Er sites in Si for quantum information processing

Alexey Lyasota[1], Ian R. Berkman[1], Gabriele G. de Boo[1], John G. Bartholomew[2,3], Shao Qi Lim[4], Brett C. Johnson[5], Jeffrey C. McCallum[4], Bin-Bin Xu[1], Shouyi Xie[1], Rose L. Ahlefeldt[6], Matthew J. Sellars[6], Chunming Yin[1,7], Sven Rogge[1]

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

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

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

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

[5]*School of Science, RMIT University, Victoria 3001, Australia*

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

[7]*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*

s.rogge@unsw.edu.au

Rare-earth ions in a solid-state host exhibit low homogeneous broadening and long spin coherence at cryogenic temperatures, making them promising for a range of quantum applications, such as optical quantum memories and optical-microwave transductions. Emitters with long electron spin and optical coherence in Si, a leading material platform for electronic and photonic technologies, are especially attractive for quantum applications.

Here, we report on the extension of instrument-limited millisecond spin coherence of Er in Si to 40 ms using CPMG-like sequences, homogeneous linewidths below 100 kHz and inhomogeneous broadening approaching 100 MHz. This is achieved in a nuclear spin-free silicon crystal (<0.01% ^{29}Si) doped at 10^{16} cm^{-3} Er level. The Er homogeneous linewidth and spin coherence were addressed using optical comb-based spectral hole burning and optically detected magnetic resonance techniques. To enhance Er emission collection efficiency, samples were directly positioned atop specially fabricated superconducting single photon detectors and resonantly excited via fibre optics. Measurements with naturally abundant Si revealed that the Er electron spin coupling to ^{29}Si nuclear spins significantly shortens Er spin coherence times. The demonstration of a long spin coherence time and narrow optical linewidth show that Er in ^{28}Si is an exceptional candidate for future quantum information and communication applications [1,2].

References

[1] Ian R. Berkman et al., Phys. Rev. Applied **19**, 014037 (2023)

[2] Ian R. Berkman et al., arXiv:2307.10021(2023)