Multi-qubit-enhanced phase estimation in one- and two-dimensional ion crystals with up to 91 particles

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Correlation spectroscopy of multi-qubit systems is a powerful technique to probe phase differences between qubits in the presence of correlated phase noise even if the probe times are significantly longer than the coherence time of the qubits [1]. The quantification of these phase differences, which are caused e.g. by different transition frequencies, is essential if the multi-qubit system is utilized for applications such as quantum computers, simulators or atomic clocks [2]. Here we show specific applications of correlation spectroscopy for linear chains with 51 ions and 2D planar crystals with up to 91 ions, which are trapped in a novel monolithic Paul trap (Fig.1 (a)). Among these applications are measurements of ion–ion distances to reconstruct trapping potentials, transition frequency differences due to Zeeman and quadrupole shifts or the sensing of magnetic field gradients. Furthermore, we quantify fluctuations of the laser-ion detuning via single-shot Ramsey measurements by analyzing multi-particle correlations. Employing the planar 91-ions crystals, we demonstrate that the information contained in the 91-particle correlations enhances the phase estimation by reducing its measurement uncertainty as compared to the case where only two-particle correlations are analyzed (Fig.1 (b)).

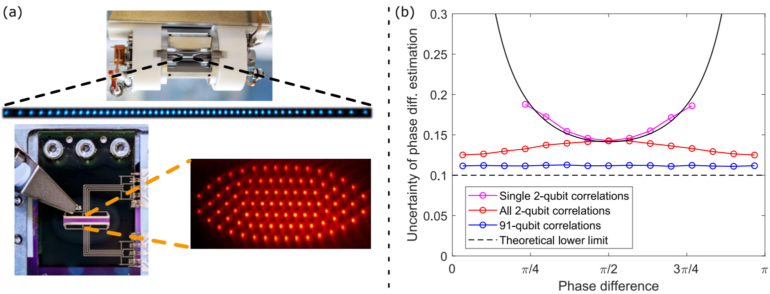

Fig. 1: (a) Our exp. platforms: a linear Paul trap to store 1D crystals with 51 ions and a monolithic Paul trap capable of trapping 2D crystals up to 91 ions. (b) Enhanced phase estimation via correlation spectroscopy with 91-particle correlations.

References

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