

# NISQy Business

## A Full Stack Quantum Computer for Near-Term Quantum Chemistry

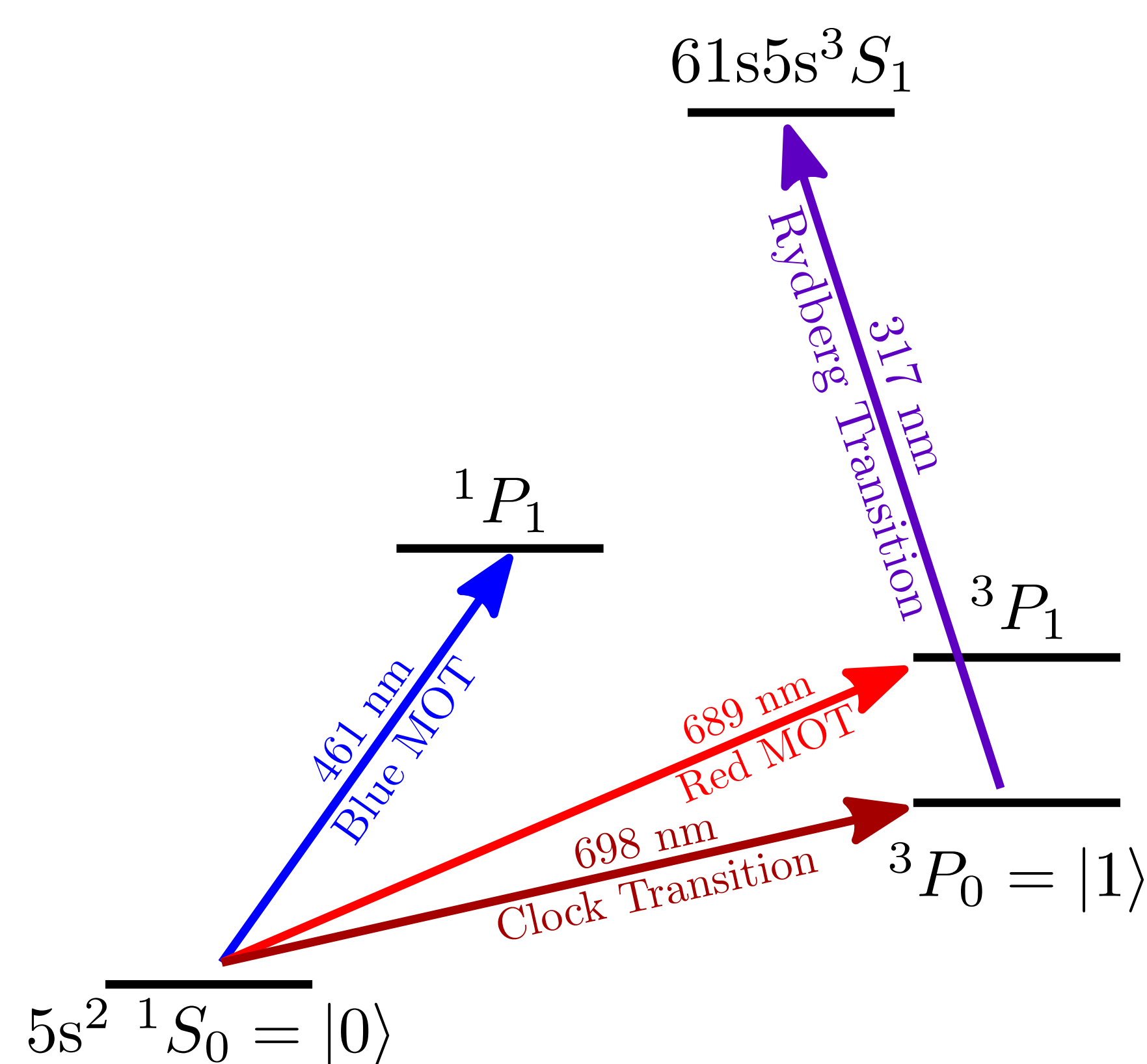
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At the Eindhoven University of Technology, in collaboration with the University of Amsterdam, we are constructing a full-stack, web-addressable neutral-atom digital quantum computer with applications in quantum chemistry. Our experiment will utilise Strontium atoms in a re-configurable optical tweezer array as our qubit register, with the ground and clock states of the Sr atoms acting as the qubit states. Entangling gates are mediated by long-range Rydberg interactions.

### The Problem

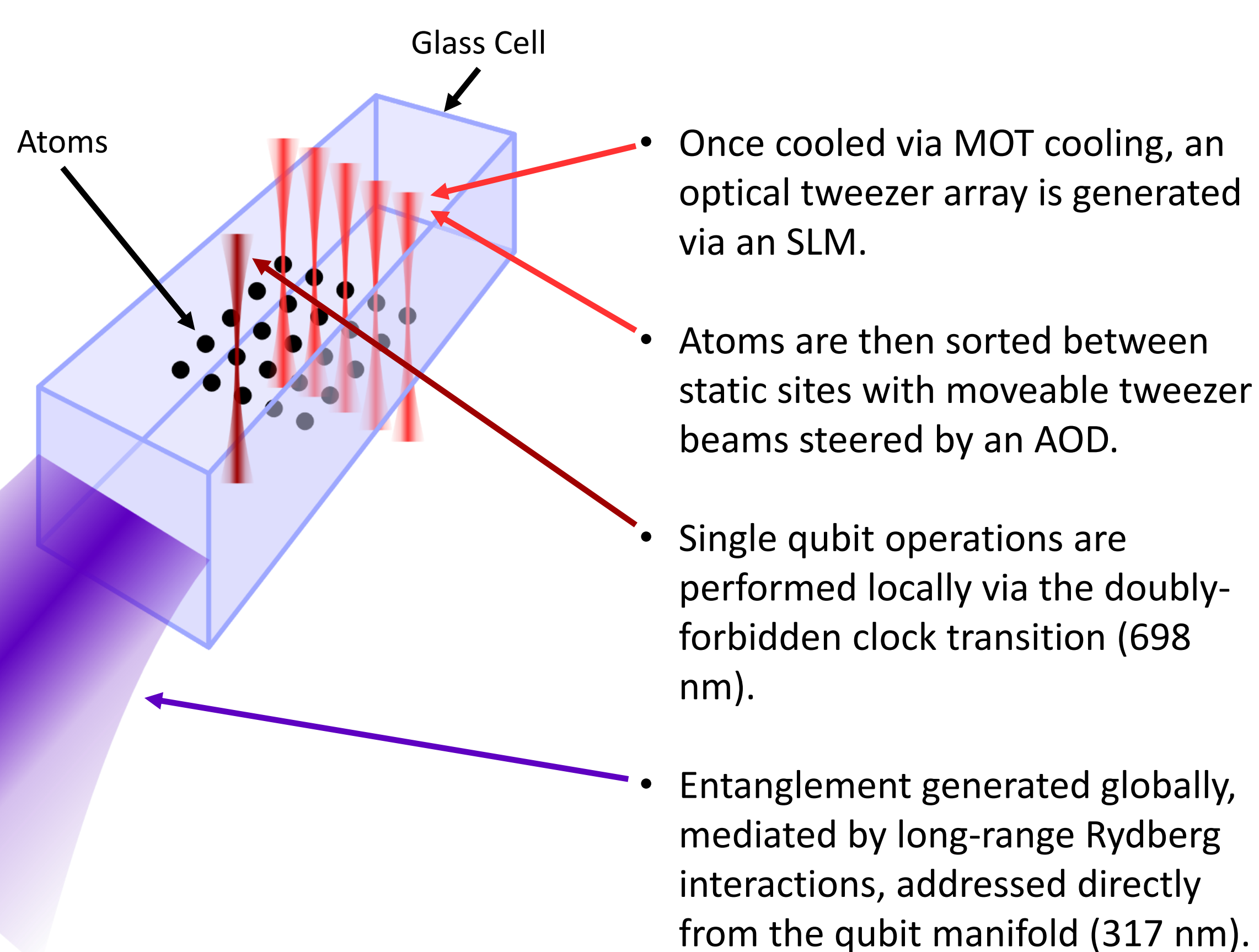
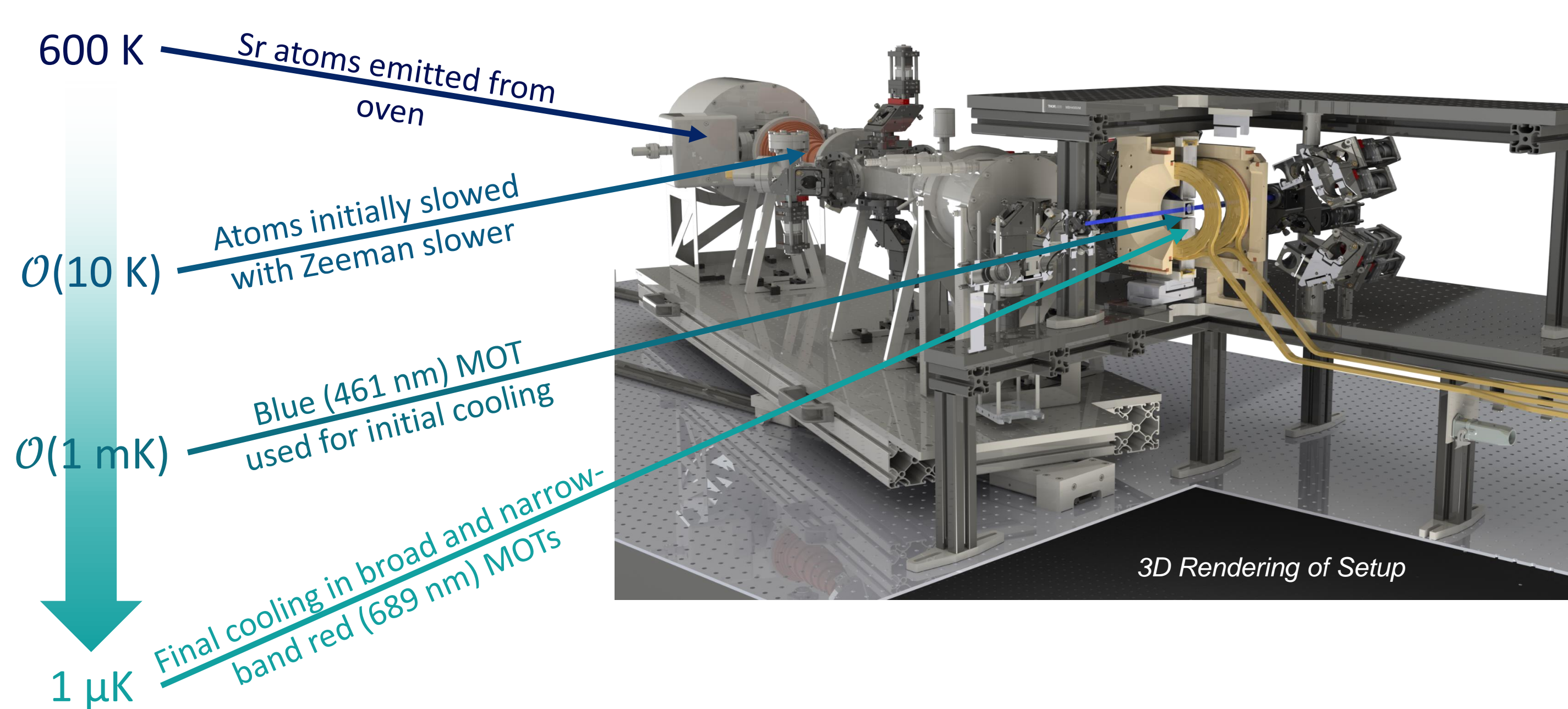
- Finding the exact form of the ground state energy (GSE) of molecules is a hugely computationally taxing problem [1].
- Classical computers have not been able to find the GSEs of molecules larger than a few atoms without making approximations to allow for simulation [2].
- This problem of finding the GSE of molecules has direct applications in drug discovery.
- By applying quantum methods to this problem, speedup of  $\mathcal{O}(p^{-1})$  for a precision in calculation  $p$  is possible in the *long term* [3]. But...
- Current quantum computers are limited to the Noisy Intermediate Scale Quantum (NISQ) regime with only few qubits and significant noise [4].
- The Variational Quantum Eigensolver (VQE) algorithm is designed for this regime, offsetting some computation to classical computers and is possible in the near-term, whilst still providing  $\mathcal{O}(p^{-2})$  scaling [1].

### The Qubits

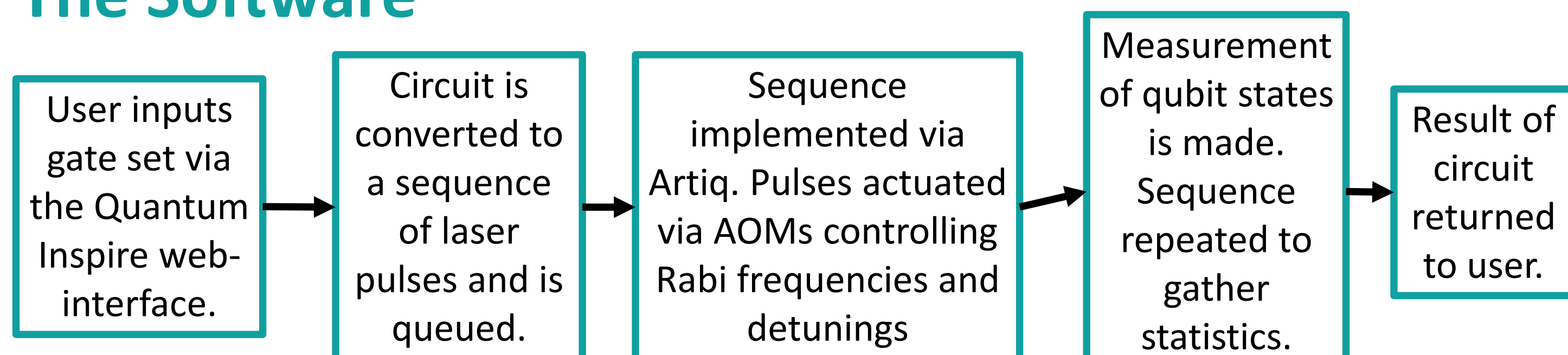


- Bosonic <sup>88</sup>Sr used.
- No hyperfine structure, simplifying setup.
- Dipole trapping light at 813nm provides equal trap depths for ground and clock state (known as a *magic wavelength*).
- Tunable, ultra-narrow 'clock' transition used to directly optically address qubits.
- Entangling operations mediated by long-range Rydberg interactions.

### The Hardware



### The Software



### Progress and Outlook

#### So Far

- Atoms cooled to target temperatures in red MOT.
- Atoms loaded into tweezers.
- Sorting algorithms being optimized on neighboring Rb setup.

#### Still To Do

- Parity projection of atoms in static tweezers.
- Sorting of atoms in Sr setup.
- Implement single qubit gates.
- Implement entangling gates.
- Web interface with Quantum Inspire.

#### References

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- [4] D. Bluvstein et al., *Logical Quantum Processor Based on Reconfigurable Atom Arrays*, *Nature* **626**, 58 (2023).

#### Affiliations

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#### ACKNOWLEDGEMENTS

This project is partially funded by the National Growth Fund through Quantum Delta NL  
 This project is partially funded by the European Union through the Horizon Europe programme HORIZON-CL4-2021-digital-emerging-01-03 via the project 10170144 (EuRyQa)