Semiclassical theory for transport through clean quantum dots: from qualitative reasoning to quantitative agreement

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Abstract

Within Feynman’s formulation of quantum mechanics transport properties of quantum billiards can be understood as the result of path interference. We use two-dimensional Fourier-transforms (“length-area spectra”) of the quantum mechanical transport amplitudes to gain information on contributing paths and their weights. We present a semiclassical theory that can account for quantum mechanical transport properties (weak localization, conductance fluctuations) on a quantitative level provided all relevant classical and non-classical contributions to the length-area spectra are represented.

Motivation

- Semiclassical theories are intuitive – transport as interference of paths (classically regular/chaotic dynamics enters).
- Standard theories do not give quantitative results [1]
- No prediction for weak localization in regular billiards

Quantum mechanical spectra

Fourier transform of the exact quantum S-matrix elements
- Contains the information on contributing paths (length and enclosed area) and their weights

Semi-classical Green’s function

G_{nm} = \frac{2\pi}{2\pi} \sum_{q} G_{q} G_{q}^{*} \delta_{nm} \frac{1}{S_{q}^{2}}

Improved diffraction theory (beyond Fraunhofer diffraction)

Results

Conductance & Resistance

- Pseudo-path semiclassical approximation (PSCA)
- Standard semiclassical approximation (SCA)

Quantum mechanical path spectra give information on contributing paths
- This information can be implemented into a semiclassical theory
- Previously not considered quantum effects (diffraction) prove to be essential for weak localization

Conclusions

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- This information can be implemented into a semiclassical theory
- Previously not considered quantum effects (diffraction) prove to be essential for weak localization

References:


Acknowledgements:

This work was supported by the Austrian Science Foundation FWF (Grants No. SFB016 and No. P17359), the Max-Planck, and the W. M. Keck foundations, and the French Paternosterial Hubert Curien “Amadis”