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Partitioning dysprosium's electronic spin to reveal entanglement in non-classical states

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Quantum spins of mesoscopic size are a well-studied playground for engineering non-classical states. If the spin represents the collective state of an ensemble of qubits, its non-classical behavior is linked to entanglement between the qubits. In this talk, I will present an experimental study of entanglement in dysprosium's electronic spin. Its ground state, of angular momentum J = 8, can formally be viewed as a set of 2J qubits symmetric upon exchange. To access entanglement properties, we partition the spin by optically coupling it to an excited state J' = J − 1, which removes a pair of qubits in a state defined by the light polarization. Starting with the well-known W and squeezed states, we extract the concurrence of qubit pairs, which quantifies their non-classical character. We also directly demonstrate entanglement between the 14- and 2-qubit subsystems via an increase in entropy upon partition. In a complementary set of experiments, we probe decoherence of a state prepared in the excited level J' = J + 1 and interpret spontaneous emission as a loss of a qubit pair in a random state. This allows us to contrast the robustness of pairwise entanglement of the W state with the fragility of the coherence involved in a Schrödinger cat state. Our findings open up the possibility to engineer novel types of entangled atomic ensembles, in which entanglement occurs within each atom's electronic spin as well as between different atoms.

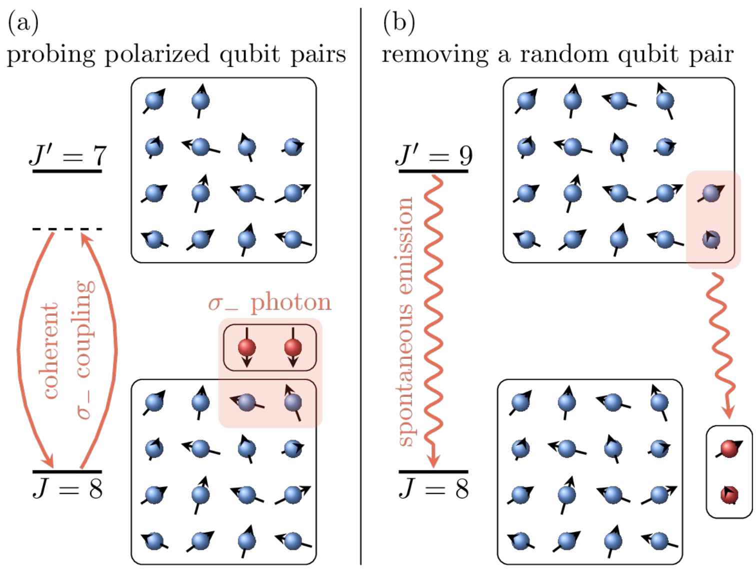

Figure 1 : Scheme of the experiments manipulating qubit pairs in the electronic spin of dysprosium. a) The coherent coupling to an excited state J' = J − 1 with σ − polarized light probes the probability to find a qubit pair polarized in ↑↑ along z . (b) The spontaneous emission from an excited state J' = J + 1 removes a random pair of qubits.