Terahertz dynamic signatures of spin accumulation and spin-to-charge conversion at topological insulator–ferromagnet interfaces

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Topological insulators are a promising class of materials for terahertz spintronics research and devices. Their topologically protected surface states with spin-momentum locking unveil additional channels for spin-charge interconversion and, thus, offer the opportunity to improve the spin-charge interconversion efficiency. While in the inverse (Rashba) Edelstein effect, the charge current scales with the interfacial accumulation of spin angular momentum, the charge current due to the inverse spin Hall effect is proportional to the spin current and occurs in the bulk. Because these bulk and interface effects have identical macroscopic symmetries, they are difficult to separate experimentally.

Here, we use femtosecond laser pulses to excite F|TI heterostructures consisting of a ferromagnetic metal layer F and a topological-insulator film TI. The resulting transient spin voltage in F [1,2] drives an ultrafast spin current from F into the adjacent TI. Spin-to-charge conversion launches a transverse charge current that emits a broadband terahertz electromagnetic pulse. The field of the latter is recorded in the time-domain via electro-optic sampling.

Our measurements allow us to extract phase-sensitive changes in the dynamics of spin transport and spin-to-charge conversion on femtosecond timescales. We find significantly longer charge-current relaxation times in different TIs in comparison to a reference Pt layer, which we assign to spin accumulation at the topological insulator interface.

References

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