S3-3: Heisenberg limited Rabi spectroscopy

Authors: Ravid Shaniv, Tom Manovitz & Roee Ozeri

Affiliation of authors: Physics of complex system department, The Weizmann Institute, Rehovot, Israel

Speaker: Ravid Shaniv

Speaker email: ravid.shaniv(at)weizmann.ac.il

Abstract: The most precise clocks in the world measure time by performing spectroscopy on narrow dipole-forbidden optical atomic transitions [1]. Through the use of $N$ identical particles the uncertainty of the spectroscopic measurement can classically be decreased, scaling as $1/\sqrt{N}$. However, by quantum-mechanically entangling the particles, one can improve the uncertainty scaling to $1/N$, fundamentally limited by the Heisenberg energy-time uncertainty relation [2]. In this work we generate an entangling Ising $\sigma_x \sigma_x + \delta \Sigma \sigma_z$ Hamiltonian acting on two ion-qubits trapped in an effective harmonic trap. The Hamiltonian detuning $\delta$ is scanned through the transition resonance creating a correlated Rabi spectroscopy measurement. We observe a spectral peak which is twice as narrow as the one given in a single-ion spectroscopy, demonstrating the Heisenberg-limited nature of the measurement. This is the first demonstration of a Rabi-type Heisenberg-limited spectroscopy. Furthermore, we show that the Ising Hamiltonian acts independently on two separate subspaces of the two-ion system. We show that one subspace is susceptible to changes in the mean transition frequency between the ions while being invariant to changes in the difference between the ions’ frequency, and vice versa for the other subspace. Each of these subspaces can therefore be addressed and probed individually, with the Ising interaction providing a correlated spin-flip rotation term. Hence, we can perform Heisenberg-limited spectroscopy of the difference frequency in one subspace while remaining invariant to mean frequency noise and vice versa in the other sub-space.