Carrier-Resolved Spectroscopy of the Strontium Clock Transition in Programmable Tweezer Arrays

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Precision frequency measurements are key to testing fundamental physics and advanced timekeeping. Ensembles of neutral strontium atoms are a leading experimental platform for optical clocks, owing to the ultranarrow $^1S_0 \rightarrow {}^3P_0$ transition at 698 nm, which provides an exceptionally stable and accurate frequency reference.

In our experiment, ^{88}Sr atoms are prepared in a 2D tweezer array operated at 813 nm, the magic wavelength for the clock transition, with a spatial light modulator (SLM) used to produce arrays of arbitrary geometry. The array is loaded from a narrow-linewidth magneto-optical trap (nMOT) acting as a reservoir of cold atoms. To achieve scalable loading, we use a technique, termed 'painted loading', in which the nMOT detuning is swept to lower the MOT across the array.[1] With this method, we have demonstrated loading of up to 90 tweezer sites with atoms at temperatures of 1.49(3) µK while also enabling control over site occupancy and spatial distribution for spectroscopy on regions with different atom numbers within a single array.

We have performed site-resolved magnetically induced spectroscopy. The observed spectra exhibit both radial and axial motional sidebands, which broaden the transition and suppress coherent Rabi dynamics.

To suppress coupling between the clock transition and vibrational motion, we are implementing a probe geometry in which the excitation beam is oriented orthogonal to the principal axis of tweezer confinement. This is expected to suppress axial sidebands and enable carrier-dominated excitation with improved coherence and spectral resolution. Combined with precise control over atomic occupancy, this will allow systematic measurements of Rabi oscillations as a function of tweezer density, providing a controlled microscopic probe of excitation dynamics and coherence.

[1] M. J. Walker *et al.*, *Painted loading: a toolkit for loading spatially large optical tweezer arrays*, Quantum Sci. Technol. **11**, 015047 (2026).

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