Proposals for Quantum Logic Operations with "Hot" Ions

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Individual or multiple ions can be confined in a radio-frequency Paul trap and using sophisticated laser techniques cooled to the quantum mechanical ground state. Such systems allow experimental preparation and measurement of non-classical motion states of the ions, and important technological applications for such systems, such as the practical implementation of quantum computation, have recently attracted considerable attention [1,2]. Quantum information can be stored in the internal quantum states of the ions (which constitute the quantum bits, or "qubits" of the computer), and, using ultra narrow bandwidth lasers, quantum gate operations can be realized between pairs of qubits using quantum states of the collective motion of the ions in the harmonic confining potential as a quantum information bus. If this bus were to become degraded by heating, information would be lost, and so it is of great importance to maintain the ions in their motional ground state as long as possible. Of the many practical roadblocks standing in the way of success in realization of an ion trap quantum computer, one of the most important is the very fragile nature of this motional ground state, due to interactions with various ambient electromagnetic fields.

In this presentation I will give a theoretical description of the heating of ions due to "stray" electromagnetic fields, and review various methods that have been proposed to circumvent this problem. Poyatos *et al.* [3] have proposed an ingenous method using non-harmonic trapping potentials which unfortunately does not appear to be useful for more than two ions. King *et al.* [4] and independently James [5] have pointed out that the higher order modes of ion oscillation (i.e. modes other than the center of mass mode) have much longer heating times, and might therefore be employed as a reliable qunatum bus. Further investigations using carefully tuned values of the Lamb-Dicke parameter which avoid the problem of heating are also under consideration [6].

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[4] B. E. King *et al.*, "Initializing the collective motion of trapped ions for quantum logic", quant-ph/9803023.
[5] D. F. V. James, "The theory of heating of the quantum ground state of trapped ions", quant-ph/9804048.
[6] S. Schneider and D. F. V. James, "Quantum computation with hot ions", in preparation, 1998.