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Visit to Dortmund where an experiment aimed at demonstrating partial entanglement between rare-earth-ions in an inorganic crystal was performed in Prof. Dieter Suters laboratory using their 50 kHz line-width dye laser system.

Project responsible: Stefan Kröll, Lund Institute of Technology (LTH)

Within the EU FET ESQUIRE project (Experimental realisation of quantum gates and development of Scalable QUantum computer schemes In Rare-Earth-ion-doped inorganic crystals) a critical issue is to make one qubit control another qubit. The quantum computing (QC) scheme in the ESQUIRE project is an ensemble-based QC scheme where each qubit consists of an ensemble of rare earth ions. The different qubits are distinguished by the optical absorption frequency of the ions in the qubits. The qubits can be coupled through dipole-dipole interactions. We have observed that the absorption frequency of the rare earth ions in a qubit shifts when other ions in the crystal are excited. However if, *e.g.*, a C-NOT operation should work it is necessary to distil our present qubits. Distilling the qubits in this case means that ions in the target qubit that only experience a small frequency shift when the control bit is excited must be removed and only ions experiencing a large shift should be left in the target qubit.

The visit in Dortmund was very fruitful. An uptime of the laser system of essentially 100% (!) assured that the efforts could be fully focussed on the data collection. The following measurements were carried out during the visit in Dortmund.

1. Optical pumping between hyperfine levels was used to successfully prepare a spectrally isolated ion group in a selected hyperfine state.

2. Coherent laser pulses were applied to such prepared ion groups demonstrating Rabi oscillation between the ground state and an electronically excited state.

3. Chirped hyperbolic secant pulses designed for robust adiabatic transfer between the ion states [1, 2] were applied to the prepared ion groups to demonstrate adiabatic state-to-state transfer. These experiments were only partly successful. We believe that insufficient control of phase and amplitude of the acousto-optic modulators that generated the hyperbolic secant pulses in part caused this.

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4. Distillation of qubits was performed using optical pumping as planned. Approximately 10% of the weakly interacting ions in the qubits could be removed which was less than we had hoped for. To improve this result we either have to improve our control of the spatial beam profile so that all ions that we detect sees the same excitation pulse area, or to develop more efficient techniques for adiabatic transfer between the ionic states.

It is in our opinion clear that partial entanglement was achieved in these experiments and we aim to improve these results in further visits to the laboratory in Dortmund.

References

1 "*Theoretical investigation of robust quantum computing in rare-earth-ion doped crystals*", MSc Thesis, Ingela Roos, Lund Reports on Atomic Physics, **LRAP-298**, Department of Physics, LTH, Lund (2003).

2 I. Roos and K. Mølmer, *Robust quantum computing with composite pulses and coherent population trapping*, http://arxiv.org/abs/quant-ph/0305060.