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Fachbereich Physik, Universität Stuttgart
Max-Planck-Institut für Festkörperforschung
Max-Planck-Institut für Intelligente Systeme

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Entangling spins & photons for quantum technologies

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Abstract

Recent breakthroughs in quantum technologies are bringing us closer to harnessing the unique properties of spins and photons for applications in quantum computing and quantum networks. Central spin systems, such as semiconductor quantum dots and diamond-based color centers, provide platforms where highly coherent spins and efficient photonic interfaces can be realized, overcoming longstanding material science and quantum coherence challenges. In the realm of semiconductor quantum dots, advances in lattice-matched GaAs-AlGaAs devices have nearly eliminated strain inhomogeneity, extending the electronic spin coherence time beyond 100 microseconds—an improvement of almost two orders of magnitude. These enhanced coherence properties enable reversible quantum information transfer between the electron spin and a nuclear spin register, establishing quantum dots as robust platforms for quantum memory and multi-qubit registers. In parallel, group-IV color centers in diamond, such as the Tin-vacancy center, are proving to be exceptional hosts for spin-based quantum information. We demonstrate quantum control of the Tin qubit and achieve photon coherence benchmarks with Hong-Ou-Mandel visibility exceeding 85% in nanostructured devices. These advances highlight solutions to some of the most punishing material challenges, enabling the realization of highly coherent spin-photon systems.