Cerium ions as a quantum state probe for rare earth quantum computing

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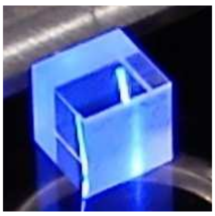
Experimental quantum information science deals with the difficult task of accurately controlling quantum mechanical systems, with the aim to use the extraordinary properties of such systems in future technology.

Rare earth ions that are doped into an optical crystal have very long coherence times, which enables them to be in a superposition state during a large number of logical operations. They interact with each other in a controllable way via their permanent electric dipole moment and this interaction makes it possible to create entanglement between qubits.

Our current project aims at a scalable quantum computing approach, where each qubit is represented by a single rare earth ion [1]. Cerium is added to the crystal as a local probe to enable read out of the state of a qubit ion (0 or 1) by observing fluorescence from a single cerium ion. The change in permanent electric dipole moment when selectively exciting a nearby qubit from either state 1 or 0 (arrow x) can shift the cerium ion out of resonance with the laser (arrow y) and stop the fluorescence (arrow z), hence giving information of which state the qubit ion was in. In this work the relevant properties of cerium doped into a Y_2SiO_5-crystal were measured and the progress towards a scalable rare earth quantum computer will be presented [2].

a)



b)

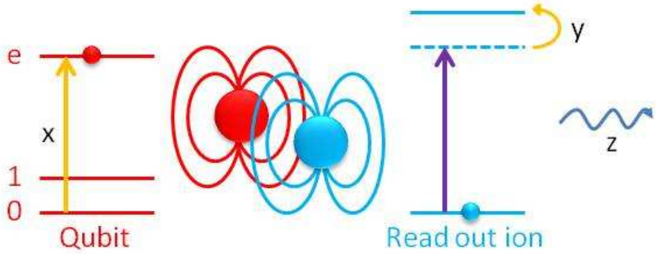


Figure: a) Fluorescence from a cerium doped Y_2SiO_5-crystal b) Conceptual image of the read out procedure. For an explanation, see the text above.

References:
[1] A. Walther, B. Julsgaard, L. Rippe, Y. Yan, S. Kröll, R. Fisher and S. Glaser, Phys. Scr. T137, 014009 (2009).
[2] Y. Yan, J. Karlsson, L. Rippe, A. Walther, D. Serrano, D. Lindgren, M-E. Pistol, S. Kröll, P. Goldner, L. Zheng and J. Xu, arXiv:1303.0877 (2013).