Time-resolved photoionization detection of a single Er^{3+} ion in silicon

G. Hu[a], G.G. de Boo[a], B.C. Johnson[b], J.C. McCallum[b], M.J. Sellars[c], C. Yin[a] and S. Rogge[a]

[a] *Centre of Excellence for Quantum Computation and Communication Technology, University of New South Wales, Sydney, New South Wales 2052, Australia*

[b] *Centre of Excellence for Quantum Computation and Communication Technology, University of Melbourne, Parkville, Victoria 3010, Australia*

[c] *Centre of Excellence for Quantum Computation and Communication Technology, Research School of Physics and Engineering, Australian National University, Canberra, Australian Capital Territory 0200, Australia*

The optical detection of individual rare-earth ions inside solid hosts is challenging because of their long radiative lifetime resulting in weak luminescence. An alternative to detecting the photons emitted by an ion is to detect a local change in charge induced by the optical excitation of the ion. This could enable faster detection of the excitation and single-shot read-out of the spin state if the optical transition is spin-selective.

In this paper, we investigate the charge signal that results from optically exciting a single erbium ion in a silicon FinFET [1]. The current through the FinFET is used to detect a discrete charge signal following the resonant excitation of an erbium ion. We find that the duration that it persists depends on the gate voltage of the FinFET. We also find that the charge signal can be turned off with a light pulse and study the dependence of this process on the intensity and duration of the pulse. Similarly, we measure the probability of the charge signal appearing, following the resonant excitation of the ion with varying optical intensity and pulse length.

We study how quickly the charge signal appears after the excitation and find that this process is faster than can be determined within the measurement bandwidth. We estimate this has an upper bound of 23.7 μs, indicating that the non-radiative decay rate is much faster than the typical radiative decay rate of erbium in silicon.

[1] G. Hu, G. G. De Boo, B. C. Johnson, J. C. McCallum, M. J. Sellars, C. Yin and S. Rogge, *Nano Lett.* **22**, 396 (2022).