THz Spin Resonance and Magnon Currents in Antiferromagnetic Heterostructures

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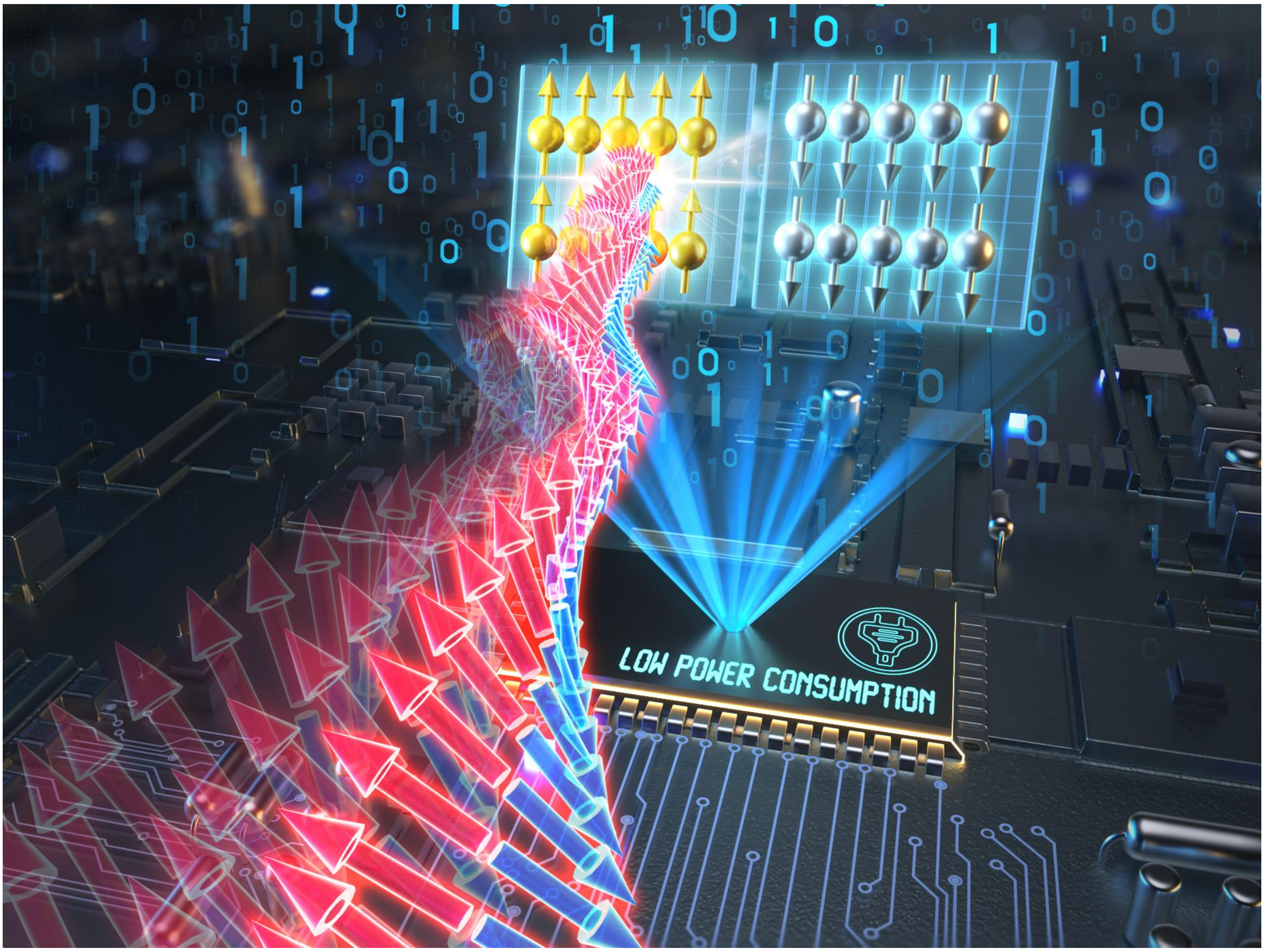
Magnons, the quasiparticles of spin waves, are the elementary low-energy collective excitations in magnetic materials. Antiferromagnetic insulators (AFMIs) can host THz frequency magnons to carry angular momentums without moving charges, however not much is known about the propagation of magnons in antiferromagnetic materials so far. We first detect THz spin resonance in an antiferromagnetic NiO heterostructure by employing both low-wavenumber Raman and continuous-wave THz spectroscopy techniques. Using THz emission measurements, sub-picosecond magnon currents can be identified through the antiferromagnetic NiO layer, which can even manipulate the magnetization, enabling high-speed and low-dissipation operation of spin devices [1]. In addition, compact AFMI devices at nanoscales are desirable due to the absence of stray fields. However, the magnon propagation speed, which is a key parameter to determine data operation time, remains elusive in AFMIs, particularly at nanometer distances due to the lack of sufficiently fast probes. We report the direct time-domain measurement of the velocity of antiferromagnetic magnons in NiO with optical-driven THz emission [2]. We find the magnons propagate in nonmagnetic Bi_2Te_3/antiferromagnetic insulator NiO/ferromagnetic Co trilayers at a superluminal velocity (up to 650 km/s) at nanoscales in NiO (< 50 nm), which exceeds far beyond the limiting magnon group velocity (~40 km/s) obtained by dispersion relation using inelastic neutron scattering. We attribute this finding to the fact that finite damping makes the dispersion anomalous at small wavenumbers and yields superluminal magnon propagation. Our observation suggests the prospects of energy-efficient nanodevices using AFMIs considering finite dissipation in real materials.

[1] Wang, Y. et al., “Magnetization switching by magnon-mediated spin torque through an antiferromagnetic insulator” Science 366, 1125–1128, 2019.

[2] Lee, K. et al., “Superluminal-like magnon propagation in antiferromagnetic NiO at nanoscale distances” Nat. Nanotechnol. 16, 1337–1341, 2021.



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