Progress on the fast photoionisation detection of a single Er^{3+} ion in Si

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Efficient detection of individual optical centres in solids is essential for applications in quantum information processing, sensing, and single-photon generation. For example, The nitrogen-vacancy (NV) centres in diamond enabled single-photon emission relies on strong and spin-dependent fluorescence. However, the pure optical readout method limits the readout fidelity and efficiency due to the photon collection efficiency and spin-flip error. The recent spin-to-charge conversion method for NV centres in diamond and divacancy centres in SiC provides a promising path towards deterministic readout. In these results, the final charge state readout is based on the fluorescence rate but could be greatly improved by adopting high-bandwidth deterministic electrical detection developed in quantum electronics.

Here, I will present our recent progress on efficient detection of single Er^{3+} ions in a Si nano-transistor, in two parts. The first part highlights fast photoionization of a single Er^{3+} ion using use radio-frequency (RF) reflectometry. The high bandwidth and sensitivity allow single-shot detection of the single trap ionisation with sub-100-ns time resolution. With this technique, the optically excited state lifetime of a single Er ion in the Si SET is measured for the first time to be 0.49±0.04 μs. Our experiment presents an efficient approach for detecting a charge state change induced by Er excitation and relaxation. This approach could be used for deterministic readout of other single optical centres in solids and is attractive for large scale integrated optical quantum systems thanks to the multi-channel RF reflectometry demonstrated with frequency multiplexing techniques.

The second part of the presentation focuses on the spectral broadening of a single Er^{3+} ion [1], as sufficiently narrow linewidths are required for potential quantum applications of the single ions. The ionisation rate is found to be an appropriate quantity to represent the optical transition probability for spectroscopic studies, and the single ion spectra display a Lorentzian lineshape at all light intensities in use. In the low intensity regime, the linewidth remains nearly constant at 32±2 MHz. In the high intensity regime, the linewidth increases monotonically with the total intensity, independent of the resonant intensity or the Zeeman shift. The underlying mechanisms for the broadening are studied in additional experiments, and the results could be used to optimise the device design and to reduce the single ion linewidth.

[1] Jiliang Yang, et al., *arXiv*:2201.11472 (2022).