

Er:Si and SiC on insulator for quantum information processing

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Optically active spins in solid-state systems present significant potential for a range of quantum information science applications, including their use as entanglement distribution nodes within quantum networks, single-photon sources for linear optical quantum computing, and as platforms for cluster state quantum computation. Furthermore, the inherent optical connectivity of these systems enables the implementation of low-density parity check (LDPC) error correction codes. Among these platforms, erbium ions implanted in silicon and silicon carbide are particularly promising due to their superior optical and electron spin coherence characteristics, erbium's emission compatibility with the Telecom C band, and the advanced state of silicon nanofabrication technology. In this work, we report on erbium sites in silicon that simultaneously exhibit extended optical coherence and long electron spin lifetimes. Specifically, we observed spin coherence times of 1 ms in nuclear spin-free silicon crystals. The measured homogeneous linewidths were below 100 kHz, with inhomogeneous broadening approaching 100 MHz [1]. Spectral hole burning and optically detected magnetic resonance techniques were employed to examine both the homogeneous linewidth and spin coherence properties. The demonstration of long spin coherence times and narrow optical linewidths in multiple sites underscores the exceptional suitability of erbium in ²⁸Si for future quantum information and communication technologies, including single-photon frequency multiplexing schemes. Further discussions address the integration of these systems into silicon-on-insulator nanophotonic devices as well as thin-film 4H-SiC-on-insulator (SiCOI) devices. In silicon carbide, we observed an inhomogeneous broadening of 6.22 GHz and homogeneous linewidths as narrow as 440 kHz from a weak ensemble of emitters [2]. Site-selective spectroscopy identified that Er ions primarily occupy two distinct lattice sites in 4H-SiCOI. Additionally, we characterized the optical lifetimes and magneto-optical properties of these narrowband transitions. Collectively, these findings position Er-doped SiCOI as a highly promising solid-state platform for integrated, on-chip quantum information processing applications.

- [1] Berkman, I.R., Lyasota, A., de Boo, G.G. et al. Long optical and electron spin coherence times for erbium ions in silicon. npj Quantum Inf 11, 66 (2025). <https://doi.org/10.1038/s41534-025-01008-x>
- [2] Alexey Lyasota, Joshua Bader, Shao Qi Lim, Brett C. Johnson, Jeffrey McCallum⁴, Qing Li, Sven Rogge, Stefania Castelletto, in preparation

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