Erbium sites in Silicon for Quantum Information Processing

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Rare-earth ions incorporated in several solid-state hosts were shown to exhibit low homogeneous broadening and long spin coherence at cryogenic temperatures making them a promising candidate for quantum applications, such as optical quantum memories, optical-microwave transductions, and quantum communication. However, long electron spin coherence has not been demonstrated in Si, a leading material platform for electronic and photonic applications. Here, we present the first demonstration of Er sites in semiconductor (Si) with a millisecond electron spin coherence time, optical homogeneous linewidths below 100 kHz, spin and optical inhomogeneous broadening approaching 100 kHz and 100 MHz, correspondingly. Er properties were measured using photoluminescence excitation spectroscopy within a nuclear spin-free silicon crystal (<0.01% ^{29}Si) doped at 10^{16} cm^{-3} Er level. Er homogeneous linewidth and spin coherence were addressed using optical comb-based spectral hole burning and optically detected magnetic resonance. To enhance Er emission collection efficiency, samples were directly positioned on top of dedicatedly fabricated superconducting single photon detectors and resonantly excited using fiber optics. Measurements in naturally abundant Si revealed that the Er electron spin coupling to ^{29}Si nuclear spins significantly shortens Er spin coherence times. Long spin coherence time and narrow optical linewidth show that Er in ^{28}Si is an excellent candidate for future quantum information and communication applications.

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