Time-domain observation of ballistic orbital-angular-momentum currents with giant relaxation length in tungsten

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The emerging field of orbitronics exploits the electron orbital momentum L, which may allow magnetic-information transfer with significantly higher density over longer distances in more materials than possible with spin-polarized electrons. However, direct experimental observation of L currents, their extended propagation lengths and their conversion into charge currents has remained challenging. Here, we optically trigger ultrafast angular-momentum transport in Ni|W|SiO_2 thin-film stacks. The resulting terahertz charge-current bursts exhibit a marked delay and width that grow linearly with W thickness. We consistently ascribe these observations to a ballistic L current from Ni through W with giant decay length (~80 nm) and slow velocity (~0.1 nm/fs). At the W/SiO_2 interface, the L flow is converted into a charge current by the inverse orbital Rashba-Edelstein effect. Our findings establish orbitronic materials with long-distance ballistic L transport as possible candidates for future ultrafast devices and an approach to discriminate Hall- and Rashba-Edelstein-like conversion processes.

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