Emergent Electromagnetic Induction in Helical-Spin Magnets

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Upon the discovery of short-period (a few-nm) spin helices and skyrmoin lattice in RKKY-mediated hexagonal magnets [1,2], the enhanced emergent-electromagnetism phenomena have begun to be actively explored, including the gigantic topological Hall and Nernst effects [1, 3]. One other important example is the inductor function as designed and realized via emergent electromagnetic field (EEMF) arising from helical spin orders. An inductor is one of the most fundamental circuit elements for modern electronic device. The magnitude of such a conventional inductance is proportional to the volume of an inductor's coil, which is known as a hardly-solvable hindrance to miniaturization of inductors. Here, we demonstrate an inductance of quantum-mechanical origin, that is originating from the emergent electric field induced by current-driven dynamics of spin helices in a magnet. In microscale rectangular-shaped devices of a magnet with nanoscale spin helices, e.g. $Gd_3Ru_4Al_{12}$ [4] and YMn_6Sn_6 [5], we observed that the inductance is prominently enhanced in spin helically-modulated phases, showing a typical inductance value (L) as large as micro-henry for the device whose volume is ~10^{-6} times smaller than the inductor available at present. The observed inductance is enhanced by the nonlinearity in current and shows non-monotonous frequency dependence, both of which result from the current-driven dynamics of the spin-helix structures. We discuss the possibility of the highly inductive helimagnets working beyond room temperature as a most distinct outcome of EEMF in quantum materials.

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[3] M. Hirschberger et al., Phys. Rev. Lett. 125, 076602 (2020).
[4] T. Yokouchi et al., Nature, 586, 232 (2020).
[5] A. Kitaori et al., arXiv:2103.02814