Quantum Simulation
An overview of quantum simulation and its applications
Summer 2022
This is a publication from the Quantum Computing & Simulation Hub, an EPSRC funded collaboration of seventeen universities, bringing together academia and industry as part of the UK National Quantum Technologies Programme.

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The authors would like to thank, in no particular order, the following individuals for their invaluable support and advice throughout the creation of this report: Andrew Daley, Anthony Laing, Stefan Kuhr and Ulrich Schneider.
Introduction

Quantum simulation is an often overlooked part of the Quantum Information Technology (QIT) revolution that is currently happening around the world. QIT promises new approaches to computing, inherently secure communications and the ability to solve intractable computational problems. However, perhaps one of the most essential offerings will be a better ability to understand nature and its fundamentals.

Existing digital computers make valiant attempts to mimic the complex processes we find in nature, but despite the ever increasing and cheaper volumes of processing power, few can match the complexity of quantum physics. For many of the most fundamental problems – often the most valuable in chemistry and physics – classical computing proves to be inadequate. Quantum computers are expected to perform better in these areas, but the best modelling of quantum dynamics could be provided by a quantum system that we can manipulate. This is known as a quantum simulator.

Developing these tools faces tough technological challenges, but good progress is being made towards practical applications in industry and science. Quantum simulators offer unique strengths and should be considered as viable near-term solutions for high-value applications in fields such as logistics, materials discovery and chemistry. This report provides an accessible overview of quantum simulators, their technology and their likely applications.

"Nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical, and by golly it's a wonderful problem, because it doesn't look so easy."

Richard Feynman
What are quantum technologies?

The behaviour of nature at the atomic and subatomic scales has intrigued and divided scientists, writers and philosophers over many decades. This branch of physics, called ‘quantum mechanics’, has given us incredible insights in how nature operates beyond our everyday experience, and introduced new terms like superposition, entanglement, interference, tunnelling and teleportation.

Now we are at the stage where we can harness these unique properties of the quantum world and, coupled with quantum information science, engineer entirely new technologies across imaging, sensing, timing, communication, computation and simulation.

Imagine being able to discover new materials and medicines, optimise logistics, and enhance online security – these are just some of the applications being pursued by researchers and businesses across the world.
Why simulation matters

Simulation is the representation of some physical or natural system by another, in order to advance understanding, explore theories and predict outcomes. Simulation is not a new concept – planetary motion, for instance, has long been of interest and various physical models have been constructed throughout the ages. [1]

Electronics and digital computing have played an important role in advancing simulation techniques. The first electronic analogue simulator was proposed and developed in 1938 by George A. Philbrick, an ‘Automatic Control Analyzer’ which saw considerable use as a training tool. [2] Analogue computers have seen use in subsequent decades in applications such as modelling control systems (e.g. flight simulators). [3]

In just a few minutes of demonstration, it could impart considerable knowledge of process dynamics, controller tuning, and the effects of load and control-point upsets.

George A. Philbrick [2]

Nowadays, common applications for simulation include: designing buildings and other complex structures, studying chemical processes, analysing vehicle aerodynamics, and modelling geological activity, the behaviour of crowds and even the spread of disease. [4] [5]

The terms simulation and emulation are often used interchangeably to suggest the representation of one system on another but in the context of this report, they are different entities.

A quantum simulator is a physical quantum system used to model another quantum system (or a problem that can be mapped to it, such as optimising traffic routing for example).

An emulator is used to represent hardware. For example, quantum computers can be emulated in software (up to a point) while the hardware is being developed. The open source software QuEST is one such emulator, used by researchers to run quantum algorithms on a variety of problems. [6]

Source: Hobby - Das Magazin der Technik, issue 6, 1965

A RAT 700 analogue computer (left) simulating a car suspension system in the scope (right)
With digital computers becoming more powerful and cheaper, there is an increasing demand for engineering simulation and tools, with the global market for the simulation and analysis industry forecast to exceed $10 billion by 2024. [7] Analogue quantum simulation will be a very interesting addition to this growing field.

CIMdata Publishes Simulation and Analysis Market Report. [7]

Simulators can help us to understand real-world behaviours that are too big, too small, too expensive, too far away or too dangerous to study directly. As this report shows, they are emerging as a key tool in areas that cannot be tackled using existing technologies, including natural quantum systems (e.g. in chemistry or particle physics) and similarly complex phenomena.

The advent of quantum simulators brings new tools for studying systems and quantum systems in particular, offering capabilities beyond the reach of classical computers. [8]

* A qubit is the most basic unit of information in QIT.
Building analogue quantum simulators

Analogue quantum simulators could be considered analogous to analogue simulation devices such as the pictured string model or wind tunnels, the latter of which still sees widespread use in aerodynamics today.

<table>
<thead>
<tr>
<th>Specialised devices</th>
<th>Accelerate progress using real hardware dedicated to a particular class of problem. A ‘family’ of simulators can target related or different problems of interest.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>Some problems that are intractable today can be addressed in a practical manner. For instance, it would take thousands of years to compute the equations of motion for 100 atoms on a classical computer, but could take seconds on a quantum simulator. [9]</td>
</tr>
<tr>
<td>New frontiers in science and technology</td>
<td>The potential to study complex quantum systems with ground-breaking tools will enable new discoveries, and transform our understanding of nature, with the potential to translate research innovation to benefit wider society.</td>
</tr>
<tr>
<td>New tools for industry</td>
<td>Analogue simulators can help industry address a variety of use cases in materials design, optimisation problems and chemistry.</td>
</tr>
<tr>
<td>Skills and training</td>
<td>Resources for quantum educators and the next generation quantum workforce.</td>
</tr>
<tr>
<td>Fill a gap</td>
<td>Alongside the so-called NISQ devices, quantum simulators can occupy the space between conventional supercomputers and universal fault-tolerant quantum computers, which may be many years away.</td>
</tr>
</tbody>
</table>

NISQ: Current digital quantum devices are error-prone, and typically limited in size to tens of qubits. We refer to the era as noisy intermediate-scale quantum, or NISQ.

Image Credits: (Top) KK Clark / Blogspot - (Bottom) Memetician / Livejournal
A System View

Various technologies may be used to build quantum simulators. Each approach requires a multidisciplinary effort to integrate hardware and software, possibly with cloud services potentially providing remote access to a range of global users.

Right: High-level system view of the components required for useful quantum simulators

There are other important considerations in the development of quantum simulators:

<table>
<thead>
<tr>
<th>Supply Chain</th>
<th>Cloud Services</th>
<th>Government</th>
<th>Investors</th>
<th>Networks</th>
<th>Skills</th>
</tr>
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<tbody>
<tr>
<td>Quantum simulators rely on a range of existing technologies in the supply chain, such as lasers, microwaves, electronics, vacuum systems and cryogenic refrigeration. [10] For high-performance devices, new technologies and methods will require development in areas such as lasers, optics, and chip fabrication.</td>
<td>Cloud services can provide access to a new set of tools and possibilities, without the investment and maintenance costs for users.</td>
<td>Governments play a crucial role to balance national interests, commerce and collaboration to foster innovation and growth, as well as fund dedicated programmes to accelerate progress.</td>
<td>Quantum simulators require significant investment to develop and this can be supported by “deep tech” investors who are excited by the potential applications and their benefits.</td>
<td>Quantum simulators as nodes, in a hybrid or fully quantum network, could form an important part of the overall solutions delivery for complex problems.</td>
<td>It is important to develop and attract a highly-skilled workforce into the field of QIT. This relies on and benefits both educators and industry.</td>
</tr>
</tbody>
</table>
Quantum Simulators share many of the same base technologies as quantum computers. These include ultracold (aka neutral) atoms, trapped ions, superconducting, and photonic systems. A comparison of these is shown below. Other candidate technologies include quantum dots and colour-centres in diamond, which are still relatively early in their development phase and are not included here.

### Trapped Ions

**Charged particles trapped in electromagnetic fields.**

Trapped ions (based on a chain of ionised atoms trapped in rotating electromagnetic fields) are heavily developed for digital quantum computing. Spins can be encoded on the internal electronic states, and controlled with laser light. Spin models with long-range interactions can be implemented directly, mediated by the collective motional modes of the system of trapped ions. In the last few years they have been used to study out of equilibrium dynamics, and to implement variational quantum eigensolver routines. The challenge is to scale this beyond ca. 50 ions in a single trap, either by working with 2D arrays of ions, or by generating electronic or photonic interconnects between traps.

Examples: IonQ, Quantinuum, Universal Quantum

### Superconducting Circuits

**Superconducting electronic circuits.**

Superconducting qubits are presently one of the most developed architectures for quantum computing, based on well-developed microwave technologies and micro- or nano-electronic circuits that are cooled to milliKelvin temperatures. For quantum simulation, these platforms can also be used to explore the dynamics in a variety of spin and bosonic models. Existing systems with around 100 qubits have been used to study advanced models of condensed matter physics, demonstrating the applications of these hardware platforms for fundamental science. The next stage of development will involve scaling to larger numbers of qubits while improving the local calibration of qubits.

Examples: Google, IBM, Rigetti

### Photonics

**Uses photons as information carriers.**

Programmable photonic circuits are well suited to simulating so-called “bosonic” systems, such as vibrations in molecules. Quantum states of light such as ensembles of photons or squeezed states can be injected into miniaturised and interferometrically stable chips, made from silicon or other materials. Chip-scale reconfigurable systems with up to 18 photons have been demonstrated, within the limit of what can be simulated with classical computers. Larger scale systems of 100 photons with small levels of programmability have challenged the capabilities of supercomputers to simulate experiments at this scale. The next stage of development will include the introduction of programmability and error mitigation.

Examples: Duality Quantum Photonics, Orca Computing, Photonic Inc, Xanadu

### Ultracold Atoms

**Programmable lattices of cold atoms.**

Ultracold atoms trapped in laser light can be used to build lattice models usually used to describe electrons moving in a solid crystal, with atoms moving in crystals of laser light (an “optical lattice”). Neutral atoms have the unique benefit that they can directly implement models for fermions (like electrons), and this has been applied to study problems in condensed matter physics in the past few years. The state of the art involves over 1000 atoms in a 2D lattice (or ca. 250 trapped in optical tweezers, implementing spin models through Rydberg excitations). Individual addressing has been realised in quantum gas microscopes, and the next steps will involve improvement of local calibration.

Examples: Atom Computing, Pasqual, QuEra
Illustration of an optical lattice-based quantum simulator

An overview of a cold atom-based quantum simulator is shown below.

1. The rules by which electrons move in a material are often known. However, the dynamics are in many cases too complex to be classically simulated.

2. In a quantum simulator, synthetic quantum systems are constructed that implement these rules.

\[ \hat{H} = -\sum_{i,j} t_{i,j} \hat{a}_i \hat{a}_j^\dagger + \sum_i g_i \hat{n}_{i,\uparrow} \hat{n}_{i,\downarrow} \]

3. In the interference pattern of laser beams ultra-cold atoms move not like the electrons in the crystal structure on the left. The rules – the Hamilton operator of the system – are set by the laboratory.

4. Now one can gradually change the Hamiltonian into one whose ground state is not known.

5. The atoms keep rearranging to find their lowest energy configuration – the unknown ground state.

6. At the end, the position (or other properties) of the atoms can be imaged, thereby providing information about the state in question.

Quantum-Gas Microscope.
A Quantum gas microscope enables one to observe individual atoms with single-site spatial resolution.

Image Credit: CHIP magazine / Immanuel Bloch - https://tinyurl.com/chip-magazine
The practical uses: applications

The range of applications for quantum simulators covers fundamental areas from science and metrology through to industrial processes. Examples in various categories are shown.

**Categories of use cases**

- **Fundamental Physics**
  - Many-body physics
  - Quantum phases
  - Non-equilibrium dynamics

- **Metrology**
  - Gravity
  - Particle physics
  - Cosmology

- **Programmable Simulation**
  - Precision measurement
  - Quantum sensing
  - Next-generation clocks

- **Programmable Simulation**
  - Materials science
  - Optimisation problems
  - Quantum chemistry

**Illustration of an atomic clock**

Simulating complex molecules with possible applications in pharmaceuticals and battery chemistry

Correlated Quantum Materials with applications including high-temperature superconductors
Cold Atoms in Space – CAL and BECCAL.

In 2018, NASA launched “CAL”, the Cold Atom Lab, to the International Space Station (ISS). CAL’s purpose is to study quantum phenomena and future quantum sensors based on laser-cooled atoms of rubidium and potassium. [11]

In contrast to earth-based laboratories, the microgravity environment of the ISS enables longer observation times (over 10 seconds) and even cooler temperatures (< 100 pK is possible) making a wider range of experiments possible. [12]

The successor to CAL, called “BECCAL” – Bose-Einstein Condensates and Cold Atom Laboratory (Below), is being planned in collaboration with DLR, the German Aerospace Centre, to be launched in 2025. [13]

Nature cover from June 2020: Bose-Einstein Condensates created in orbit for the first time.

Read more here: https://coldatomlab.jpl.nasa.gov/news/nature-cover/

The apparatus for BECCAL.

Source: https://arxiv.org/pdf/1912.04849
Quantum simulator specialists

The majority of expertise in quantum simulation lies in university research groups world-wide, funded by government or through international collaboration, such as the EU Quantum Flagship*. This field is nascent but growing, and continued international cooperation is essential to accelerate innovation.

The shoots of progress can be seen in the emergence of commercial entrants with a small user community. Some organisations have been given early-access to prototype devices, while others are actively exploring applications on more mature platforms that could give them a business advantage across a variety of industry sectors.

A research group, businesses and a large-scale project are highlighted on the next page to illustrate activities in the field.

* One of the largest and most ambitious research initiatives of the European Union, with a budget of at least €1 billion and a duration of 10 years. [14]
From 51 to 256 atoms in 3 years

In 2017 a team led by the MIT-Harvard Center for Ultracold Atoms announced a 51 qubit neutral atom simulator to model interactions between certain atoms. [15]

Three years later this team demonstrated a substantial update – a programmable 256 atom simulator to explore quantum phases of matter. [16]

QuEra – Cloud access to a programmable simulator

QuEra launched in 2019, with a team including leading researchers from the aforementioned 256 atom simulator. It exited stealth mode in 2021, with $17 million in funding, and is providing customers access to its neutral atom-based development machines with full-stack software. Its current analogue simulator has a specialized application in sampling probability distributions. [18]

PASQuanS – A €10m, multinational Flagship project

PASQuanS is an EU Quantum Flagship project, which ran from 1st October 2018 to 31st March 2022. 14 partners across 5 countries (Austria, France, Germany, Italy and the UK) collaborated to improve control methods and develop fully programmable simulators, with an ambition to scale from 20 to more than 1000 atoms or ions. [17]

Pasqal – 1000 qubits in 2023?

PASQuanS is co-ordinated by Antoine Browaeys, who is also the co-founder and Chief Science Officer of Pasqal. Pasqal see quantum simulation as one of the most promising applications of their neutral atom technology [19] and, following their 2022 merger with Qu&Co, have announced a 1000 qubit quantum solution to be delivered in 2023. More information on Pasqal is available in the Commercial Activities Appendix.
UK Activity

Below is a map showing some of the research into quantum simulators happening in the UK, many with direct involvement with either the QCS Hub or the UK’s National Quantum Technology Programme.

University of Strathclyde:
The University of Strathclyde has a large expertise in cold atom quantum simulation, with three quantum simulators with cold atoms in optical lattices, optical tweezer arrays, and a large theory programme on the design and application of quantum simulators.

University of Bristol:
Specialises in photonics, investigating areas such as the simulation of molecular quantum dynamics, as well as theory of quantum simulators. Bristol runs the Quantum Engineering Technology Labs with over 100 academics, and has spun out Duality Quantum Photonics (see Commercial Activities appendix).

University of Edinburgh:
Research in the verification and application of quantum simulators.

Heriot-Watt University:
Work in the theory of quantum simulation with cold atoms and photons.

University of Nottingham:
Aiming to develop quantum simulators capable of providing insights into the physics of the very early universe and black holes. Part of the Quantum Simulator for Fundamental Physics (QSimFP) consortium.

University of Oxford:
Work across quantum simulation, including with cold atoms, trapped ions and superconducting systems, in both theory and experiment.

University of Cambridge:
Significant experimental programme in quantum simulation using cold atoms in optical lattices and in continuum (QSimFP), as well as color centers in diamond. Related theory of condensed matter systems.

London:
Several London-based universities are actively conducting research into quantum simulation including QCS Hub partners Imperial College and UCL, with the latter also setting up the QLABS innovation centre. King’s College are a QSimFP partner.
Saudi Arabia:
Vision 2030 is designed to diversify the economy and unlock new sectors. King Abdullah University of Science and Technology research is an example of work into quantum simulators, in this case focusing on computational fluid dynamics.

USA:
Major joint centres with strong elements of quantum simulation research, including:
- Harvard–MIT Centre for Ultracold Atoms
- Joint Quantum Institute
- JILA

Israel:
Previously invested NIS 100m into funding quantum technologies, including quantum simulators, with NIS 200m further funding announced in February 2022.

Canada:
Launching a National Quantum Strategy. The Institute for Quantum Computing, based at the University of Waterloo, is active in trapped-ion-based quantum simulation.

European Union:
The EU has strong capability in both theory and experiment, with major projects in the Quantum Simulation Pillar of the EU Quantum Technologies Flagship, namely:
- PASQuanS
- QOMBS

Japan:
Q-LEAP (Quantum Leap) initiative launched in 2018, with quantum simulation and computation one of three key R&D areas. Research into simulators based on cold-atoms, trapped ions and photonics is happening at the National Institute of Informatics.

China:
The latest five-year plan included quantum as one of the seven key technological development areas, with results in cold-atoms recently emerging from the University of Science and Technology of China.

New Zealand:
Strengths in photonics, with funding until 2028 for the Dodd–Walls Centre provided in summer 2021.

India:
Announced a national Mission on Quantum Technologies & Applications in 2020, with the Indian Institute of Science developing quantum simulators after previous funding from the earlier Quantum Enabled Science and Technology (QuEST) program.

Canada:
Launching a National Quantum Strategy. The Institute for Quantum Computing, based at the University of Waterloo, is active in trapped-ion-based quantum simulation.

Australia:
Recent government investment with a focus on commercialising quantum technology, with active groups researching quantum simulations including:
- University of Queensland
- Australian National University

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Major joint centres with strong elements of quantum simulation research, including:
- Harvard–MIT Centre for Ultracold Atoms
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Programming Quantum Simulators

The below examples illustrate the software which can be used when programming quantum simulators. There is not a hard boundary between quantum computing and simulation, and some of these will find application in both.

**Low-level Control Software**

**Pulser from Pasqal**

Pulser is an open-source software library (in Python) from Pasqal, a French startup developing neutral atom quantum technologies. Pulser facilitates the design and emulation of pulse sequences for neutral-atom quantum platforms, allowing for a range of tasks such as quantum-circuit programming and quantum simulation of many-body systems.

*Above: Architecture of Pulser*
Source: https://arxiv.org/pdf/2104.15044

**Quantum Operating System**

**Deltaflow.OS from Riverlane**

Founded in 2016 in Cambridge, UK, quantum software company Riverlane is developing Deltaflow.OS, a quantum operating system for QIT devices.

*Above: How Deltaflow.OS works.*
Source: Riverlane
Source: https://www.riverlane.com/products/

**High-level Programming**

**Leap from D-Wave Systems**

Launched in 2018, Leap is a quantum cloud service to access D-Wave’s hybrid solver and QPUs (Quantum Processing Units) through an integrated development environment.

*Above: Code sample*
Source: https://www.dwavesys.com/take-leap
How can my business leverage quantum simulation?

Quantum simulation requires a different approach to the usual ‘wait until it’s ready’ adoption pattern. This is because it takes time to understand the technology, identify its potential value and impact, and build the necessary skills and partnerships to become quantum ready. The QCS Hub is available to assist businesses with this journey.

It’s essential to engage early in the development phase in order to:
- learn the new capabilities
- influence technological evolution
- identify potential applications
- develop the know-how to find solutions
- exploit first-mover advantage.

Some quantum simulators are lab-based and dedicated for scientific experiments, while others are more commercially focused. In either case, cloud access is important to connect global users to the quantum simulator platforms and catalyse community building.

Working alongside specialist providers allows users to get ahead, with early-access to new devices.

New and emerging quantum simulators will support fundamental research in the laboratory, whilst commercial efforts are already producing early entrants into the market. Practical applications are imminent, with the capabilities of these devices applicable to fields outside of quantum – such as in logistics, whose total market value is estimated at circa $10 trillion. [20]
**ColdQuanta**

Founded 2007

Founded as a spin-off from the JILA Institute and Physics Department at the University of Colorado

Jan 2018

Announces the first commercial Bose-Einstein condensation system.

ColdQuanta’s QuantumCore is deployed aboard the International Space Station, as part of the Cold Atom Laboratory.

May 2018

ColdQuanta joins steering committee of the US Quantum Economic Development Consortium (QED-C).

July 2018

Raises $8.8m in a seed funding round led by Global Frontier Investments.

April 2020

US $7.4M DARPA award to develop a scalable, cold-atom-based quantum computing hardware and software platform.

**Commercial Activities**

There are a growing number of companies building quantum simulators for commercial exploitation. Some have been active for some time, others are very recent. A selection are shown below to illustrate activity in this field.

**At a glance:** Coldquanta is a spinout from the University of Colorado and develops quantum computers and quantum sensing technologies based on cold atoms. They offer a wide range of products and services, with a 100 qubit cloud-based quantum computer and high precision clock prototypes due to launch this year.

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- Announces the first commercial Bose-Einstein condensation system.
- ColdQuanta joins steering committee of the US Quantum Economic Development Consortium (QED-C)
- Raises $8.8m in a seed funding round led by Global Frontier Investments.
- US $7.4M DARPA award to develop a scalable, cold-atom-based quantum computing hardware and software platform.

**Total Investment raised:** US $71.6M over 5 rounds [21]

**Duality Quantum Photonics**

www.dualityqp.com

Main office: Bristol, UK

At a glance: Duality Quantum Photonics is a spinout from the University of Bristol, with a goal to design and fabricate photonic quantum processors that can simulate phenomena relevant to drug design in the pharmaceutical industry.

- Total Investment raised: Undisclosed

**Commercialising Quantum Technology Large Collaborative Projects Round 1.pdf**

- Partner in Riverlane led consortium to develop new quantum operating system, DeltaFlow OS. The project is funded by a £7.6M award from UK Research and Innovation.
- Partner in BT led consortium to trial end-to-end quantum secured encryption for 5G and connected cars. The 3-year trial is funded with £7.7M by UK Research and Innovation.
- Connectorising Integrated Quantum Photonics Devices – a joint UK-Canada funded project with partners from both countries – kicked off with a goal to develop efficient and robust fiber connections for integrated quantum photonic devices operating at low temperature.
- The Riverlane led consortium announce a new open-source hardware abstraction layer (HAL) that will enable users to write programs that will be interoperable with multiple kinds of quantum hardware.
At a glance: D-Wave develops quantum computing systems based on low-temperature superconducting technologies that operate using quantum annealing (in contrast to circuit-based quantum computers). In this technique, an energy ‘landscape’ of ‘hills and valleys’ is simulated where the lowest valley corresponds to the solution for a particular problem of interest. D-Wave holds 160+ patents, has published more than 100 peer-reviewed scientific papers.

Main office: Burnaby, Canada

Total Investment raised: US $256.2M [22]

At a glance: infinityQ announces cloud access to infinityQube, its first-generation machine.

Main office: Montreal, Quebec, Canada

Total Investment raised: $4.8M [24]

D-Wave

Founded 1999

May 2011

Hag-Farris, Geordie Rose, Bob Waes and Alexandre Zagoskin launch D-Wave

Aug 2012

128 qubit D-Wave One launched, described as the world’s first commercially available quantum computer.

Oct 2018

D-Wave One used by Harvard University to solve protein folding problem.

Sep 2020

D-Wave launches its 5,000+ qubit “Advantage” system

Pharma giant, GSK, uses D-Wave Advantage on mRNA codon optimisation problem

Collaboration with Google demonstrates 3 million times speed-up of simulation of exotic magnetism (compared with classical approaches).

NEC Australia and D-Wave selected by the Australian Department of Defense on the “last mile resupply” problem.

InfinityQ

www.infinityq.tech

InfinityQ announces cloud access to infinityQube, its first-generation machine.

Main office: Montreal, Quebec, Canada

Total Investment raised: $4.8M [24]

Pasqal

At a glance: Pasqal is a spinout from the Institut d’Optique, France, building “quantum processing units” made of neutral atoms in large 2D and 3D arrays for computing and simulation of quantum systems. Their aim is to bring their processors to market, working in a hybrid scheme with supercomputers in France and Europe

Main office: Palaiseau, Ile-de-France, France

Total Investment raised: $30.4m [23]

Pasqal founded by Georges-Olivier Reymond, Christophe Jurczak, Professor Dr. Alain Aspect, Dr. Antoine Broways and Dr. Thierry Lahaye

Dec 2020

€7m award from European Commission EIC Accelerator program

Pasqal founded

Apr 2020

Partnership with Miquans (quantum sensing company) to accelerate development of Pasqal’s processors.

Passion

Jan 2021

Release of open source software “Pulser” to control neutral atoms-based processors at the level of laser pulses.

Jul 2020

Partnership with EDF to tackle smart charging challenges

Pasqal

Jan 2022

Merger with Qu&Co, a quantum algorithm and software developer, announced. The combined company will continue as Pasqal, and a 1000+ qubit quantum solution in 2023 has been announced.

InfinityQ

May 2021

InfinityQ announces a pre-seed funding round, led by Investissement Quebec

Aug 2021

Atos founded by Alain Aspect, Dr. Thierry Lahaye and Dr. Antoine Broways

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References and further reading


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