Theory of emergent inductance in spiral magnets

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Emergent electromagnetism in magnets originates from a nontrivial Berry phase resulting from strong coupling between spins of conduction electrons and non-collinear magnetic moments. This offers possibilities to develop new functionalities associated with quantum transport and optical responses. The emergent inductance [1, 2, 3] in spiral magnets is one of the most intriguing phenomena resulting from the emergent electric field, which has been recently experimentally confirmed [4, 5]. The experimentally observed inductance is around $\sim$ 100nH, which is comparable to the best commercial values, whereas the potential device's size is $\sim 10^{-5}$ smaller.

In this talk, we introduce a theory of the emergent inductance in spiral magnets, which explains its magnitude, sign, frequency dependence, and nonlinearity. We conduct an analytical micromagnetic study based on the dynamics of collective excitations in spin spirals. Furthermore, our spin dynamics simulations observe the nonlinearity and sign change of the inductance, which explain experimental observations. Our theory provides the fundamental understanding of the phenomenon and opens a way to design the emergent nanoscale inductors.

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