Quantum cloning under decoherence and an application of the cloning

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(Dated: April 4, 2003)

abstract

Universal quantum cloning machines (UQCMs), sometimes called quantum cloners, generate many outputs with identical density matrices, with as close a resemblance to the input state as is allowed by the basic principles of quantum mechanics. Any experimental realization of a quantum cloner has to cope with the effects of decoherence which terminate the coherent evolution demanded by a UQCM. We examine how many clones can be generated within a decoherence time. We compare the time that a quantum cloner implemented with trapped ions requires to produce M copies from N identical pure state inputs and the decoherence time during which the probability of spontaneous emission becomes non-negligible. We find a generic method to construct an $N \to M$ cloning circuit, and estimate the number of elementary logic gates required. It turns out that our circuit is highly vulnerable to spontaneous emission as the number of gates in the circuit is exponential with respect to the number of qubits involved. We also present recent results of an attempt to find a practical application of quantum cloning to quantum error-correction of single qubit states. Classical information gained by performing measurements on ancilla qubits in the UQCM can be used to partially restore the initial state after passing it through a noisy channel. Under certain cicumstances, the proposed protocol is able to improve the fidelity of the final state even if the error rate is considerably high, as classical information is much more error-proof than quantum information.