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Topological electric currents in nonadiabatic quantum systems

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The semi-classical equations of motion have been the corner-stone for describing electrons dynamics in solids. In recent years, they have been extended with a term called anomalous velocity, derived under adiabatic approximations. We derive an exact equation with no adiabatic approximations for the evolution of electronic average position, with the electron being in an extended state. This is accomplished by extending the Hellmann – Feynman theorem to time-dependent parameters with quantal dynamics. A direct application gives a general formula for the electronic current in a solid that consists of three terms. The first one has the well-known group velocity form and the other two are anomalous corrections that seem to have a simple interpretation, the second one being a magnetization current and the last one a polarization current. Both currents are found to have a profound topological nature originating from Berry curvature quantities. Employing discrete symmetries we find that, when an external electric field is applied to a crystal with inversion symmetry, the total bulk magnetization current is zero and a dissipation-less topological current is produced on the surface (owing to inversion symmetry breaking) which is found to be quantized as a consequence of the non-trivial topology of the wave functions in the Brillouin zone. When the electron wave functions are not single-valued in the entire momentum space, this quantization can be attributed to dislocations lines (lines of wave-function-phase-singularities with respect to the momentum variables) where the wave-function does not vanish. The method can also be directly applied to the quantum Hall effect resulting to the quantization of the Hall conductivity with no adiabatic approximations or Kubo formula.

Biography

Kyriakos Kyriakou is a PhD Graduate student in the University of Cyprus.

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