

Title: QuEra - quantum computing with neutral atoms:

Speakers: Anna Knärr

Collection: New Frontiers in Machine Learning and Quantum

Date: November 23, 2022 - 4:30 PM

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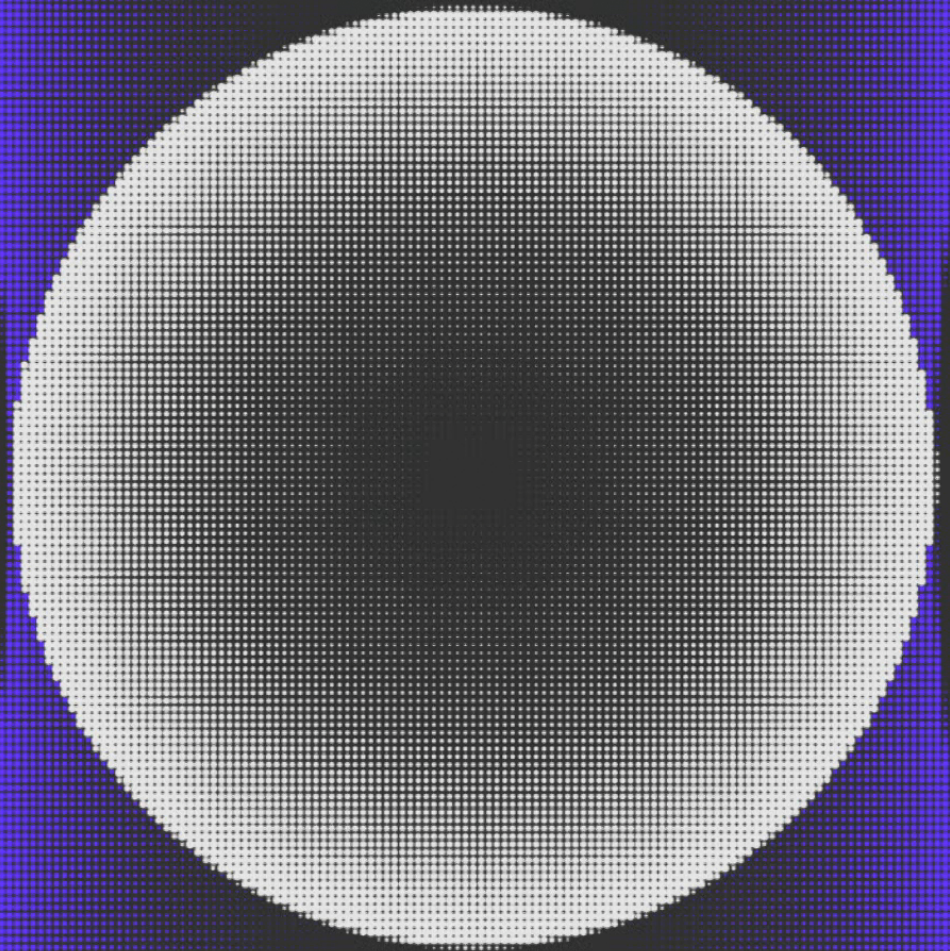
Abstract: QuEra is a quantum computing start up located in Boston, spinning off from the groups in the physics and engineering departments of Harvard and MIT. I have spent this fall working at QuEra and will introduce you to the company and its neutral-atom quantum computing technology.

QUERA

QUANTUM COMPUTING WITH NEUTRAL ATOMS

New Frontiers in Quantum & ML
@Perimeter Institute
November 23th, 2022

| QuEra >



Born out of an outstanding scientific community



Mikhail Lukin

Professor of Physics.
Father of quantum computing with
neutral atoms



Markus Greiner

Professor of Physics.
Pioneer in quantum simulation



Alex Keesling

CEO, QuEra



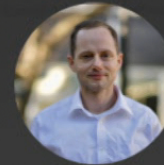
Nathan Gemelke

CTO & cofounder,
QuEra



Vladan Vuletic

Professor of Physics.
Pioneer in creating and controlling large
entangled systems



Dirk Englund

Professor of EECS.
Expert in photonics and
systems architecture

Built on a series of breakthroughs



November 2017

World's largest quantum computer with 51 qubits built by the Harvard team

July 2021

First demonstration of control over 256 atoms

December 2021

Simulation of quantum spin liquids on a neutral atom processor

February 2022

Demonstration of scaling advantage for optimization over classical benchmark

July 2019

QuEra was founded as a spin-off from Harvard and MIT



November 2022

Launch of Aquila

Now **available to you!**
On Amazon Braket

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Meet Aquila

Quantum power

256 entangled neutral-atom qubits

Coherent throughout the computation

Architecture

Analog operation mode

Field programmable qubit arrays

Modular architecture



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What can Aquila do?

Applications

What can Aquila do?

IOuEra>

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What can Aquila do?

Applications



Hamiltonian Simulation

- Equilibrium quantum phase of matter
- Non-equilibrium quantum dynamics
- Quantum thermalization
- Lattice gauge theories



Optimization

- Maximum independent set
- Maximum clique
- Minimum vertex cover
- Minimum dominating set
- Graph coloring
- QUBO*
- Weighted maximum independent set*

*Coming soon

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Machine learning

- Leveraging post-classical probability distributions as input for classical machine learning algorithms

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Algorithmic range

Adiabatic Protocols

Quench Dynamics

Variational
Quantum
Algorithms

QAOA

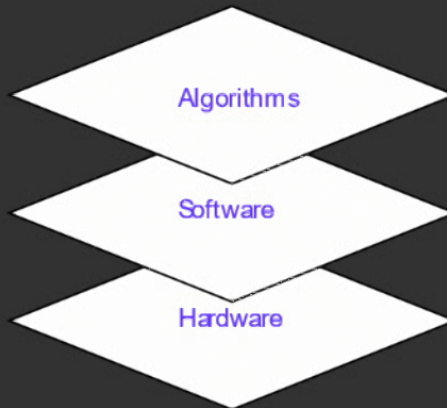
Quantum Sampling

*Coming soon

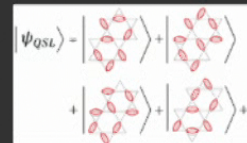
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A full-stack company

Tightly integrated hardware, software, and applications



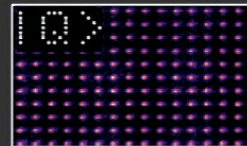
To leverage unique hardware features and **maximize** the quantum **compute power**



Non-standard algorithms
e.g., simulating quantum spin liquids through Rydberg blockade



Emulation and programming tool
to test and program our hardware



Large and flexible quantum hardware
with unique natural features

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Entanglement through Rydberg blockade

Animation of
trapped atoms



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Entanglement through Rydberg blockade

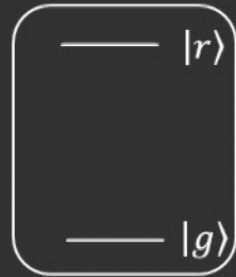
Animation of
trapped atoms



IQuEra>

Entanglement through Rydberg blockade

Animation of
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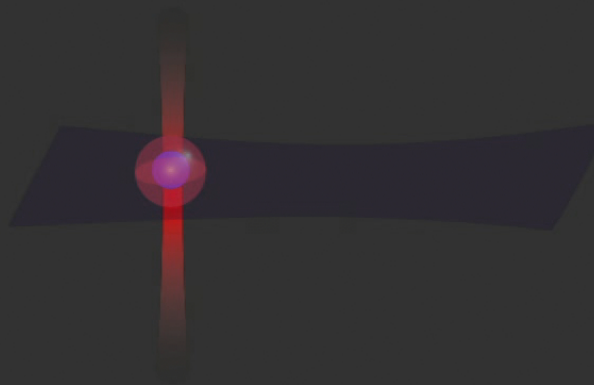
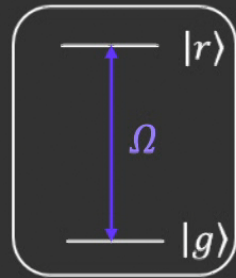


$\Omega(t)$ Rabi drive

`|QuEra>`

Entanglement through Rydberg blockade

Animation of
trapped atoms



$\Omega(t)$ Rabi drive

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Analog quantum many-body simulator

Hamiltonian with field programmable parameters

\hat{n} - number of atoms in the Rydberg state

$$\frac{H}{\hbar} = \sum_{i < j} \frac{C_6}{|\vec{r}_i - \vec{r}_j|^6} \hat{n}_i \hat{n}_j + \sum_{i=1}^N \frac{\Omega(t)}{2} (e^{i\phi(t)} |r_i\rangle \langle g_i| + e^{-i\phi(t)} |g_i\rangle \langle r_i|) - \sum_i \Delta(t) \hat{n}_i$$

Field programmable parameters:

Rydberg Interaction

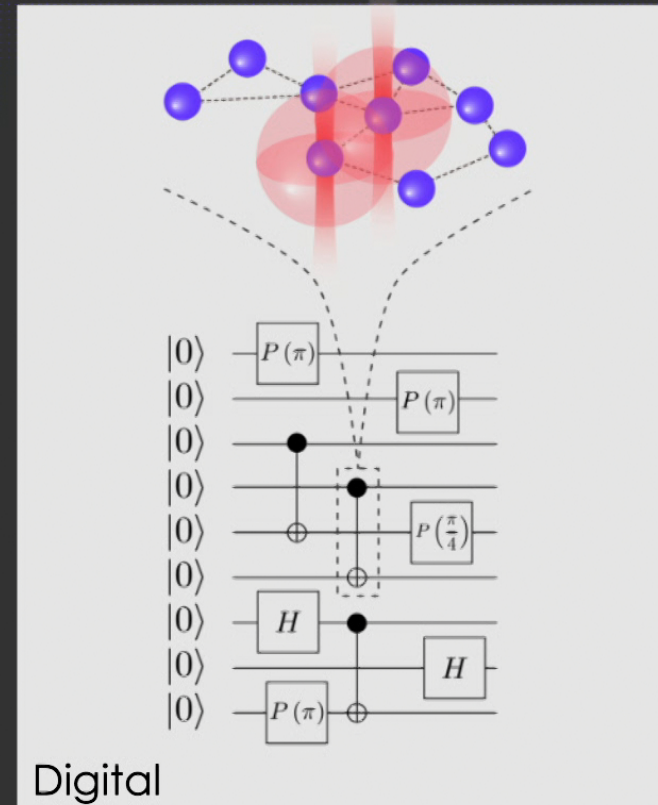
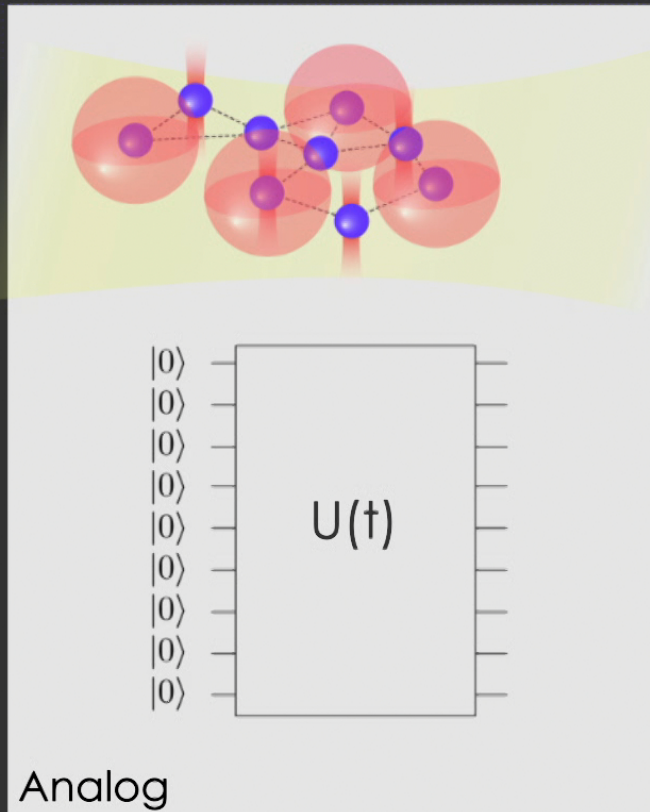
Coherent coupling

Excitation cost

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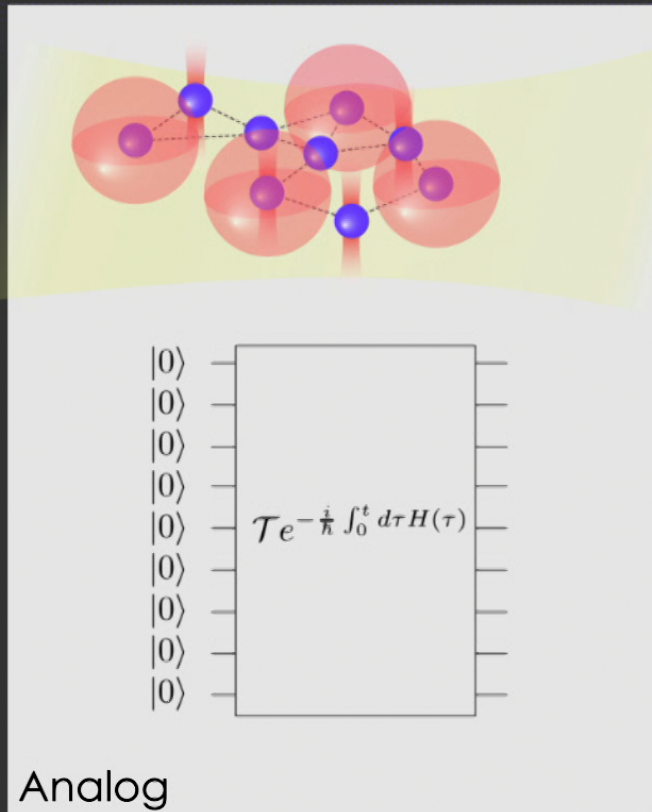
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Analog vs. Digital processing



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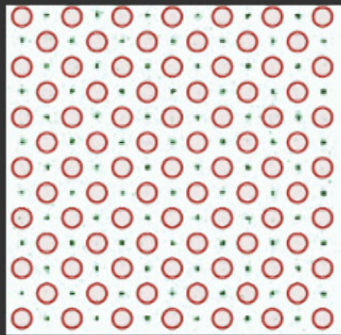
Analog vs. Digital processing



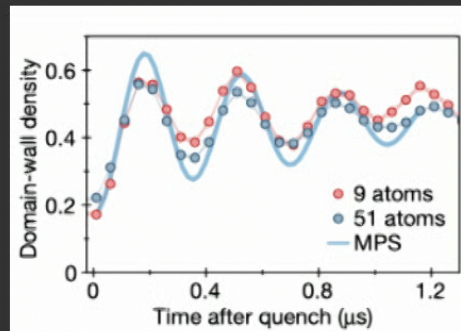
- ✓ Robustness of errors
- ✓ Easy control
- ✗ Universal applicability

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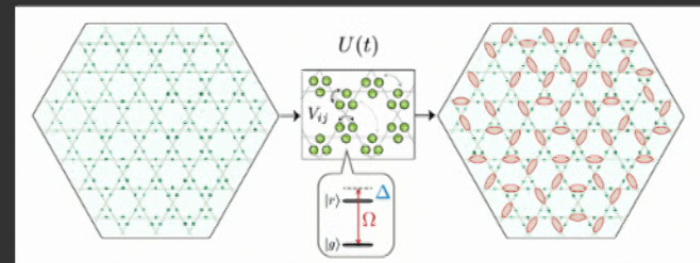
Applications of Analog quantum simulator



Checkerboard phase
Nature 595, 227 (2021)



Quantum many-body scars
Nature 551, 579 (2017)



Exotic phase, quantum spin liquid
Science 374, 1242 (2021)

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FPQA's

Field-programmable qubit arrays offer near-arbitrary configuration of atoms and flexible connectivity

Near-arbitrary qubit configurations

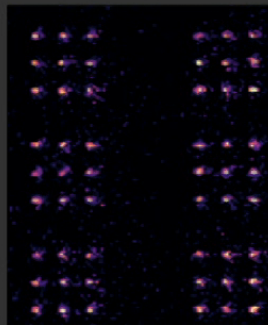
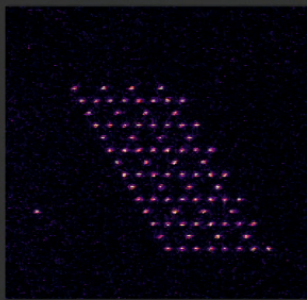
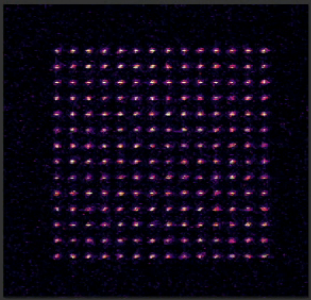
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FPQA's

Field-programmable qubit arrays offer near-arbitrary configuration of atoms and flexible connectivity

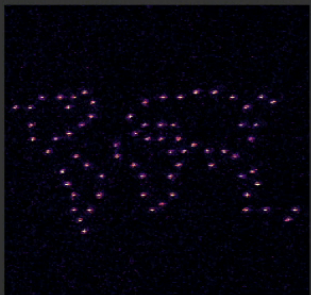
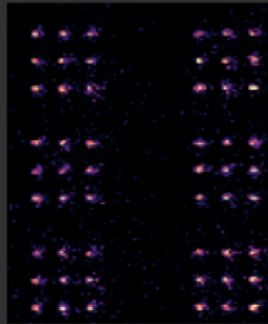
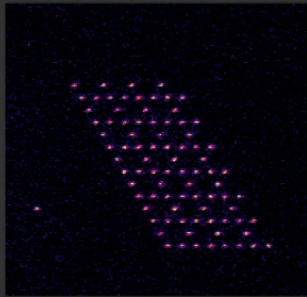
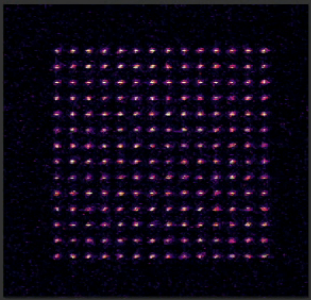
Near-arbitrary qubit configurations



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Near-arbitrary qubit configurations

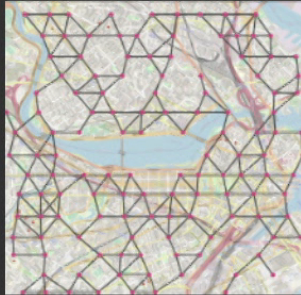
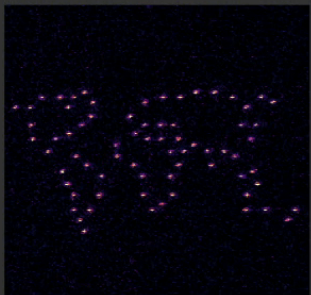
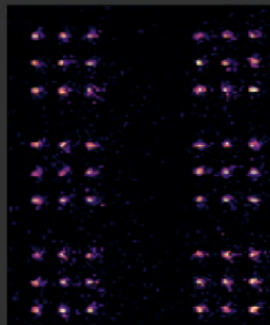
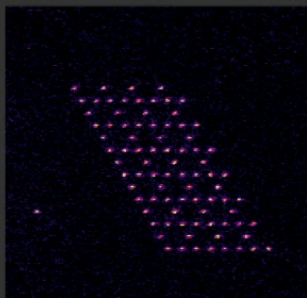
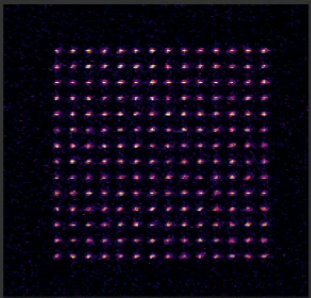


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Near-arbitrary qubit configurations

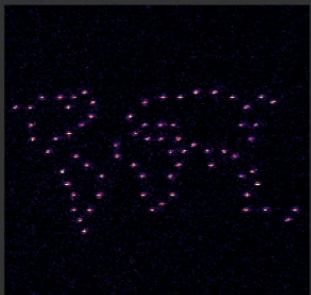
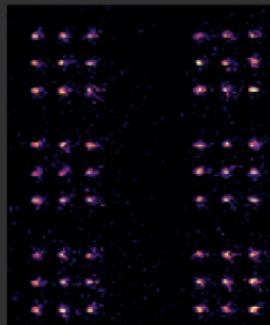
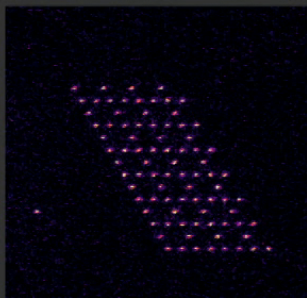
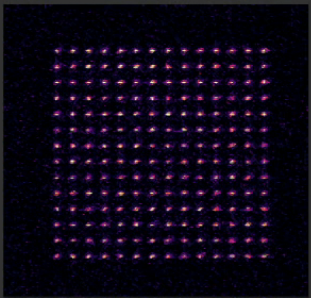


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FPQA's

Field-programmable qubit arrays offer near-arbitrary configuration of atoms and flexible connectivity

Near-arbitrary qubit configurations



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This flexibility allows for:

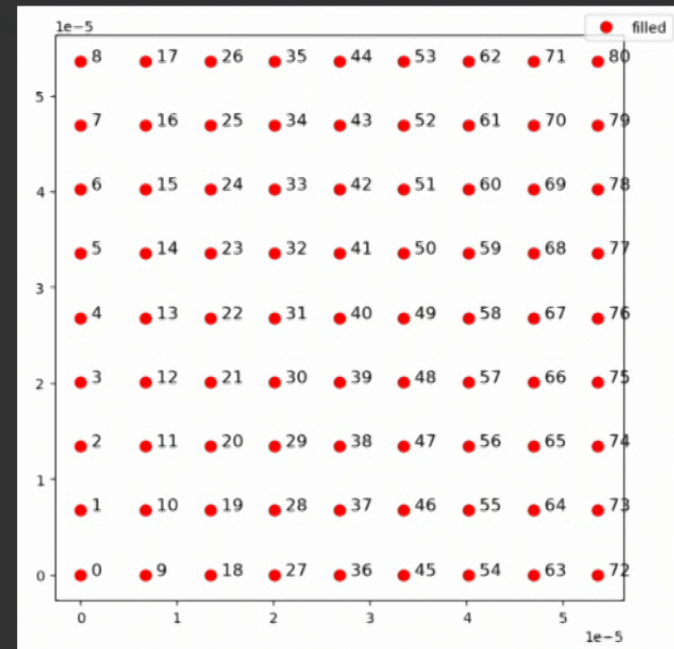
- ✓ Exploration of exotic geometries
- ✓ Easy encoding of algorithms
- ✓ Quick testing and performance optimization

Programming Aquila

Step 1: Specify the qubit geometry by inputting atom coordinates $\{r_i\}$

Step 2: Specify the waveforms of $\Omega(t)$ and $\Delta(t)$ and $\phi(t)$

Step 3: Run and process the data!



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AWS Braket Interface

The screenshot displays the AWS Braket console interface. On the left is a navigation sidebar with links to Dashboard, Devices (highlighted), Notebooks, Jobs, Tasks, Announcements, and Permissions and settings. The main content area is titled 'Amazon Braket > Devices' and shows a list of 9 devices. At the top of this section is a search bar labeled 'Filter devices' and a toggle for 'Show retired devices'. A 'View device' button is also present. The device list is organized into columns: Hardware provider, Device, Availability, and Description. Each device entry includes a radio button for selection.

	Hardware provider	Device	Availability	Description
<input type="radio"/>	Amazon Web Services	SV1	AVAILABLE NOW	Amazon Braket state vector simulator
<input type="radio"/>	Amazon Web Services	TN1	AVAILABLE NOW	Amazon Braket tensor network simulator
<input type="radio"/>	Amazon Web Services	DM1	AVAILABLE NOW	Amazon Braket density matrix simulator
<input type="radio"/>	IonQ	IonQ Device	AVAILABLE NOW	Universal gate-model QPU based on trapped ions
<input type="radio"/>	Oxford Quantum Circuits	Lucy	20:28:28	Universal gate-model QPU based on superconducting qubits
<input type="radio"/>	QuEra	Aquila	1 day 02:28:27	Analog quantum processor based on neutral atom arrays
<input type="radio"/>	Rigetti	Aspen-11	OFFLINE	Universal gate-model QPU based on superconducting qubits
<input type="radio"/>	Rigetti	Aspen-M-2	01:28:27	Universal gate-model QPU based on superconducting qubits
<input type="radio"/>	Xanadu	Borealis	01:28:27	Gaussian Boson Sampling on a programmable photonic processor



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BLOQADE

- Benchmarking Aquila
- Programming Aquila (soon)
- Learning platform for neutral atom quantum computing



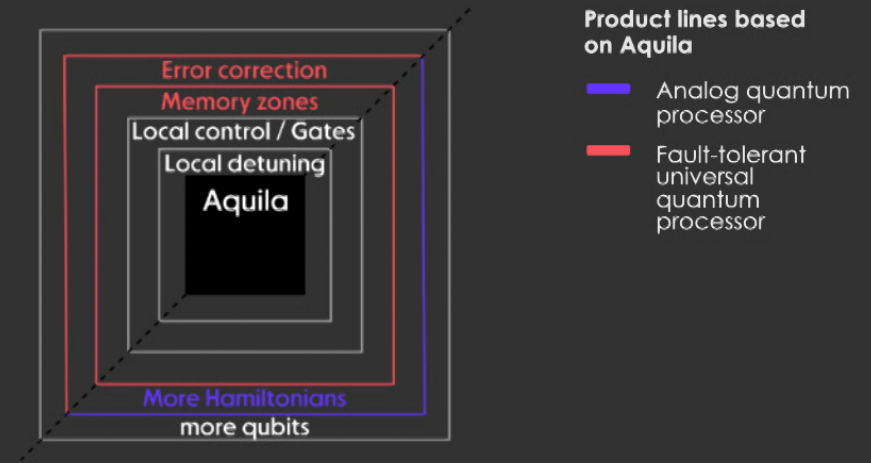
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New features coming up...

New features can be added to Aquila as **modules**

- ✓ Enabling digital, analog, and hybrid computing
- ✓ Without rebuilding the system

Aquila's upcoming features



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What's next?

Join our upcoming events



Office hour

- Technical discussions
- How to connect to Aquila

Monday November 28th, noon EST

Register on www.quera.com

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Try Aquila for yourself!

Apply for free research credits:
<https://aws.amazon.com/awscredits/>



Get in touch!
info@quera.com