Seminar announcement

Tuesday, July 2, 2024
1:30 pm
WSI, Seminar room S 101
Exclusively in person

"Spectrally-multiplexed optical readout and coherent control of individual Erbium spins"

In spite of decade-long research into different physical systems, the demonstration of a scalable platform for quantum networks and distributed quantum information processing remains an outstanding challenge. In this context, our group investigates the use of erbium dopants in silicon and silicate crystals. This platform offers unique potential for up-scaling: First, erbium dopants can exhibit second-long coherence in a temperature range that is accessible with 4He cryocoolers [1]. Second, the optical transition of erbium is among the narrowest spectral features ever measured in a solid. Thus, frequency-multiplexed addressing of individual dopants [2,3] gives access to an unprecedented qubit density. Finally, by embedding the dopants into optical resonators with a high quality factor, the optical lifetime can be reduced via the Purcell effect [4,5]. This has enabled lifetime-limited photon emission [3] in the telecommunications C-band, where loss in optical fibers is minimal.

In a first line of research, we use a micron-scale Fabry-Perot resonator. By improving the integration of erbium via co-doping, we recently enhanced the qubit multiplexing and thus observe more than 360 spectrally resolved emitters with Purcell factors exceeding 35 [6]. We further combine this with long-lived nuclear spin memories with second-long coherence, which we can initialize, rotate and readout using optical fields. In a second line of research, we integrate erbium dopants into nanophotonic silicon structures to control their coupling to light [5]. We thus observe optical Rabi oscillations and single-photon emission with more than hundred-fold Purcell enhancement [7]. We recently implemented the optical readout of electronic spins [8], whose narrow optical spectral diffusion linewidth approaches the lifetime-limit of the best-coupled emitters. Taken together, our results thus establish individual erbium dopants as a promising new hardware platform that may facilitate the implementation of scalable quantum networks and repeaters based on single emitters at telecommunications wavelength.

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[2] S. Chen, M. Raha, C. M. Phenicie, S. Ourari, and J. D. Thompson, Parallel Single-Shot Measurement and Coherent Control of Solid-State Spins below the Diffraction Limit, Science 370, 592 (2020).

[3] A. Ulanowski, B. Merkel, and A. Reiserer, Spectral Multiplexing of Telecom Emitters with Stable Transition Frequency, Sci. Adv. 8, eabo4538 (2022).

[4] A. Reiserer, Colloquium: Cavity-Enhanced Quantum Network Nodes, Rev. Mod. Phys. 94, 041003 (2022).

[5] A. González-Tudela, A. Reiserer, J. J. García-Ripoll, and F. J. García-Vidal, Light–Matter Interactions in Quantum Nanophotonic Devices, Nat. Rev. Phys. 1 (2024).

[6] A. Ulanowski, J. Früh, F. Salamon, A. Holzäpfel, and A. Reiserer, Spectral Multiplexing of Rare-Earth Emitters in a Co-Doped Crystalline Membrane, Advanced Optical Materials 12, 2302897 (2024).

[7] A. Gritsch, A. Ulanowski, and A. Reiserer, Purcell Enhancement of Single-Photon Emitters in Silicon, Optica 10, 783 (2023).

[8] A. Gritsch, A. Ulanowski, J. Pforr, and A. Reiserer, Optical Single-Shot Readout of Spin Qubits in Silicon, arXiv:2405.05351.

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