Production of entanglement in Raman three-level systems using feedback

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The production and manipulation of entangled states has been a major feature of quantum information research in the last several years. The efforts in this direction were rewarded with extraordinary experimental advances that led to the realisation of entangled states in a variety of physical systems, including entanglement involving multiple particles and long-lived entangled states. A promising approach to deal with the problem of decoherence is the use of active quantum feedback control. In fact, quantum feedback has been recently proposed and used to improve entanglement production and stability in both continuous and discrete variable systems.

Recent work by Carvalho and Hope [1] has uncovered a direct feedback scheme that, under an appropriate detection strategy leads, to the production of highly entangled states of two atoms or ions in a cavity. Motivated by the perspective of experimental implementations, and the possibility of improving the proposed scheme even further, we analysed the use of Raman transitions in place of the optical dipole transitions to reduce the rate of decoherence due to spontaneous emission. We also characterised the decoherence effect of other imperfections; delocalisation of the trapped ions, and inefficiency in the detection apparatus.

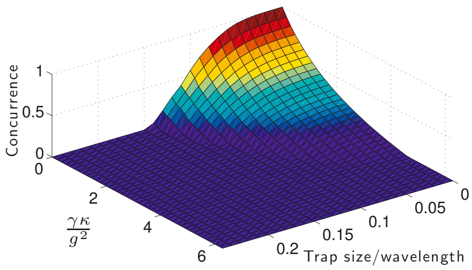

Fig. 1: Steady state concurrence of the two atom system as a function of the ion delocalisation and the spontaneous emission rate. The x axis is a measure of the standard deviation of the particles as a fraction of the cavity mode wavelength λ. The y axis is the total spontaneous emission γ rate as a fraction of g. The z axis is the steady state concurrence. The detector efficiency is 50%.

We found that, although the Raman transitions slow down the decoherence, they also slow down the feedback process, and these two effects cancel out. While this doesn't help with reducing the effect of decoherence it does help with some practical implementation issues. The use of Raman transitions slows down all important rates in the system, which means that the rate at which feedback pulses need to be applied is reduced.

We also found that a reduced efficiency detector greatly reduces the range of the other parameters (ion localisation and spontaneous emission rate) that allow a highly entangled state to be produced, though the allowable parameters are reasonably within modern experimental capabilities.

The manuscript describing these results is currently in the production stage at Eur. Phys. J. D, and can be found in [2].

References

[1] A. R. R. Carvalho and J. J. Hope, (2007) "Stabilizing entanglement by quantum-jump-based feedback" Physical Review A 76 010301.

[2] R. N. Stevenson, A. R. R. Carvalho and J. J. Hope, (2009) "Production of entanglement in Raman three-level systems using feedback" arXiv:1001.1567v1 [quant-ph].