

IQM

IQM Product Offering



IQM Research

This is an ideal solution for research institutions and national labs to accelerate research and get full access to the hardware.

While most of today's quantum computing is provided as a cloud service only, we deliver physical on-premises systems for research and early exploration of quantum algorithms and enabling technologies with complete access to our hardware.

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DR. JAN GOETZ

Co-founder and CEO, IQM Quantum Computers



IQM delivers fully integrated quantum computers to your premises

National quantum initiatives worldwide are currently (Q1 2022) reaching roughly €28.5 billion (\$30B). Also, private investments in the quantum space are, in effect, rising. Furthermore, we have started to see public listings of quantum-computing companies in the US. These developments mean that when funding is abundant, the rate of development is rapid and grows exponentially. However, there is an enormous shortage of quantum talent, and the proficiency needed is rather researcher-academic and scientific, mostly consisting of post-doctoral scientists and quantum engineers rather than, say, computer science practitioners. Therefore, the competition for this expertise will be fierce in the coming years.

As the global competition over quantum leadership becomes more important in the coming years, now it is the perfect time to start building quantum readiness by investing in the future.

IQM QUANTUM COMPUTERS IS LEADING THE WAY

We have a world-leading understanding of how national quantum research programs should be designed, built, and managed. Having collaborated with numerous international quantum programs and already delivering fully integrated quantum computers for our customers, we have the capability to provide an expedited path for **research institutions** and **national labs** to gain a significant lead in their quantum programs.

DELIVERING FULLY INTEGRATED QUANTUM COMPUTERS TO YOUR PREMISES

Our offering is unique, as IQM's quantum computers can be located at your premises with full access to the hardware. We have a world-class team of quantum experts to train the customer personnel on the build, hardware, and software-algorithm operations as well as safe and effective maintenance. We are offering support with flexible service levels that best suit your needs.

KEY TAKEAWAYS

- With IQM, you will get full and secure access to the hardware, thus accelerating your research capability and speeding up innovation.
- IQM is a full-stack system integrator. With our experience in building national programs, we provide an expedited way to gain a significant lead in building your national quantum ecosystem.
- IQM offers quantum hardware which can be regularly upgraded to deliver technological sovereignty.

We were very impressed with IQM, their vision, their technology and their ability to turn those two into a credible project. We were also looking for a co-innovation partner with whom we can develop our own competencies and put our own technology into using the quantum computer. And that's also where we found IQM to be very open to collaboration and have a clear win-win attitude.

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PROF. ANTTI VASARA

President and CEO of VTT and President and Member of the board for the European trade association of Research and Technology Organisations (EARTO). IQM is building Finland's first 54-qubit quantum computer with VTT Technical Research centre of Finland.

IQM Quantum Accelerators



IMAGE: ILLUSTRATION OF IQM QUANTUM COMPUTERS IN A SUPERCOMPUTING FACILITY

How to accelerate your existing HPC infrastructure

Large-scale scientific computation is in transition. The grand challenges of the 21st century require increasing computational power as the fundamental barriers to technology loom ahead. Moore's law and the implied exponential growth every two years are drastically being challenged as integrated circuits are approaching atomic limits. Fitting more transistors onto a microchip will become extremely hard and expensive in the next decade and will ultimately become impossible. This difficulty is starting to hinder technological progress sooner than we realize.

ACCELERATE YOUR TRANSFORMATION TO MEET GROWING COMPUTATIONAL DEMAND

IQM's stance is that we are nowhere near the computational limits of our time. With our quantum solutions, we are bringing **quantum-accelerated high-performance computing capability** to supercomputing centers. This capability makes it possible for our customers to combine the best of both worlds, classical high-performance computing and quantum computing, in which certain computational tasks are specifically assigned to quantum processing units (QPUs), both technologies running in parallel. This combination will speed up overall computational performance where specific parts of exceedingly difficult computations are addressed by a QPU, exponentially accelerating those tasks.

KEY CHALLENGES FOR HPC CENTERS

- Time to output is too long
- To find sustainable computing solutions
- High capex requirements
- Inadequate computing power for large research projects

Source: IQM and Atos — State of Quantum Computing in HPC Research by IDC Europe, August 2021 (n = 110)

Soon, all HPC centers will be Quantum accelerated – the time to act is now.

Quantum computers are on a trajectory to solve certain problems which are impossible even for powerful supercomputers, and the outcome will be greatly beneficial for computing performance in an HPC environment. (In the light of HPC infrastructure upgrade costs, with a relatively modest investment, considering the total operation and running costs, a huge increase in computing power can be obtained with a quantum accelerator.)

IQM conducted a study with Atos and found that 71% of global HPC data centers will adopt on-premises quantum computers by 2026.

Link to study: <https://www.meetiqm.com/technology/iqm-atos-state-of-quantum-research-2021/>

A sustainable alternative to supercomputing

Quantum technologies hold the promise of addressing key sustainability issues, including:

- Reducing the energy consumption of datacenters and servers that contribute significantly to the growing climate crisis.
- Accelerate the development of new innovations to solve global sustainability such as carbon capture and efficient battery breakthroughs.
- Limiting the energy requirement for complex computations even as demand continues to rise in data-centric applications, AI, simulation, and more.
- Minimize quantum computing's own potential climate and environmental impact, with technological breakthroughs.

KEY TAKEAWAYS

- IQM for HPC offers computational acceleration with on-premise quantum computing hardware, ensuring the fastest, most secure, and low-latency data transfer between the classical and quantum systems.
- Quantum technologies deliver a sustainable alternative to growing computational needs.
- IQM is a full-stack system integrator. With our experience in building quantum accelerators and working with supercomputing centers in Europe, we provide an expedited way to gain a significant lead in building your hybrid computational solutions.
- Extend your return on investment and access an exponential performance increase in certain computations by combining the best of both worlds: classical supercomputing and quantum computing – the future of hybrid computing.

IQM Quantum Computers-led consortium (Q-Exa) has been selected to provide a quantum computing system that will be integrated into an HPC supercomputer to create an accelerator for future scientific research. The delivery is part of a €45.3 million consortium project, funded by the **German Federal Ministry of Education and Research (BMBF)**.

IQM is working with **Leibniz Supercomputing Centre**

(LRZ), one of Germany's three national supercomputing centers; Europe's leading HPC and quantum system provider **(Atos)**; and one of Germany's leading innovators of quantum computing applications **(HQS)** on this project.

Link to press release: <https://www.meetiqm.com/articles/press-releases/q-exa-consortium-to-integrate-german-quantum-computer-into-hpc-supercomputer-for-the-first-time/>



FEDERAL MINISTER ANJA KARLICZEK HANDS OVER THE GRANT CERTIFICATE TO JAN GOETZ, CEO OF IQM

Picture credits: Hans-Joachim Ricket (BMBF)

IQM for Industries

IQM is offering innovation partnerships for forward-thinking enterprises to jointly co-design optimized quantum hardware and algorithms. The aim is to deliver quantum advantage for industry-relevant problems today.

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DR. INÉS DE VEGA

Head of Quantum Innovation, IQM Quantum Computers

Accelerating innovation through Application Specific Co-Design

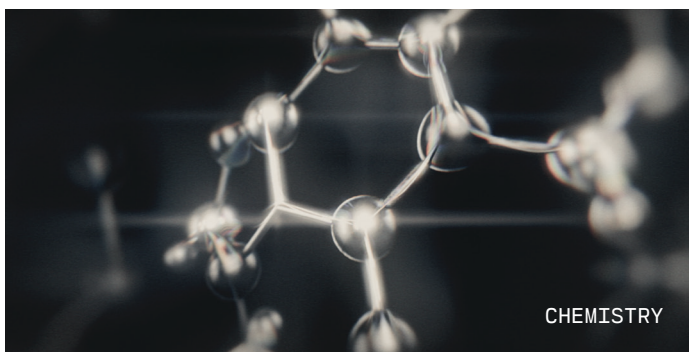
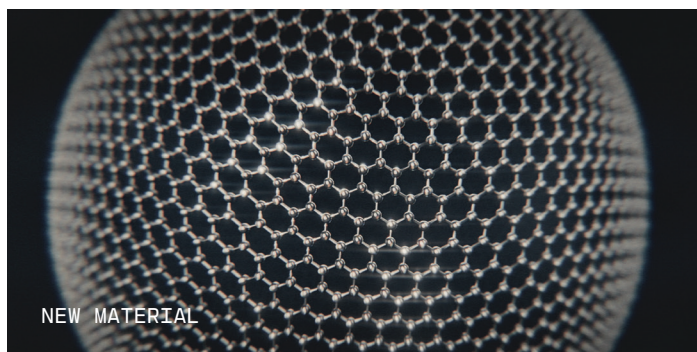
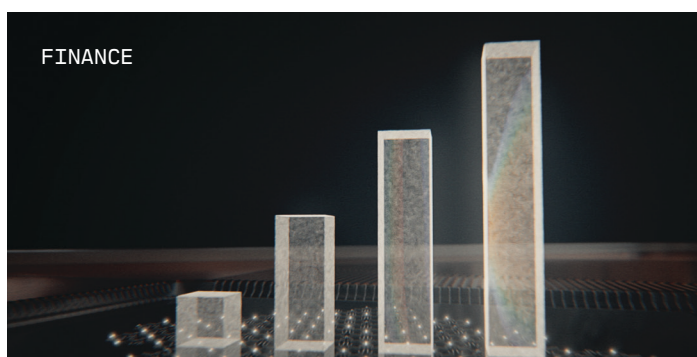
Quantum computing presents an enormous opportunity for solving the most expensive and difficult problems in the modern business landscape. Its biggest promise is to speed up discoveries and breakthroughs in science and engineering, but also to reboot computational approaches for the coming quantum age.

One of the most demanding competitive struggles for any company is finding the right problems, the right value drivers, and staying ahead of the curve as the pace of development accelerates. The challenge is to adopt the right technologies, keep innovating, and maintain continuous improvement to stay relevant. Great companies are constantly looking at problems from diverse angles and

investing in unconventional methods to innovate more quickly and offer their customers more value.

HOW TO PREPARE YOUR COMPANY FOR THE QUANTUM AGE?

Today, it has become apparent that building critical knowledge for the upcoming quantum era is becoming imperative for major industries and leading organizations. It is just too big of a transition to ignore and omit when the pace is accelerating. The most convenient and fastest way to start building your **quantum readiness** is to find a partner with the right technological capability and begin uncovering entirely new avenues for accelerating innovation.



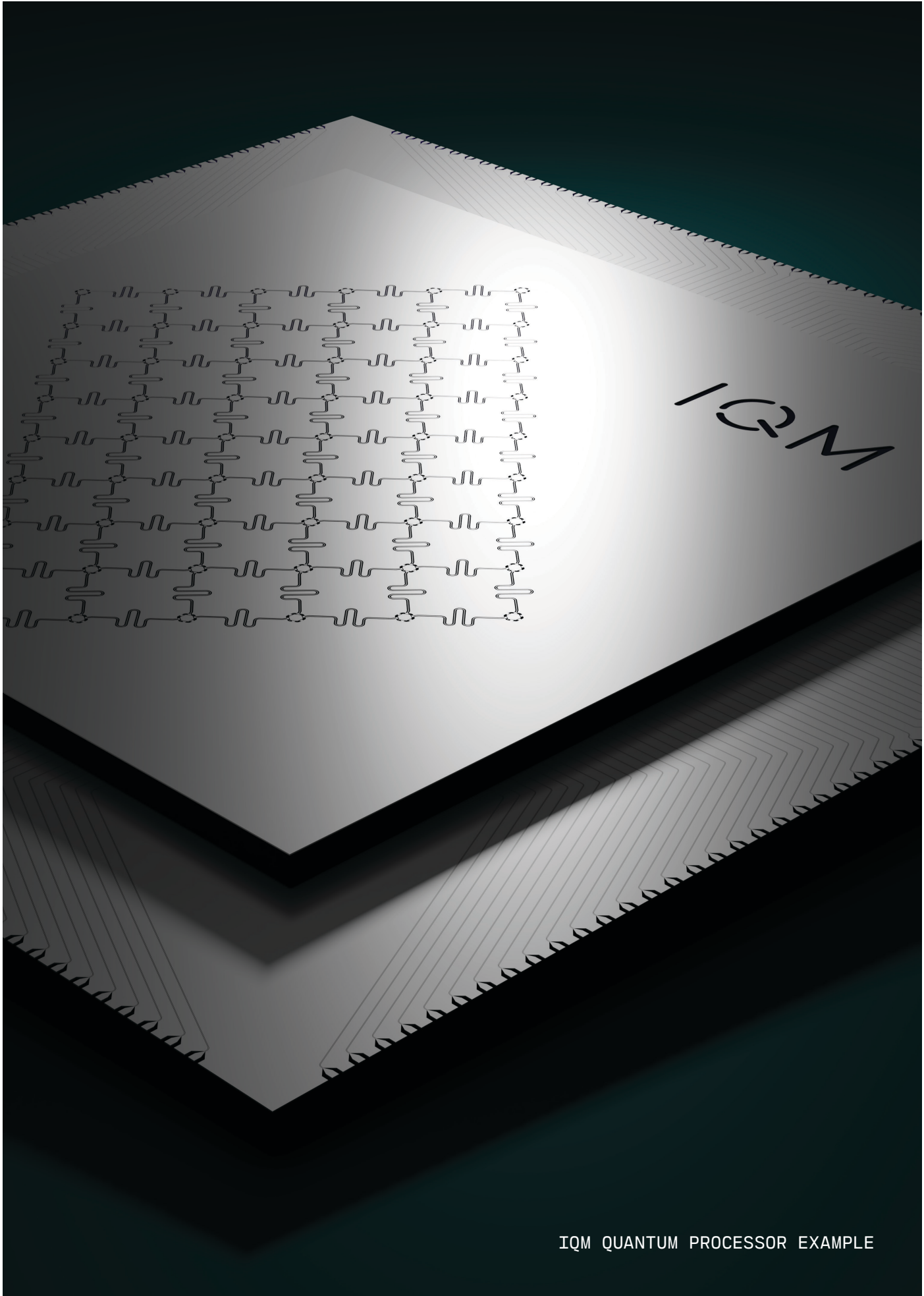
Supercharge your research and development with IQM

IQM is offering **innovation partnerships** for forward-thinking enterprises where quantum computing expertise and business design meet to solve the most demanding applications. This innovation means that, within the partnership, we will co-design optimal adaptations of quantum hardware and algorithms to address industry-relevant problems.

The aim is to bring quantum advantage to business problems with optimized algorithms and application-specific quantum processors that classical supercomputing resources simply cannot address alone.

KEY TAKEAWAYS

- Accelerate innovation with quantum computing.
- The fastest way to start building quantum readiness is to partner with IQM. We have the largest quantum hardware team in Europe, comprising of world-renowned quantum experts.
- IQM is offering co-design partnerships. The aim is to bring quantum advantage to relevant business problems with the help of application-specific quantum processors and algorithms running on them.



IQM QUANTUM PROCESSOR EXAMPLE

IQM Solution

SOLUTION OVERVIEW

The quantum computer solution provided by IQM consists of an on-premises quantum computer with all required hardware, built around the QPU. In addition to the QPU, the hardware contains enabling technology needed for cryogenic conditioning of the QPU and electronics needed to operate the system.

Furthermore, the system is integrated with the software components up to the level of enabling the user to run

quantum algorithms. The system also provides the user with wide access to different technology layers, including directly addressing hardware abstraction, i.e., enabling the use case of defining low-level QPU control sequences by programming arbitrary microwave control. Figure 1 illustrates the technology stack of the QPU, pointing out the core system provided by this offer. The Figure also illustrates potential applications and concepts of integrating to classical high-performance-computing systems.

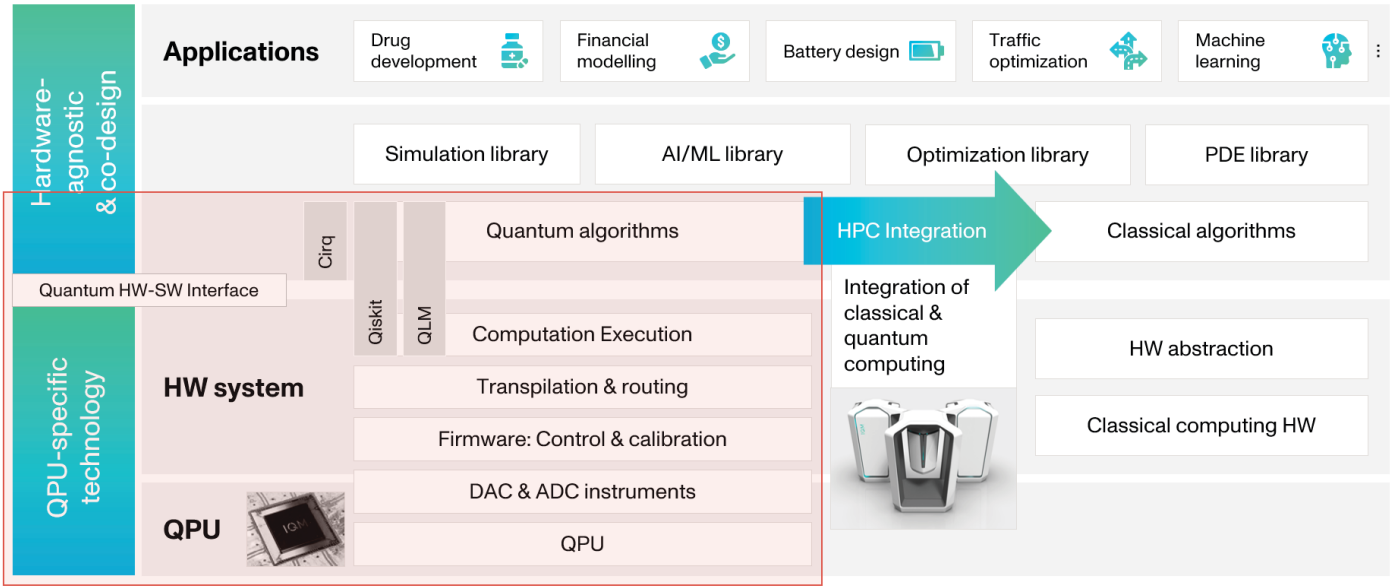


FIGURE 1. A QUANTUM COMPUTING FRAMEWORK ENABLED BY IQM’S TECHNOLOGY. THE TECHNOLOGY STACK OF THE CORE QUANTUM COMPUTING SYSTEM DESCRIBED BY THIS OFFER IS ENCLOSED IN RED.

IQM's offering comprises of 5/20/54-qubit systems with an option to upgrade the system to higher qubits when available, including all hardware and software required for the continuous operation of the quantum computer.

The delivery of the system depends on the customer requirements and QPU specifications. The 5-qubit system is available with the shortest lead time, and the exact lead time depends on the availability of key components. The delivery schedule for higher qubit systems can be agreed separately.



FINLAND'S FIRST 5-QUBIT QUANTUM COMPUTER DELIVERED TO VTT

Picture credits: VTT Technical Research Centre of Finland

HARDWARE DESCRIPTION AND SPECIFICATIONS

IQM’s Quantum Hardware offering consists of the subsystems as listed in the breakdown structure below:

QUANTUM PROCESSING UNIT

- Superconducting integrated circuit (IC) with qubits and couplers
- QPU package

TRAVELLING WAVE PARAMETRIC AMPLIFIER (TWPA) SETUP

- TWPA IC
- TWPA package
- TWPA supporting infrastructure

MECHANICAL ASSEMBLY AND CRYOGENIC INFRASTRUCTURE, INCLUDING

- Closed-cycle dilution refrigerator and mechanical frames
- Cryogenic connectivity
 - Microwave and DC cables for control and readout signals, and flux bias
 - Attenuated input cables
 - Low-loss output cables
 - DC wiring
 - Signal conditioning electronics
 - Isolators and circulators
 - Semiconductor amplifiers (HEMTs)
 - Directional couplers
- Magnetic shielding

ROOM TEMPERATURE CONTROL ELECTRONICS, INCLUDING

- Electronics rack
- Pulsed microwave electronics for qubit and coupler operation and readout
- Amplifiers and up/down conversion modules
- Bias sources
- Computer workstations and servers providing the user interface for the quantum computer and running the related software
- Power sources

The benchmarks listed below are for reference only to showcase IQM's 5-qubit quantum computer, which was delivered to the VTT Research Centre in Finland.

Qubit count	1Q fidelity, %	2Q fidelity, %	Readout fidelity, %	Native 2Q gateset	T1, µs	T2, µs	Gate time, ns		Quantum volume	Co-design	Hardware access for customer
							1Q	2Q			
5 <i>(20 in Q32022)</i>	99.91	99.14	97.33	CZ	36.60	17.52	40	60	8	yes	yes

ALGORITHMS EXECUTED ON AN IQM 5-QUBIT QPU

Some examples of algorithms executed on the IQM quantum computer delivered to VTT include:

- A generalized GHZ state which demonstrated 5-qubit entanglement
- A Bernstein-Vazirani algorithm
- A simple MaxCut problem using vanilla QAOA

As can be seen from the below charts, the IQM quantum processor performed equally well or better than the competition. This project is still in its early stages and the teams at VTT and IQM will publish further results in due course of time.

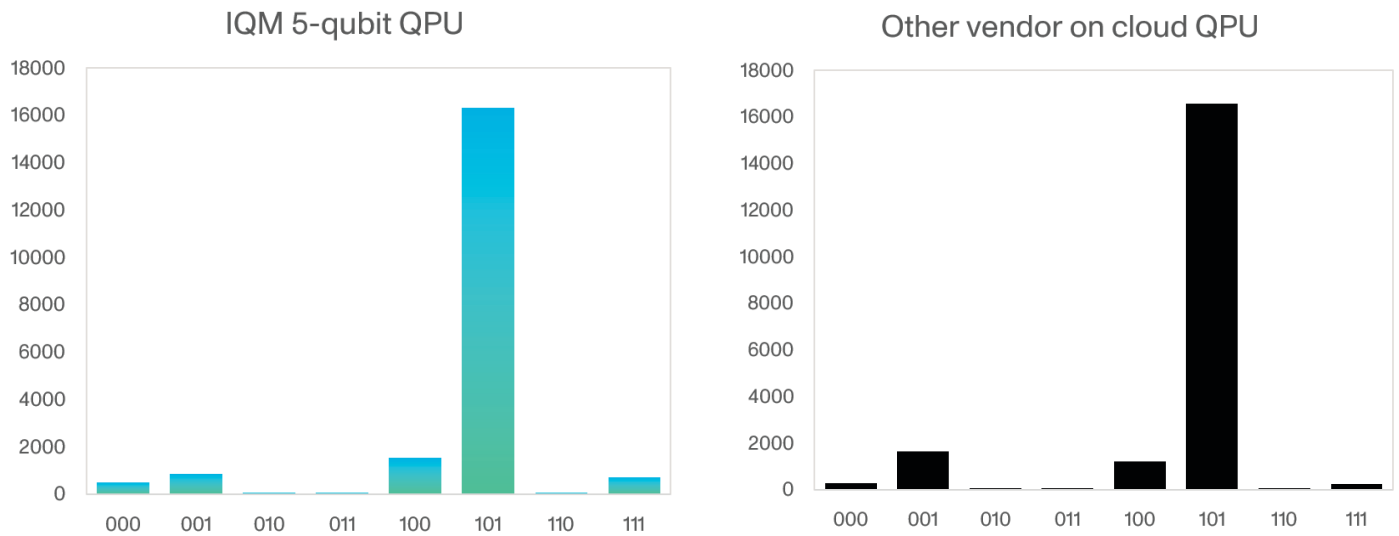


FIGURE 2. BERNSTEIN-VAZIRANI ALGORITHM RESULTS PERFORMED ON VTT QUANTUM COMPUTER IN FINLAND

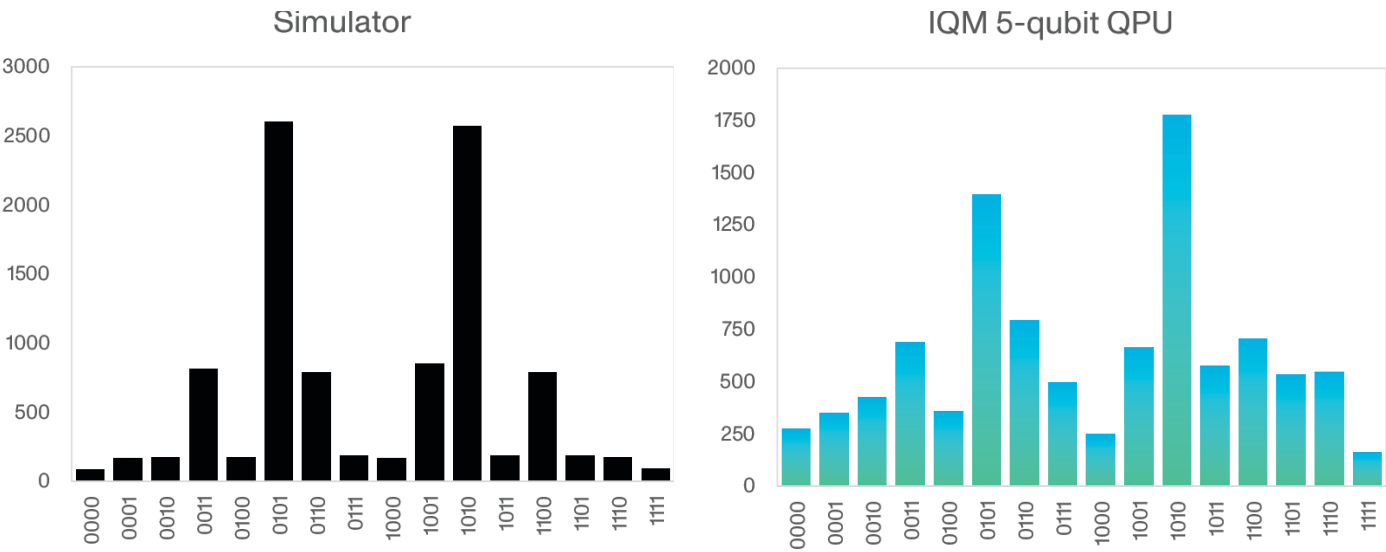


FIGURE 3. MAXCUT PROBLEM USING VANILLA QAOA RESULTS PERFORMED ON VTT QUANTUM COMPUTER IN FINLAND

SOFTWARE DESCRIPTION AND SPECIFICATIONS

IQM will also provide the following part of the software stack (refer to red rectangle in Figure 1 above).

QUANTUM COMPUTER CONTROL SOFTWARE STACK

High-level: Quantum circuit and quantum algorithm execution

- Logical control
- Quantum Circuit Optimizer

Mid-level: Definition and execution of customer and standard quantum experiments

- Experiment layer
- Common library
- Data layer

Low-level: Instrument configuration and control

- Backend service
- Instrument drivers

The software has various layers for different levels of quantum computing hardware abstraction. It includes a low-level control layer for defining microwave pulse shapes, and a high-level interface for programming and executing quantum algorithms.

The software also includes APIs to connect to third party compilers like Atos QLM, Google Cirq, and IBM Qiskit such that quantum algorithms executed on the IQM computer can be defined in a flexible and hardware-agnostic manner. It can work as a part of a larger platform, such as the one from Strangeworks, which provides access control for a large number of users.

IQM will also have its own proprietary quantum circuit transpiler/compilers for digital-analog algorithms that can run specific algorithms more efficiently. At the quantum processor (QPU) control level, IQM's proprietary measurement automation software (EXA) will enable automated recalibration of the QPU to ensure sustained optimum quantum computer performance. Through EXA, the customer will also have low-level access to the QPU and therefore the capability to further optimize the qubit control.

In addition to quantum computer control software, IQM has developed a design software framework supporting rapid prototyping of physical quantum processors. The core of the framework is the layout generation software framework [KQCircuits](#), which IQM has recently provided as open source. KQCircuits enables seamless and automated superconducting circuit design based on primitive elements. It also supports layout generation at wafer scale, and the ability to export the designs for photomasks production, or to export the features into a simulation software. IQM uses the same software to produce its state-of-the-art processors. Thus, it is under active development and supported by IQM's design and software teams.

CONNECTIVITY TO EXISTING INFRASTRUCTURE

As part of the offered solution, IQM can also offer a software solution that is interoperable with the Atos QLM. As part of this, IQM will provide an adapter which allows run-

ning quantum circuits defined on the Atos QLM. The connectivity to a High-Performance Computing infrastructure can also be discussed separately.



IMAGE: ILLUSTRATION OF AN IQM QUANTUM COMPUTER IN A SUPERCOMPUTING FACILITY

EXCLUSIVE QUANTUM FABRICATION FACILITY

Manufacturing the quantum processors in our own fabrication facility in Espoo, Finland gives us tremendous flexibility and the ability to make sure the chips' quality passes the highest requirements.

This quality also speeds up research and project turn-around times considerably and provides a fast lane to address the customer needs of the future.



IQM FABRICATION FACILITY IN ESPOO, FINLAND

EDUCATION AND TRAINING

As a part of our Quantum offering, IQM can provide a complete education package to support kickstarting the competence development for quantum computing. The complete offering would include quantum hardware combined

with educational resources. This unique offering creates a strategic advantage for educating the next generation of experts and leaders in quantum computing. An overview of the offering is given below in Figure 2.

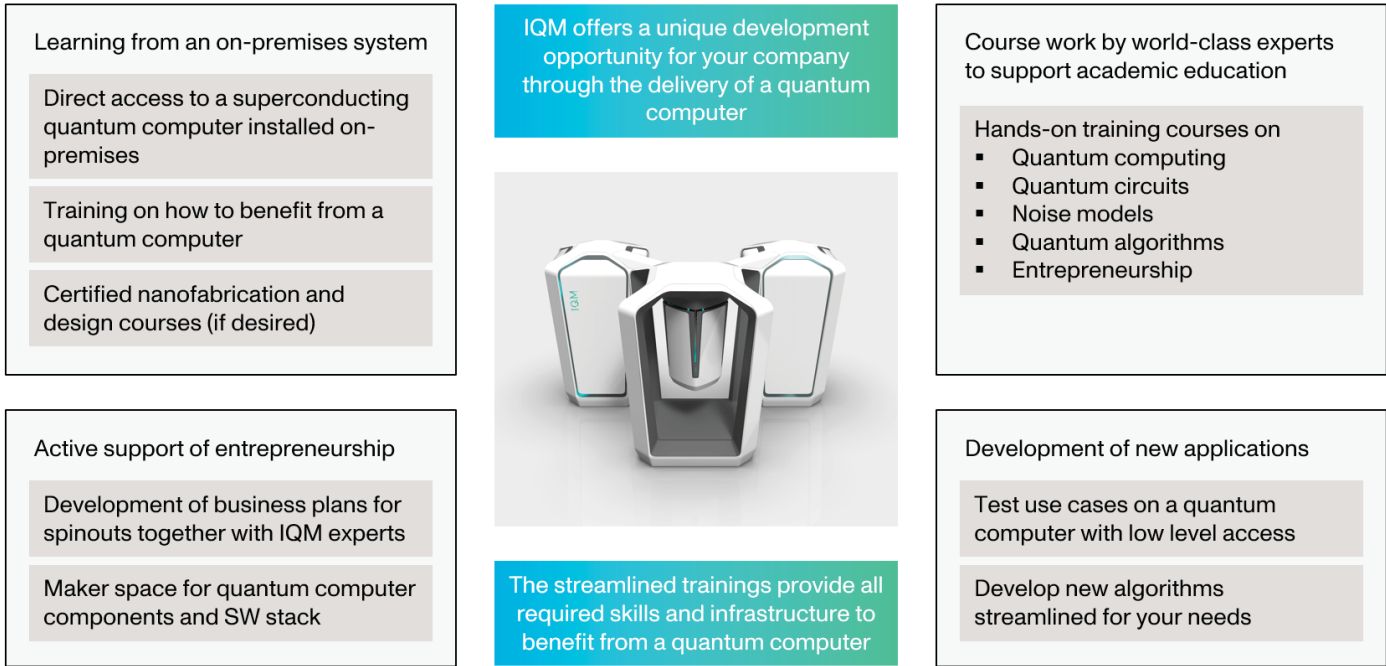


FIGURE 4. IQM EDUCATION PACKAGE TO KICKSTART QUANTUM READINESS

About IQM

IQM is the Pan-European leader in building quantum computers.

IQM has built Finland's first commercial 5-qubit quantum computer with a co-innovation project with VTT Research Centre. This project will be upgraded to 20- and a 54-qubit processor by 2024.

An IQM-led consortium (Q-Exa) is also building a quantum accelerator in Germany. This quantum computer will be integrated into an HPC supercomputer at Leibniz Supercomputing Centre, LRZ - one of Germany's three national supercomputing centres to create an accelerator for future scientific research and hybrid computing.

WHAT WE OFFER

We provide on-premises quantum computers for supercomputing data centres and research labs and offer full access to the quantum hardware. For industrial customers, we deliver quantum advantage through a unique application-specific, co-design approach.

WHERE WE OPERATE

From our roots in Finland, where IQM headquarters is based, we have grown our business to include operations in Germany, Spain, France and Singapore. We have one of the largest quantum hardware teams in the world.

More information: www.meetiqm.com



Contact us



We have the largest European industrial hardware team of world-renowned quantum computing experts. We are manufacturing the processors for our quantum computers in our own factory, speeding up innovation, and providing a fast lane to address the customer needs of the future.

Let's start exploring exponential opportunities together and accelerate innovation!

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