Quantum technologies and the advent of the Quantum Internet in the European Union - Brochure

The second quantum revolution is unfolding now.
The European Union and its Member States are building the innovation ecosystem and infrastructures needed to create the next generation of disruptive quantum technologies that will effect Europe’s society, making the region a worldwide knowledge-based industry and technological leader in the field.

What are quantum technologies?

Past (first quantum revolution)

- understanding and applying the properties of quantum mechanics

Present (second quantum revolution)

- Engineering quantum systems

Development of quantum technologies that use...

- photons
- electrons
- atoms
- molecules

...for the development of devices and systems.

This will trigger a wave of new technologies that will create many new businesses and help solve many of today's global challenges.

The ultimate goal: Quantum Internet

The Quantum Flagship

In numbers

- October 2018
- 2000+ experts
- 10 years

- €1 billion

Ramp-up phase 2018-2021

- €152 million
- 24 EU-funded projects

About the Quantum Flagship

- A long-term, large-scale research initiative
- Bring quantum technologies from the lab to the market
- Develop technologies and open research facilities for quantum in Europe
- Bring together research institutions, academia, industry and policy makers in a joint initiative on an unprecedented scale
- Foster world-leading knowledge and skills

Goals

1. Consolidate and expand European scientific leadership and excellence in quantum research
2. Kick-start a competitive European industry in quantum technologies and position Europe as a leader in the future global industrial landscape
3. Make Europe a dynamic and attractive region for innovative research, business and investments in quantum technologies

Pillars of activity of the Quantum Flagship

Developments in leading areas of quantum technologies can be expected to produce transformative applications with real practical impact on society. That is why the Quantum Flagship has divided research and innovative efforts in five main areas of research and innovation.

Technical pillars

1. **Simulations**

   Simulating complex systems for advanced design and development

   Projects:

   - Qombs

   - PASquanS

2. **Communications**

   For a secure digital society and a quantum-enabled Internet

   Projects:

   - Uniqorn

   - CiviQ

- Qrange

- QIA

3. **Sensing and Metrology**

   Bringing accuracy and performance to unprecedented levels

   Projects:

   - AsteriQs

   - Metaboliqs

   - macQsimal

   - iqClock

4. **Computing**

   Computing power to overcome currently unsolvable problems

   Projects:

   - aQtion

   - OpenSuperQ

   - QLSI (started 1.9.2020)

   - NEASQC (started 1.9.2020)

5. **Basic Science**

   Addressing foundational challenges for development of quantum technologies

   Projects:

   - Square

   - Qmics

   - S2quip

   - 2d Sipc

   - MicroQC

   - Phog

   - PhoQuS

Horizontal activities

Addressing challenges such as Flagship coordination & community building, eduacation & training, and international cooperation.

Projects

- QFlag
- QTEdu
- InCoQFlag

Read more about the Flagship's achievements in its first 18 months in the mid-term review.

From vision to reality

Funding opportunities now and in the future

- ### Quantera

  Give funding support to international research projects in the field of quantum technologies

- **Quantum Flagship**

  Bring quantum technologies from the lab to the market and consolidate European scientific leadership in quantum research

- **Quantum Communication Infrastructure (QCI)**

  Build and deploy in the next decade a certified secure pan-European end-to-end QCI for cybersecurity services

- **Quantum Computing Infrastructure**

  Build and deploy an infrastructure for big data, artificial intelligence, high performance computing, and more

The Quantum roadmap

Establishing the future of quantum technologies

The roadmap outlines the major achievements and state-of-the-art accomplishments for the different research pillars of the Quantum Flagship, as well as future applications and targets

Major achievements so far:

1. **Sensing/Metrology**

    1. Quantum sensors for niche applications (health care, geosurvey, security...)
    2. More precise atomic clocks for synchronisation of future smart networks
    3. Quantum sensors for larger volume applications (automotive, construction…)
    4. Handheld quantum navigation devices
    5. Gravity imaging devices based on gravity sensors
    6. Integrate quantum sensors with consumer applications, including mobile devices

2. **Communications**

    1. Quantum repeaters and quantum memories
    2. Secure point-to-point quantum links
    3. Quantum networks between distant cities
    4. Quantum repeaters with cryptography and eavesdropping detection
    5. Secure Europe-wide internet merging quantum and classical communication

3. **Simulations**

    1. Simulator of motion of electrons in materials
    2. New algorithms for quantum simulators and networks
    3. Development and design of new complex materials
    4. Versatile simulator of quantum magnetism and electricity
    5. Simulators of quantum dynamics and chemical reaction mechanisms to support drug design

4. **Computing**

    1. Operation of a logical qubit protected by error correction or topologically [A qubit, or quantum bit, is the basic unit of quantum computing]
    2. New algorithms for quantum computers
    3. Small quantum processors executing technologically relevant algorithms
    4. Solving chemistry and materials science problems with special purpose quantum computer > 100 physical qubits
    5. Integration of quantum circuit and cryogenic classical control hardware
    6. General purpose quantum computers exceed computational power of classical computers

Future applications and targets

1. Sensing and metrology

2023 -> achieve compactness and integration necessary to deploy commercial sensors.

2027-30 -> for unprecedented earth monitoring and universal quantum standards.

- Integration of quantum measurement standards for self-calibration in instrumentation
- Fabrication of optically and electronically integrated lab-on-chip platforms
- Quantum-enhanced measurement and imaging devices
- Commercial products such as magnetometers improving MRIs, quantum RADAR and LIDAR
- Development of networks of quantum sensors including optical clocks and optical inertial sensors

2. Communication

2025 -> demonstrate long-distance (above 500 km) entanglement distribution and large-scale, quantum communication networks.

2027-30 -> create quantum-safe networks for intercity and intra-city communication and connect all countries in Europe.

- Self-driving vehicles
- Financial transactions
- Cryptographys
- Secure communications
- Cloud services
- Banking
- Health records
- Cybersecurity
- Blockchain
- Artificial intelligence
- Post quantum security

3. Computing

2025 -> reach a universally programmable processor of at least 100 physical qubits opoerating in the NISQ domain.

2027-30 -> reach full stack, highlighy connected, high fidelity quantum computers, with at least one thousand physical qubits.

- Machine learning
- Blockchain
- Route optimisation
- Big data
- Internet of Things
- Artificial intelligence
- Simulations
- Parallel processing
- Acceleration of calculations

4. Simulations

2023 -> develop a fully programmable quantum simulator and demonstrate quantum advantage in optimisation applications, such as routing, image recognition, optimisation and machine learning.

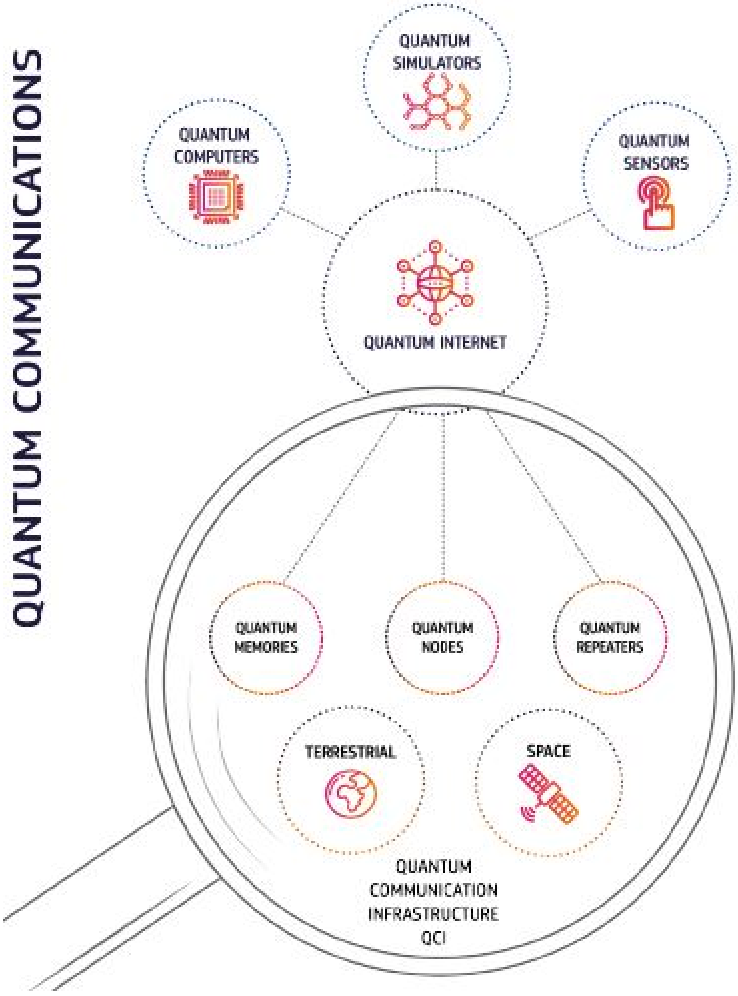
2027-30 -> solve problems beyond supercomputer capability with quantum simulators with more than 1000 indicidual units, to design new materials or train artificial intelligence.

- Traffic flow optimisation
- Sustainable energy and agriculture
- Synthesis simulations

- Drug development & personalised drugs
- Energy consumption
- Distribution of resources
- New materials

The ultimate goal in the development of quantum technologies: Quantum Internet

Distributed quantum computers, and quantum sensors interconnected via quantum communication networks.



The EU's flagship infrastructure investment in quantum technologies

1. EuroQCI: a quantum communication infrastructure --> building a Euroepan cybersecurity shield

The EU's objective is to build and deploy in this decade a quantum communication infrastructure (EuroQCI) covering the whole EU, including its overseas territories. This infrastructure will enable information and data to be transmitted and stored ultra-securely, and will keep the EU's government data, smart energy grids, air traffic control, banks, healthcare facilities and other critical

communications infrastructure safe in the medium and long term.

The EuroQCI will integrate quantum technologies and systems into conventional communication infrastructures, and consist of two complementary segments: an earth-based segment making use of existing fibre communication networks linking strategic sites at national and cross-border level, and a space-based segment to cover long distances. Member States can use Recovery and Resilience Facility (RRF) funding to finance their contributions to both these segments.

2. EuroHPC: Deploying a quantum computing infrastructure all over the EU

The Quantum Flagship's projects are developing some of the most advanced physical quantum computing platforms in the world. Under the European High Performance Computing Joint Undertaking (EuroHPC JU), the plans for the period 2021-2027 are to equip major European supercomputing centres with the best available European quantum computers either as standalone machines or serving as accelerators of high-end supercomputers. This entire infrastructure will be interconnected and accessible to a wide number of users from the public and private sector, via the cloud.

Member States can use RRF funding to boost their supercomputing and high-speed connectivity capacities, including the acquisition of quantum computers and quantum simulators.

Related topics

Advancing in digital science and infrastructures
Quantum
