Fidelity of the surface code in the presence of a bosonic bath

Abstract

We study the resilience of the surface code to decoherence caused by the presence of a bosonic bath. This approach allows us to go beyond the standard stochastic error model commonly used to quantify decoherence and error theshold probabilities in this system. The full quantum mechanical system-bath dynamics is computed exactly over one quantum error correction cycle. Since all physical qubits interact with the bath, space-time correlations between errors are taken into account. We compute the fidelity of the surface code as a function of the quantum error correction time. The calculation allows us to map the problem onto an Ising-like statistical spin model with two-body interactions and a fictitious temperature which is related to the inverse bath coupling constant. The model departs from the usual Ising model in the sense that interactions can be long ranged and can involve complex exchange couplings; in addition, the number of allowed configurations is restricted by the syndrome extraction. Using analytical estimates and numerical calculations, we argue that, in the limit of an infinite number of physical qubits, the spin model sustain a phase transition which can be associated to the existence of an error threshold in the surface code. An estimate of the transition point is given for the case of nearest-neighbor interactions.

---

[1] P.Jouzdani, E. Novais and E. R. Mucciolo, arXiv:quant-ph/1304.2975v1.