

# Single Strontium atoms trapped in optical tweezer arrays for quantum simulation

Veronica Giardini,<sup>1,\*</sup> Andrea Fantini,<sup>1</sup> Shawn Storm,<sup>1</sup> Vladislav Gavryusev,<sup>1,2</sup> Jacopo Catani,<sup>3,2</sup> and Leonardo Fallani<sup>1,3,2</sup>

<sup>1</sup>*Department of Physics and Astronomy, University of Florence, via G. Sansone 1, 50019 Sesto Fiorentino, Italy*

<sup>2</sup>*European Laboratory for Non-Linear Spectroscopy (LENS), University of Florence, via N. Carrara 1, 50019 Sesto Fiorentino, Italy*

<sup>3</sup>*National Institute of Optics (CNR-INO), National Research Council, via N. Carrara 1, 50019 Sesto Fiorentino, Italy*

I present the realization of an experimental platform for quantum simulation based on individually trapped strontium atoms in optical tweezer arrays, combining laser cooling, optical control, and high-resolution imaging for the manipulation and high-fidelity detection of single atoms.

I developed and optimized a two-stage three-dimensional magneto-optical trap producing cold and dense samples of strontium atoms from a thermal beam. Atoms are captured and precooled on the dipole-allowed  $^1S_0 \rightarrow ^1P_1$  transition at 461 nm ( $\Gamma = 2\pi \times 32$  MHz), and subsequently further cooled and compressed using the narrow intercombination transition  $^1S_0 \rightarrow ^3P_1$  at 689 nm ( $\Gamma = 2\pi \times 7.5$  kHz), yielding temperatures around 5  $\mu$ K and densities above  $10^{10}$  cm<sup>-3</sup> suitable for loading into optical tweezers.

A  $3 \times 3$  array of 360  $\mu$ K deep optical tweezers is generated by spatially modulating an 813.4 nm laser beam using two crossed acousto-optic deflectors and then focused into the science chamber with a high-numerical-aperture objective, which also collects atomic fluorescence. The emitted light is imaged onto a scientific qCMOS camera, enabling site-resolved detection of individual atoms.

I optimized in-trap cooling to prevent atom loss during imaging and reduce residual motion. By tuning light-assisted collisions, multiple occupancies are removed and a single-atom regime is reached with a filling fraction of about 50%. A single-atom detection fidelity of 99,986(1)% and a survival probability of 97(2)% between subsequent images are achieved, while release-and-recapture measurements yield a temperature of 12.95(5)  $\mu$ K for the trapped atoms.

These results demonstrate a robust and high-fidelity platform for trapping and imaging single strontium atoms, providing the foundation for future quantum simulation experiments with alkaline-earth atoms excited to Rydberg states and scalable programmable arrays.

---

\* veronica.giardini@unifi.it; <https://www.unifi.it/it>