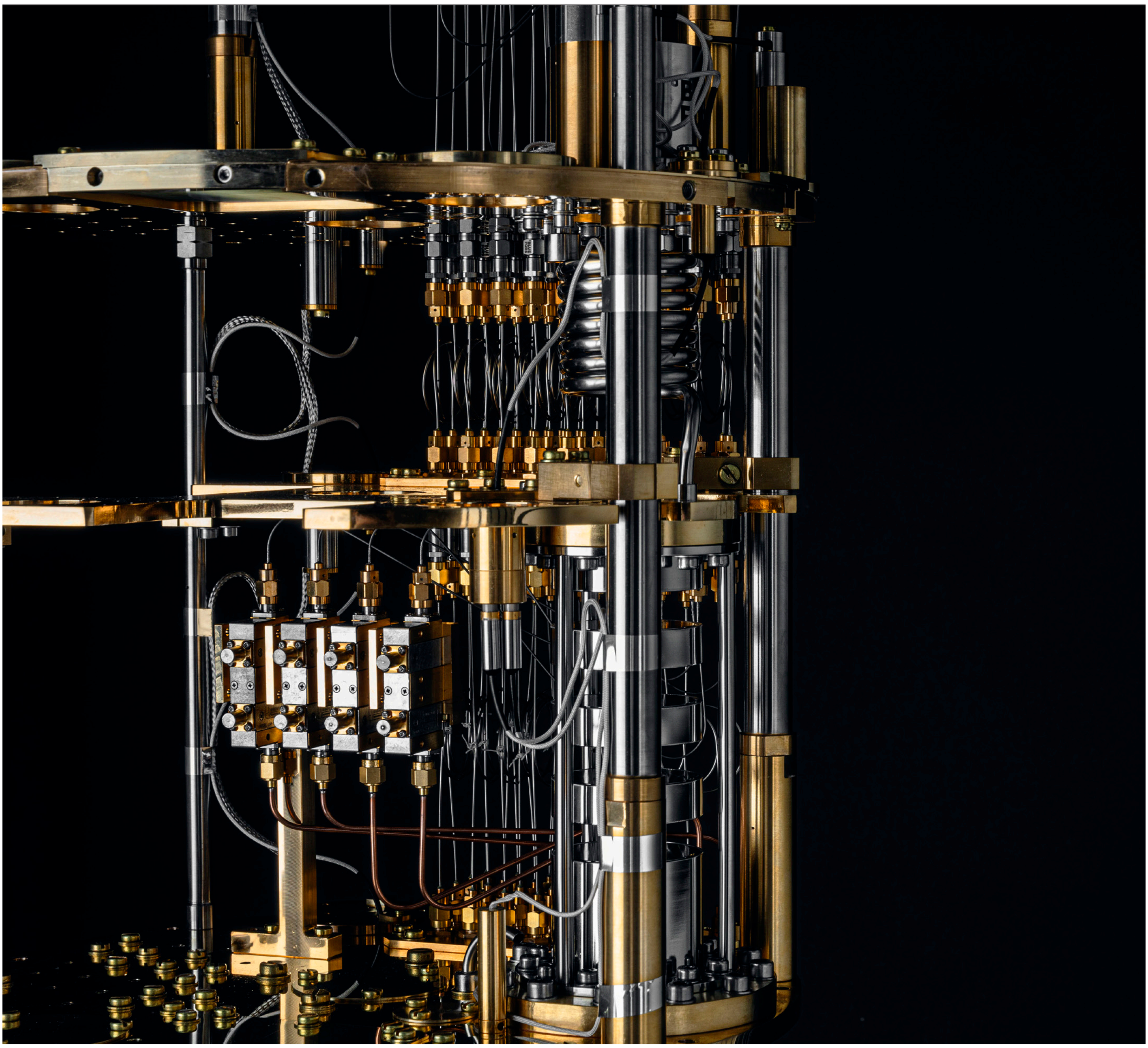
IQM

Leading the way to quantum business.



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IQM's 54-qubit quantum computer

IQM is providing a fast lane for quantum business. Our offering is unique because IQM quantum computers can be located at your premises, while most commercial quantum computing is provided as a cloud service only. Moreover, we provide an integrated end-to-end solution, taking advantage of our patented quantum technology and hardware-software co-design, that is, combining the design of quantum hardware and algorithms in a novel way. Our mission is to place quantum computing at your fingertips.

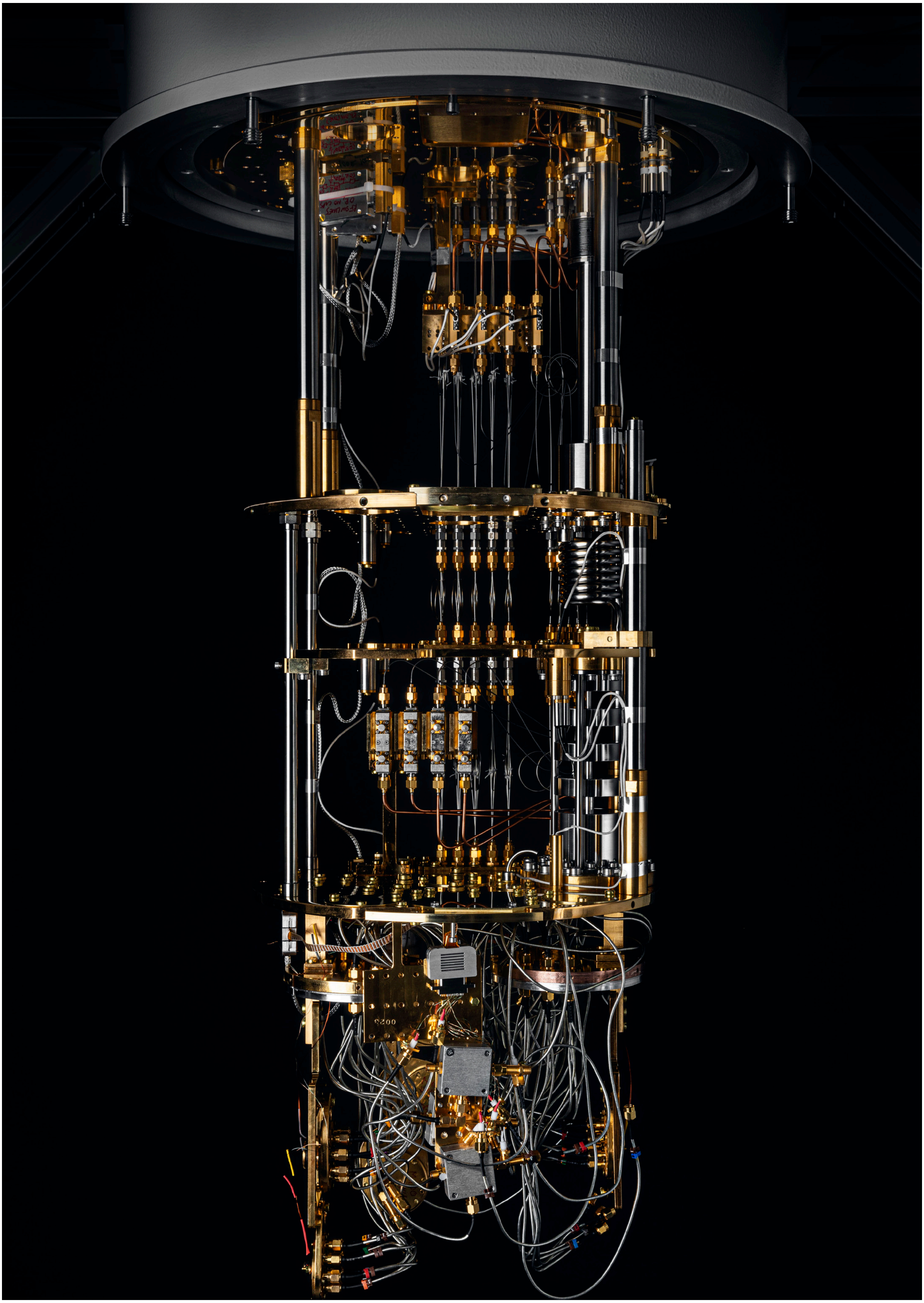
IQM-54 is built on a universal gate-based quantum processing unit (QPU) based on 54 superconducting qubits. It can be delivered as a turnkey solution or tailored to the customer needs using the co-development approach. For this purpose, IQM has the largest hardware team of world-class quantum experts in Europe, building quantum computers for both private and public sectors. We deliver the product to the location where it is actually being used, for instance, a research laboratory or data center where high-performance computers are situated.

The technical capabilities of IQM-54 are considered to be beyond the threshold of achieving quantum supremacy, that is, demonstrating computation at a level at which existing computers cannot achieve results. The IQM-54 architecture is a state-of-the-art system employing the so-called noisy intermediate scale quantum (NISQ) paradigm. The known NISQ applications include, but are not limited to, quantum chemistry and optimization methods such as variational quantum eigensolvers (VQEs) and quantum approximate optimization algorithms (QAOAs). We foresee that foremost, the benefit of adopting IQM's 54-qubit quantum computer gives the customer potential to be in a forerunner position in the emergence of quantum computing applications. IQM will be providing a hardware platform and recommends reliable partners for software application development for the optimal utilization of the hardware.

The QPU of IQM-54 is based on a 2-dimensional architecture of qubits with controllable interqubit couplings to allow for desired two-qubit operations. The processor will come as a fully packaged solution including necessary connectivity within the QPU as well as to and from the QPU. The system is a full entity including cryogenics; room temperature and cryogenic digital, analog, and microwave electronics; and software interfaces. We emphasize that the system will include the full chain of customer control and programmability needed to program and operate the system. Thus, IQM provides a generic platform that gives customers full access to build and test their own control and readout sequences, as well as algorithms on top of the hardware. It provides interfaces including high-level access for running quantum algorithms with state-of-the-art programming languages adapted to the customer's needs. Furthermore, we will provide the customer with low-level access to manipulate and read out the qubits by directly defining the control and readout sequences as defined at the microwave pulse level, which offers the unique opportunity to access features beyond the definitions of the gate sequences. To operate the IQM quantum computer, the end user only needs 10 m2 of space, electricity, and cooling water.

IQM is the European leader for superconducting quantum computers. Our vision is to make quantum computing available to everyone. We are creating value by utilizing the power of quantum technologies. We build quantum computers to answer the most challenging questions in science, technology, and business. Our products will boost quantum computing and help to find solutions benefiting the industry and society at large. Applications range from more efficient medication to discovering planet-saving materials and sustainable industrial processes. We foresee new technologies that will arise from the possibilities opened by quantum computing. We believe the future is in the quantum. This path also supports the competitiveness of businesses globally.

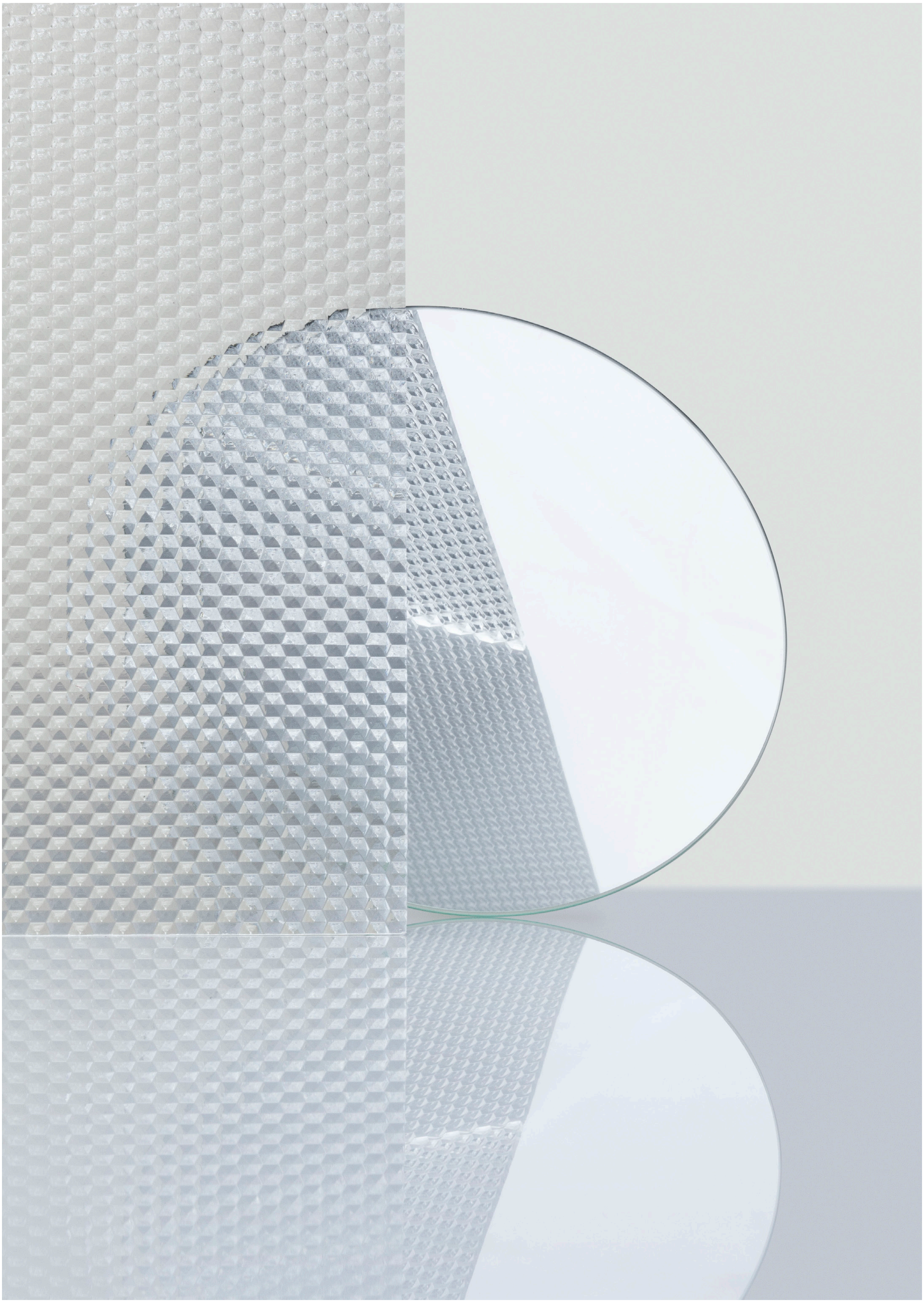
This is the beginning of a new era of quantum computing.



At the brink of a new era of quantum computing

“The IQM 54-qubit quantum computer is the optimal entry point into the next stage of computing. Our technology will help you to boost your business beyond current state-of-the-art.”

DR. JAN GOETZ
CEO, COFOUNDER OF IQM



Introduction

Time and again in the history of humankind, bursts of innovation and technological leaps have pushed the boundaries of what is possible. Every significant technological breakthrough will spring new industries and further well-being for those who are fast enough to build the critical knowledge and infrastructure around it. Today, every major industry and leading organization is investing in quantum computing, and you should too.

The world's infrastructure is becoming ever more complex, and the amount of collected data is growing exponentially. Technology and connectivity have become almost ubiquitous in the developed parts of the world and generated enormous efficiency and well-being in all walks of life, including ways to reduce CO2 emissions and fight climate change. Classical computing has given us the recent rise of artificial intelligence and automation, starting a major paradigm shift in the way efficiency can be achieved. However, we are witnessing an exponential growth of complexity in problems, beyond what is possible for classical computers to solve. The astronomical amount of calculations needed to maintain a competitive edge in computational solutions requires totally new technologies because high-performance computing is no longer capable of solving such problems.

Quantum physics is bringing the next exponential leaps in technological advancement in the form of quantum computers. These computers can emulate the physical world by harnessing the enigmatic laws of nature. This gives quantum computers an innate ability to solve immensely difficult problems that are impossible for classical computers. Even though the common observation that the number of transistors on a microchip doubles every two years (i.e., "Moore's Law") has been valid for decades, there exists a certain class of problems that cannot be solved with conventional computers. Even the most powerful high-performance computers cannot handle the exponentially growing complexity of the world's needs. The potential to overcome the limitations of classical computing is the reason the leading tech corporations and research institutes in the world are investing in quantum computing right now.

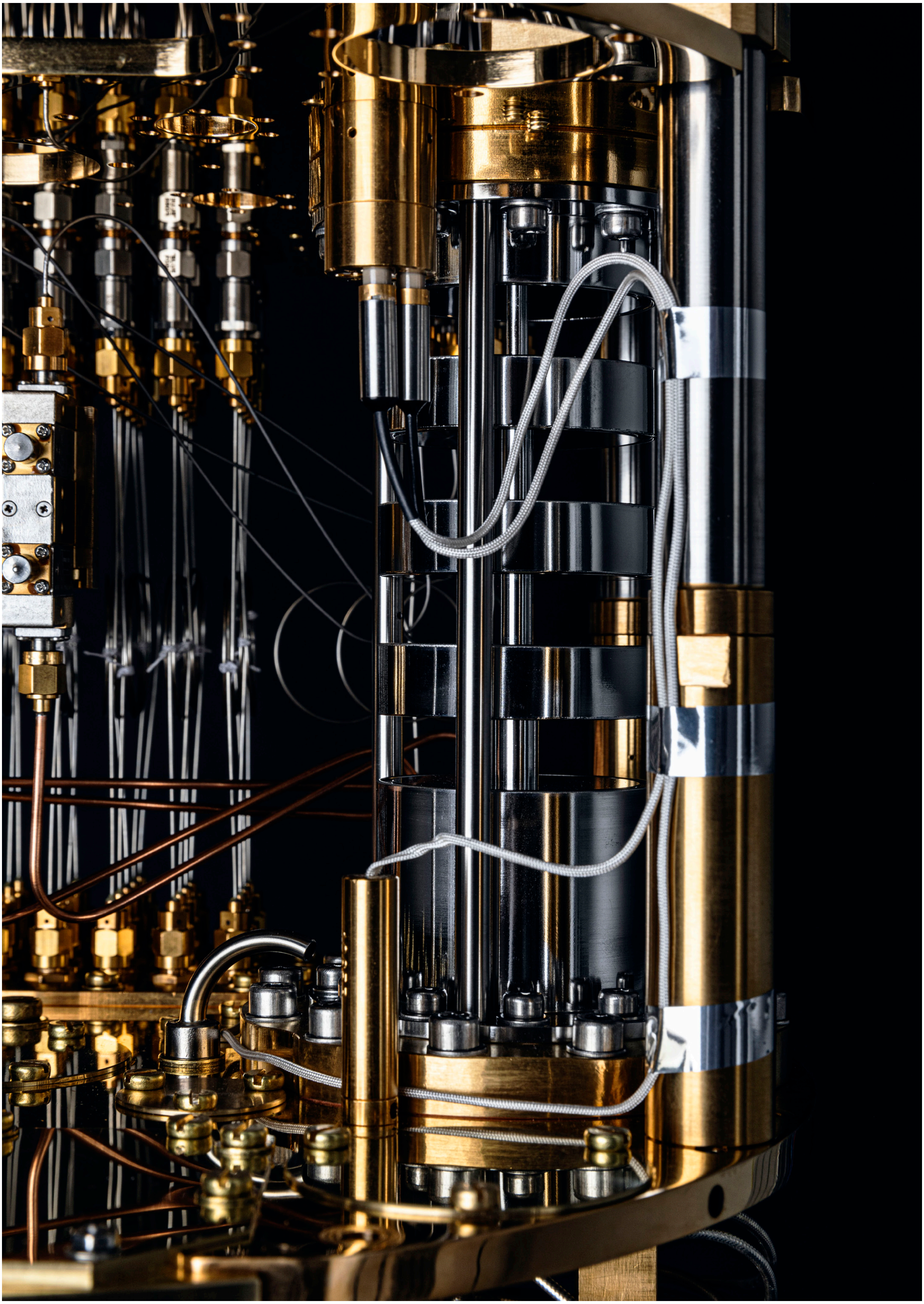
IQM is providing its clients with a fast lane for quantum computers by developing the hardware for the next computing paradigm. IQM's stance is that quantum computing will radically transform the lives of billions of people. The early applications range from creating more efficient medication to discovering planet-saving materials and sustainable economy models. IQM is on a mission to increase the speed of quantum computers and making breakthroughs in this technology possible.

The value and opportunities of quantum computing for its end users will increase rapidly as quantum techniques and their commercial viability mature in the next few years. Despite the rather elusive nature of quantum physics in science and its exceptionally high barrier of entry, early adopters will nevertheless gain a significant advantage in the upcoming quantum revolution. Quantum computing is no longer a scientific pipe dream; it is a reality. This is the time to act.

What is a quantum computer and how is it different from a supercomputer?

A quantum computer is groundbreakingly different from a classical computer. Whereas a classical computer performs like an abacus, calculating tasks in sequential order, a quantum computer calculates the corresponding tasks in a parallel fashion. This paradigm can be illustrated by thinking about a maze: Whereas a classical computer tries to find one route at a time, a quantum computer will test all possible routes at once. Even though this concept sounds elegant and simple, one must keep in mind that when operating a quantum computer, there is also a classical computer involved that manages the tasks assigned to the quantum computer. In this sense, the quantum computer can be seen as an accelerator, similar to graphical processing units in parallel computing.

Classical high-performance computing and mathematical modeling have brought an advantage in solving scientific problems for the past several decades. This has culminated in, for example, making airplanes and passenger cars safer, as well as improving fuel and aerodynamic efficiency. All of this has been achievable when the number of variables, or computational grid, has remained limited. However, when the number of variables increases, the problem becomes too large even for high-performance computers. Consider drug discovery as another example. There, the challenge is to design a compound that will attach itself to, and modify, a target disease pathway. The critical first step is to determine the electronic structure of the molecule. However, modeling the molecular structure of an everyday drug such as penicillin, which has 41 atoms at ground state, requires a classical computer with 10 to the power of 86 bits (source: Zapata Computing), which is more transistors than there are atoms in the observable universe. Such a transistor-based computer is undoubtedly a physical impossibility. However, for quantum computers, this type of simulation is well within the realm of possibility, requiring a processor with only 286 qubits (source: Zapata Computing).



Bits

Classical computers use microprocessors containing billions of small on/off switches called transistors that are electrically controlled to implement logic gates in integrated circuits. The arrangement of the logic gates together with sequential switching of on or off, called clock pulse, eventually amounts to a set of instructions for how the microprocessor will perform. One switch in either an on or off state controlling voltage difference over it is called a binary digit, a so-called “bit.” The two states, or bits, are represented with numbers 0 and 1. If we have a 2-bit system, the numbers (0 and 1) can be in four possible states (00, 01, 10, or 11), but only in one of them at any time. If we have a 3-bit system, we can represent eight different combinations. Thus, each step doubles the number of combinations exponentially.

In fact, exponential growth is quite often explained vividly with the classic story about a traveling wise man playing against a king who was a chess enthusiast. The king wished to challenge random visitors, and in this story, he motivated the wise man by offering any reward he could think of, if he won. The wise man modestly asked the king to reward him with rice grains in such a way that a single grain of rice would be placed on the first chess block and two grains on the second block, so that on each consecutive block, the number of grains would double. The wise man won the challenge, and the king realized on the 20th block that he was already at over a million grains of rice, yet there were 44 blocks still to go, each block doubling the number on the previous block. The total number of grains at block 64 was about 210 billion tons, allegedly able to cover the whole territory of India with a one-meter-thick layer of rice.

We can basically represent anything with these numbers, such as instructions to a computer’s screen to display letters, numbers, or images by turning individual pixels on or off, coloring them, etc. The outcome of these instructions is called a “computer program” that will be stored in the computer’s memory.

The bit is the tiniest unit in a classical system such as a smartphone, laptop, desktop computer, or even a supercomputer. Bits are represented in computer (or smartphone) applications by extremely large strings of ones and zeros. In your typical smartphone application (50 MB [megabytes]), the number of bits is over 400 million: 419 430 400 to be exact. To instruct the microprocessor with the exact number of ones and zeros in the exact sequential order for it to perform the task required, computer programming languages are needed, which are better suited for human input. Programming languages are based on exact syntaxes that represent a set of guidelines and building blocks that will be translated to the microprocessor with the right instructions in ones and zeros.

Qubits

Quantum computing is not built on bits that are either 0 or 1; instead it is built on quantum bits, or “qubits,” which are in a so-called “superposition” of both states. Furthermore, a quantum computer can contain a superposition of not only single bits, but bit strings. This is called “entanglement.” For example a classical computer with only two bits would have four possible states (00, 01, 10, or 11) and process only one state at a time. In contrast, two qubits in a quantum computer can represent any of the countless combinations of the four states at the same time, for example 00 and 11.

Adding more bits to a classical computer does not change the logic; it still must process one state at a time. However, when more qubits are added to a quantum computer, its computational power will grow exponentially in each step. This means that in an idealized scenario, every additional qubit doubles the state space of a quantum computer. With 54 qubits (2 to the power of 54), the number of possibilities is a staggering 18 014 398 509 481 984, which would take around 17 years for a modern desktop computer to go through, at a rate of around 2 billion instructions per second. For a 54-qubit quantum computer, however, it would need one cycle to open up this state space. With 10 qubits more, at 64, it would take a classical desktop computer around 292 years at the same rate of 2 billion instructions per second. The vast number of different bit configurations that can be stored in a quantum computer’s memory is the enabler of so-called quantum supremacy, which is the ability to solve problems that no classical computer can feasibly solve.

It is worth considering that if one had a sufficiently powerful supercomputer in a huge data center with a massive need for power and cooling, equivalent to the processing power of a 53-qubit quantum computer, as an example, adding 1 more qubit to a quantum computer would require doubling the whole supercomputer infrastructure. In each step, when you added more qubits, you would have to double the supercomputer infrastructure, which is not realistic.

Why is this important?

Quantum computing has the potential to revolutionize information processing in the same way quantum science revolutionized physics in the first quantum revolution, a century ago. Scientists understood the principles of quantum mechanics and built devices based on those principles. This gave us semiconductors, lasers, and transistors, the essential foundation for modern computers. In fact, almost all technologies shaping our modern world (e.g., nuclear science, chemistry, material science, electronics, computers) result from harnessing these quantum effects. However, in these discoveries and their advancements, quantum effects are only passively exploited, following the principles of quantum mechanics.

The second quantum revolution, on the other hand, is about efficiently controlling quantum effects. Scientists are manipulating quantum mechanics to do everything needed, not just following a set of guiding principles and building a system within the barriers of those rules. Quantum computers are expected to become game changers in domains such as cryptography, machine learning, and chemistry (i.e., materials science, agriculture, and pharmaceuticals).

Quantum computing is also green technology, as it holds the potential to drastically reduce the energy consumption of high-performance computers. Whereas a high-performance computing cluster requires up to 10 MW of energy and a massive amount of space, a quantum computer on average requires 1000 times less (10 kW), as well as a significantly smaller area for its operation. In today's binary computers, computing power and energy requirements increase linearly as more processors are added. In quantum computing, the power consumption is driven mainly by the cryostat, which is used to maintain low temperatures, whose size only modestly increases as more qubits are deployed. Even more importantly, the computing time, and therefore energy consumption, needed to solve the same problem is drastically shorter, for example minutes instead of years in early quantum supremacy experiments.

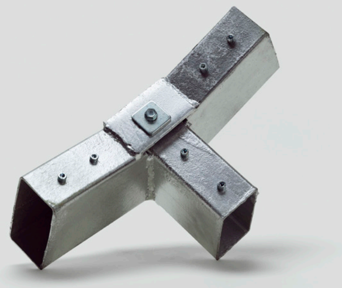
Many of the future use cases for quantum computers include green technologies, which will have a high impact especially on emission-intensive industries. New solutions will arise from discovering new techniques for energy production, energy storage, and carbon capture. Discovering lighter, stronger, and better insulating materials for construction processes that will emit less carbon, or modeling of fluid dynamics for aircraft and maritime vessels, is something for which quantum computing will provide a tremendous advantage. One area of business where a vast number of variables are also present is logistics. Optimizing supply chains involves, for example, interdependencies on variables such as cost, product, route, means of transportation, and agreement constraints with the client, eventually leading to a situation in which each variable change can result in an exponential increase to the problem.

Quantum computing is a disruptive computer technology that makes it possible to solve problems that classical supercomputers cannot solve. Many of these problems are among the most urgent problems of humanity, such as combating disease through the development of new medicines, reducing air pollution by developing better batteries for electric vehicles, or reducing hunger by developing more efficient fertilizers. Solutions to all these problems can efficiently be found with computers that use the multidimensional quantum world to exponentially accelerate the calculations.

NEW MATERIALS

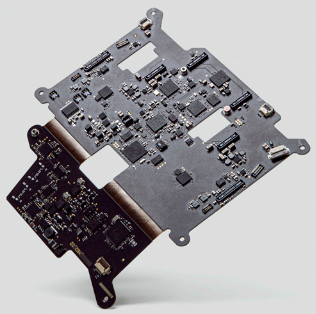
ENERGY / SUSTAINABILITY

MEDICAL INDUSTRY



CONSTRUCTION

CHEMISTRY



AI / MACHINE LEARNING

FINANCE

Quantum readiness

Building the critical knowledge for this upcoming new industry is becoming imperative for all private and public entities. The main reason is security. Another is competition over quantum advantage. Thus, it is time to start familiarizing oneself with quantum computing methods and appliances, as well as exploring the opportunities.

SECURITY

For many decades, scientists, fueled with curiosity over quantum physics for its potential advantage in science and computing, remained in their tiny branch of science departments. Because it was something difficult to define and control, it did not raise much public interest. Then, unexpectedly, in 1994, a mathematician named Peter Shor demonstrated how a quantum computer has the power to break widely used cryptographic schemes. Suddenly, interest and funding from governments for quantum computing started to increase substantially. The approaching threat of a new technology that could compromise defense systems and the security of communication, or even obliterate financial markets and ultimately dissolve trust altogether, elevated quantum computing from fringe to mainstream.

However, 1994 might have been a bit early for compromising security systems; the current understanding is that one of the widely used encryption methods, RSA, might be cracked 10-15 years from now. How can we prepare for this? Quantum computers have the potential to shift power structures and ultimately the balance of power in politics, if it would not be a tie.

QUANTUM ADVANTAGE

Pharmaceutical and chemical companies are already starting to experiment with modeling of large molecules with the help of quantum simulations, to understand their intricacies and chemical properties at the atomic level. For a pharmaceutical company, success in speeding its way into innovating new drugs, and, for instance, designing molecules that have fewer unintended side effects gives it an enormous competitive edge. In other branches of science and research, such as search and machine learning, quantum computing can uncover the true value drivers from exponentially growing datasets in financial markets—medical, traffic, and climate, to mention a few. Furthermore, as there will be tens of billions of new devices connected to the internet, from normal everyday items to passenger vehicles, in the near future, the amount of data available is rapidly growing. Autonomous vehicles are one area where machine learning needs to be trained with massive datasets, and this is where quantum computing will also bring tremendous acceleration in the amount of relevant information that can be processed.

Scientists and engineers are steadily developing better algorithms for quantum-accelerated machine learning, and eventually, there will be groundbreaking advancements that will ultimately lead to surpassing high-performance machine learning and computing. This is when we step into an era of quantum advantage, where quantum computers in certain fields are surpassing classical computers in their usefulness, solving real-world problems, and ultimately displacing classical computing altogether. However, long before the "quantum advantage," the adoption of quantum techniques in any market or branch of science and research will proceed extremely quickly.

Turbulence, the oldest unsolved problem in physics

IQM has the capability to develop QPUs specifically optimized for certain purposes, such as financial applications and chemical simulations. One monumental challenge in science is to be able to solve the fundamental problems in fluid turbulence within the realm of so-called Navier-Stokes equations. Turbulence is the oldest unsolved problem in physics, and overwhelmingly difficult for a classical computer to compute. This is where density, pressure, temperature, and velocity of a moving fluid are related. Turbulence is prevalent everywhere. We can see it, for example, in swirling smoke, in the mixing of two different liquids, and in air currents in the atmosphere. Turbulence is a complex and chaotic motion of swirls that unpredictably break into a seemingly infinite number of smaller and smaller swirls. In addition, these swirls interact with each other in what physicists call a turbulent cascade, creating an erratic chain of interactions that are impossible to predict. Supersonic turbulence adds yet another dimension of complexity to this problem.

The unpredictable nature of turbulence is a great mystery, yet it is incredibly important for science and technology. It is an essential factor in designing jet engines, determining the mass flow rate of gas in pipelines, aerodynamics, and predicting natural phenomena such as the weather. Wind tunnels exist only because we cannot yet compute turbulence.

IQM's co-design approach, which is specifically developing optimized quantum processors for application-specific tasks, is also aimed at solving the fundamental problems in fluid turbulence. Successfully modeling supersonic turbulence with a quantum-accelerated supercomputer also extends to better understanding nature and the cosmos.

Hybrid model

Quantum computers alone are rarely optimal machines to solve complex problems, but they can be operated as accelerators to existing high-performance computers. While high-performance computers can execute certain tasks efficiently, quantum computers come in to help with tasks that would otherwise be impossible, or simply just take too long to complete with traditional supercomputers. Principally, quantum computers are not in the trajectory to replace high-performance computing per se; instead, they coexist with classical computers, offering completely new perspectives to tackle the hardest problems in the world smarter, better, and faster.

Most of the current quantum computer resources that are commercially available are provided as a cloud service. This means that the physical machine is located in a separate facility to where the service is being used, possibly even on a different continent. However, physically locating all the computers in their own data center is of prime importance, especially when processing sensitive data, or when there are requirements for data or technological sovereignty. On a technical side, locating a quantum computer close to a high-performance computer enables secure, fast, and low-latency data transfer between them, as well as optimization of resources such as power supply, cooling, and backup power. This helps not only to cut operational costs and achieve better performance, but also in delivering the results in a more environmentally friendly way.

Quantum software stack

As an end user, you will have access to the actual quantum computer to solve your own business or research problems with this new technology. The quantum software stack spans the software layers from the quantum hardware all the way up to the end user. As we ascend the stack, the level of abstraction rises from the bottom of the stack, with direct access to the physical quantum states, to the highest level, with quantum algorithms providing valuable answers to business problems.

IQM ensures value for end users by strategic selective vertical integration in the stack. The lowest layers—those closest to the hardware—are developed and maintained in-house, whereas for the higher abstraction levels, we bridge the gap with partnerships or by building our own solutions. These individual decisions are driven not only by superior technologies but also by optimal user experience and considerations of effective distribution channels.

We create and release open source software where we see the open source model creating added value for IQM and the quantum computing ecosystem as a whole, also building on and contributing to existing open source components.

IQM's on-premise quantum computer deliveries allow specialists full access to low-level control interfaces, providing untethered customization and experimentation options close to the quantum hardware.

Reaching quantum advantage faster

IQM is helping companies and organizations to develop a strong capability in quantum computing. We have a unique way of utilizing design thinking in our approach to quantum leadership. Our creative approach is to bring application-specific problem solving to a multitude of industries by also understanding our clients' businesses in a profound way. Through combining hardware and software design in developing quantum processors, we can bring application-specific capabilities to our clients. This approach is one of a kind; for example, it offers entirely new avenues for health care, machine learning, financial modeling, materials science, and chemistry, and it is massively speeding up discoveries and breakthroughs in science and engineering.

The superiority of the co-design approach can be demonstrated in the operation time reduction in quantum algorithms. For this benefit, IQM's quantum computer can reach much higher quantum volume, meaning that it can do much more computing at the same time, as it is particularly tailored to specific tasks, in both its hardware and software. IQM's ultimate goal for the co-design approach is to reach so-called quantum advantage faster. It is a critical moment when quantum computers in certain fields are surpassing classical computers in their usefulness, solving real-world problems, and ultimately displacing classical computing altogether.

Contact us

Are you interested to hear more?
Reach out to us.

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