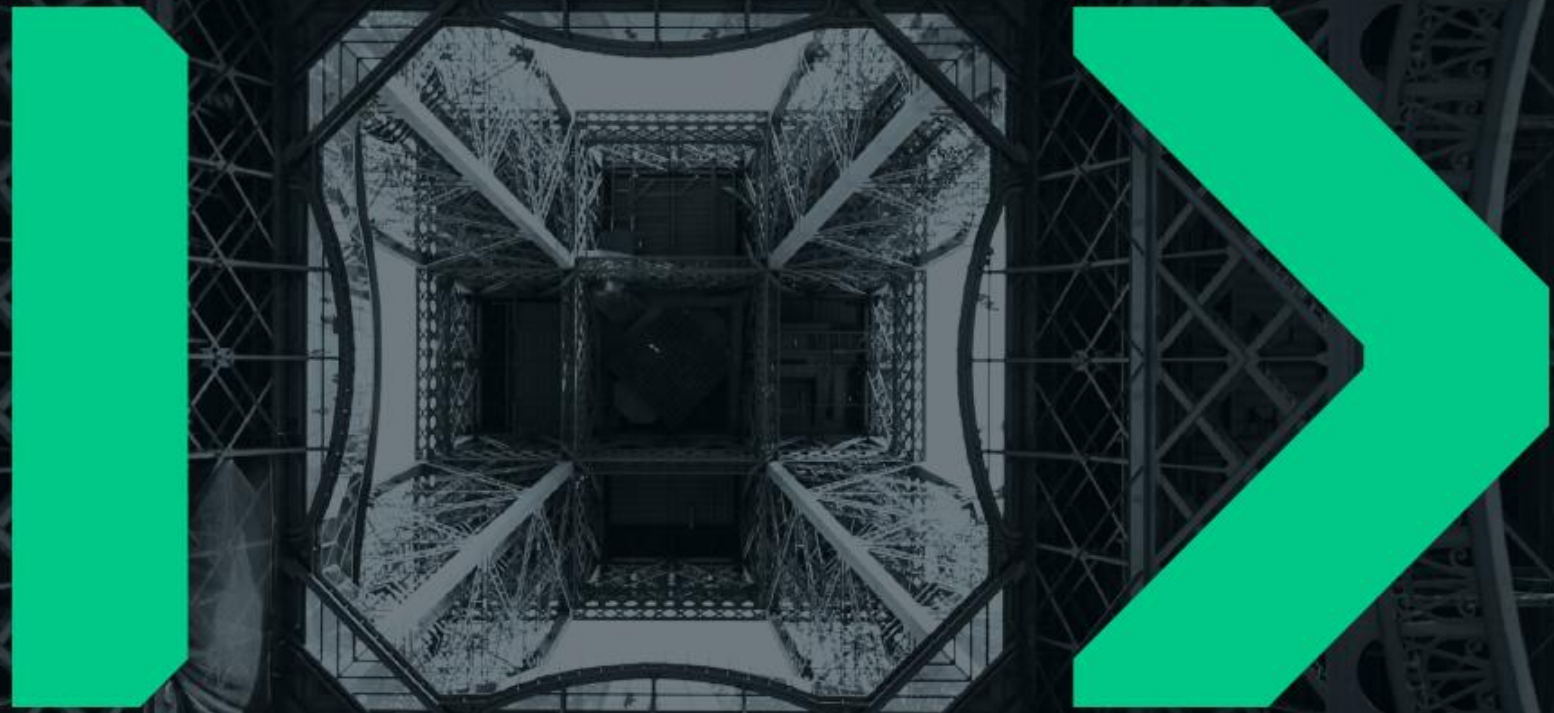
Pasqal

QTML | 2024

Nov 27, 2024



Pasqal QPUs toward Quantum Reality

Dr. Heejeong Jeong, Head of Quantum Computing, Pasqal Korea

Pasqal is a Unique Mix of Science and Engineering

"When there are no fundamental limitations, engineers find a path."

- Prof. Alain Aspect

Georges-Olivier Reymond

Co-founder & CEO

16 years in bringing new tech to the market

Prof. Alain Aspect

Co-founder & Scientific Advisor

2022 Nobel Prize Laureate in Physics

Prof. Antoine Browaeys

Co-founder & Scientific Lead

2022 Solvay conference attendee, Nature 2021 & 2023

Pasqal Defining the quantum reality

2019
Pasqal Founded
Headquarters: France

≈5 employees

2021
Pasqal raises €25 M in Series A

2022
Pasqal merges with Qu & Co.

2022
Pr. Alain Aspect, co-founder, is awarded the Nobel Prize in Physics

2022
First Neutral Atoms Quantum Computer available on the cloud

2023
Highlighted by BCG company developing enterprise-grade ready offer

2023
Pasqal raises €100 M in Series B

≈300 employees

2024
CMA CGM Group and Pasqal join forces

2024
First quantum computer delivered to GENCI and CEA

2024
First quantum computer acquired by a private company (Aramco)

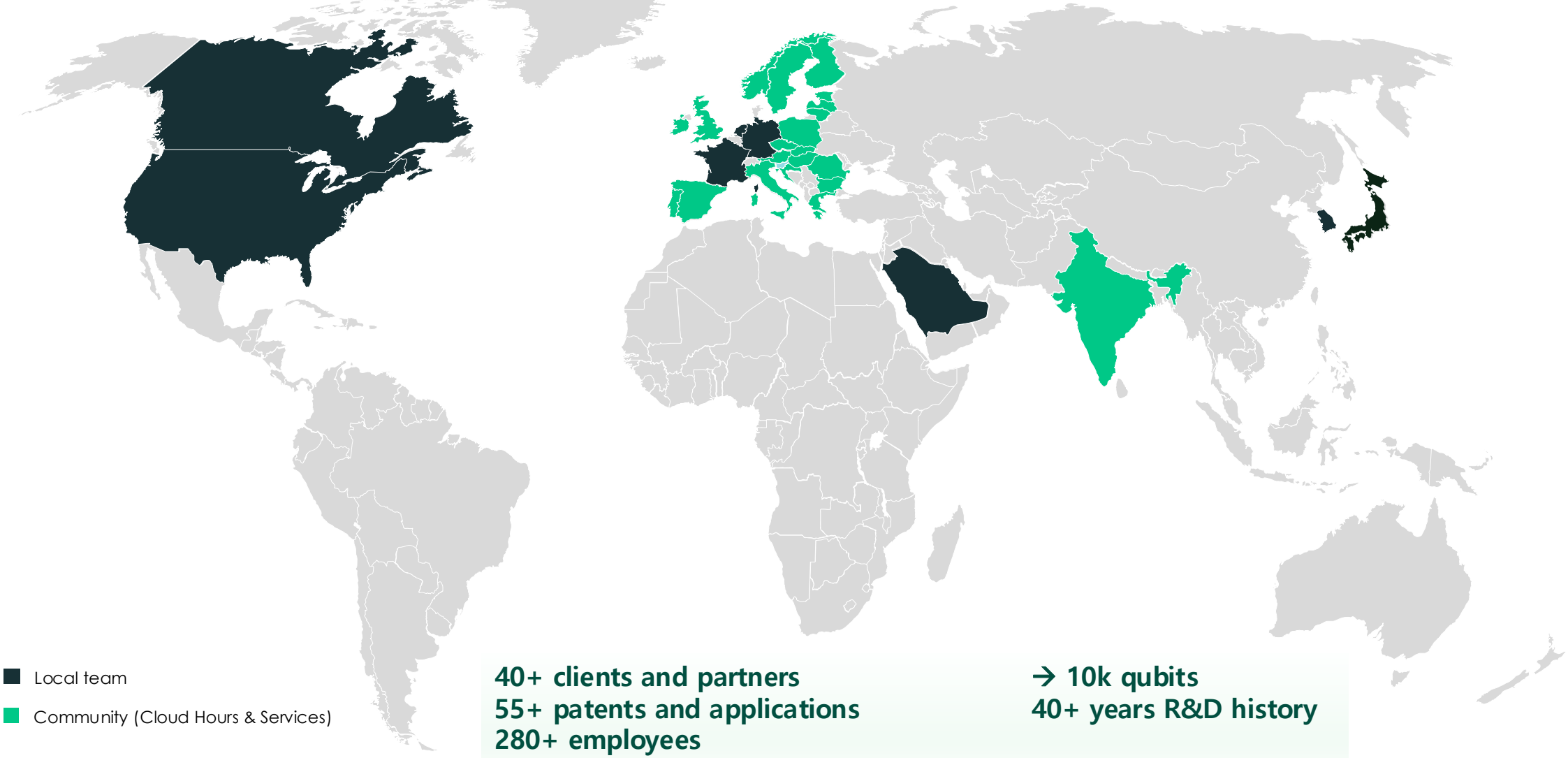
2024
IBM collaboration

2024
Pasqal exceeds 1,000 atoms in quantum processor

PASQAL's Global Presence (2019~)

Full-Stack QC (HW, SW, Algorithm) Company, HQ in France

Pasqal



Local team

Community (Cloud Hours & Services)

40+ clients and partners
55+ patents and applications
280+ employees

→ 10k qubits
40+ years R&D history

Pasqal

1

Pasqal: from lab to integrated product ecosystem


PASQAL

Neutral Atoms Drive Our Quantum Technology

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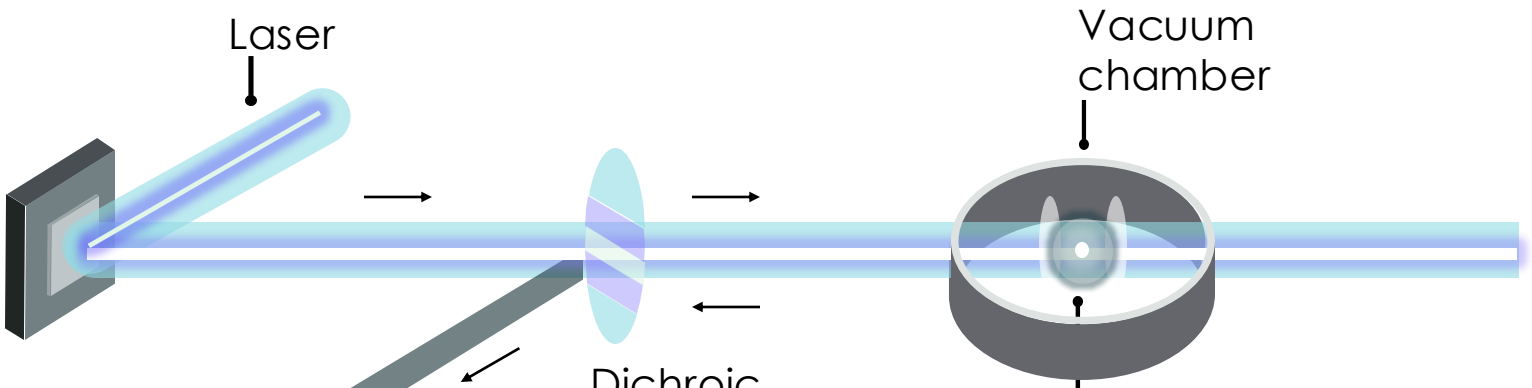
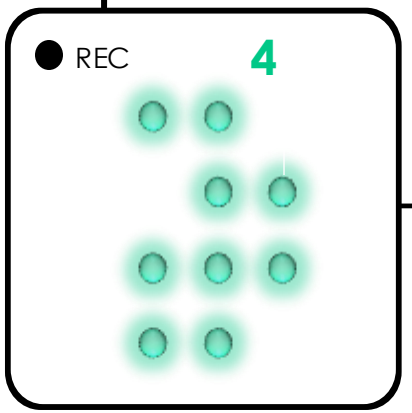


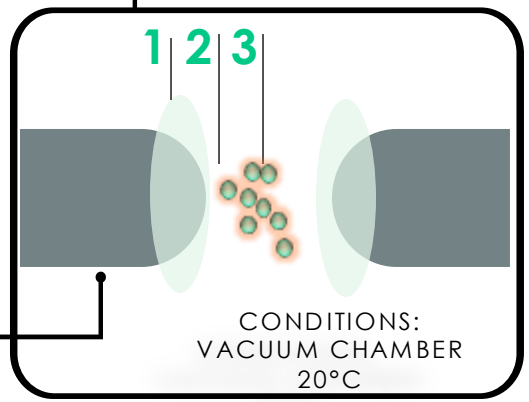
Camera
The mirror sends the reflection back to the camera, and therefore the image of what is happening in the vacuum chamber



4 | The light points come from photons emitted by the trapped atoms

Zoom laser pattern:
Atoms trapped in laser beams

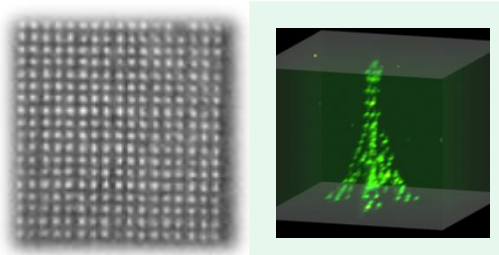
Zoom vacuum chamber



1 | Optical system allows the laser beam to be divided into several beams called "optical tweezers"

2 | Multiple optical tweezers

3 | Trapped rubidium atoms (1 atom = 1 qubit)



Neutral Atom QPUs can implement Algorithm with High Number of Equivalent Gates

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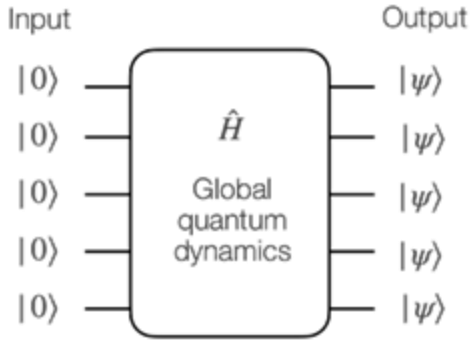
Analog Control

Programming a Hamiltonian sequence

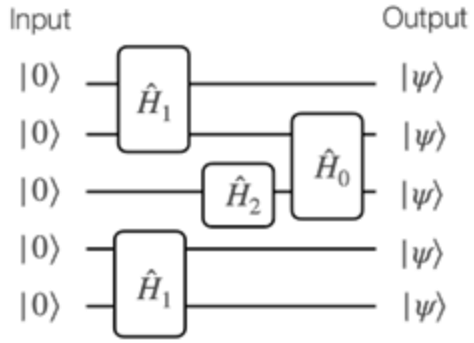
The Hamiltonian faithfully describes the dynamics of a physical quantum system or a reformulation of an operational case. Parameters can be tuned continuously.

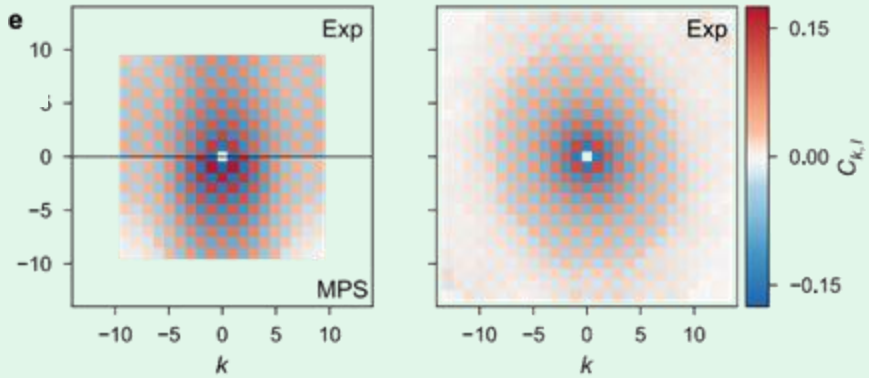


Digital Control

Programming a quantum circuit with digital quantum gates

Elementary operations are discrete digital quantum gates, that can act either on individual qubits, or on several qubits at the same time.





Staggered magnetisation histograms for 10 × 10 and 14 × 14 arrays, with MPS shown on the lower part of the 10 × 10 array (14 days for simulation with TeNPy) [1].

With typical error level of 1% of the analog mode, 10^6 gates are required with 1-F < 10^{-6} to simulate the same quantum dynamics of a 10x10 2D Ising-like model system[2].

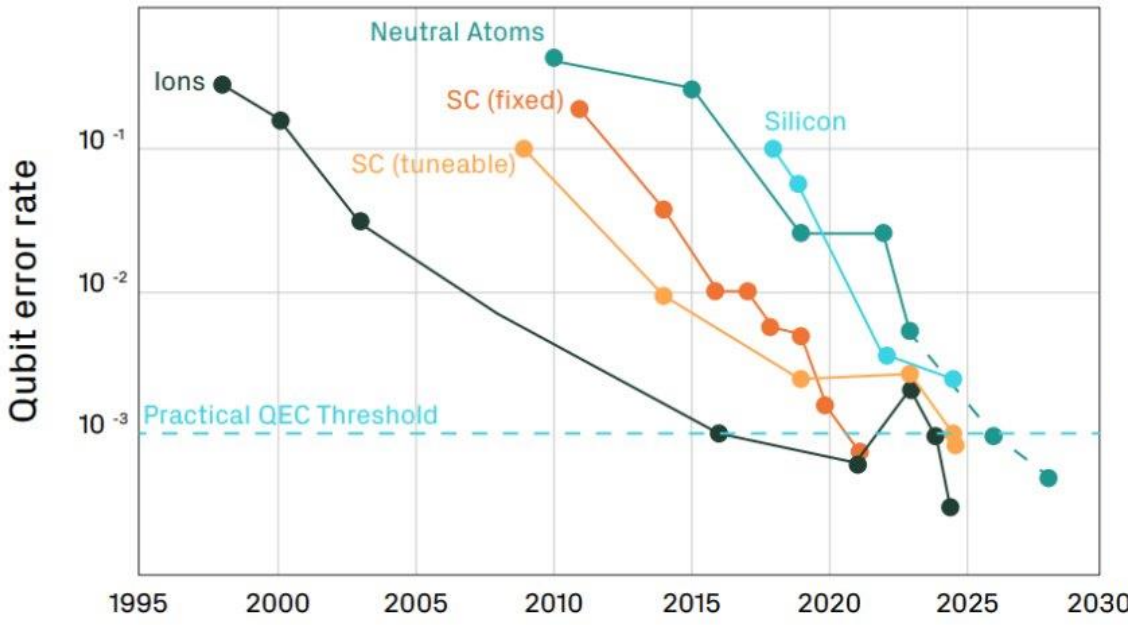
[1] Scholl, et al., Nature 595 (2021)
[2] Flannigan, Pearson, Low, Buyskikh, Kokail, Bloch, Zoller, Troyer, Daley (Nature 2022, Q Sci. Technol. 2022)

QEC: strong momentum for Neutral atoms

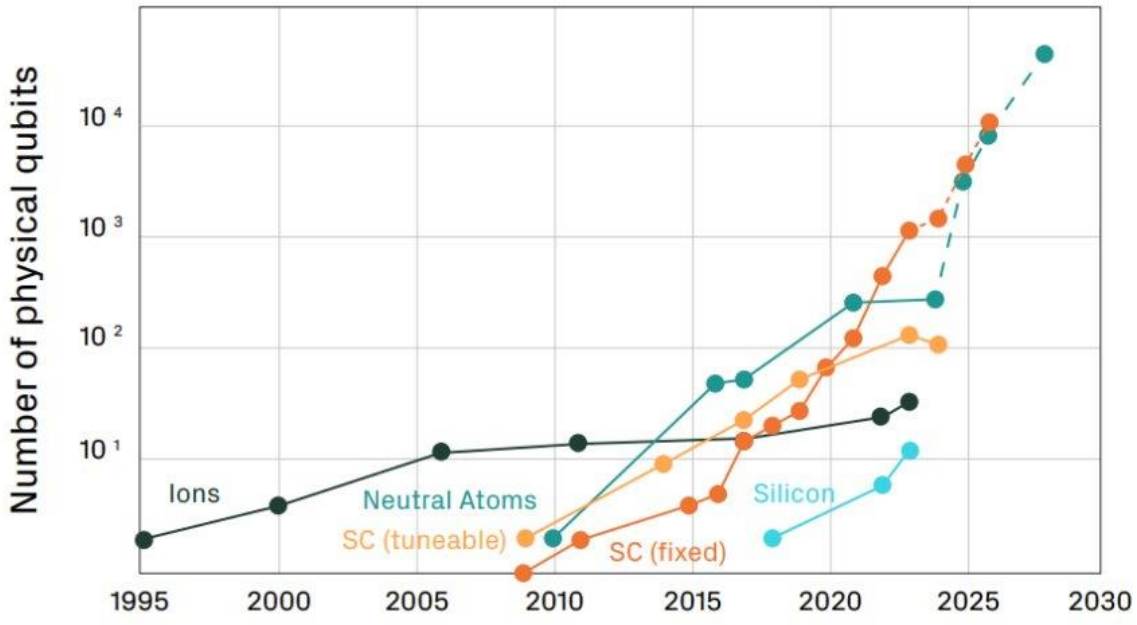
Pasqal

Neutral Atoms toward the goal of fault tolerant quantum computing (FTQC)

- Gate error rates approaching below 10^{-3}



- Qubit number moving towards 1000



[Ref] Riverlane "The Quantum Error Correction Report 2024"

Innovation on Common Platform to Boost qubits Scaling

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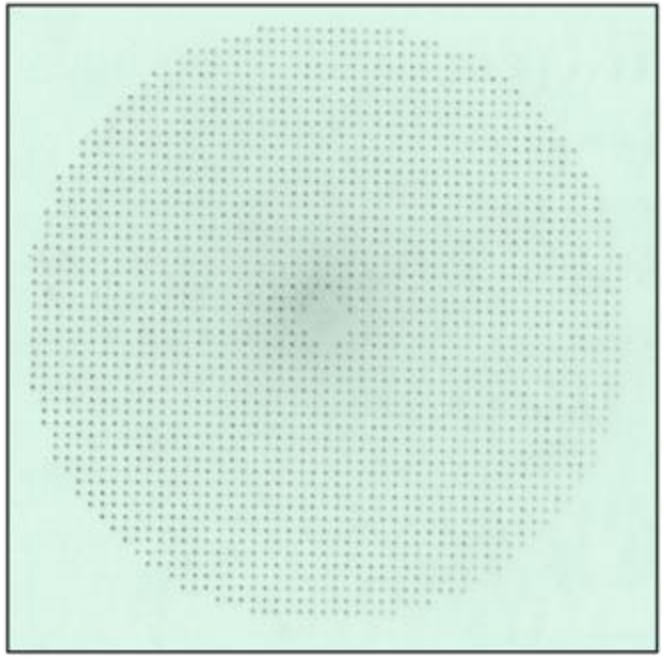
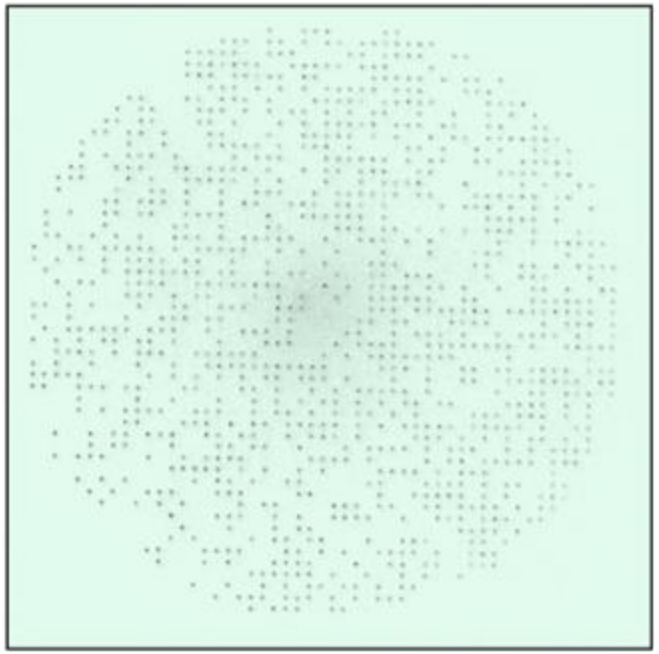
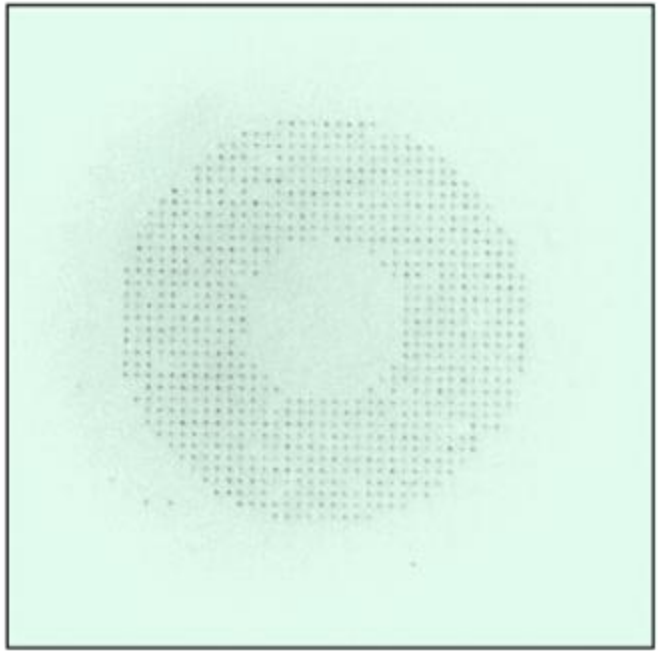


40x40 maximum fluorescence atom array [1]



Single shot 1100+ atoms[1]



Rearrangement with a target array of 828 atoms selected (95% occupancy) [1]

[1] G. Pichard, D. Lim, E. Bloch, J. Vaneecloo, L. Bourachot, G.-J. Both, G. Meriaux, S. Dutartre, R. Hostein, J. Paris, B. Ximenez, A. Signoles, A. Browaeys, T. Lahaye, D. Dreon, "**Rearrangement of individual atoms in a 2000-site optical-tweezer array at cryogenic temperatures**", *Phys. Rev. Applied* **22**, 024073 (2024)

Engineering Approach

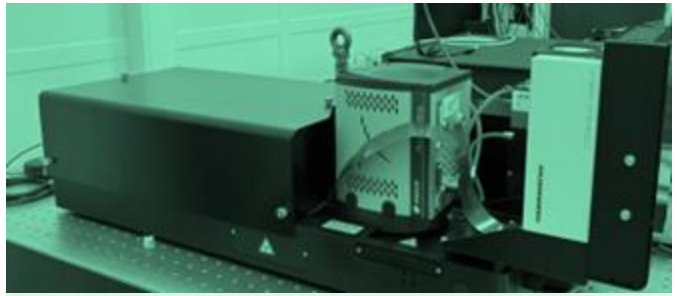
Pasqal

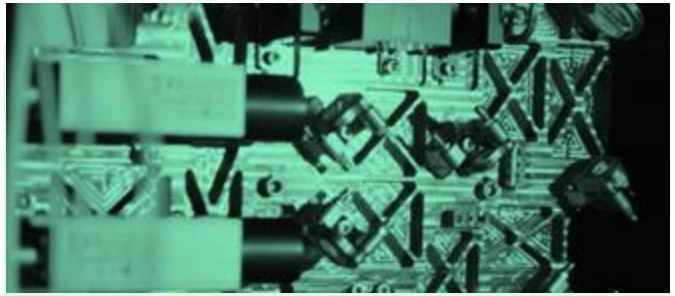
Higher Stability, Uptime, and Repeatability, so that practitioners can use our devices.

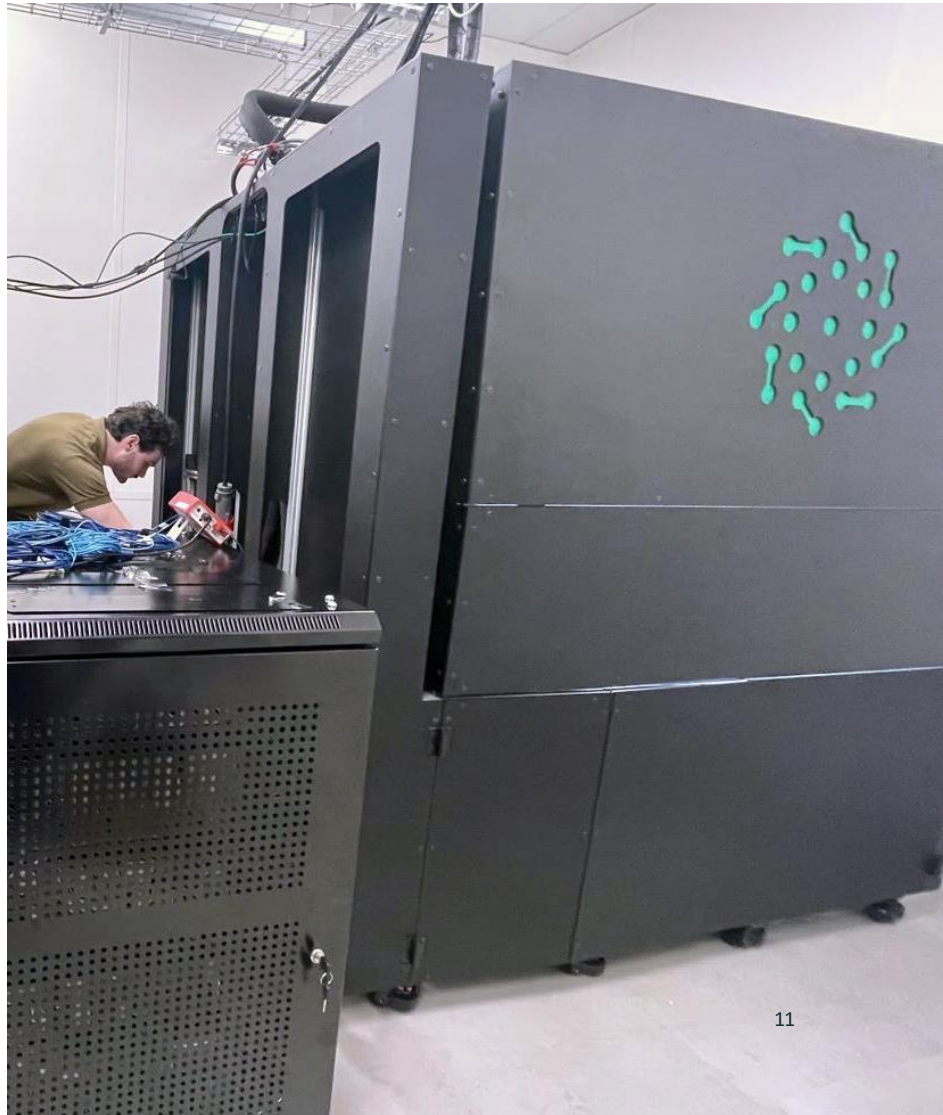
Improve modular design, sub-modules with well-defined interfaces

Stability, ease of maintenance & development

Continuous improvement while keeping compatibility with interfaces







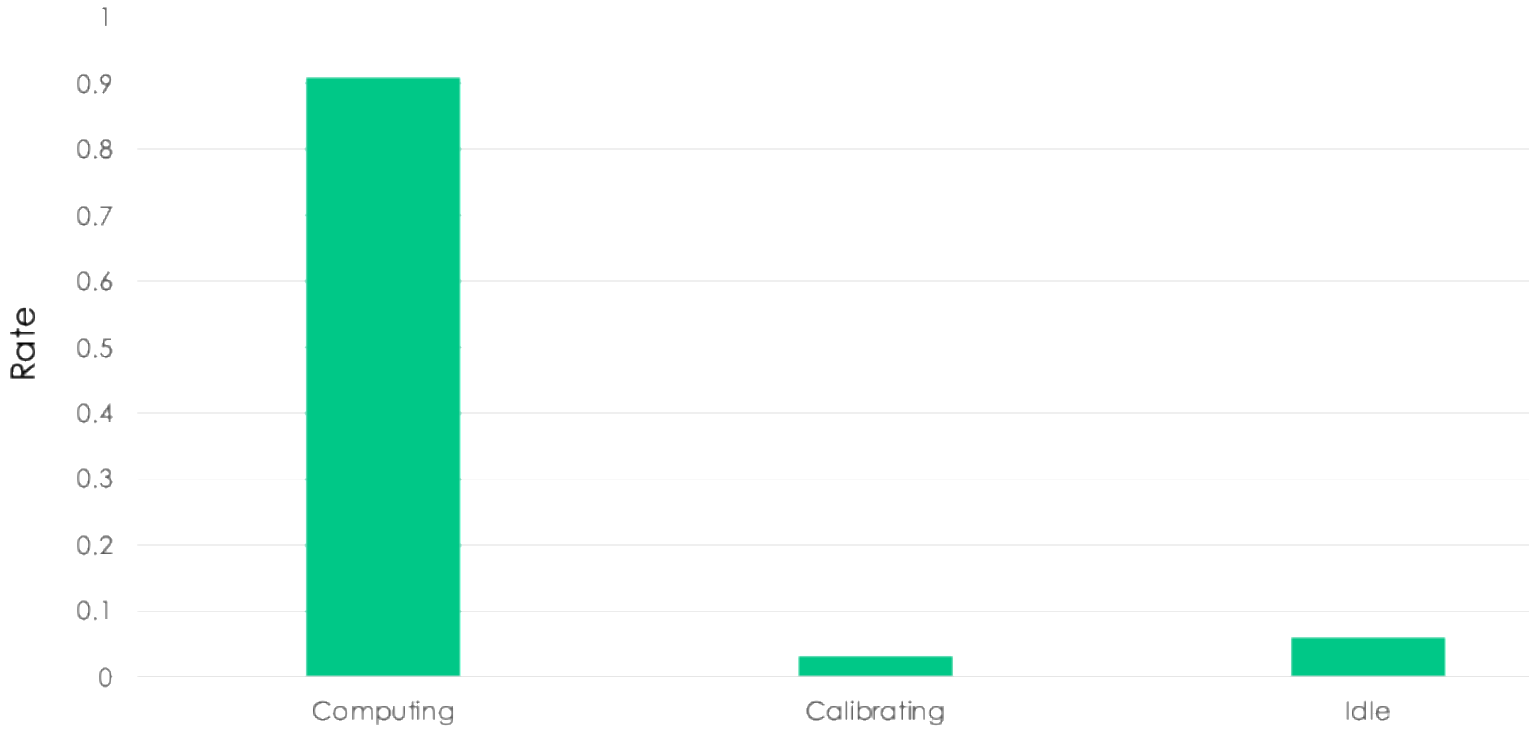
Orion Alpha first generation of QPU, already provides opportunities for concrete use cases

Pasqal

Orion Alpha

✔Custom:

- Mechanical Design for Stable Structure
- Electronics
- Optical Setups to Ensure Stability
- Software to Automatize the QPU



Many use cases have been implemented on Orion Alpha

Orion Alpha

✔Custom:

- Mechanical Design for Stable Structure
- Electronics
- Optical Setups to Ensure Stability
- Software to Automatize the QPU

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Qubit Pharmaceuticals
CINECA links
JÜLICH Forschungszentrum
CINECA
MULTIVERSE COMPUTING
EDF
PASQAL
THALES Building a future we can all trust

ALGORITHM/PRIMITIVE	USE CASE DESCRIPTION
Graph Machine Learning	Toxicity Screening & Molecular structure
Optimization	Protein Hydration
Optimization	Graph coloring for telcom networks
Quantum Materials	Dynamics of Ising model
Optimization	Analog QAOA
Optimization	Credit risk analysis
Optimization	Smart charging of electric vehicles
Quantum Simulation	Variational algorithm
Graph Optimization	Mission planning for satellites

4 Main Algorithmic Pillars

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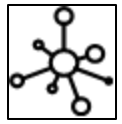
Quantum Simulation

- Spin model dynamics (Ising/XY). In 2021, IOGS/CNRS lab implemented quantum Ising model beyond what could be simulated classically [1].
- Chemistry & Material Science Applications

Graph Machine Learning



- HW-native Quantum Evolution Kernel (QEK) [2], Quantum Graph transformers [3]
- Extensions to state-of-art graph ML models (*graph transformers, shortest path*, …)

Optimization

- Graph-based optimization problems (*MIS, MaxCut,* …)
- Network optimization, scheduling, mission planning, …

Differential Equations

- Differentiable Quantum Circuit (DQC) proposal [4].
- Many extensions including *stochastic* differential equations.

[1] Scholl, et al., Nature volume 595, pages 233–238 (2021)
[2] Henry, et al., Phys. Rev. A 104, 032416 (2021)
[3] Thabet et al., 41st International Conference on Machine Learning
[4] Kyriienko, et al., Phys. Rev. A 103, 052416 (2021)

Pasqal is gaining traction

Pasqal

Remarkable progress with major players in the global industry recognizing the momentum at Pasqal.

Welcomed the President of the European Central Bank to Pasqal's Headquarters

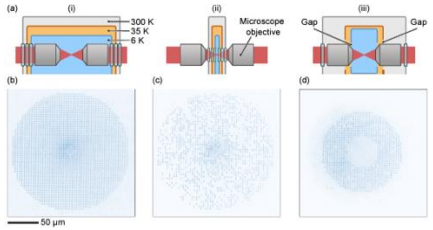
Pasqal x IBM

Pasqal and IBM Collaborate to Define Future of Quantum and HPC Integration and Development

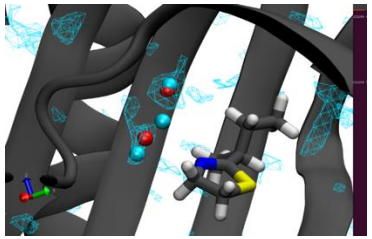
Pasqal delivered two 100+ qubit QPUs to GENCI and Julich in 2024 marking its first QPU delivered to a third party

Aramco Signs Agreement With Pasqal To Deploy First Quantum Computer In The Kingdom Of Saudi Arabia

Pasqal event with BMW, J&J, BCG, IDC, French Minister of Digital Affairs



Rearrangement of Single Atoms in a 2,000-site Optical Tweezers Array at Cryogenic Temperatures



Highlighted in Science Magazine for Work with Drug Discovery and Predicting Toxicity of Molecules

Pasqal Paper on Quantum AI Accepted at ICML 2024

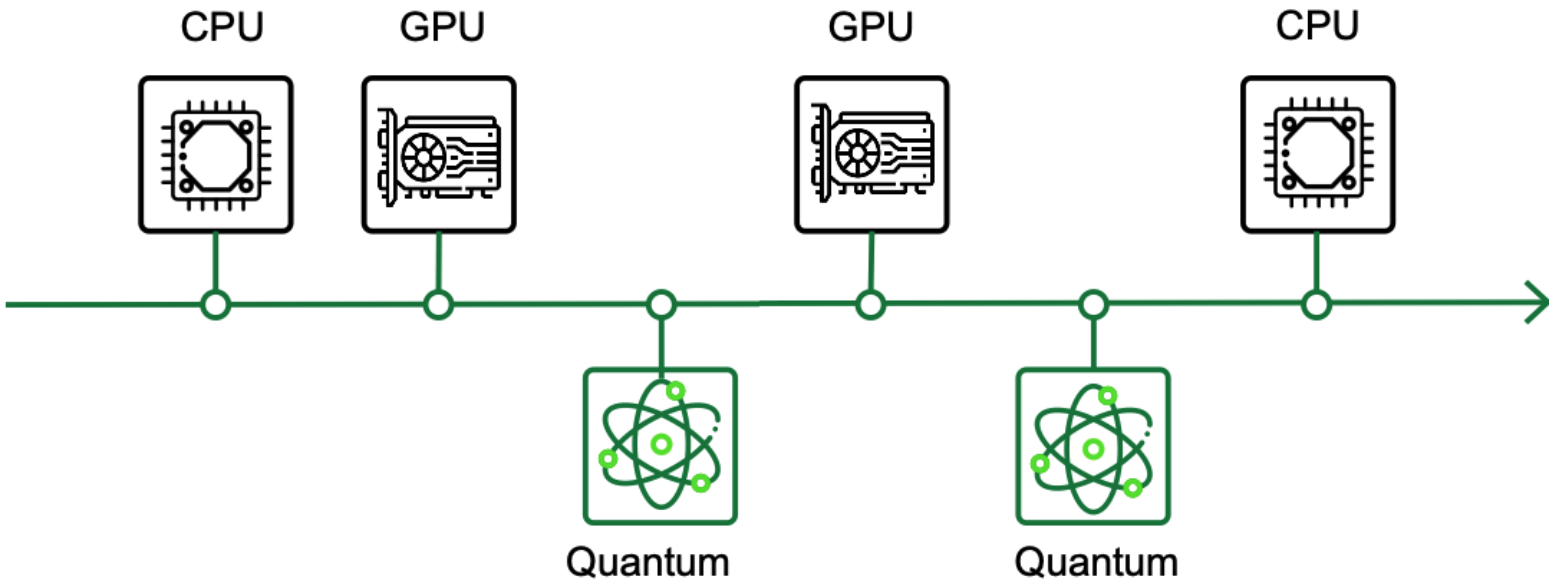
Future of HPC = Quantum-Centric Supercomputing

Pasqal

- HPC workflows combine multiple type of specialized computing resources: **Quantum computing** will be one of them.

- Standardization of the quantum-centric HPC approach: Pasqal and IBM joined forces to develop this standard.

Diversity in computational resources employed in a future HPC workflow



Pasqal & IBM for Quantum-Centric Supercomputing

Pasqal

- Annouced on Nov. 21st

Pasqal

IBM and Pasqal Plan to Expand Quantum-Centric Supercomputing Initiative

As part of intended quantum-centric supercomputing collaboration between Pasqal and IBM, unified programming model built on Qiskit will aim to integrate various quantum and classical hardware resources for advanced HPC workflows.

https://www.pasqal.com/ko/news/ibm-and-pasqal-plan-to-expand-quantum-centric-supercomputing-initiative/

https://www.ibm.com/quantum/blog/supercomputing-24?social_post=sf208076574&sf208076574=1

Pasqal

2

Pasqal Full-Stack Roadmap towards Quantum Readiness

PASQAL, the First Company Pushing Engineering for Neutral Atoms QPU

Pasqal

Engineering

A choice that enables us both to boost our technologies and develop products that can be used by the community

Boosting performance

NEAR-TERM QC

Qubit scaling +

Increase # of qubits in same QPU

Addressability +

Run and parallelize multiple qubit ops

Repetition rate

Increase the max # of calculations per second

+

ERROR CORRECTED QC

Error Correction +

Implement active error correction on logical qubits

Interconnect

Increase logical computational power

Mature Products & Community-driven application development

QPU generations +

Increasing hours of QPU for users +

Collaborative platform +

Open-source software stack

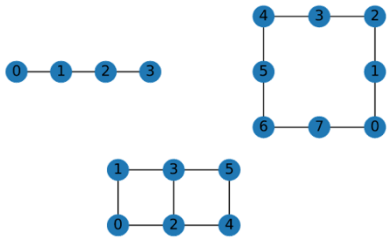
Developing an open-source SW community

Pasqal

QADENCE

A high-level library for Digital-Analog circuit design

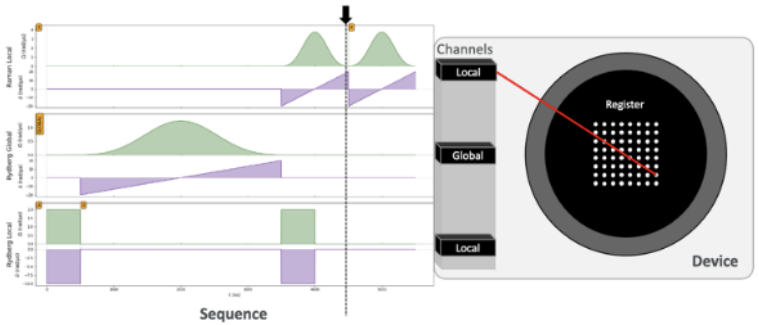
- Automatic Differentiability via PyTorch integration.
- Parametric quantum programs with an intuitive symbolic system
- A simple interface to work with neutral-atom qubits using arbitrary registers topologies.



PULSER

A low-level library to design and simulate pulse sequences at fine-tuned mashine-level for neutral atoms QPUs .

- Programmable atomic arrays
- Control over relevant physical parameters
- Simulation with noise and errors



and more...

- State-vector emulators interfaceable with Qadence and Pulser (PyQ, QuTip)
- Tensor-network-based emulator upcoming (Q4 2024)
- Algorithmic libraries upcoming (2025)

Our Roadmap

Pasqal

Technology

PASQAL & affiliated ecosystem

		2022 - 2023	2024 - 2025	2026 - 2027	2028+
HARDWARE PLATFORM	Max qubits	200	1,000	10,000	
	Addressability	Z add	Z+X add	Addressable 1Q and 2Q gates	
	Base repetition rate	1 Hz	3 Hz	10 Hz	100 Hz
	FTQC Program		Atom shuttling; Ultra High-Fidelity Gates	Scalable logical qubits architecture	
HARDWARE ACCELERATED LIBRARIES	Quantum Matter & Quantum AI	Algorithm Blueprint	Algorithm Development	Production	

Products

QUANTUM PROCESSORS	Generation	**Orion Alpha** ~3M gates	**Orion Beta** ~5M gates On premise delivery	**Orion Gamma** ~10M gates On premise delivery	**Vela** ~40M gates	**Pegasus** ~200M gates	**Centaurus FTQC QPU** 128+ Logical qubits 200M+ gates
	Total hours of QPU for users	500	5-10,000	20-30,000	60-70,000	200-250,000	500-550,000
	Factories	France	Canada	Factory 3			
COMMUNITY	Platform		Learn	Interact	Collaborate		
	Open-source Software Stack	Pulser	Qadence	Solvers & Emulators			

Pasqal delegation at QTML 2024

Pasqal

Vytautas Abramavicius

Casper Gyurik

Annie Paine

Roberto Mauro

Heejeong Jeong

Thank you for your attention!

Pasqal