Quantum Europe 2016: A New Era of Technology

EU
2016

Quantum Europe 2016: A New Era of Technology
European FLAGSHIP launched
17-18 May Amsterdam

A new, young generation of engineers is building quantum machines. They are creating devices on the basis of phenomena that even Albert Einstein found too strange to believe. Yet, these machines are very real, highly useful and will likely change our world.

Quantum computers, for example, meet the ever-growing demand for computing power and data processing. Their huge calculating power can push artificial intelligence and the development of smart materials, super solar cells, high-temperature superconductors, and new pharmaceuticals. Nearer term applications of quantum technologies include secure data transfer, ultra-precise brain imaging, atom clocks and navigation.

To fully reap the benefits of this quantum revolution a European effort is needed. Academia, industry and institutions need to join forces towards ambitious unifying goals building. In this context the EU Presidency organized the Conference Quantum Europe 2016 on 17-18 May, in cooperation with the European Commission and the QuTech institute in Delft. Leading scientists, industrialists and investors from Europe and the world gathered in Amsterdam to deliberate on how to place and keep Europe at the front of developing quantum technologies.

EU Commissioner for Digital Economy and Society, Günther Oettinger, announced the investment of one billion Euro in a new **Flagship*** on quantum technologies. "Building on the strong support for the Quantum Manifesto, we aim to launch an ambitious, large-scale Flagship initiative to unlock the full potential of quantum technologies, accelerate its development and bring commercial products to the consumer marketplace."

The Quantum Manifesto was written by the European quantum community and is endorsed by over 3400 supporters: industries, research institutes and scientists in Europe. It is a call to develop Europe's capabilities in quantum technologies creating a lucrative knowledge-based industry, leading to economic, scientific and societal benefits. It paved the way for the European Flagship.

The following notions were highlighted at the Conference:

- A European Flagship initiative is both timely and needed. Technologies are at a tipping point and global investments are rising.
- Ambitious unifying goals and roadmaps need to be established. The preparation and set-up should be efficient, open and flexible to ensure a quick start and a solid base.
- Partnerships with the private sector are key for commercialization and the involvement of industries.
- High risk, high gain technologies should be at the core of the Flagship programme.
- Training and education at all levels is vital to attain a future workforce for quantum industries.
- International cooperation is necessary to meet the scientific and technological challenges ahead.

To organize the preparations of the Flagship, a High Level Group (HLG) will be established with a broad European representation of academia, industries and institutions.

* **Flagships** are visionary, science-driven; they are large-scale research initiatives addressing grand scientific and technological challenges. They are long-term initiatives bringing together excellent research teams across various disciplines, sharing a unifying goal and an ambitious roadmap on how to achieve it. Flagships run for about ten years, with a total budget of around one billion Euros. Quantum Technology is the third Flagship. The other two, 'Graphene' and 'The Human Brain Project', were launched in January 2013.

Some promises of quantum technology

0-5 years
- More accurate sensors for health care and geosurvey
- More accurate atom clocks
- Safe data encryption

5-10 years
- Quantum credit cards
- New functional materials i.e. solar cells, superconductors
- Improved navigation systems

10-15 years
- Secure European internet
- New pharmaceuticals
- Super computers

Quantum technologies are based on the 'peculiar' world of quantum physics. A world where particles can be at two places at the same time and where one particle can influence another over a kilometres distance without any visible connection. Often this quantum world is called bizarre, weird or spooky. But the machines that quantum engineers are building are very real and reliable. Quantum laws are written by nature. Plants which pick up sunlight to grow and flourish are also quantum machines, clarified Quantum Europe's co-host Leo Kouwenhoven. "Nature itself speaks quantum language. We are now learning to speak it too."

Günther Oettinger:
"This initiative cannot be 'more business as usual', or should I say, 'more science as usual'. It has to make a difference for Europe and for European industry. In the coming months, we need to further mobilise actors in the preparations as success will depend on a strong commitment of all relevant stakeholders, on the concrete engagement of European industry players and on the support of Member States. We should also build from the experience of the two ongoing flagships to design an open initiative, with clear and ambitious goals and with an effective governance structure. We need to identify priorities and map them to the potential funding sources within H2020 but also locally at national level. I expect the most high risk – high gain part of the agenda to be at the core of the flagship effort which should be taken-up by our risk taking Future and Emerging Technology programme. Other chapters with shorter time to market like communication and sensing may be better served by more industry oriented funding schemes. In this context, the Commission will soon call an independent High Level Steering Committee to take the drive of this important preparatory phase. The members should represent all stakeholders and I will announce their names in the coming weeks."

"Any sufficiently advanced technology is indistinguishable from magic"

Writer and futurist Arthur C. Clark

“Let it happen in Europe”

Henk Kamp, Minister of Economic Affairs said in his speech:

“It’s a cycle: scientists transform money in science, industry transforms science in money”

Mike Lazardis

“Europe has proved fertile grounds for physics. Quantum theory was born in Europe in the first decades of the 20th century. A generation of young physicists such as Bohr, Planck, Einstein, Heisenberg, Schrodinger and Pauli established the fundaments. Today, almost hundred years later, Europe still plays a leading role in the field. The continent counts more quantum scientists, invests more money, and has a broader scope than any other player worldwide.”
“The time has come to build on this scientific excellence”, said Henk Kamp. “Today quantum physics is on the realm of delivering quantum tools and devices. Europe is in pole position to start reaping the economic and societal benefits of quantum technologies.” But the time to act is now, Mr Kamp warned“Competitors don’t wait.”
“ What’s the best strategy to turn quantum physics into commercial products for future prosperity and safety? The European Flagship programme should include education, basic research, engineering and start-up venture funding. It is vital to provide sustained support to the entire **quantum ecosystem***.”
At Quantum Europe 2016 the gathered scientists, industrialists, entrepreneurs, politicians and policy makers were invited to make recommendations, suggestions and advice for the flagships strategy:

Do’s and don’ts for the Quantum Flagship

- Don’t divide the budget in small pieces. Working together makes a programme larger than the parts. – Mike Mayberry (Intel)
- Use the European dimension, use every brain – Vladimir Buzek (Slovak Academy of Sciences)
- Avoid politics and bureaucracy – Freeke Heijman (Ministry of Economic Affairs)
- Industry still regards quantum technology as risky. Co-funding can bridge the technology gap - Andrew Shields (Toshiba)
- High expectations may result in disillusion. Support a mix of feasible goals and blue sky research – Michael Bolle (Bosch)
- Don’t force people to work together. Support bottom-up partnerships– Leo Kouwenhoven (QuTech)
- Quantum technology development needs centres of excellence at scale, a critical mass – Marc de Jong (McKinsey & Company)
- Leave room for blue sky research – Serge Haroche (Collège de France)

The JRC (Joint Research Centre) is the ‘in house science service’ of the European Commission. Maive Rute, Deputy Director-General at JRC, announced the publication of a paper ‘Quantum Technologies: Implications for European Policy’, and invited everyone to provide input and join the debate.

* **Quantum ecosystem** is the environment in which quantum technology thrives. A combination of excellent scientists, industrial involvement, sufficient funds, good education, trained engineers, good facilities and infrastructure, willingness to cooperate, openness, etc.

“We have a FLAGSHIP!”

Leo Kouwenhoven, scientific director of **QuTech***, co-host of Quantum Europe 2016

Satisfied?
Yes, absolutely! We can now move on to the next phase: start building research partnerships in quantum technology.

Most valuable result?
The full endorsement from politics, industry and academia, the support by Commissioner Günther Oettinger, and the willingness to form good partnerships. We have a **Flagship***!

Proud of ...
The quantum community to have pulled this off. And of the organizers who were able to organize this perfect conference.

Most surprising?
The magician, Victor Mids. And that the answer to the universe is indeed 42.

Best advice heard?
Charles Marcus quoted a paper ‘Why Europe missed the transistor’. Both Europe and the US developed a prototype shortly after World War II. However, the US outran Europe in development. It had the advantage of an extensive infrastructure, i.e. Bell Labs. It implies that sustainable funding is crucial.

It was an honour to ...
As a Dutchman welcome the community in the Rijksmuseum, and to finally meet Prince Constantijn.

Favourite quote heard?
“We need a Lazaridis[1] too”. Philanthropy can be very powerful.

Also enjoyed?
The more scientific reports by Charles Marcus (University of Copenhagen) and John Martinis (University of California and Google)

Next time .....
We could try to stimulate more interaction and discussion on stage and with the audience.

“Join forces on the grounds where quantum physics were born”

Serge Haroche

1 Mike Lazardis, founder of BlackBerry, is partner and co-founder of Quantum Valley Investment, a large, advanced quantum research facility in Waterloo, Canada.

* **QuTech** is the Netherlands Advanced Research Center on Quantum Technologies and a National Icon. Delft University of technology and TNO established the public-private partnership organization in 2013. Industrial partners include Intel and Microsoft.

“Let’s build the QUANTUM COMPUTER together”

John Martinis (Google)

“Building a quantum computer is simply too hard to pull off alone somewhere in a garage”. John Martinis, professor at the University of California and member of Google’s Quantum Artificial Intelligence Lab, knows the difficulties of handling single atoms well. “To maximize success the quantum world needs to work together, sharing knowledge about what works and what doesn’t.”
The **quantum computer*** is definitely the ‘holy grail’ of quantum technology. It scales exponentially with every qubit (quantum byte) added. At 50 qubits a quantum computer will already beat every known supercomputer in calculating power. Today, quantum engineers can combine about 5-10 qubits. Martinis’ team is working on a demonstration of their exponential processing power. “That will attract the attention of all CEO’s in Silicon Valley.”
Yet a single tiny error may lead to decoherence which disrupts quantum computation in a collection of qubits. Martinis: “We need high quality qubits. The clue to a working quantum computer may well be in understanding the tiniest errors.”

“The INTERNET OF THINGS asks for quantum sensors”

Michael Bolle (Bosch)

It’s very likely that your smartphone contains a sensor made by the Germany-based multinational Bosch. Worldwide, three out of four phones hold a Bosch sensor. These sensors count steps, measure air quality, change screen orientation or help find your way. Bosch produces over four million sensors every year. But that is only the beginning, told Michael Bolle, President of Corporate Research and Development. The upcoming Internet of Things (IoT) is expected to connect 14 billion devices in 2020, not only smartphones, but also cars, electric gear, tablets and solar panels. Even your home microwave or heater will become part of the IoT. Therefore IoT requires billions of high-quality, tiny sensors.
Quantum sensors* promise to be just that. Although an ultra-precise quantum sensor based on the Zeeman-effect may weigh two kilos today, Bosch is highly interested in this emerging technology. Their R&D-roadmap leads to such a sensor fitting on a chip by the year 2020. Bolle: “Bosch wants to be among the pioneers and is developing and investing in new public-private partnerships.”

* **Quantum computers** process quantum information. A quantum computer can test lots of possibilities for solving a problem simultaneously. It will soon beat supercomputers in calculating power, but a quantum approach does not work for all types of computation. Therefore, the quantum computer will be working next, or together with, conventional (super)computers.

* **Quantum sensors** are based on single atoms, ions or photons. Because they are identical by nature, calibration is no longer needed. And they can capture the smallest change in gravity, magnetic or electrical fields, resulting in the highest possible precision. Applications are wide, from brain imaging to automated driving and environmental analytics.

“Delighted to witness fundamental physics COMING TO APPLICATION”

Alain Aspect (Paris-Saclay University)

The first quantum revolution (1900-1960) has changed our world. Through inventions such as the transistor, lasers and chips it leaped us into the information and communication age. Likewise, the current second quantum revolution will create a new world of possibilities, argued quantum physicist Alain Aspect. An exciting world, added the Augustin Fresnel Professor at Paris-Saclay University enthusiastically. “I’m so delighted to witness a highly fundamental field coming to application.”

At the roots of this the second quantum revolution lies the concept of **quantum entanglement***: the counter intuitive phenomenon that a relationship between a pair of elementary particles continues to exist even after they are separated. Aspect himself provided crucial experimental evidence for quantum entanglement in the early 1980s.

Hardware based on the principles allows the emergence of quantum sensing, quantum processors, quantum simulation and quantum cryptography. Aspect: “To develop actual prototypes and devices we need above all more research and more collaboration between academia and industry.”

“A big space to work with the VERY SMALL”

Mike Lazaridis (Quantum Valley Investments)

In his first venture entrepreneur Mike Lazaridis built the smart phone company BlackBerry, together with his close friend Doug Fregin. Since 1999, the two focus on positioning their home country Canada as a leader in “the next great technological revolution: quantum technology”. Lazaridis: “As a student, I followed a night course in the early 1980s on the latest discoveries in physics. I was stunned by this idea of a quantum world. Ever since, I wanted to be a pioneer in the field.”

Lazaridis’ company Quantum Valley Investments provided half of the total investment of 1,29 billion US$ in Quantum Valley, a centre for the development and commercialization of quantum information science in Waterloo, Ontario. Quantum Valley has the highest concentration of quantum physicists and engineers worldwide and has already yielded five spin-off companies. Lazaridis: “It’s a cycle: scientists transform money in science, industry transforms science in money”

At Quantum Europe 2016 Lazaridis gave an impressive virtual roundtrip of Quantum Valley. The centre includes the Perimeter Institute for Theoretical Physics, the Quantum-Nano Centre and a business centre. The facilities cover in total more than 50.000 square meters and include quit labs (vibration control), cleanrooms, ultra-high vacuum and low temperature systems, and **ultra-precise mechanics*.**

* **Quantum entanglement** is a phenomenon at the roots of quantum information and technology. Particles can be connected even if the distance between them is very large. Measurement of one influences the state of the entangled other. Entanglement of photons has been proven over 150 km distance.

* **Ultra-precise mechanics** are needed to build quantum devices as they are based on individual atoms, electrons or photons. Engineers work at the limits of equipment and possibilities, often in high vacuum and near the absolute zero (-273 °C).

“It may be nothing. It may SWIPE AWAY all other ideas”

Charles Marcus (University of Copenhagen)

“Quantum physics does not stop, now that the engineers have rolled in”, stressed Charles Marcus, Villum Kann Rasmussen Professor at the University of Copenhagen. He gave the audience at Quantum Europe 2016 a glimpse of a possible next generation **qubit***, the building block for a quantum computer.
Marcus’ idea is based upon so-called Majorana quasi particles, a special ‘particle’ that is its own anti-particle. Their existence is predicted by theoretical physicist Ettore Majorana in the 1930s, but only very recently actual proof was found.
Marcus’ next generation qubit is unique as it may memorize or store information in contrast to current qubits in development. He compared his design with a knot in quipu, the 5000 year old system used by Inca to collect data and keep records (‘talking knots’).
It’s a highly fundamental high-risk, high gain project. “It may be nothing”, he announced enthusiastically. “It may also swipe away all other ideas.”

“Together we can go FASTER”

Mike Mayberry (Intel)

“We think we can help”, is the clear message to the audience of Mike Mayberry, Vice President & Managing Director of Intel Labs. Intel, one of the world’s largest chipmakers, offers the quantum community its knowledge and experience in the precise control of materials. Why? “Because quantum computing promises to solve problems which are insurmountable by today’s silicon-based circuits.”
Intel doesn’t think that **Moore’s law*** is coming to its end, nor does the company think the quantum computer is almost ready, stressed Mayberry. But “together we can go faster in augmenting tomorrow’s computers”. The company has valuable skills in manufacturing on the nanoscale, in integrating physics with other disciplines, and in collaborating over the world.
Last year, Intel selected QuTech in Delft, The Netherlands, as its partner in a ten year intensive partnership in quantum technology. Goals in this collaboration are improvement of qubit quality and connectivity, scaling-up QuTechs 5-qubit chip and creating single spin qubits in silicon. Intel and QuTech are for example trying to improve qubit lifetime by using 99.9 percent isotopically pure silicon-28. A collaboration with the industrial gas multinational Air Liquide and nuclear fuel company Urenco.
Looking five years ahead, Mayberry foresees 50+ qubit prototypes and a broad community of algorithm researchers exploring practical applications.

* **Qubits** are the smallest storage unit in a quantum computer. The equivalent of the bit in a current computer. However, where a bit can be 0 or 1, the qubit can be both, allowing special algorithms in a quantum computer giving it calculating power that grows exponentially with every qubit added.

* **Moore’s law** states that computer power doubles every two years. This is obviously no natural law but an empirical observation. A prophecy which has been said to end very soon, ever since its formulation in 1970. But it hasn’t up till now.

Promises and challenges

Quantum technology programme is expected to deliver applications in five areas each with its own timeline. In parallel working sessions the participants discussed latest developments, defined promises and challenges, discussed methods to stimulate interplay with industry and the possible role of Europe.

	Promises	Challenges	Involving industry	Role Europe
Quantum communication	Protection against cyber attack Trusted communication	Develop quantum repeater networks	Demonstration pilots Standards and certification	Foster collaboration Building a European quantum backbone
Quantum simulation*	Solve hard optimization problems Predict material properties	Hardware development Problems classification	Formulate joint vision Joint development of infrastructure	Fund and encourage research Involve more players
Quantum sensing and metrology	Improved precision and sensitivity New applications	Noise and decoherence System imperfections	Collaboration necessary Fair competition	Testing systems Support during 5 years from idea to prototype
Quantum computing	Quantum supremacy with 50-100 qubits New applications	Interface flying and stationary qubits Fabrication quality	Concerted multidisciplinary efforts Know-how exchange	Framework for collaboration Develop value chain
Quantum software/ algorithms	Modelling materials and chemistry compounds Applications beyond computing	Develop a new way of thinking Mapping algorithms to physical hardware	Forums for learning same language Guidance on worthy problems	Open up borders Funding is the start of collaboration

A complete overview of the results can be found at: j.mp/qe2016-session-results.

"Don't let the future be invented elsewhere"

Bertholt Leeftink

* **Quantum simulation** allows exploring properties of materials before they even exist. A highly valuable tool for designing new materials because supercomputers cannot yet predict material properties accurately.

Also happening at Quantum Europe 2016

- The 2000 km **quantum backbone*** between Shanghai and Beijing is nearly finished, reported **Qiang Zhang** (University of Science and Technology of China)
- The quantum community thanked **Tommaso Calarco** (IQST Ulm) for chairing the programme committee of Quantum Europe 2016 and a lot of other committees. He is confident that the Manifesto is a good starting point for the flagship and is looking forward to preparing it with the whole community.
- 2012 Nobel Prize winner in quantum physics **Serge Haroche** send an inspiring video message from Japan. “Quantum physics is coming of age”
- Moore’s law is still alive and kicking, showed **Markus Matthes** (ASML). “Above all, quantum computing is a solution for the ‘exploding’ volume of data.”
- **Marc de Jong** (McKinsey & Company) presented worldwide figures and numbers on quantum technology. “The field is developing at pace. I’m impressed.”
- **Cora van Nieuwenhuizen** stressed that it is vital to attain public awareness and political support througout Europe for the impact of the new technologies

“I met my quantum heroes today: Alain Aspect and Anton Zeilinger”

Mike Lazardis

* **A quantum backbone** (QBB) is a stretch of high quality optical fibre allowing the end connectors to exchange quantum security keys. It is the start of a quantum network that may ultimately result in a worldwide quantum internet.

Dinner talks

Anton Zeilinger was very explicit in his dinner speech: there is every reason to believe that in the not too distant future all information will be quantum information. “Why not?” he challenged. To achieve this, he feels that collaboration across Europe is needed, and observes that the only limitation to the size of entangled states which can be generated is money. He described his own research, experiments on long-range quantum communication taking place in the Canary islands, noting that China, too, is planning similar satellite missions. In a few personal recollection, Zeilinger mentioned that when he started in physics, he wasn’t into quantum mechanics, that came later in his career. He also revealed a point of pride, which is having in his office the blackboard of Ludwig Boltzmann, the Austrian physicist who, in deriving the relationship between entropy and probability, first glimpsed the deep connection between physics and information.

Krysta Svore talked during dinner about the efforts of Microsoft to develop quantum algorithms and software. Of course Microsoft historically is a software company, and will continue to be in the quantum era. But quantum, makes the future concrete. One program she discussed, for simulating quantum circuits, called “Liquid” is an online program. Svore expressed her hope that classrooms around the world would start teaching quantum computer programming. Svore also discussed how Microsoft is working closely with European labs in Denmark and The Netherlands, emphasizing that such open collaboration with academic partners was necessary in this field. Bright minds are needed from all over the world to meet the scientific and technological challenges of quantum information, she stressed. As an example of a real-world problem for quantum computing, one with significant economic impact is the quantum chemistry problem of nitrogen fixation to make fertilizer. This application, solving quantum problems with a quantum machine, was Feynman’s original motivation for building quantum computers in the first place.

Link to all delegates:
http://dl.quantumeurope.eu/participants.pdf

Link to speeches:
https://ec.europa.eu/commission/2014-2019/oettinger/announcements/speech-quantum-technologies-conference-amsterdam-17-may-2016
https://www.rijksoverheid.nl/documenten/toespraken/2016/05/17/speech-to-be-given-by-the-minister-of-economic-affairs-henk-kamp-at-the-opening-of-quantum-europe-amsterdam-17-may-2016

Links to all pictures of the conference:
https://www.flickr.com/photos/eu2016nl/sets/72157668258455621
https://www.flickr.com/photos/eu2016nl/sets/72157668265345271
https://www.flickr.com/photos/eu2016nl/sets/72157668474406696
https://www.flickr.com/photos/eu2016nl/sets/72157668450275701

Link to all plenary presentations:
http://j.mp/qe2016-presentations

Link to session results:
j.mp/qe2016-session-results

Link to JRC white paper:
http://publications.jrc.ec.europa.eu/repository/handle/JRC101632

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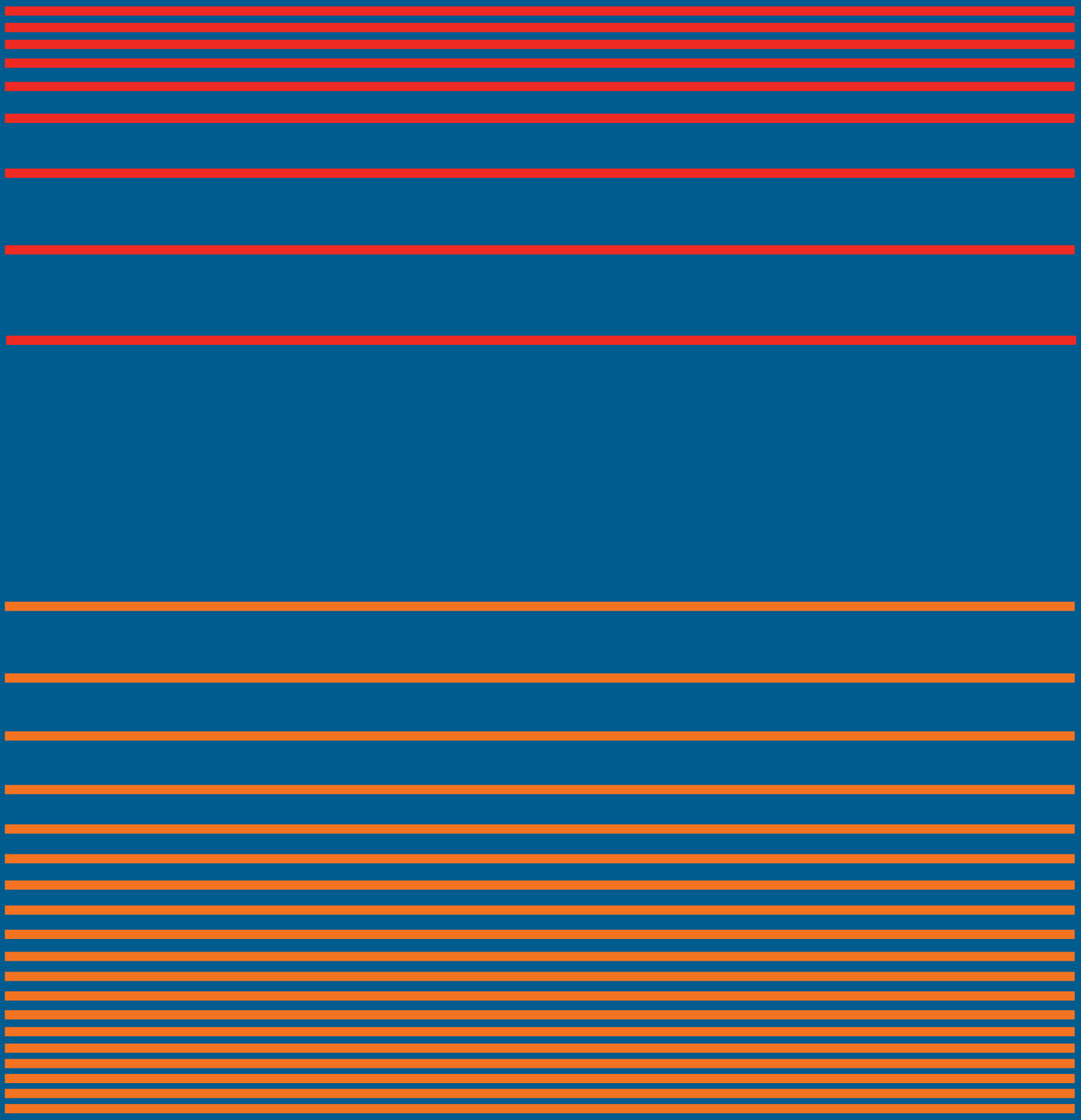
Quantum technology

7000 scientists worldwide

1.5 billion euros invested annually, expected to rise to 5 billion

Industrial investors include Microsoft, IBM, Google, Intel, Toshiba, Thales, Airbus



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