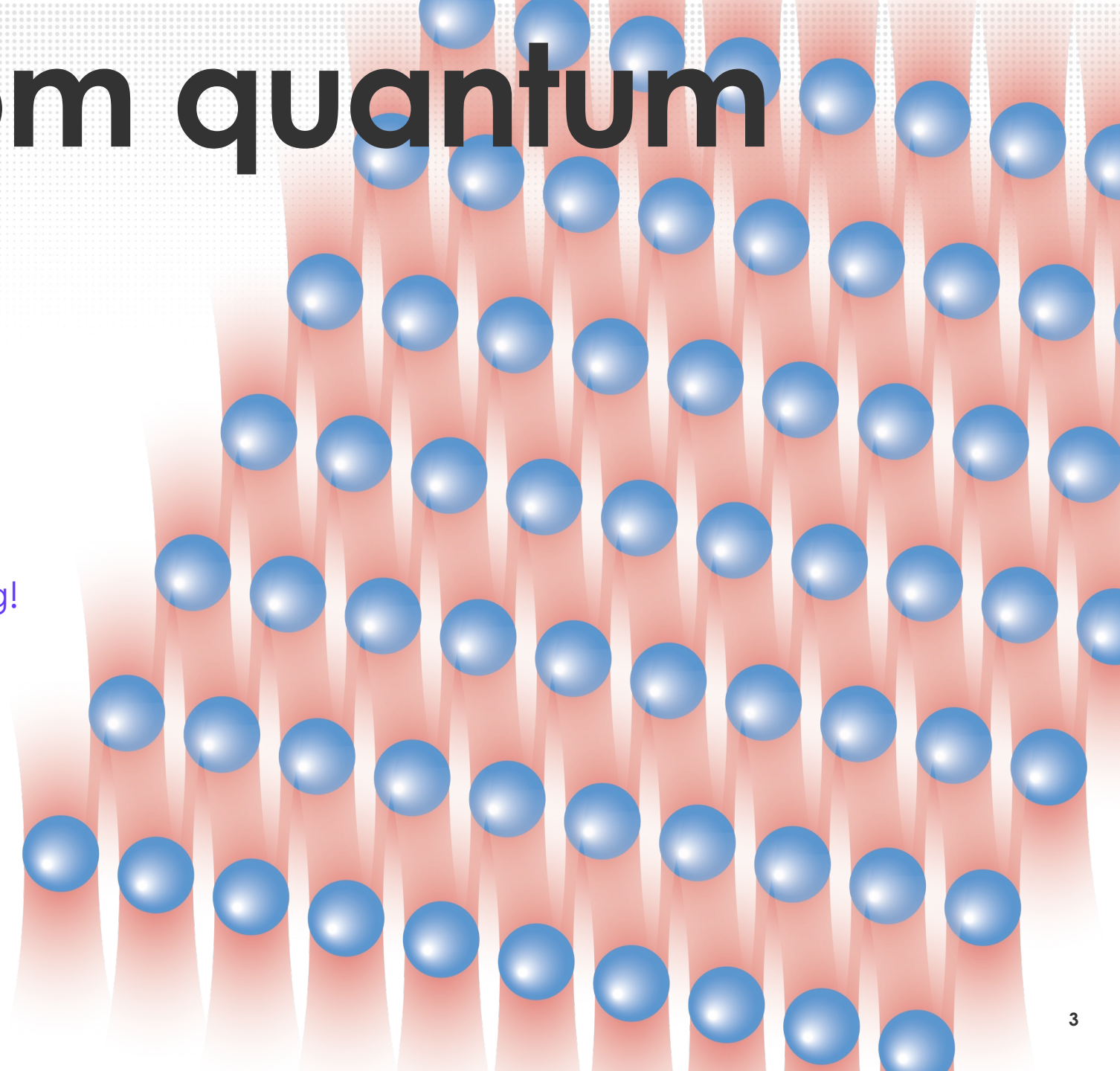
SESSION I: BASICS

|QuEra⟩

Neutral-atom quantum processor

- Densely packed qubits (atoms)
- Efficient qubit control
- Flexible problem encoding
- New ways to think quantum computing!

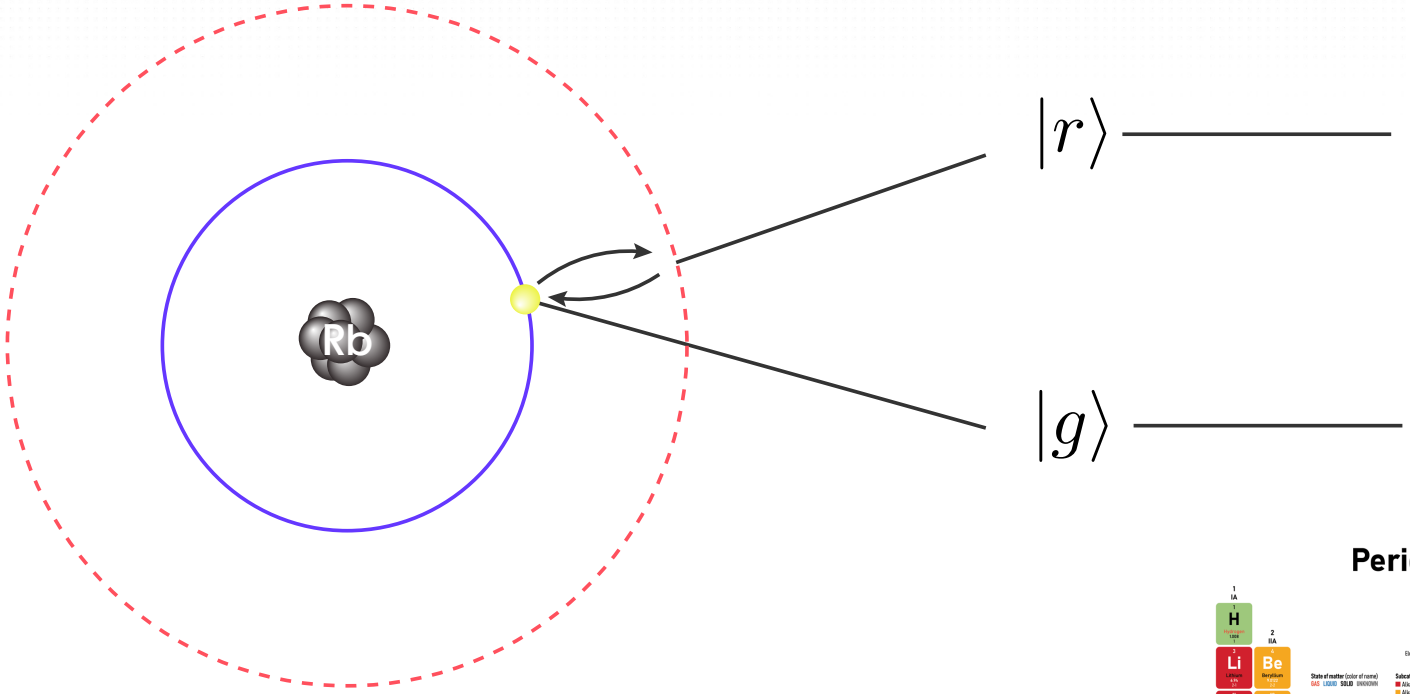


Learning objectives

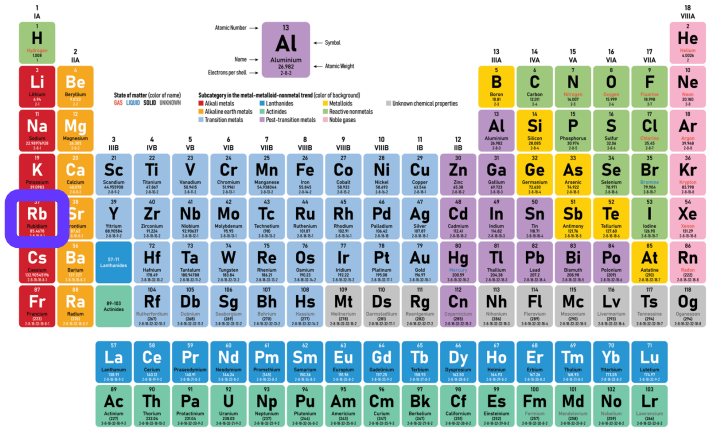
By the end of the session, you will be able to:

- **Explain** how **neutral atoms** can be used as a **platform** for quantum computing
- **Distinguish analog** and **digital** (gate-based) quantum computing
- **Define field-programmable qubit arrays** and **exemplify** some of their **advantages**
- **Describe** Aquila's **programming** range
  - its Hamiltonian and controllable parameters, limitations of service

Qubits by puffing atoms

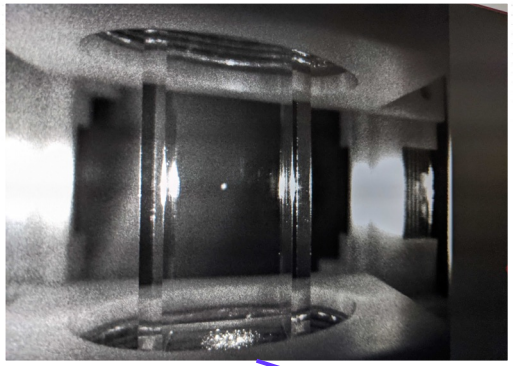


Periodic Table of the Elements



The routine

Load MOT in 20-40ms



Load 60% of traps

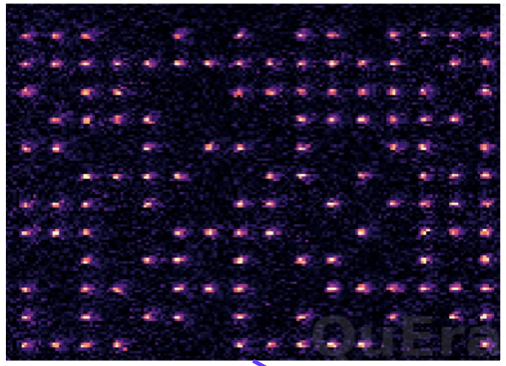
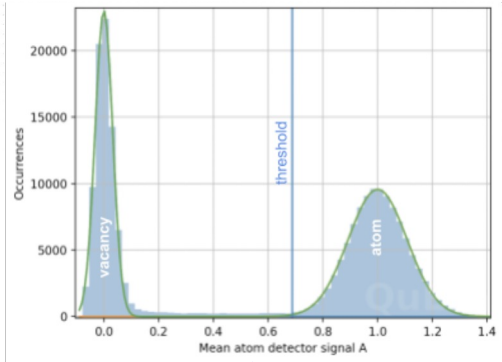
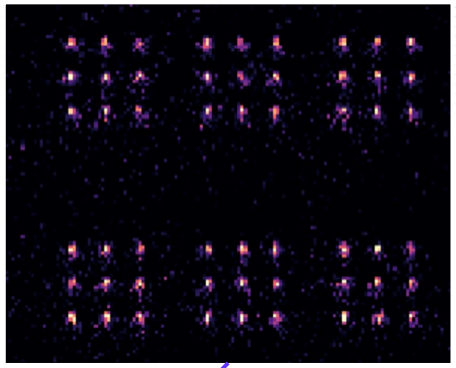


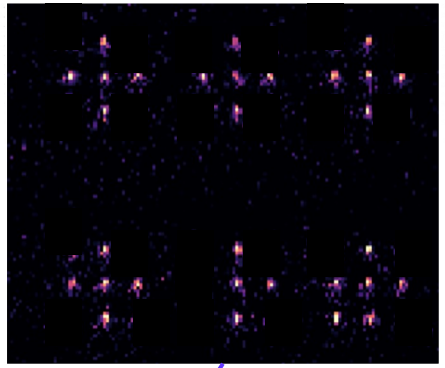
Image in 5ms

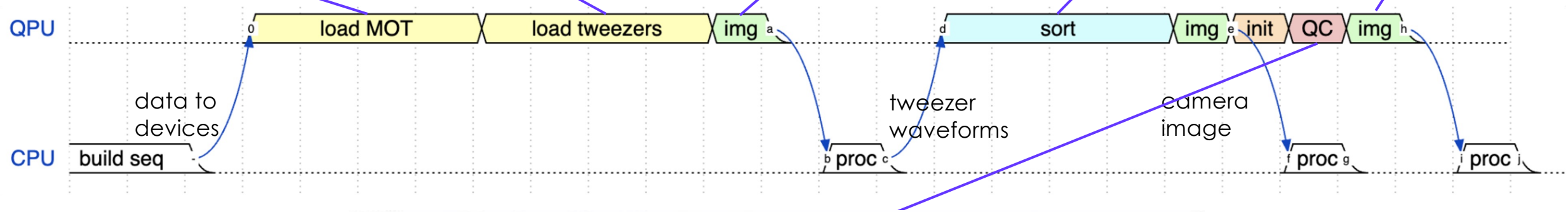


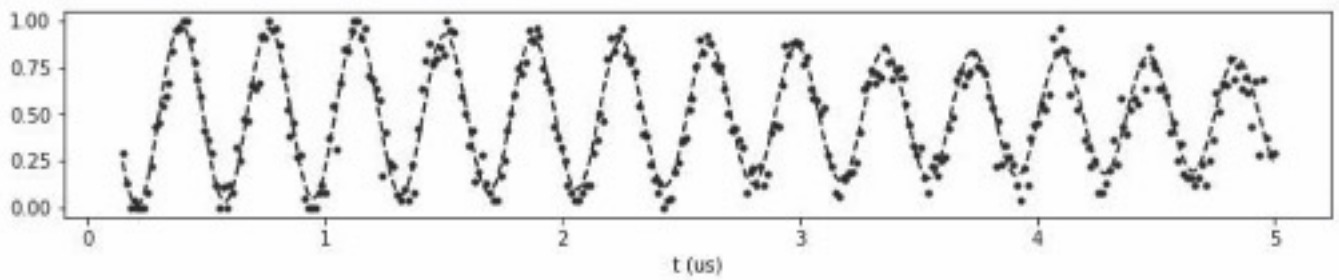
Sorting in ~30 ms



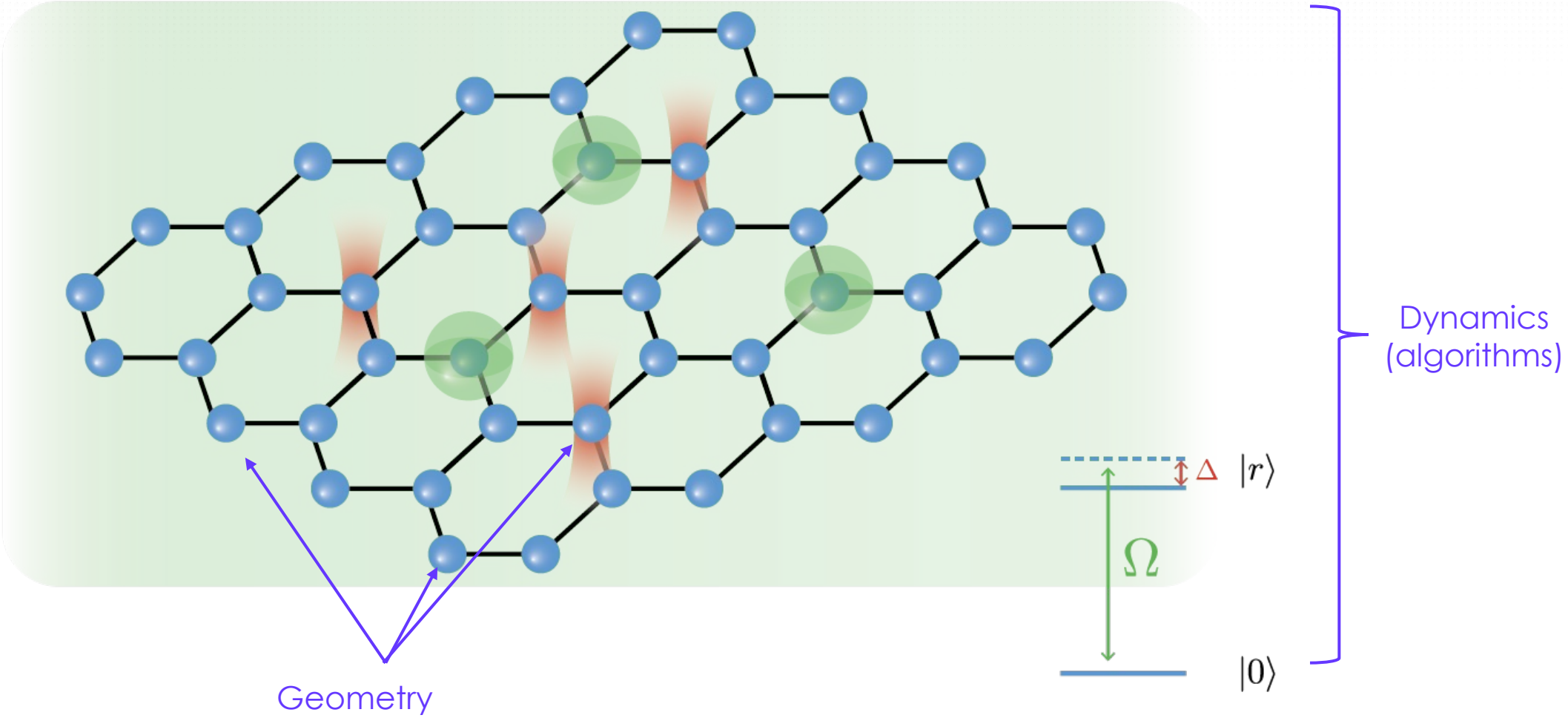
Results



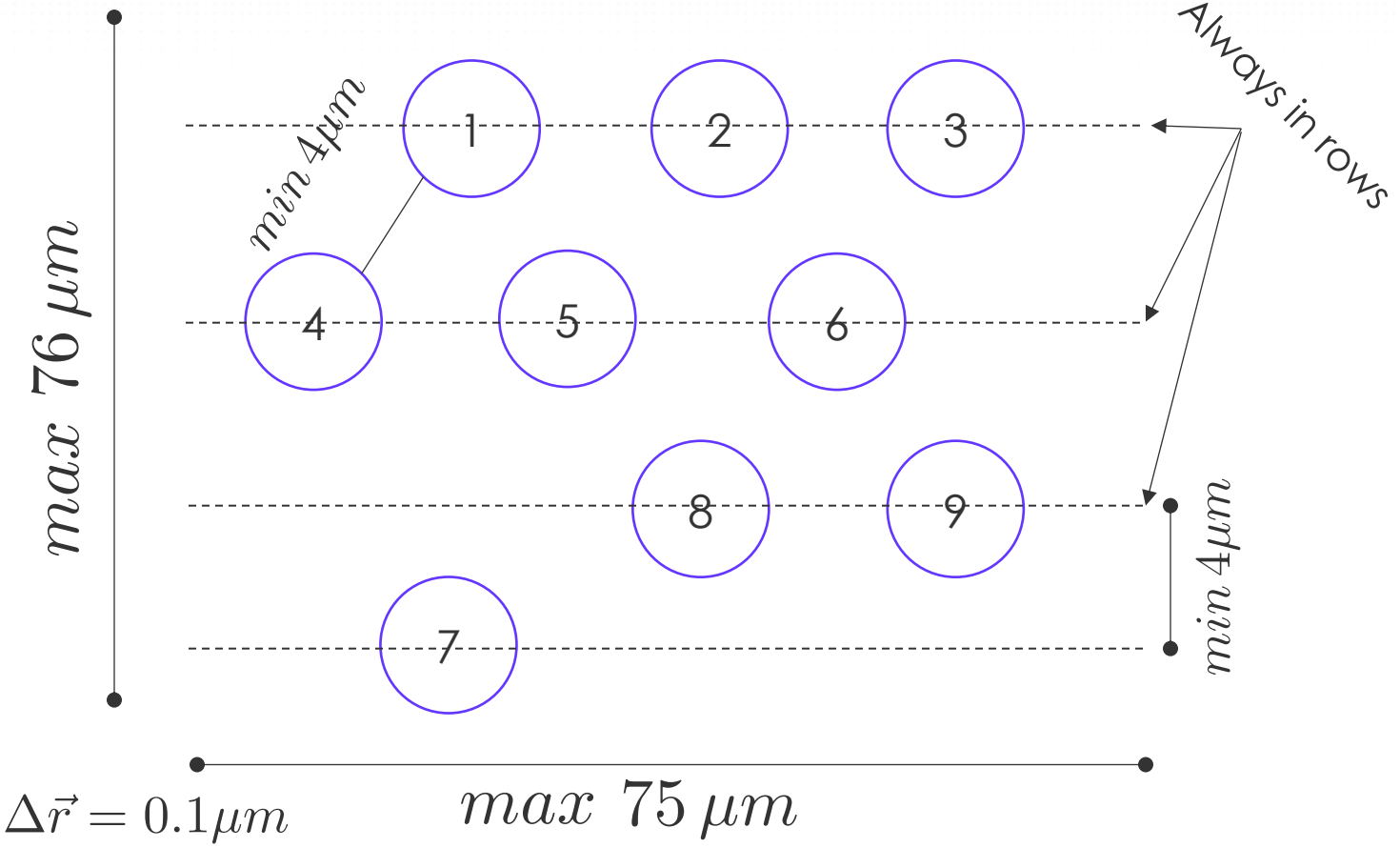




A neutral-atom quantum processor



Hardware constraints: Geometry



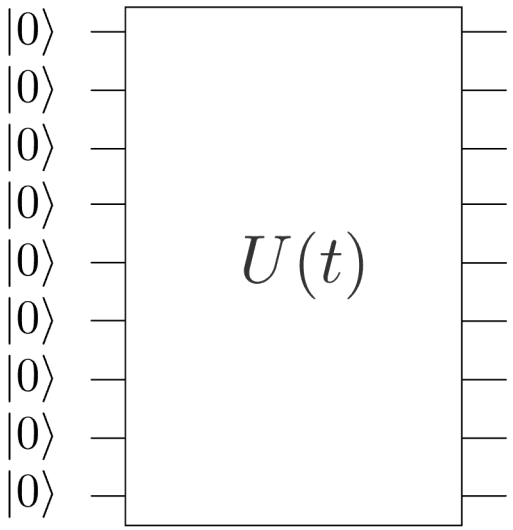
Activity 1: Think-pair-share. What do you think is the origin of each of these constraints?

Activity 2: defining qubit positions on Bloqade

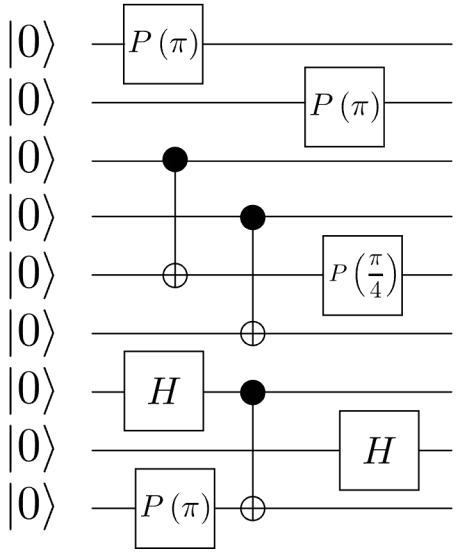
More details @ https://queracomputing.github.io/Bloqade.jl/dev/capabilities/

Information processing: Analog computing

Analog operation



Digital operation



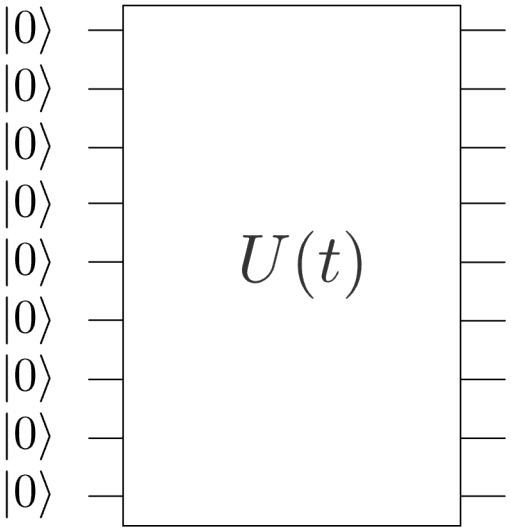
Designed for the early stage of maturity of the quantum computing resources of today...

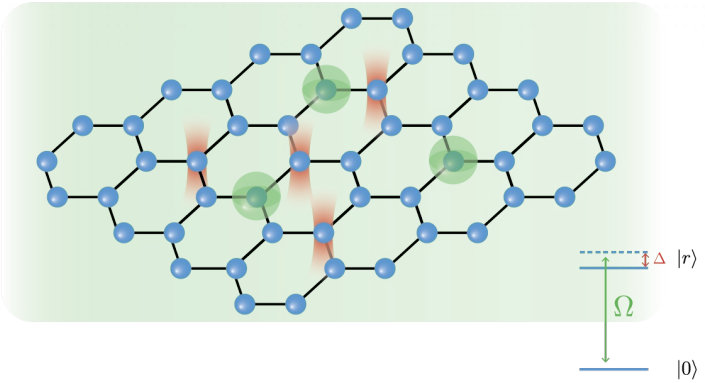
- ✓ Robustness to errors
- ✓ Efficient control
- ✓ Single-step large entanglement
- ✗ Universal applicability

More on analog processors:
Nature **volume 607**, p. 667-676 (2022)

Field Programmable Qubit Arrays (FPQAs)

Analog operation





Control qubit positions! Control qubit connectivity!

⇒ **Many possibilities!**

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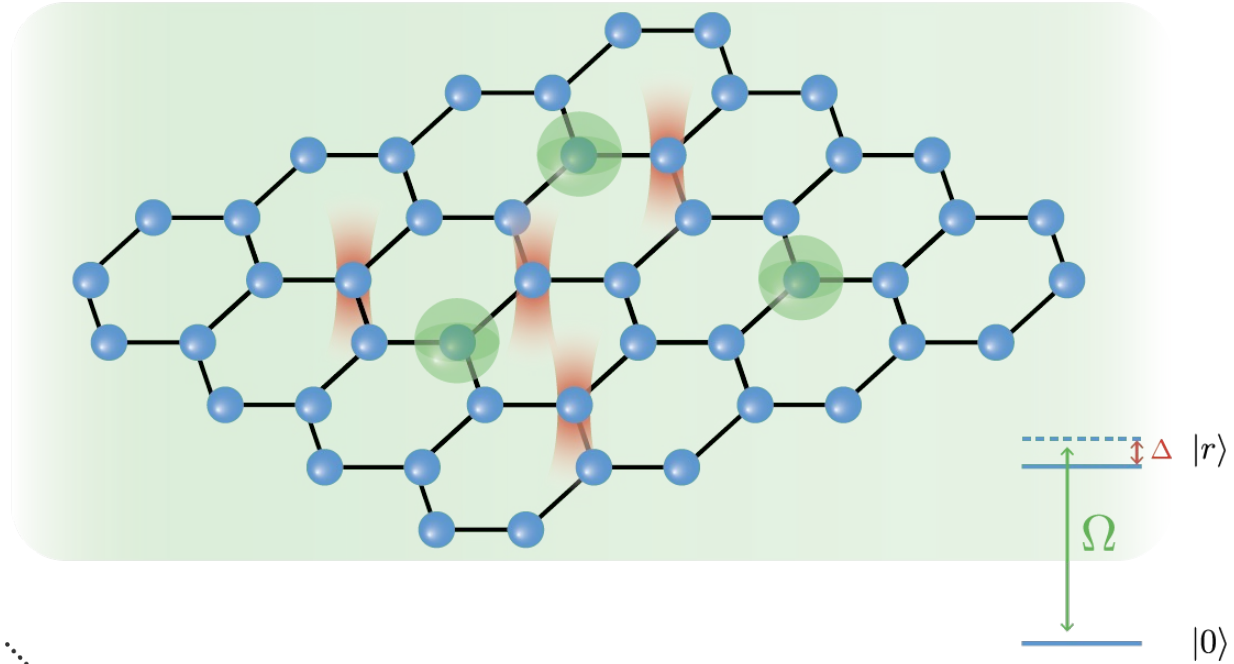
Algorithm = time evolution

$$i\frac{\partial}{\partial t}|\psi\rangle = \boxed{H}|\psi\rangle$$

Analog quantum dynamics control

$$H = \sum_i \frac{\Omega(t)}{2}\left(e^{i\phi(t)}|g_i\rangle\langle r_i| + e^{-i\phi(t)}|r_i\rangle\langle g_i|\right) - \sum_i \Delta(t) n_i + \sum_{i<j} V_{ij} n_i n_j$$



$$n_i = 1 * |r_i\rangle\langle r_i| + 0 * |g_i\rangle\langle g_i|$$

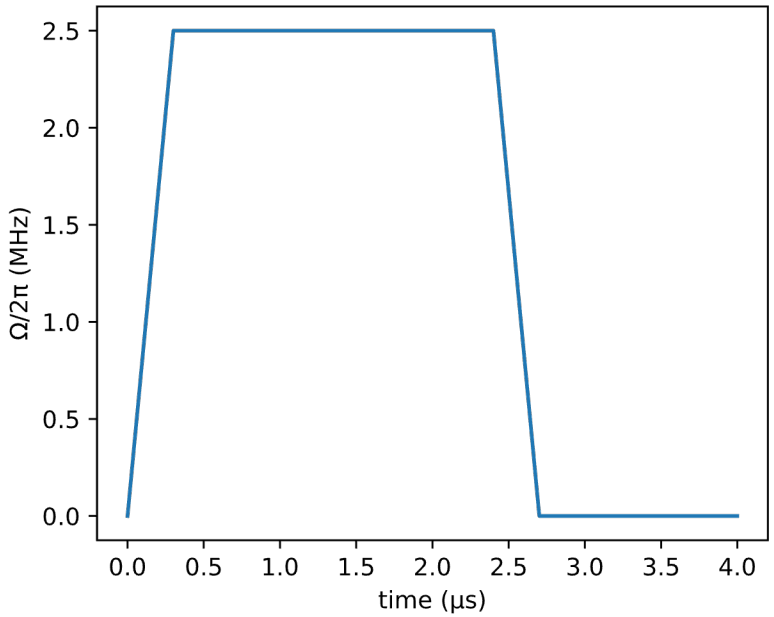
$$V_{ij} \sim d_{ij}^{-6}$$

Hardware constraints: dynamics

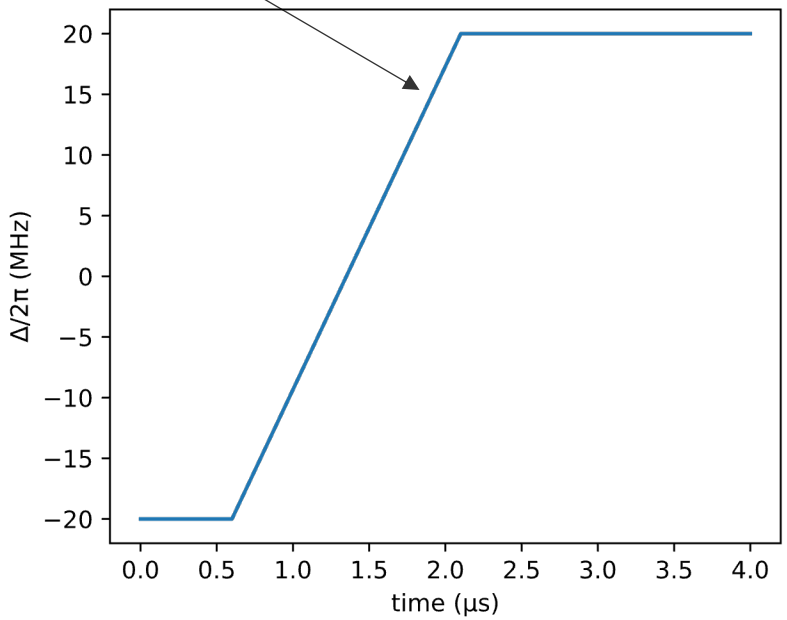
Activity: encoding waveforms on Bloqade

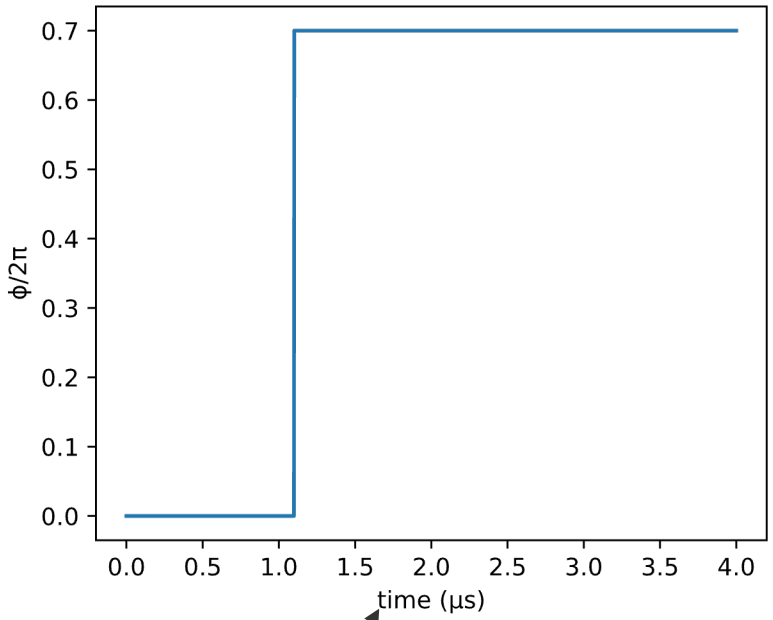
Piecewise-linear

max



max



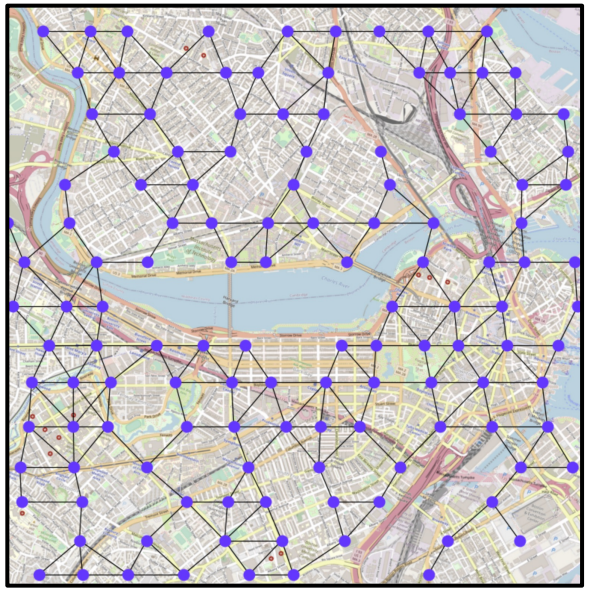


$t_{max} = 4\mu s$

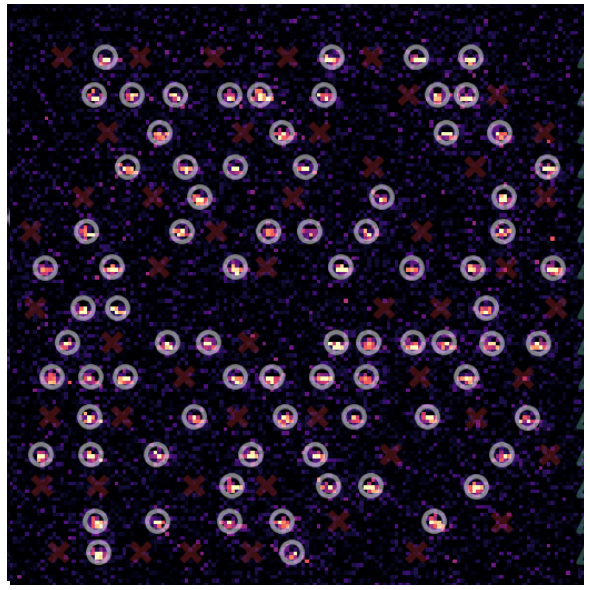
Piecewise-constant

FPQA = Efficient Problem Encoding

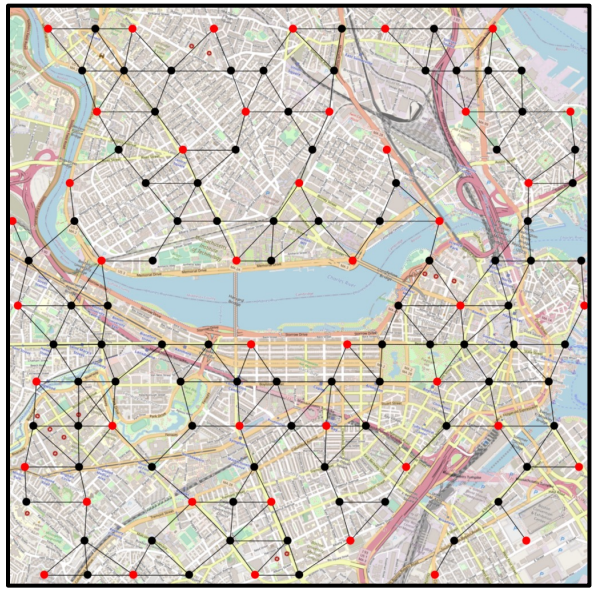
Choose possible locations



Create an atomic twin

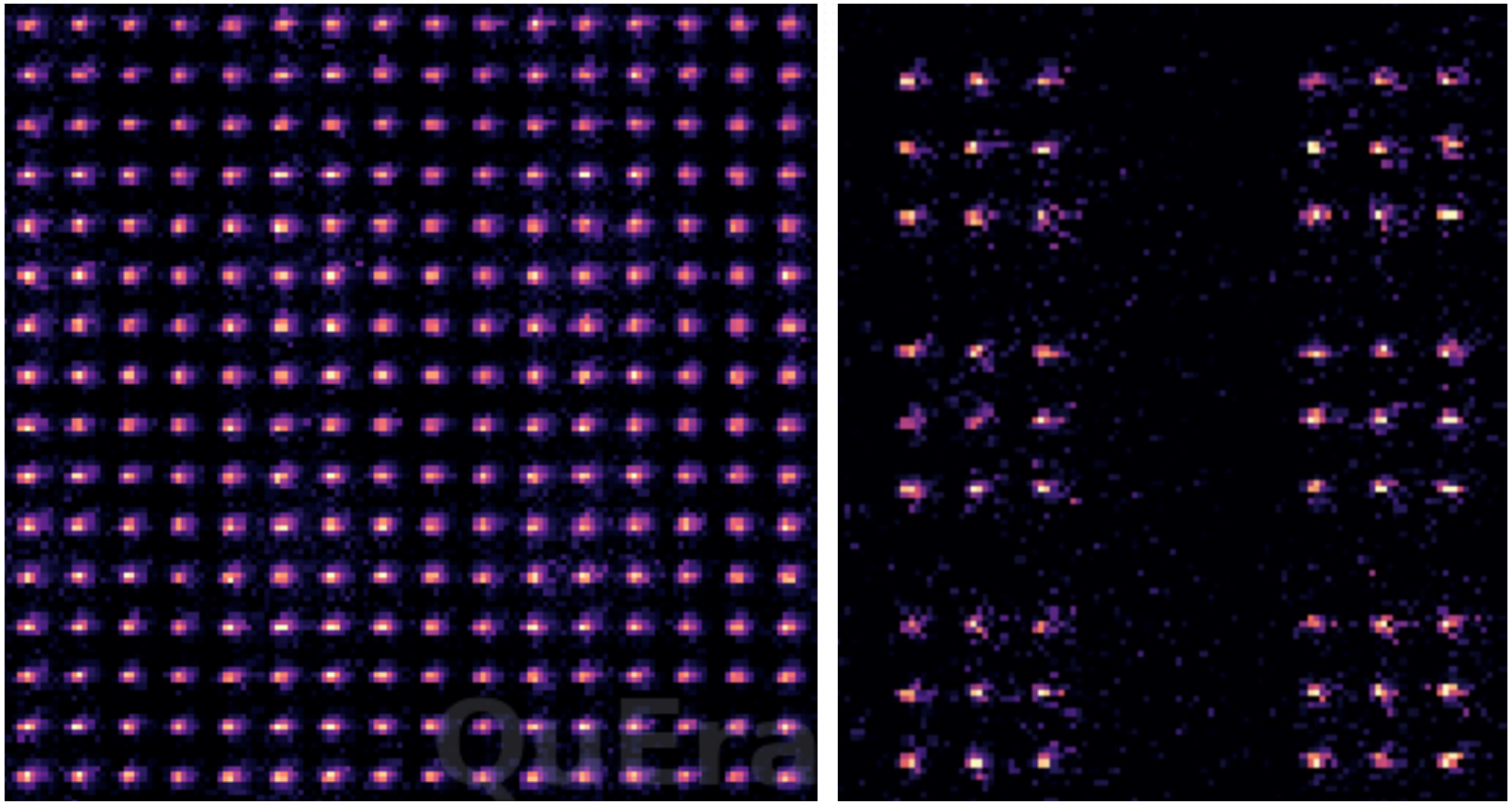


Excite atoms to find answer!



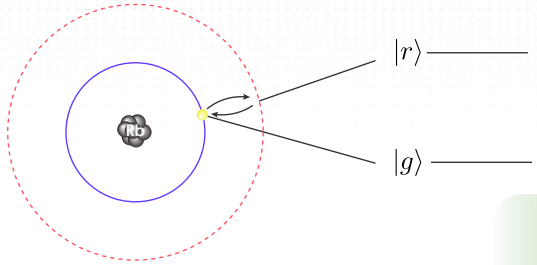
How to optimally cover Boston with coffee shops?

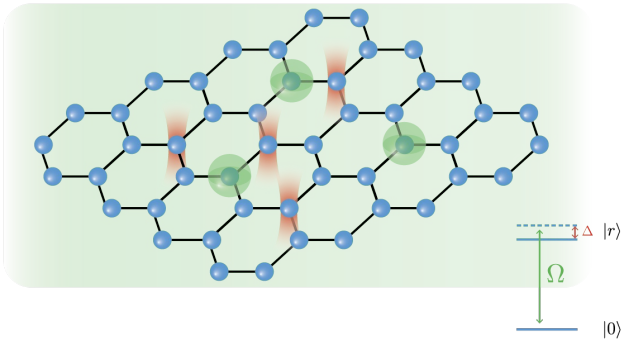
FPQA = Parallelization



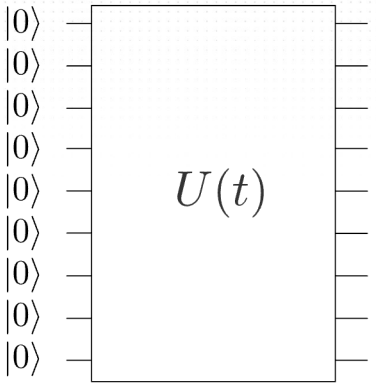
Summary

Architecture

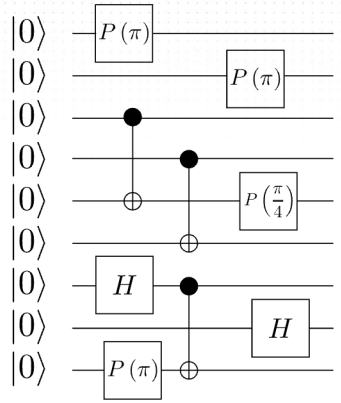




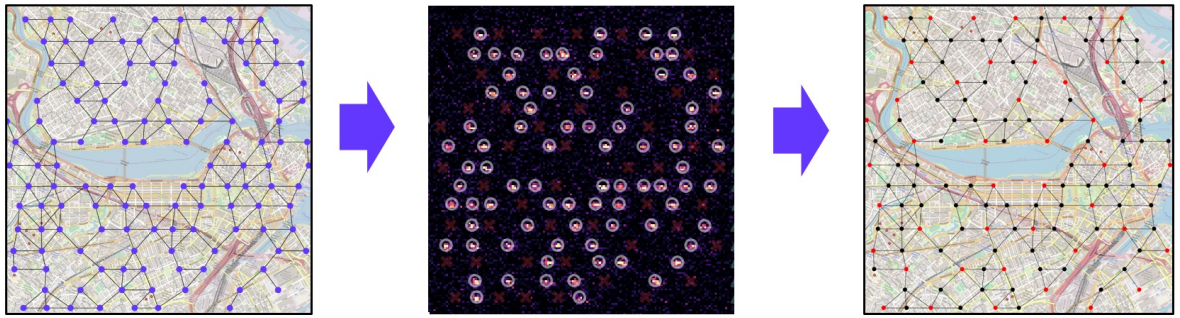
Analog operation



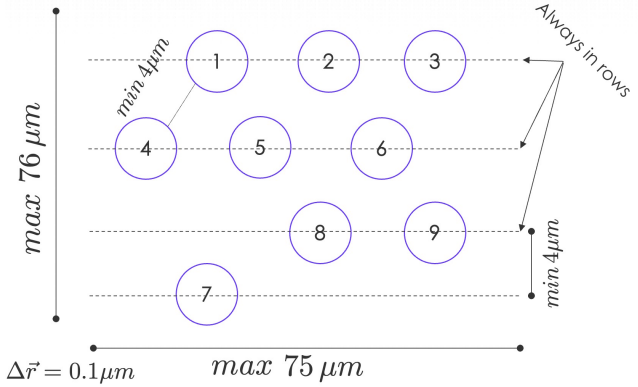
Digital operation

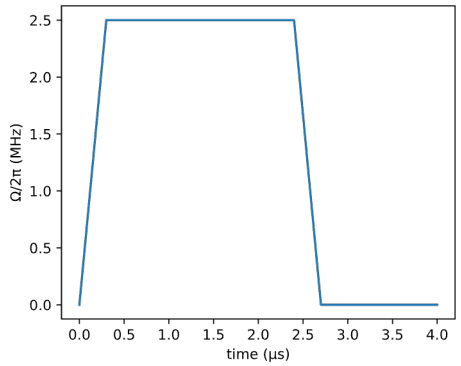


FPQA paradigm



Hardware constraints





Learning objectives

Now you are able to:

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- **Distinguish analog** and **digital** (gate-based) quantum computing
- **Define field-programmable qubit arrays** and **exemplify** some of their **advantages**
- **Describe** Aquila's **programming** range
  - its Hamiltonian and controllable parameters, limitations of service