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Non-destructive characterization of phonon number states using the Autler-Townes effect and using composite pulse sequence

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Quantum technologies employing trapped ion qubits commonly rely on the motional state of the ion. Motional states can not only be used for entanglement operations but also for example to store quantum information or can act as a tool for logic spectroscopy. Hence, a precise knowledge about the motional state of the ion is often required.

In this work we present two novel methods to measure phonon number states in a non-destructive manner. We demonstrate both techniques using a single trapped $^{88}Sr^{+}$ ion.

The first method relies on the Autler-Townes effect that arises when two levels are strongly coupled while being probed from a third level. If the two levels are coupled on a motional sideband transition, then the magnitude of the Autler-Townes splitting depends on the phonon number state. This novel technique provides a robust and efficient way of measuring motional states of an ion. It can even be applied to perform single shot measurements of phonon number states in a non-destructive way.

The second method uses an ultra-narrowband composite pulse sequence for efficient detection of the ions' motional state. It is based on a pulse sequence with optimized relative phases forming a narrow excitation profile. We characterize this technique for multiple pulse sets. This technique can even be used outside the Lamb-Dicke regime, making it a versatile tool for phonon characterization.

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