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Complex quantum systems and loops models

Some quantum problems can be mapped to statistical problems, which in turn can be framed in terms of random curves. Numerical simulations of loops models can be more efficient that the equivalent quantum models. An example are network models that belong to symmetry class C, representing quasiparticle dynamics in a gapless spin-singlet superconductor without time-reversal invariance. It is a special feature of network models with this symmetry that the conductance and density of states can be expressed as averages in a classical system of dense, interacting random walks. Using this mapping, we perform a very precise numerical study of critical behavior at an Anderson transition in three-dimensions. We also study the spin quantum Hall effect and transitions between Hall plateaus in quasi-2D class C network models consisting of several coupled layers.

A small modification of the model allows us to consider magnetotransport in high-mobility 2D electron gas in a non-quantizing magnetic field. In this limiting case, there is a strong suppression of interference, and transport reduces to classical percolation. The corresponding percolation problem is bond percolation on two layers coupled by interlayer bonds.

We finally consider a class of 3D loop models that show transitions between phases with infinite loops and short-loop phases, and can be mapped to $CP^{(n-1)}$ sigma models, where n is the loop fugacity. Using Monte Carlo simulations, we find continuous transitions for n=1, 2, 3, and first order transitions for n>4. The results are relevant to (2+1)-dimensional quantum magnets and to deconfined quantum criticality.