Origin of the helicity dependent photocurrent in electrically gated $(Bi_{1-x}Sb_x)_2Te_3$ thin films

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Experimental studies of three-dimensional topological insulators have shown that circularly polarized photons can robustly generate a directional helicity-dependent photocurrent at room temperature [1]. Surprisingly, the phenomenon is readily observed at photon energies that excite electrons to states far from those within the spin-momentum locked Dirac cone. The underlying mechanism for the helicity-dependent photocurrent is thus far from obvious and still a mystery. We resolve the puzzle by carrying out a comprehensive study of the helicity dependent photocurrent in $(Bi_{1-x}Sb_x)_2Te_3$ thin films (Figure 1) as a function of the incidence angle of the optical excitation, its wavelength and the gate-tuned chemical potential (Figure 2). Our observations allow us to unambiguously identify the circular polarized photo-galvanic effect as the dominant mechanism for the helicity-dependent photocurrent. Additionally, we relate the directional nature of the photocurrent to asymmetric optical transitions between the topological surface states and bulk bands. This is rigorously inferred from a first principles calculation that reproduces the distinctive experimental dependence of the helicity-dependent photocurrent on gate voltage and excitation wavelength. The insights provided by our study are important for engineering opto-spintronic devices whose functionality relies on optical steering of spin and charge currents.

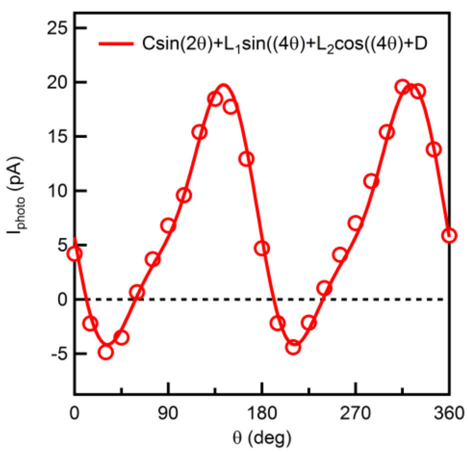

Figure 1 The photocurrent as a function of ϴ, which is the angle between the linear polarization of the light and the fast axis of the quarter waveplate.

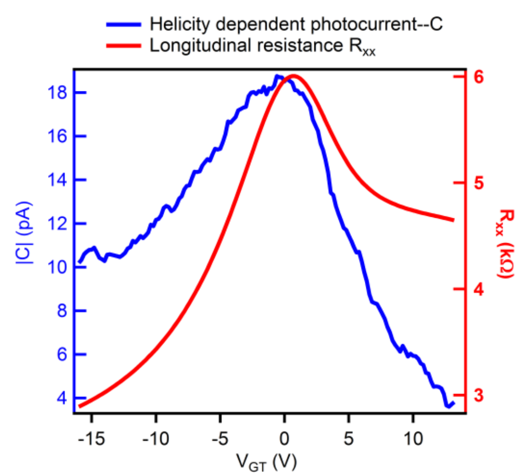

Figure 2 The helicity dependent photocurrent and the longitudinal resistance as a function of the top gate voltage.

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