Signatures of spin-optical phase entanglement generated by a spin-photon quantum-dot interface

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Semiconductor quantum-dot (QD) platforms have emerged as efficient, deterministic sources of photonic qubits, enabling information encoding across multiples degrees of freedom for quantum information processing (QIP). Under coherent excitation, neutral exciton QDs generate highly coherent superpositions of the vacuum and single-photon states, as evidenced by near-unity field interference visibility $\mathcal{V}$ between two consecutively emitted wavepackets [1]. Such vacuum—one-photon qubits constitute a compelling resource for long-distance quantum communication and gate-based quantum computing architectures. Additionally, semiconductor QDs can confine a single charge, providing access to an optically addressable host spin. Leveraging the optical selection rules of this spin-photon interface enables high-rate generation of polarization-encoded high-fidelity multipartite entangled states, positioning charged QDs as scalable resources for measurement-based quantum computing [2].

Combining these two capabilities, we demonstrate that coherent control of a charged exciton QD populations enables the emission of vacuum—one-photon qubits which internal phase carries information about the QD spin state at excitation. Comparing the relative phase between two photonic qubits emitted with a delay T, using a visibility $\mathcal{V}$ measurement, in an external magnetic field B (Voigt configuration), QD spin dynamics are observed with a measured fidelity F=95.8±2.1% [3] (**Fig. 1**). Notably, detection of vanishing visibilities signals the emission of vacuum—one-photon qubits which phases are entangled to the QD spin state, a novel type of entanglement opening pathways for multipartite entangled quantum states and perspectives for hybrid QIP architectures.

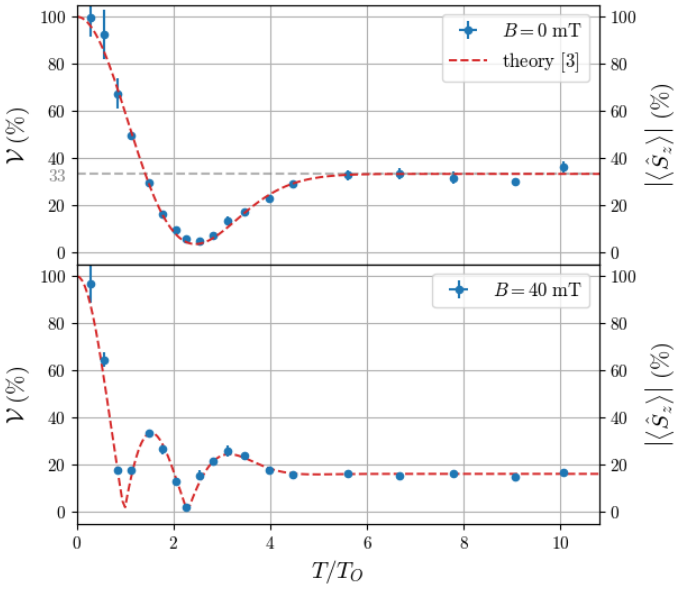

Fig. 1: *Interference visibility $\mathcal{V}$ measurement shows consistency with spin-driven dynamics described by the Merkulov model [3].*

References

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