Towards Arrays of Cryogenic Traps for Improved Quantum Simulation

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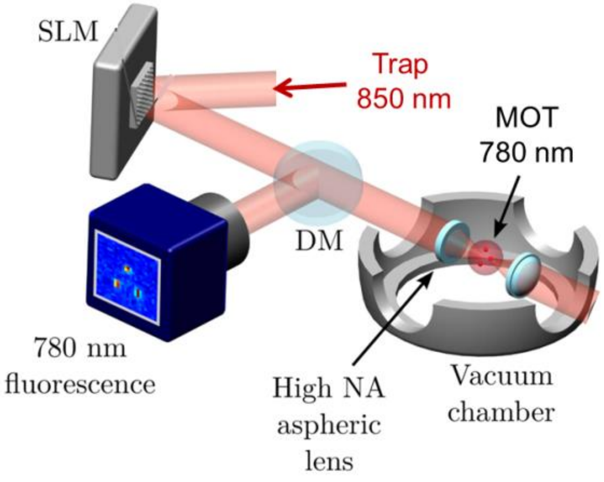
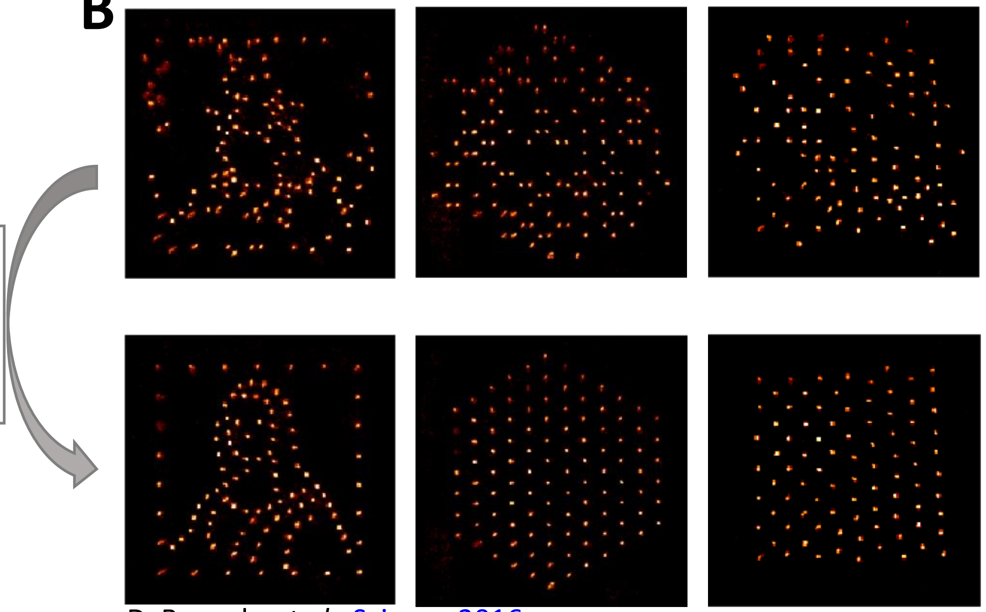
Arrays of single atoms

A



- ***Up to 200 atoms, spacing ~ 10 µm***
- ***Interactions: Rydberg states***
- ***Atom-by-atom sorting into ordered arrays with a moving tweezers:***
- ***Extension to 3D arrays***
- ***Now: cryogenic platform***

B



D. Barredo *et al.*, Science 2016

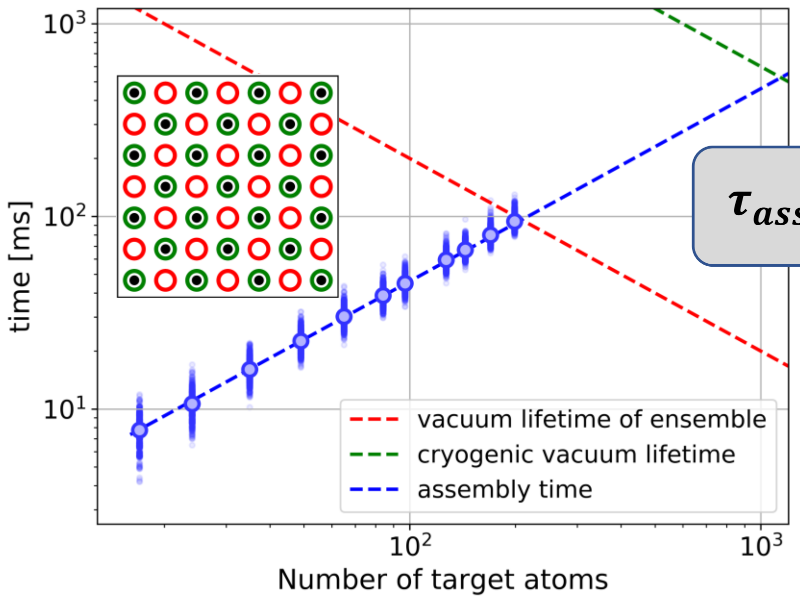
K. Schymik *et al.*, In preparation (2020)

Why Cryogenic ?

C

When scaling up the number of atoms N, the single-atom vacuum-limited lifetime τ is a limitation!

- ***Current room-temperature setup:*** $\tau \approx 20\ \mathrm{s}$
- ***Lifetime of N-atom array:*** $\tau_N = \tau/N$
- ***Assembly time of N-atom array:*** $\tau_{assembly} \propto N$

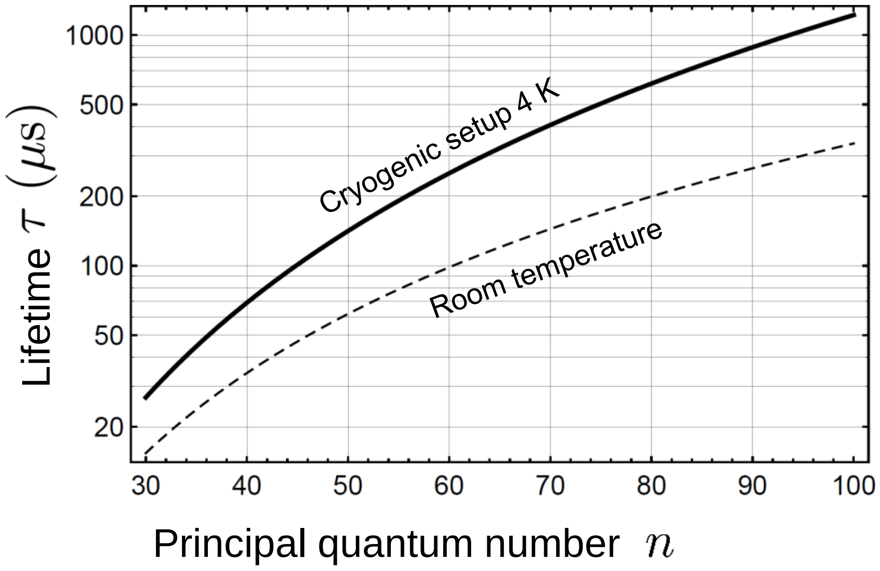


$\tau_{assembly} \ll \tau_N$!!

- ***Cryogenic lifetime*** $\tau_{cryo} \gg \tau$ ***due to better vacuum!***

D

Increased Rydberg lifetime

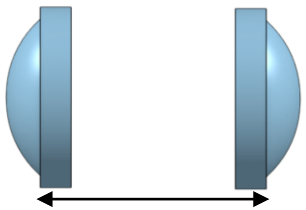


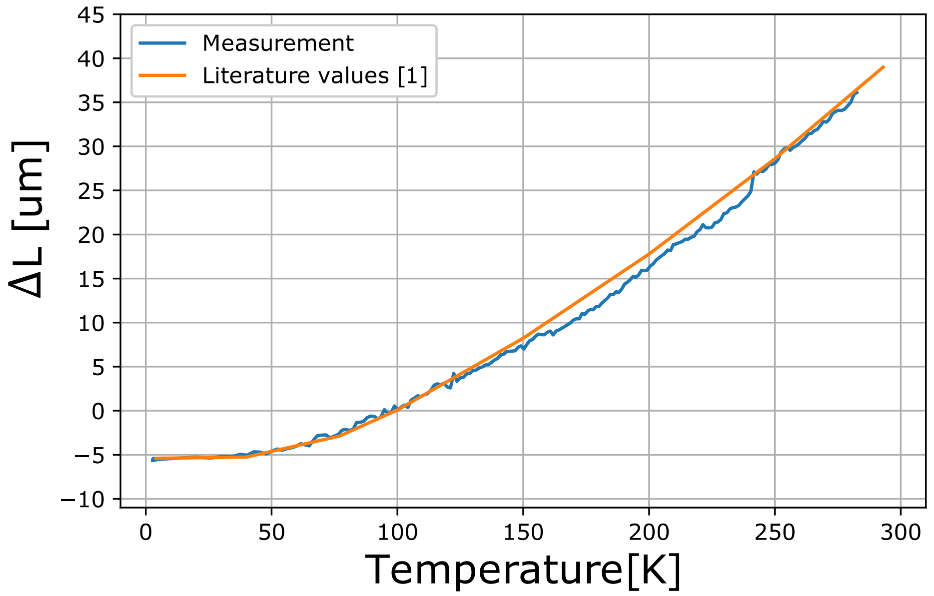
- ***Reduce black-body-induced transitions to neighboring states***
- ***Increased coherence for quantum simulation***

Technical Challenges

E Thermal contraction

- ***Stress-free mount of lenses***
- ***Compensation of 2-f configuration***

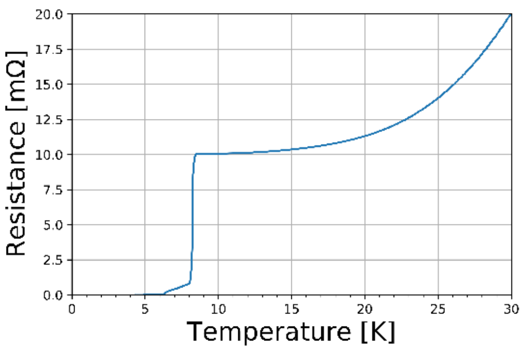




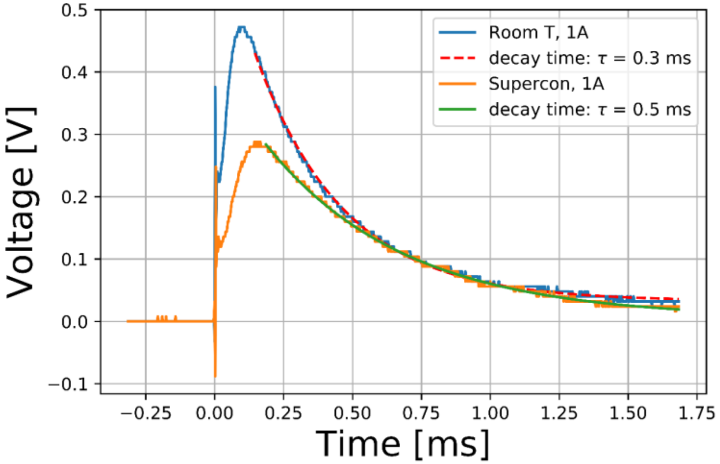
[1] R.J. Corruccini, J.J. Gniewek. *Thermal Expansion of Technical Solids at Low Temperatures.* National Bueau of Standards Monograph 29 (1961).

F Superconducting coils: No heat load!

- ***Transition temperature at 9 K***



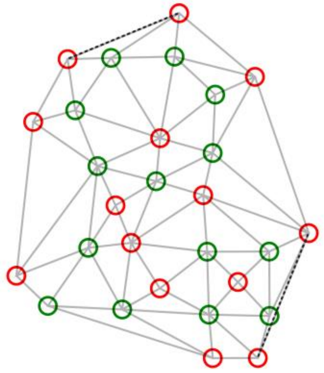
- ***Eddy currents decay ($\tau = 0.5$ ms)***
  - ***measurement with pick-up coil***



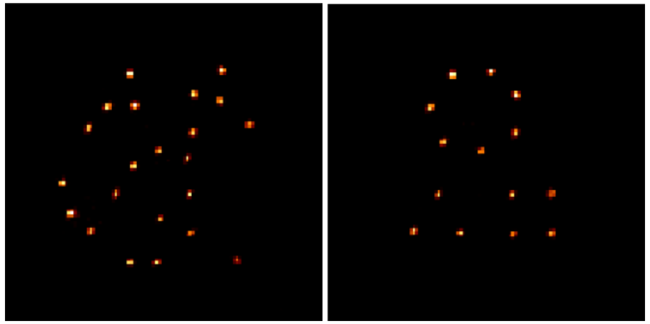
Improved Assembler

G Arbitrary patterns due to graph approach

- ***Change from Bravais lattice based algorithms***
- ***Interesting e.g. for:***
  - *crystal defects (dislocation, grain boundary, …)*
  - *disordered Arrays (e.g. Anderson localization studies)*
  - *Completely arbitrary arrays for combinatorial optimization problems (maximum independent set)*



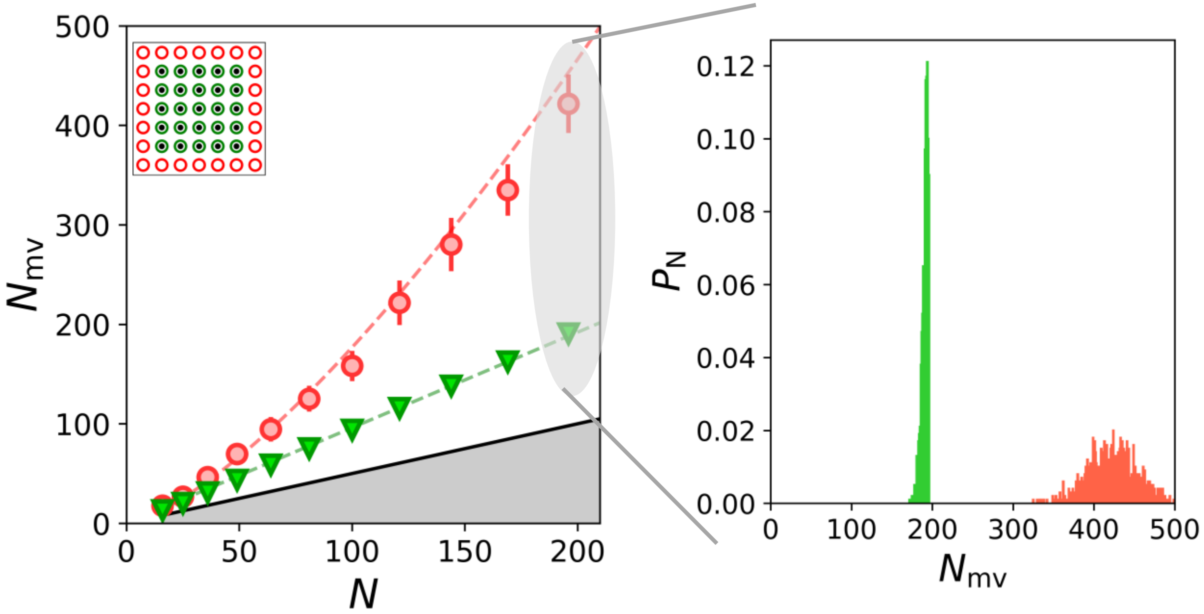
Red: reservoir traps
Green: target traps



Initial loading
Assembled Array

H *Improved algorithms*

- ***Goal: decrease number of elementary moves***
  - *Pick-up and release time dominant timescale*
- ***Best algorithm depends also on target structure***



K. Schymik *et al.*, In preparation (2020)