Nonlinear response for spin and charge

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The usual electric and thermal transport are both consequences from linear response. And the related properties from nonlinear response are commonly regarded as small quantities, which are not explored fully. In 2015, Sodemann and Fu proposed a nonlinear Hall effect (NHE) which describes a nonlinear response of charge Hall current to an ac electric field in a time-reversal symmetric (TRS) systems and the linear charge Hall current disappears. And they proposed that Berry curvature dipole in the momentum space hosts the microscopic reason. Along this line, we explore the nonlinear response of charge and spin due to the nontrivial topological properties for electric and thermal transport.

We theoretically proposed a topological nonlinear Nernst effect as the second-order response of temperature gradient which describe a nonlinear charge current induced by a longitudinal temperature gradient in a TRS but inversion-symmetry-broken system. Furthermore, in light of a thermal vector potential representation, we develop a general formulation to calculate the linear and nonlinear dynamic thermal response. At the DC limit, we recover the well-known Mott relation and the Wiedemann-Franz (WF) law at the linear order response, and find higher order Mott relation and WF law. We introduce the third Lorentz number for describing the second order and third order response.

We study the general nonlinear electric transport up to the n-order as a response to an ac electric field. For a complete description, we introduce electric field order (E-order), harmonic order (H-order), and introduce the concept of Berry curvature multipole moment. We find that any H-order current composes of infinite E-order current components. We discuss four-symmetry-type cases and derive a specific current "selection rule".

References：

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