

Entanglement Dynamics in Quantum Circuits

Unitary time evolution of quantum systems implies that information cannot be lost. However, in macroscopic systems information apparently is lost. Quantum circuits provide convenient models to study entanglement dynamics, the spreading of information throughout a system. The spreading is such that initially local information can be made to be inaccessible to local measurements. A circuit consists of a system (usually a spin chain) with no Hamiltonian that can be evolved in time using discrete unitary “gates.” In certain limits, these circuits display universal behavior that should also apply to Hamiltonian systems.

This thesis will discuss entanglement dynamics in random circuit models, in which the unitary gates are chosen randomly from the Haar distribution. In the circuits considered in this thesis, individual sites contain spins with Hilbert spaces of dimension q , and the gates act on two sites at a time. If q is taken to be large, it is possible to solve for the entanglement dynamics analytically, as long as the circuits are not fine-tuned. We will present analytic descriptions of the evolution of entanglement in states and operators.

- Definitions, Background
 - Thermalization
 - Entanglement Entropy
 - Von Neumann
 - Renyi
 - Limits on entanglement
 - Out of time order correlators
- Quantum Circuits
 - Brickwork
 - Random Architecture
 - Solvability in large- q limit
 - Models for entanglement
 - Minimum cut picture
 - Tetris (surface growth) picture
- Operator Spreading
 - Brickwork
 - Random Architecture
 - Stairways
 - Biased
 - Balanced
- Numerics