Seminario de análisis matemático y aplicaciones
Analisi matematikoa eta aplikazioak mintegia

Accuracy of Classical Conductivity Theory at Atomic Scales for Free Fermions in Disordered Media

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ABSTRACT:

The growing need for smaller electronic components has recently sparked the interest in the breakdown of the classical conductivity theory near the atomic scale, at which quantum effects should dominate. In 2012, experimental measurements of electric resistance of nanowires in Si doped with phosphorus atoms demonstrate that quantum effects on charge transport almost disappear for nanowires of lengths larger than a few nanometers, even at very low temperature (4.2 K). We mathematically prove, for non-interacting lattice fermions with disorder, that quantum un- certainty of microscopic electric current density around their (classical) macroscopic values is suppressed, exponentially fast with respect to the volume of the region of the lattice where an external electric field is applied. This is in accordance with the above experimental observation. Disorder is modeled by a random external potential along with random, complex-valued, hopping amplitudes. The celebrated tight-binding Anderson model is one particular example of the general case considered here. Our mathematical analysis is based on Combes-Thomas estimates, the Akcoglu–Krengel ergodic theorem, and the large deviation formalism, in particular the Gärtner–Ellis theorem.

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