Dissipation-assisted quantum computation in atom-cavity systems

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In this paper we review ways of overcoming the problem of decoherence in quantum information processing with many qubits. As an example we consider cold atoms trapped in an optical cavity. This is a promising technology for quantum computing and provides an ideal model for theoretical studies. Each qubit is obtained from two different ground states of one atom. To implement a two qubit gate, the corresponding atoms are moved into the optical resonator where both see the same atom-cavity coupling g. The key sources of decoherence are dissipation of cavity excitation with rate κ and spontaneous decay from excited atomic levels with rate Γ.

In recent years many schemes have been proposed for entangled state preparation and two qubit gates using atoms in optical cavities. Since it is difficult to construct a system of high quality optical cavities, proximity to the so- called *bad-cavity limit*, where the atom-cavity coupling constant is about the same size as the spontaneous decay rates,

$$g \sim \Gamma \sim \kappa \ ,$$

provides an experimentally sound basis for comparison. Several other criteria may be identified for practicality and scalability. A scheme should be simple and relatively insensitive to the precise values of the system parameters. Operations must be reliable with a fidelity close to one. The success probability for each run of the scheme can be significantly less than one as long as errors are detected and the operation is repeated as necessary.

Intuition suggests that decoherence is always damaging for quantum computation. On the contrary, we show here that dissipation can be exploited to achieve coherent control of open quantum systems with high fidelity and success rate. To do so we review the idea of *quantum computing using dissipation* and compare a quantum computing scheme based on this idea with a scheme based on *dissipation-assisted adiabatic passages*. It is shown that dissipation can stabilise the time evolution of an open quantum system. Under special circumstances, dissipation can speed up gate operations that can only be performed much slower in the absence of spontaneous decay rates.

As concrete examples we consider schemes for the realisation of a CNOT gate, a controlled PHASE and a two qubit SWAP gate which can be executed in one step by applying simultaneous laser fields. The schemes are independent of the precise value of the atom-cavity coupling constant. They perform well compared to competing proposals while being simpler and less sensitive to parameter fluctuations.

[1] A. Beige, H. Cable, and P. L. Knight, *Dissipation-assisted quantum computation in atom-cavity systems*, quant-ph/0303151.