A sensitive electrometer based on a Rydberg atom in a Schrodinger-cat state

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The projection noise that is intrinsic to quantum measurement limit the precision of metrology experiment. In particular, metrology methods based on the measurement of small rotation of a large angular momentum are usually limited by the quantum fluctuations that constrain the precision with which one can determine the direction of the angular momentum. When the measurement is perfomed using classical states, like the coherent spin states, the precision cannot exceed the standard quantum limit (SQL), that scales like $1/J^{1/2}$. To beat the SQL, one need to implement a quantum method that make use of non-classical states.

In our experiment [1], instead of looking at the classical direction of the angular momentum, we prepare the system in a Schrodinger cat state and measure the quantum phase accumulated by the angular momentum during its rotation. Our system is a Rydberg atom with a large quantum principal number n = 51. Using a radio frequency field with a well-defined sigma + polarization, we restrict the evolution of the atom to a subspace of the Stark manifold where the system behaves like a large spin J = (n-1)/2. We have then used this effective spin to perform a quantum enabled measurement of the static electric field. We show that the achieved precision exceeds the SQL and approaches the fundamental Heisenberg limit (HL) in this context. The single-shot sensitivity reaches 1.2 mV/cm for a 100 ns interaction time, (30 microvolt/cm/$Hz^{1/2}$ at a 3 kHz repetition rate). This highly sensitive, non-invasive space- and time-resolved field measurement extends the realm of electrometric techniques and could have important applications.

[1] A. Facon, et al, "A sensitive electrometer based on a Rydberg atom in a Schrodinger-cat state", Nature 535, 262-265 (2016)