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Quantum State Tomography of Spin Qubits

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Quantitative and accurate state tomography is becoming increasingly necessary to establish gate fidelities, entanglement measures, and optimize the increasingly complex gate sequences needed to perform experiments. In singlet-triplet spin qubits, to perform state tomography single-qubit rotations are used to map different axes of the Bloch sphere to the singlet-triplet axis, followed by projective measurement onto the singlet-triplet axis. The two nominally orthogonal rotations needed are provided by two physically distinct mechanisms: magnetic field gradients and exchange rotations. The complex interplay between these mechanisms, noise sources, and pulse distortions make it difficult to accurately predict the angle and axis of rotations from first principles, leading to a circular problem: how can one calibrate tomographic rotations without any calibrated tomography? We describe and experimentally demonstrate a method which, using minimal assumptions, makes it possible to detect and correct for both axis errors in tomography and losses during rotations associated with state tomography. Unlike conventional tomography tuning schemes, this technique is not iterative, allowing it be used to post-correct data with minimal overhead and effort. The technique is easily adaptable to other implementations of qubits, and should be of value wherever accurate tomography is needed but tuning up a complete set of ideal rotations is unnecessary. Finally, we will discuss the influence of non-Markovian noise on state tomography and possible approaches to circumvent state estimation errors arising thereof. Together these techniques allow us to perform state tomography with unprecedented precision in spin qubits.