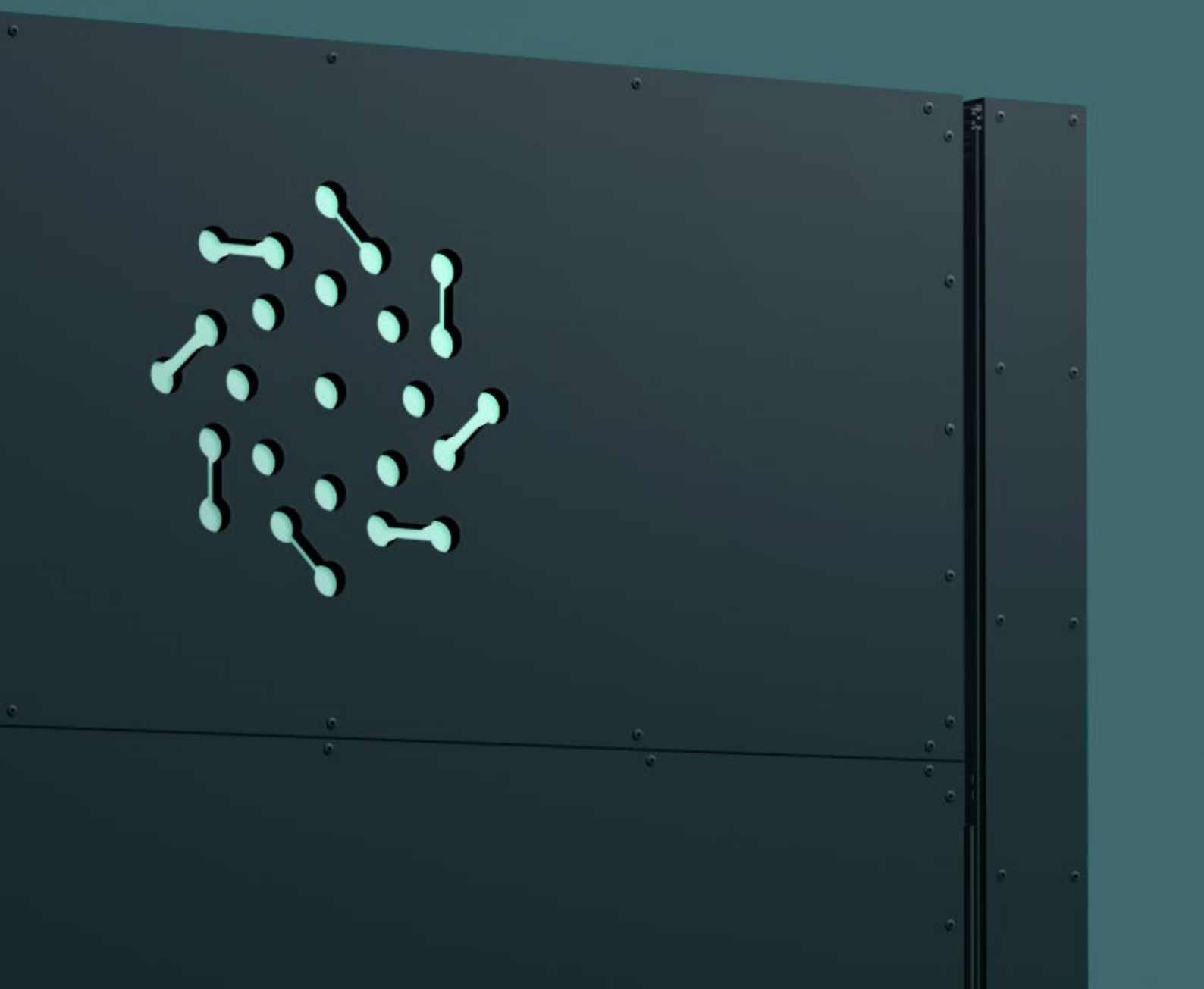
Pasqal

The Power of neutral atom quantum processors by Pasqal

Unlock Quantum Computing for Real-World Solutions



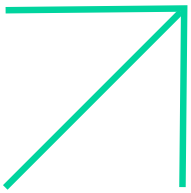
Redefining quantum computing for businesses

At Pasqal, we are redefining quantum computing to solve today's challenges and empower tomorrow's innovators. Our unique neutral atom quantum processors (QPU) are designed to bring transformative solutions to industries ranging from finance to healthcare.

This brochure is your gateway to understanding how Pasqal's hardware works, what makes it revolutionary, and how your business can benefit today.

Quantum computing, the game-changer for industries

Quantum computing leverages the principles of quantum mechanics to process information in fundamentally new ways, enabling solutions to problems that classical computers struggle to handle. The ultimate long-term goal is to outperform classical computers with so-called fault-tolerant quantum computing (FTQC) on speed, accuracy and energy consumption. And while progressing towards that ultimate goal, Pasqal's neutral atom QPU hardware is already delivering value today by addressing specific use cases in optimization, simulation, and machine learning.



$5–10 BILLION expected value creation for end users before 2030.
— The Boston Consulting Group

Addressing today's industrial challenges with quantum computing

Business leaders in industries such as energy, healthcare, and finance are grappling with:

Problem complexity
Classical computing struggles to process increasingly large, interconnected datasets efficiently.

Optimization problems
Logistics, resource allocation, and supply chain optimization demand faster, more accurate solutions.

Simulation limitations
Classical methods cannot model increasingly complex problems like molecular interactions or financial scenarios effectively.

Increasing costs
The burden of cost of computations becomes increasingly large and classical computing cannot address this efficiently.

Why Quantum is Relevant Now

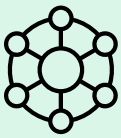
While the era of fault-tolerant quantum computing is on the horizon, quantum solutions are already delivering:

Strategic advantage & competitive edge

Early adopters of quantum technology gain a competitive edge, positioning their businesses as leaders in innovation toward transformative advancements in their fields.

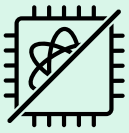
Quantum AI

With classical computing's increased energy costs to handle machine learning (ML) and complex language learning models (LLM), low-energy efficient quantum processors offer a robust platform for quantum AI that can handle complex information with more accuracy.



Enhanced simulation capabilities

Accelerate drug discovery or optimize chemical processes.



Hybrid quantum-classical integration

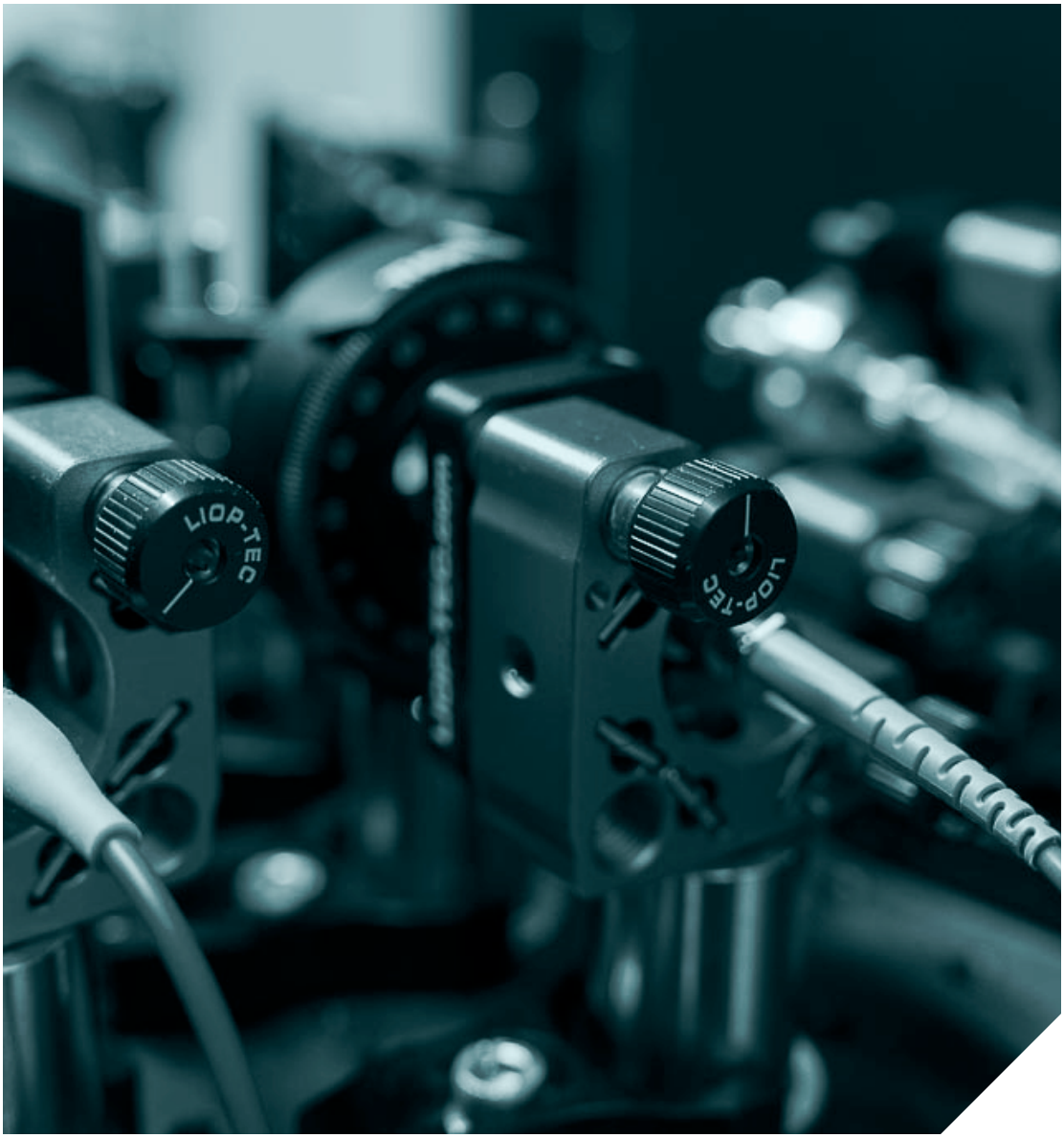
Pasqal's Quantum Processing Units (QPUs) easily integrate with High-Performance Computers (HPCs), creating powerful hybrid systems

Energy efficiency

Achieve lower energy-to-solution ratios compared to classical methods.

Pasqal's QPU seamlessly integrates with HPC systems,

forming hybrid solutions to supercharge your workflows.



How do neutral atom quantum processors work ?

Neutral atom QPUs leverage individual atoms trapped in arrays of laser light to perform computations. These systems are flexible and can operate in analog and digital modes, making them ideal for solving many problems. Both have unique strengths and limitations, making them suitable for different types of quantum applications.

DIGITAL

encodes quantum information into specific quantum states and uses gate sets that build up a circuit, similar to how classical computers operate in a universal way. This approach is versatile and suitable for a broad range of algorithms and applications, including those required for full-scale quantum advantage in cryptography, molecular simulation, and material discovery. However, digital requires quantum error correction and therefore is more quantum-resource-demanding that analog. Fault-Tolerant Quantum Computing (FTQC) aims at operating free of these errors by mitigating and correcting them.

- **Solves a wide range of problems**
- **Uses more resources and requires error-correction**

ANALOG

quantum computing uses continuous operations to model complex, specific problems directly. Analog methods are less error-prone than digital ones because they require fewer operations and encode the problem at hand natively in the hardware. This advantage makes analog systems effective for specific applications in the near term without explicit error correction.

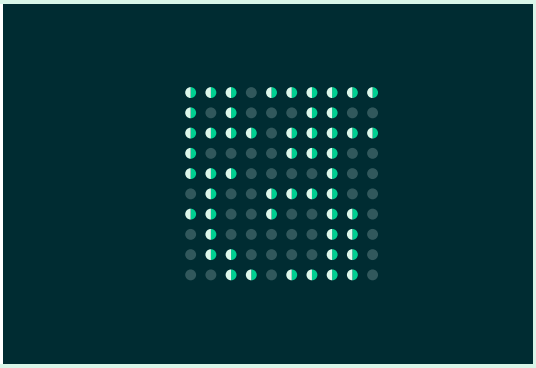
- **Solves specific problems**
- **Less prone to error**

Encoding & Processing Quantum Bits

In a neutral atom quantum computer, atoms are used to perform computations. Each atom's energy state represents a state of a quantum bit: the ground state is encoded as 0, and the Rydberg (excited) state is encoded as 1.

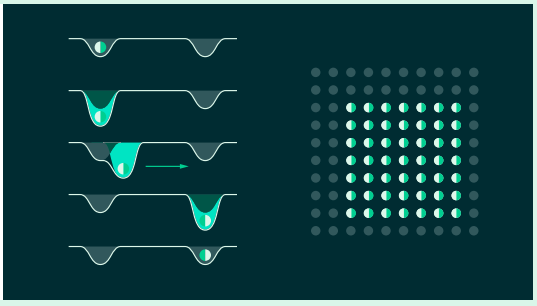
Atom loading

A laser acts like an optical tweezer, trapping atoms with pinpoint precision (at 1 micron). By splitting the laser beam into smaller beams, an array of traps can be generated, capable of catching numerous atoms. As this is a stochastic process, roughly half of the traps will contain an atom.



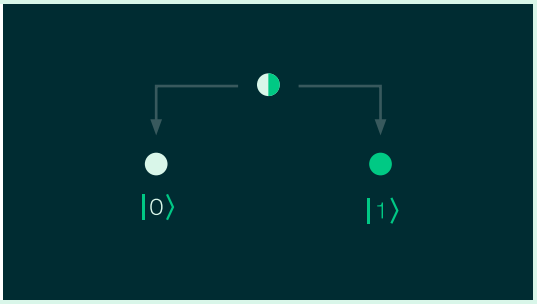
Register preparation

The atoms can then be moved to create a custom geometrical grid, forming the quantum register.



Quantum processing

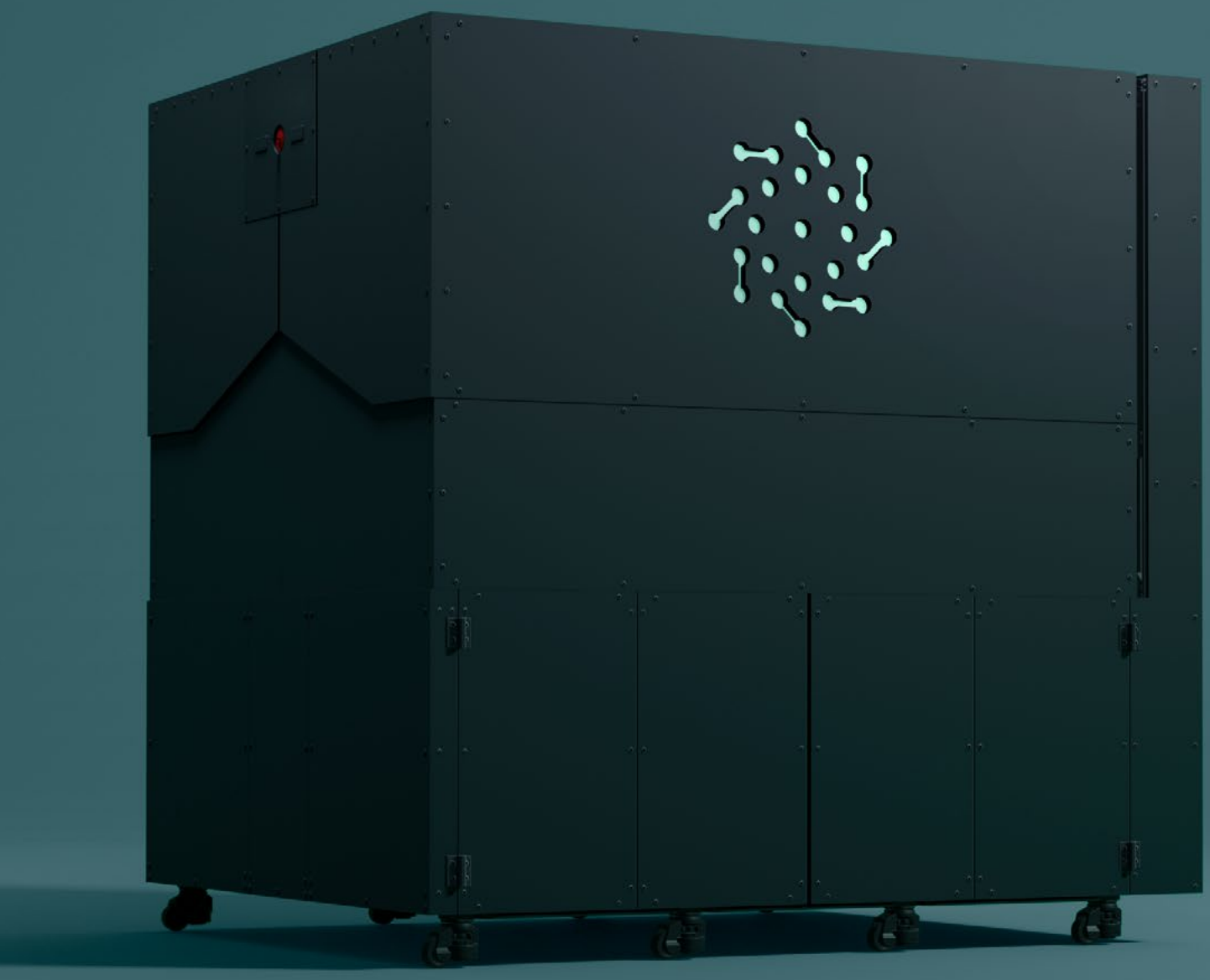
Manipulating the array of atoms using lasers allows quantum calculations to be performed by switching between energy states.



Results read-out

The final results are read by imaging the array: excited atoms (ones) appear as dark spots, while ground-state atoms (zeroes) appear bright.

Orion Beta



100
qubits

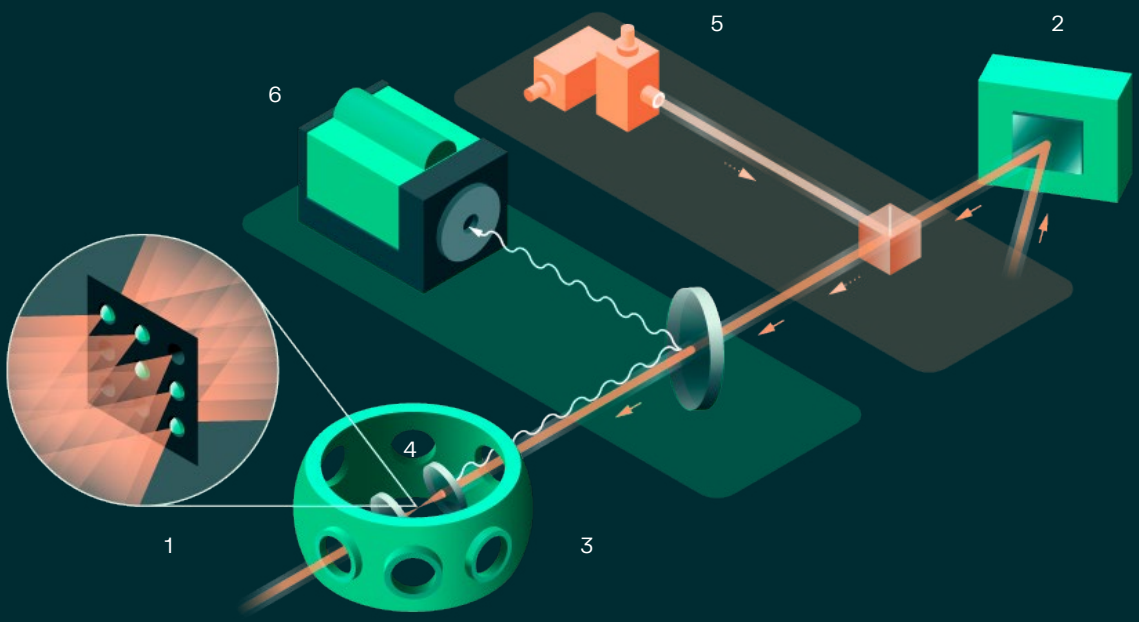
3 kW
average consumption

Room temperature
operation

Standard data center
compatible

A Pasqal Quantum Processing Unit (QPU) is built up modular and transportable, with a few key modules:

- An optical setup including the lasers to trap, move and manipulate the atoms.
- A vacuum chamber that holds the atom register.
- The electronics rack to control all the components.
- All packaged in a mechanical structure.



To realise the processing cycle of the QPU, there's a few critical components at the core of our QPU:

1. The atoms are trapped by a laser, the so-called optical tweezer.
2. To create a grid of multiple traps, the laser is split using a Spatial Light Modulator (SLM).
3. This trapping happens in a vacuum chamber, since atoms are very susceptible to disturbances in the surroundings (vacuum close to that of space).
4. Inside the vacuum chamber there are two high numerical aperture lens objectives that ensure the laser spots are focused on where the register needs to be.
5. To move atoms for creating the required geometry, Acousto-Optical Deflectors (AODs) are used.
6. Lastly, the readout of the atoms happens with a camera that detects fluorescent light.

Pasqal Offerings

Pasqal hardware

Orion Beta

100
qubits

Noise level

Analog Mode

Open-source Software

Orion Gamma

pre-order, delivery in 2027

200+
qubits

Noise level

Analog Mode

Open-source Software

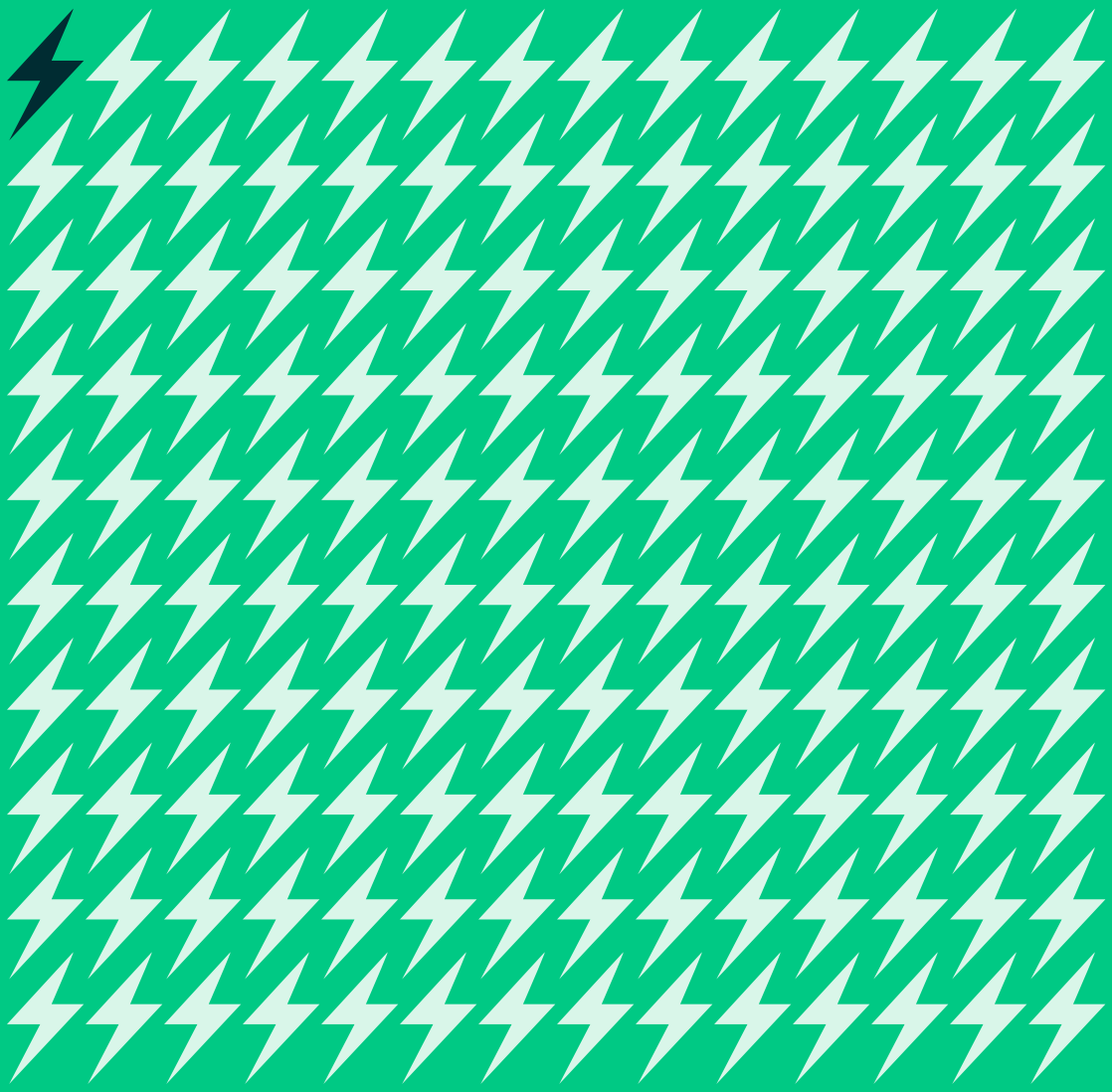
Pasqal solutions

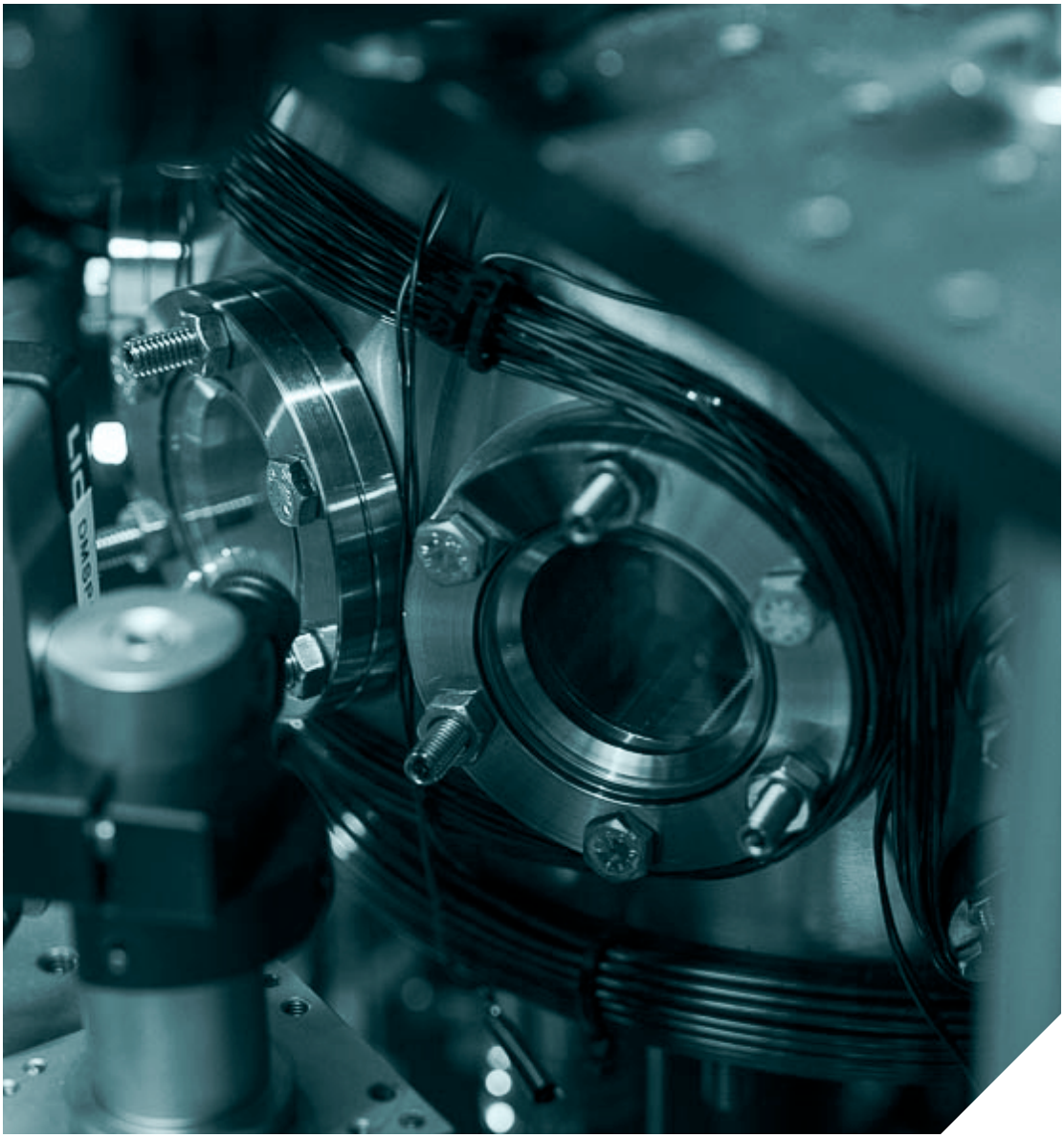
QPU on-site
Procure a QPU for delivery and installation on-site. Benefit from dedicated availability and having full control over HW updates.

Virtual QPU
An alternative offer for those that require unlimited QPU access, without owning the device.

Pasqal's flagship Orion machine requires only 3 kW

compared to 1,400+ kW
for a classical supercomputer.





Advantages of quantum computing with neutral atoms

While QPUs can be built using different technologies like superconducting, photonic, and trapped ions, there's a number of advantages that set neutral atom QPUs, and Pasqal in specific, apart:

- Scalability
- Uniformity & quality
- Both analog & digital modes
- Ease of operation
- Energy efficiency

EASE OF OPERATION

No strict requirements on environment. Just need a wall socket and a network cable to connect.

SCALABILITY

No major roadblocks near-term to scale the qubit count to 10,000 qubits and beyond, following our roadmap.

BOTH ANALOG & DIGITAL MODES

The unique capability to do both analog and digital experiments adds flexibility and offers the opportunity of near-term value with analog while developing FTQC.

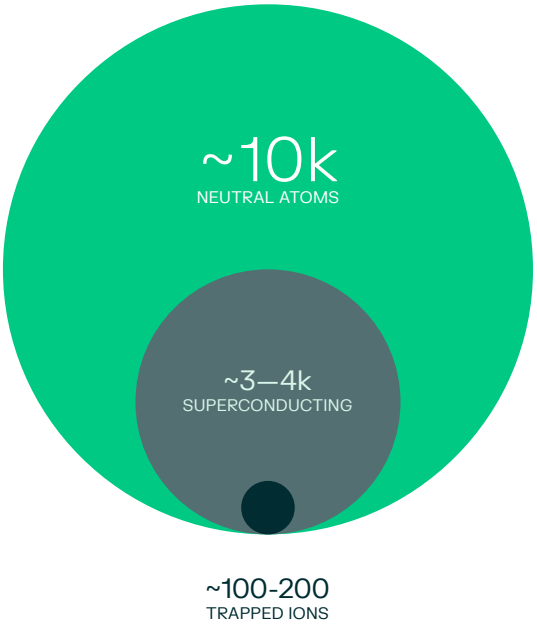
ENERGY EFFICIENCY

No cryogenics required, the system operates at room temperature, significantly reducing power consumption compared to classical computing.

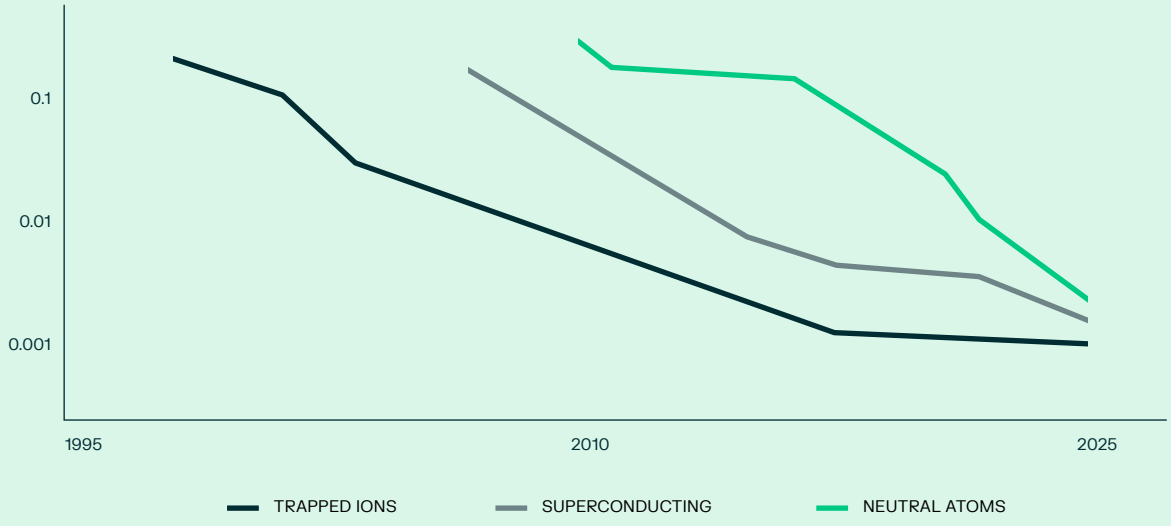
UNIFORMITY & QUALITY

This technology uses atoms as qubits, they are naturally identical and free from any imperfections.

Estimated max. number of qubits achievable in a single QPU.



Error rates of neutral atoms are inching closer to competing modalities, fast.



Why choose Pasqal?

Aside of these technological advantages of neutral atoms, there's also many other benefits of partnering with Pasqal:

Scientific foundation

Spun off from the renowned Institut d'Optique of Paris-Saclay University, co-founded by Nobel-Prize winning professor Alain Aspect, and close to 100 scientific publications since the company's founding in 2019.

Full stack

Pasqal offers both hardware and integral software solutions. Our open-source software libraries make it easy to engage with our hardware and build your own solutions.

Modular design

Individual hardware modules can be upgraded to stay on par with the state-of-the-art without needing to replace the entire QPU.

Industrialized technology

Pasqal technology is currently deployed in various data centers, and can be delivered on-site for full control of access and security.

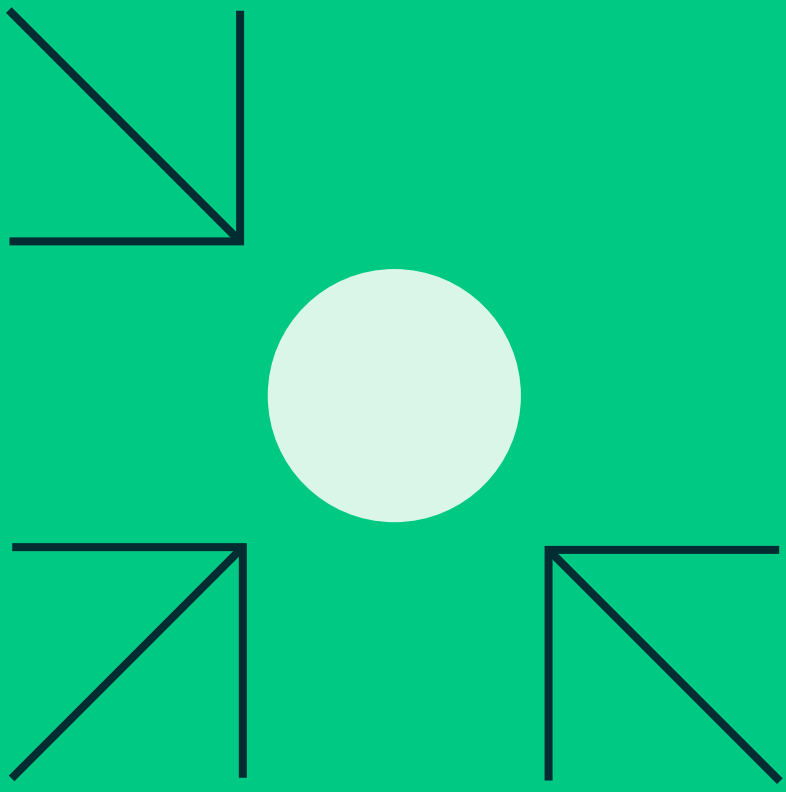
Services

We provide services in collaboration with certified partners to help in every step towards quantum computing delivering value to your business.

Community

A vibrant Pasqal community providing peer to peer support and continuously creating new applications based on Pasqal products.

Neutral atom technology offers unparalleled precision, scalability, and energy efficiency.



Quantum in action: proven industry use cases

Pasqal's QPU technology is already transforming industries.

Finance

Early detection of "Fallen Angels" for Crédit Agricole, enabling smarter, faster decisions in complex financial environments.

Pharma

Locating water molecules in proteins, crucial for drug design. Together with Qubit Pharmaceuticals.

Energy

Algorithms to maximize the loads to charge a fleet of electric vehicles at EDF.

Finance

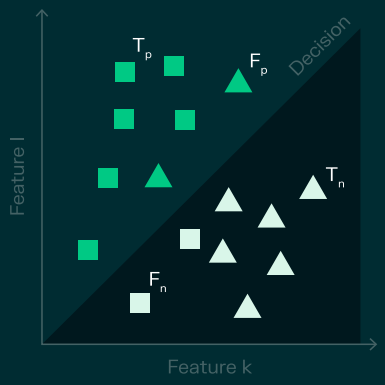
CONTEXT
Financial institutions assess debtor's ability to repay loans.

OBJECTIVE
Predicting corporate credit rating downgrades (e.g. by agencies like Moody's) offers early insights into potential loan risks.

CURRENT METHOD
Credit Agricole CIB developed a model to anticipate credit downgrades, so-called "fallen angels".

Applying a Random Forest Classifier, a machine learning (ML) technique to classify a dataset, using so-called decision trees.

Trained on a dataset of 65k records from 2,300 companies in 70 countries.



NO FALLEN ANGEL
FALLEN ANGEL

Decision
ML TRAINED CLASSIFIER

QUANTUM SOLUTION
A hybrid classical-quantum classification algorithm called QBoost was proposed.

The algorithm was implement on a Pasqal QPU with 50 qubits.

3.5×
runtime reduction vs. classical

METRIC	CLASSICAL	QUANTUM	NOTE
Recall	83%	Same	E.g. out of 100 fallen angles. 83 detected correctly.
Precision	28%	Same	E.g. if 100 fallen angles predicted, 28 truly are.
#decision trees	1,200	50	For quantum equal to #qubits, reduces runtime significantly
Runtime	>3 hrs	50 min	

Source: Financial Risk Management on a Neutral Atom Quantum Processor, L. Leclerc et al, arXiv:2212.03223v2

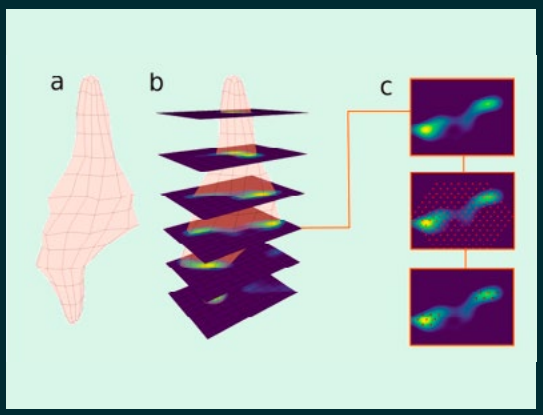
Pharma

CONTEXT
In medecine design, the presence of water molecules in cavities of harmful proteins can affect dramatically the binding strength of a drug.

OBJECTIVE
Finding the number and location of water molecules in a specific protein's cavities.

CURRENT METHOD
Molecular dynamics or Monte Carlo simulations provide accurate predictions but are time consuming and thus costly.

A faster method called 3D-RISM* only delivers a probability distribution of water densities in a protein cavity.

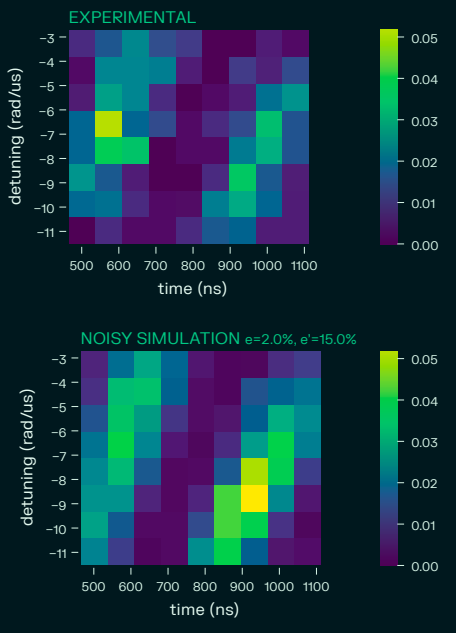


3D-RISM example result (a), sliced to 2D water density maps (b) and mapped to qubit registers (c).

QUANTUM SOLUTION
The result from a 3D-RISM simulation is used as an initial input for a quantum algorithm that can find the exact positions of the water molecules (center figure).

Next, this algorithm was implemented on the Pasqal quantum simulator and tasked to minimize the difference between this guess, i.e. the water density distribution, and the quantum solution, i.e. the expected locations of the water molecules.

Finally it was checked to match experiments (figure on the right).



*3D-RISM = 3D-Reference Interaction Site Model

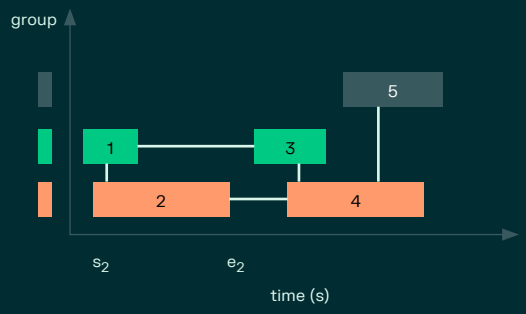
Energy

CONTEXT
Charging of EVs presents both challenges and opportunities for grid electricity management.

OBJECTIVE
Minimize the time of a number of charges, while no group (representing e.g. a vehicle fleet) is over-represented in the schedule.

CURRENT METHOD
From a dataset of 2,250 load tasks, performed in May 2017 in Paris, randomly N loads were selected and grouped using a uniform distribution.

To embed this in graphs, nodes were assigned to each load (e.g. 1 — 5 on the right) and two nodes were connected by edges when either they belonged to the same group or their intervals overlapped (e.g. black/red lines).



QUANTUM SOLUTION
Reaching the objectives equals finding the Maximum independent Sets (MIS) of the graphs (e.g. nodes 2, 3, 5).

A so-called quantum annealing algorithm was proposed to solve this and implemented on a Pasqal QPU with 100 qubits, alowing for graphs up to size 100.

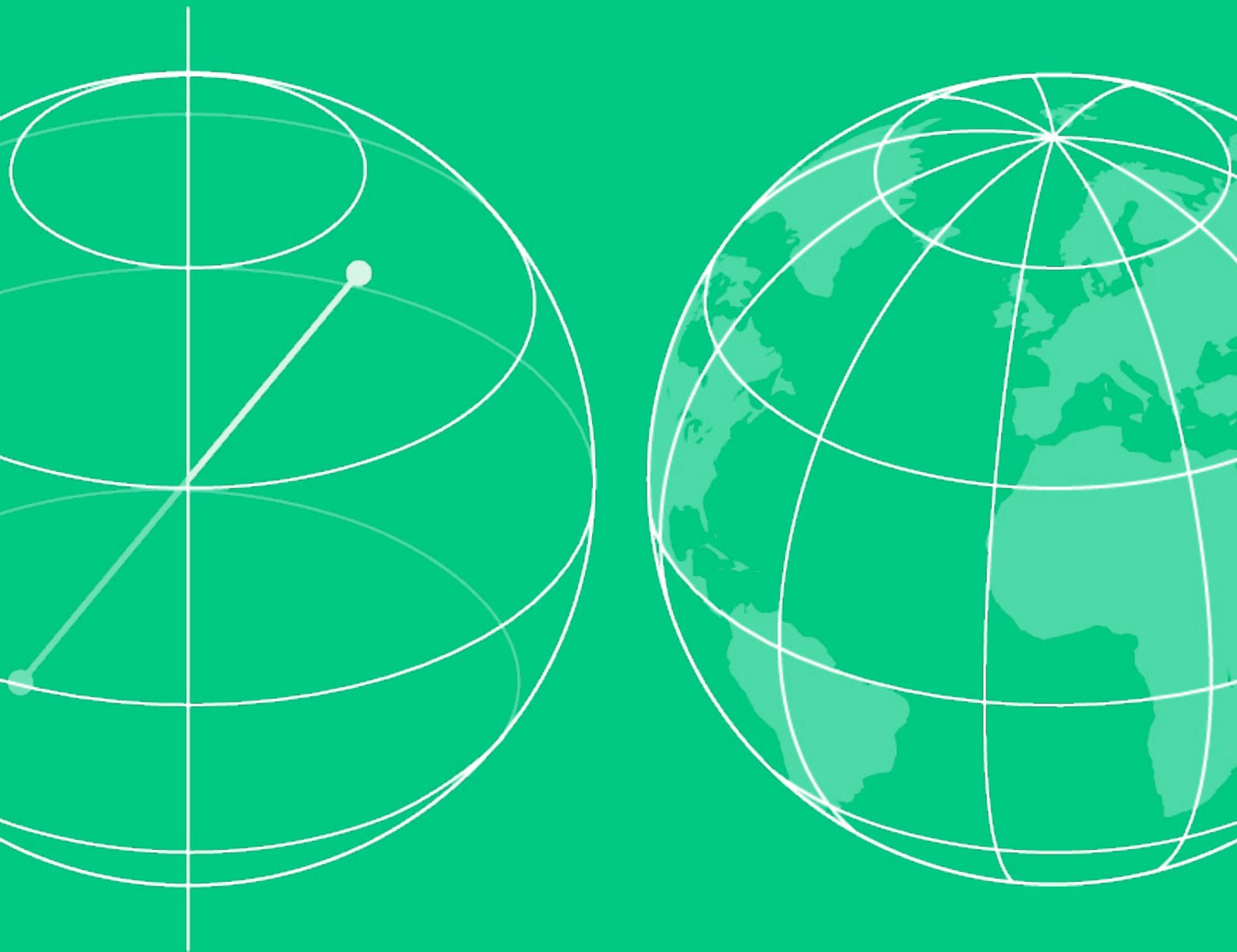
This diversity can be leveraged in hybrid classical quantum approaches for 1,000 qubit system size that promises energy performance gains vs. classical*.

Pasqal has demonstrated such a 1,000 qubit system back in 2024, and is industrializing this for commercial use soon.

>98%
approximation ratio
with a strong diversity of solutions

* Da Silva Coelho et al., Physical Review A 107.3 (2023): 032426

Pasqal's QPUs blend power, efficiency, and adaptability for real-world applications.



Our QPUs are ready to solve your toughest problems.
Let's innovate together.

1

Consult
with our experts to align quantum solutions with your business needs.

2

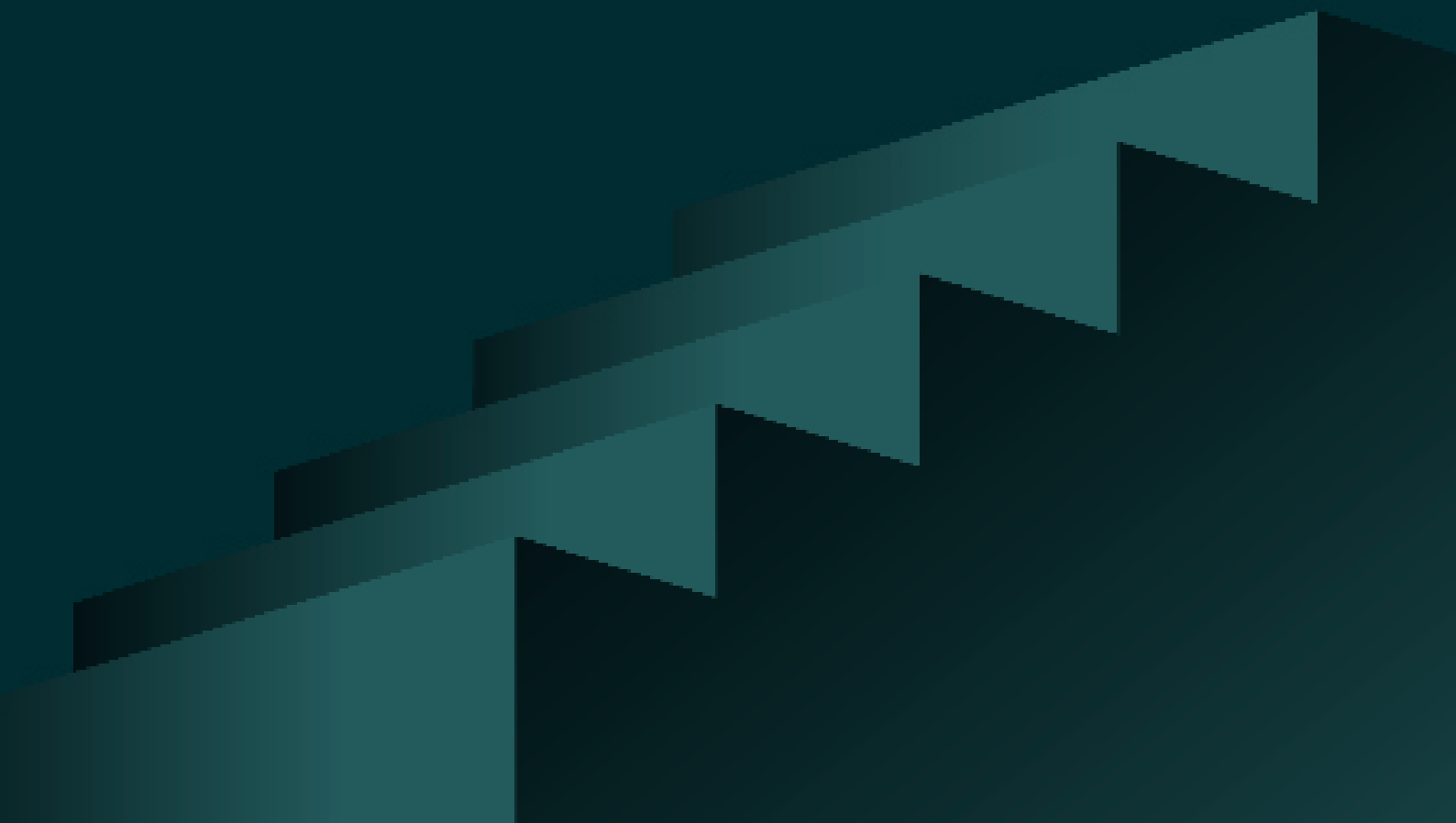
Experiment (optional)
on our neutral atom QPUs via the cloud and use our software stack to solve business challenges through quantum algorithms with support from Pasqal or our certified partners.

3

Secure
a QPU and have it delivered to and commissioned at your facility.

4

Start
your very own Quantum Computing journey.



Pasqal

Join the quantum revolution with Pasqal

To learn more about us, visit www.pasqal.com

To get in touch: www.pasqal.com/contact-us

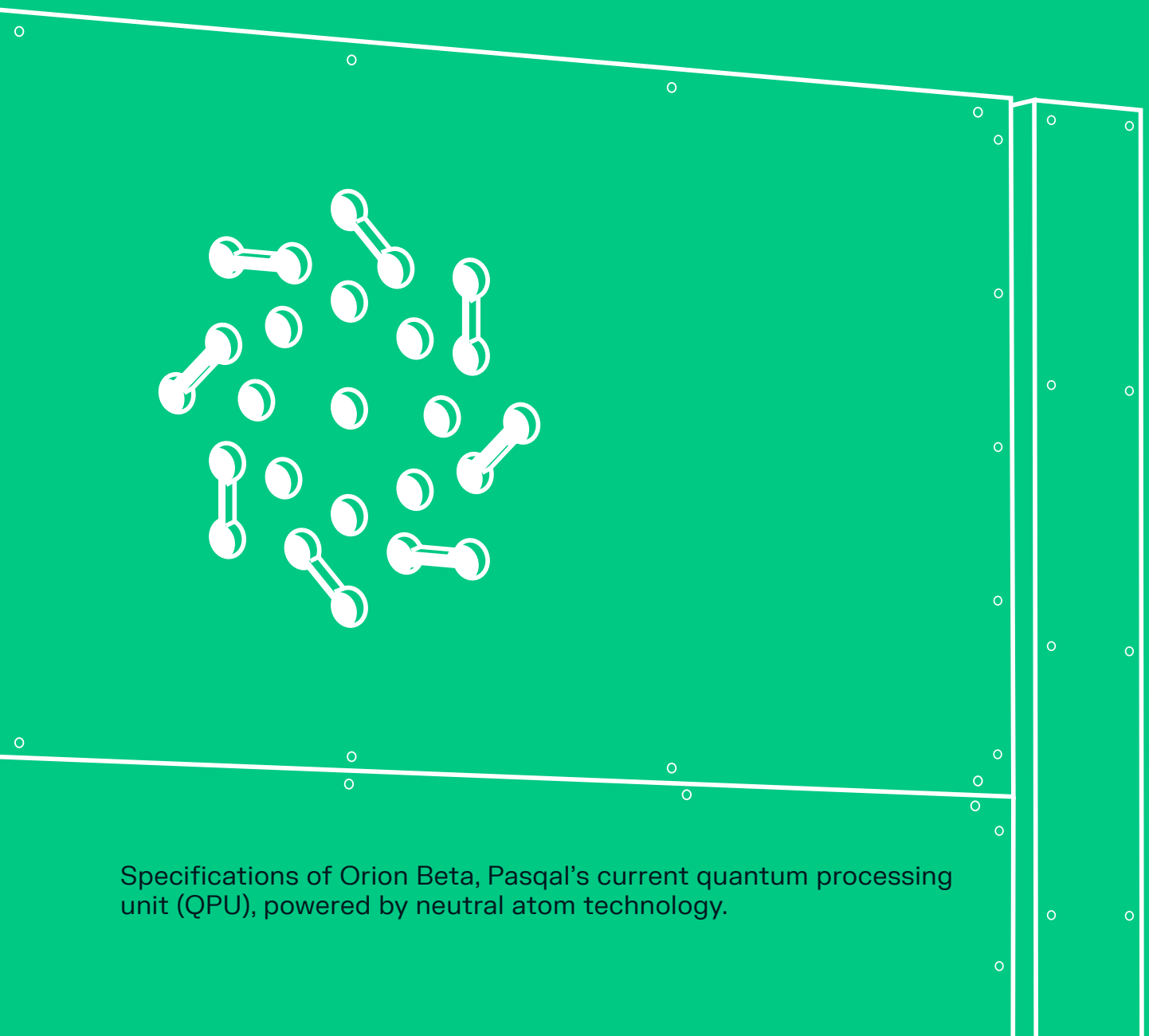
And to stay up to date with Pasqal, please visit:
https://www.pasqal.com/newsroom

www.pasqal.com

Pasqal

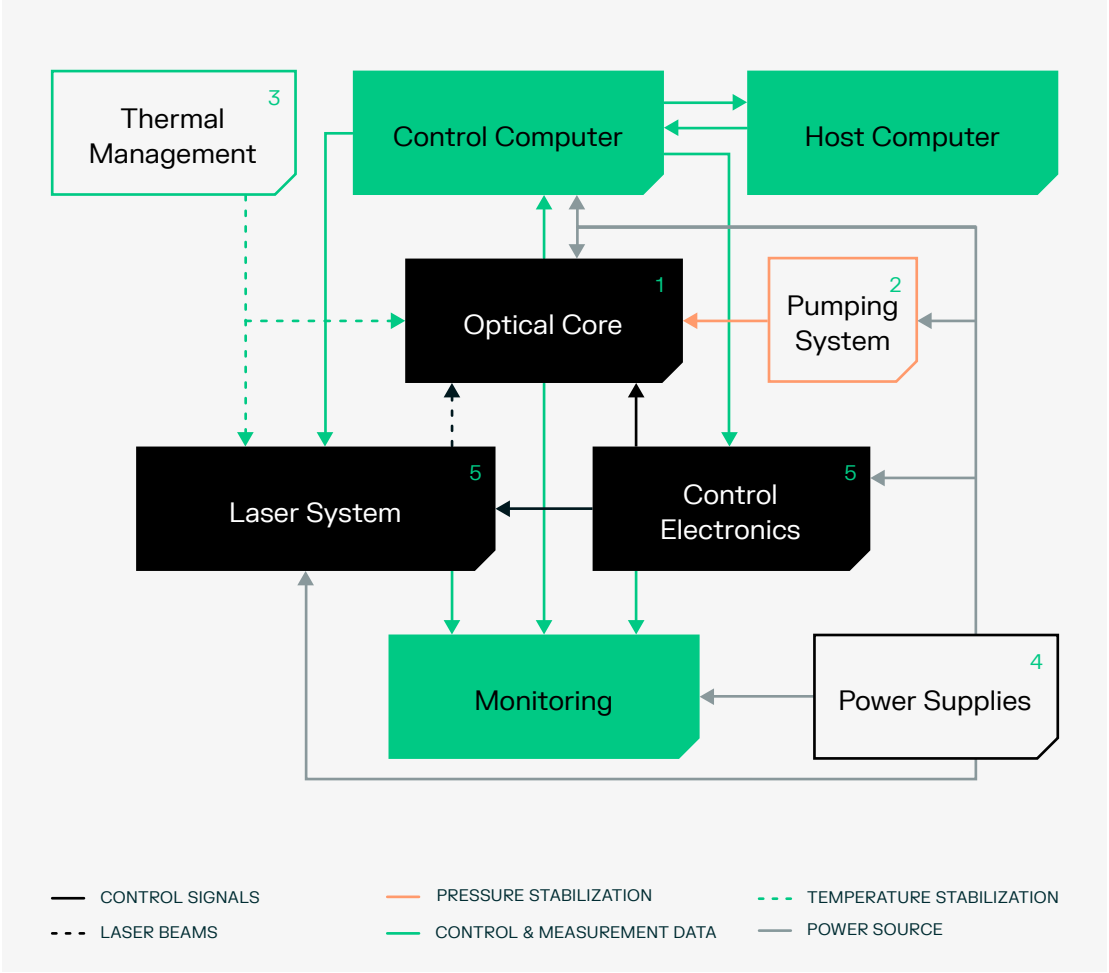
Technical overview for advanced users Orion Beta

Version 4.0



Specifications of Orion Beta, Pasqal's current quantum processing unit (QPU), powered by neutral atom technology.

QPU main building blocks



1. The “Optical core” system traps and manipulates atomic qubits to generate quantum registers and perform processing tasks.
2. The “Pumping system” ensures the ultra-low vacuum level for proper operation of the QPU.
3. The “Thermal Management” system ensures fine thermal management of all the QPU sub-systems.
4. The “Power supplies” system provides power to all the sub-systems.
5. The “Laser System” and “Control Electronics” enable atomic qubit control, including all necessary laser sources, optical benches, and electronics for configuring, manipulating, and reading the quantum register.
6. The “Control computer” manages all operations of the quantum computer and interfaces with the “Host computer,” receiving instructions and sending results.
7. The “Monitoring” system, composed of a broad range of sensors, is used to check the overall sanity of all the sub-systems and to follow the QPU status.

QPU specifications

The elementary data elements of Pasqal's Quantum Processing Units (QPUs) — quantum bits or qubits — are laser-cooled Rubidium atoms, individually trapped by tightly focused laser beams, called optical tweezers.

The qubits are encoded in the atoms' electronic states by laser beams and then manipulated using lasers.

The interaction of qubits with light enables access to the finest physical parameters, making our quantum processor a unique tool for creating and controlling complex quantum systems.

General

Maximum number of qubits	100
Minimum Effective Computation Repetition Rate Only counting successful computations	0.25 Hz The actual ECRR depends on the number of qubits
Operation Mode	Analog

Atom arrangement

Layout on demand	✓
Minimum atomic distance	5 µm
Maximum radial distance	35 µm
Maximum layout filling fraction:	0.5
Minimum number of traps	10
Maximum number of traps	200

Pulse sequences

Maximum number of runs per job	500
Maximum sequence duration	6000 ns
Minimum pulse duration	16 ns
Maximum Rabi frequency	2 MHz
Maximum detuning	7.75 MHz

Physical dimensions

Total Dimensions Height x Width x Depth	210 × 330 × 160 cm
Number of modules	5
Dimensions of Hosting Room Height x Width x Depth	270 × 530 × 310 cm
System Weight	2500 kg — 350 kg/m2 on a vibration-isolated floor
Laser Type	Class IV + Laser safety interlock

Environment specifications

Peak power consumption	10 kW (± 3kW on average during operation)
Power supply	1× three-phased line 380V, 2P+N+E 32A
Interfaces (operations / maintenance)	2× ethernet port (RJ45)
Operating Temperature	20-22°C
Ambient air humidity	60% ± 20%
Vibration Isolation	✓
Hydraulic circuit	1× inlet and 1× outlet port Water temperature: 20 — 23°C

Pasqal