocurrents can be modified under an externally applied magnetic field. We further elucidate this phenomenon by studying the spin-dependent PC as a function of the chemical potential of the TI film, as well as by examining its variation with temperature and the wavelength of the optical excitation. We observe that at higher temperatures the magnetic field-dependent PC maps out the magnetization state of the YIG layer, as confirmed by a direct comparison with magneto-optical Kerr effect measurements, but at lower temperatures there are notable deviations. We demonstrate this discovery as a potential method towards a memory component for spintronic application.

References

[1] J. W. McIver, D. Hsieh, H. Steinberg, P. Jarillo-Herrero, and N. Gedik, *Nature Nanotechnology* **7,** 96-100 (2012)

[2] Y. Pan, Q. Wang, A. Richardella, T. Pillsbury, A. L. Yeats, T. C. Flanagan, D. D. Awschalom, C. Liu, and N. Samarth *Preprint arXiv:* **1706.04296** (2017)

[3] P. Wei, F. Katmis, B. A. Assaf, H. Steinberg,P. Jarilllo-Herrero, D. Heiman, and J. Moodera, *Phys. Rev. Lett.* **110**, 186807 (2013).

[4] M. Lang, M. Montazeri, M. C. Onbasil, X. Kou, Y. Fan, P. Upadhyaya, K. Yao, F. Liu, Y. Jiang, W. Jiang, K. Wong, G. Yut, J. Tang, T. Nie, L. He, R. Schwartz, Y. Wang, C. Ross, and K. Wang, *Nano Letters* **14**, 6 (2014).

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