Optical homogeneous broadening and site identification of Er in Si

Alexey Lyasota[a], Ian R. Berkman[a], Gabriele G. de Boo[a], John G. Bartholomew[b,c], Brett C. Johnson[d,e], Jeffrey C. McCallum[d], Bin-Bin Xu[a], Shouyi Xie[a], Rose L. Ahlefeldt[f], Matthew J. Sellars[f], Chunming Yin[a,g], Sven Rogge[a]

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

[b]*Centre for Engineered Quantum Systems, School of Physics, The University of Sydney, Sydney, New South Wales 2006, Australia*

[c]*The University of Sydney Nano Institute, The University of Sydney, Sydney, New South Wales 2006, Australia*

[d]*Centre of Excellence for Quantum Computation and Communication Technology, School of Physics, University of Melbourne, Victoria 3010, Australia*

[e]*Centre of Excellence for Quantum Computation and Communication Technology, School of Engineering, RMIT University, Victoria 3001, Australia*

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

[g]*Hefei National Laboratory for Physical Sciences at the Microscale, CAS Key Laboratory of Microscale Magnetic Resonance and School of Physical Sciences, University of Science and Technology of China, Hefei 230026, China.*

Rare-earth ions in solid-state hosts exhibit low homogeneous broadening and long spin coherence at cryogenic temperatures thus making them a promising candidate for optical quantum memories and optical-microwave transductions. Here, we show optical properties of Er ensembles in Si accessed via resonant photoluminescence excitation (PLE). Samples were positioned directly on top of dedicatedly fabricated superconducting single photon detectors and resonantly excited using fiber optics. Investigated Si samples had different O doping levels and Er densities between 10^{16} to 10^{18} cm^{-3} implanted using ion beam. Spectral hole burning in samples with Er doping level of 10^{18} cm^{-3} showed a 350 kHz upper bound on homogeneous broadening and less than 400 MHz inhomogeneous linewidth. The power dependent spectral hole linewidth reveals an instantaneous spectral diffusion as the main broadening mechanism. PLE spectra strongly depended on the Er doping level and consisted of excitation spectra of only two sites at 10^{16} cm^{-3} Er doping density present in both nominally O free and 10^{17} cm^{-3} O doped samples. The measured lifetime of the electron spin in the ground state was as long as 30 seconds at a doping density of 10^{16} cm^{-3}, a magnetic field of 60 mT and a temperature of 20 mK. Long spin lifetimes allowed identifying the excitation spectra of different Er sites using bichromatic optical excitation. Narrow optical linewidths and long spin lifetimes show that Er in Si is an excellent candidate for future quantum information and communication applications.