Efficient terahertz frequency conversion in a Dirac semimetal Cd_3As_2 and terahertz anomalous Hall effect in a Weyl antiferromagnet Mn_3Sn

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Recently nonlinear light-matter interaction in terahertz (THz) frequency has attracted considerable attention for fundamental interests in physics and photonics and also for finding novel functionalities of materials bridging electronics and photonics. Here, we introduce our recent works using THz spectroscopy for topological semimetals[1,2)], *i.e.*, a Dirac semimetal and a Weyl semimetal with the massless energy dispersion, which may pave a new route for high-speed electronic and spintronics.

High harmonic generation (HHG) has been one of the central issues in modern photonics since it produces coherent high-energy photons by multiplication of an incident photon energy, which has been developed in gaseous media for attosecond science and also utilized for high-resolution angle-resolved photoemission spectroscopy. More recently, HHG in semiconductors with mid- or near-infrared laser pulse has been also reported[3)], raising the possibility for realizing stable and compact soft X-ray sources. For much lower frequency around 1 THz, however, HHG has been still very difficult due to the lack of intense light source and suitable materials. We have found efficient THz third harmonic generation in a superconductor originating from the resonance with the Higgs amplitude mode[4)]. If such an efficient THz harmonic generation is realized at room temperature, it would be a key technology for frequency conversion and mixing in high-speed electronics as well as for sensitive detection of the cosmic microwave background. Here we demonstrate room-temperature efficient THz harmonic generation with $3f$=2.4 THz in 3D Dirac semimetal Cd_3As_2 thin films[1)]. Our pump-probe spectroscopy for Cd_3As_2 reveals that the nonlinearity originates from intraband acceleration of massless electrons across the Dirac node as theoretically anticipated. The unprecedentedly efficient harmonic generation in the 3-dimensional material would open an avenue for developing a novel THz frequency convertor.

We also investigated the THz response of a Weyl antiferromagnet Mn_3Sn. Spin motion in antiferromagnets is as fast as in THz frequency far beyond that in the ferromagnets and therefore it has been expected as a candidate for high-speed data processing in spintronic devices. But the readout of antiferromagnetic spin order is difficult due to the small net magnetization. The noncollinear antiferromagnet Mn_3Sn shows a large anomalous Hall effect comparable to ferromagnets in spite of the vanishingly-small net magnetization[5)], owing to broken time-reversal symmetry by the cluster octupole moment on Kagome bilayer. Therefore, the detection of the anomalous Hall current in Mn_3Sn at THz frequency is essential for high-speed readout of the spintronic device based on the antiferromagnet. Here we report observation of the THz anomalous Hall effect in a Mn_3Sn thin film by a broadband polarization-resolved THz spectroscopy up to 6 THz[2)]. We found that the non-dissipative large anomalous Hall current appears up to around ~1 THz, while at higher frequency the dissipative part of the Hall current grows up possibly due to the interband transition across the Weyl node. Our observation of a large THz response in the antiferromagnets paves the way for ultrafast readout of antiferromagnetism with THz current on device.

Reference

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