Er sites in Si for quantum information processing

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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 observation of eight Er sites in Si that have both long optical coherence and electron spin lifetime. We measured 1 ms spin coherence for two sites in a nuclear spin-free silicon crystal (<0.01% ^{29}Si), which appeared to be instrumentally limited. Using Alternating-Phase CPMG sequence, we extended the spin coherence of one of the sites to 40 ms. Measurements with naturally abundant Si revealed that the Er electron spin coherence was limited by coupling to ^{29}Si nuclear spins. The measured homogeneous linewidths of all 8 sites are below 100 kHz, and inhomogeneous broadening approaches 100 MHz [1, 2]. These results were achieved for Er implanted from 200 and 700 nm from ^{28}Si surface at 10^{16} cm^{-3} 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. The demonstration of a long spin coherence time and narrow optical linewidth in multiple sites show that Er in ^{28}Si is an exceptional candidate for future quantum information and communication applications and can be used for single photon frequency multiplexing schemes. Finally, integration into silicon on insulator nanophonic devices is discussed.

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