The EU Quantum Technology Flagship

Elisabeth Giacobino

Laboratoire Kastler Brossel
Sorbonne Université,
Centre National de la Recherche Scientifique
Collège de France, Ecole Normale Supérieure,

Agence Nationale de la recherche
Département Numérique et Mathématiques
Fifty years ago: the invention of the laser
Seventy years ago: the invention of the transistor

Replica of the first transistor invented at Bell Labs in 1947

Integrated circuit (Intel)
It can contain billions of transistors
The future is quantum

Moore’s law: the number of transistors that can be placed inexpensively on an integrated circuit has doubled approximately every two years.

Eventually the quantum wall will be hit

- push back the hitting time (more Moore)
- change completely the technology (more than Moore)
- and quantum technologies for green IT
Quantum Technologies

Quantum technologies are already present:

- The first quantum revolution has allowed explaining and exploiting the structure and the interactions of atoms, light and matter, in order to design lasers or electronic chips.

- Second quantum revolution: reaching the level of individual quantum objects to design novel devices

In research labs individual quantum objects have been studied for several decades, although it was not obvious in the beginning.

Erwin Schrödinger, 1952

«we never experiment with just one electron or atom or (small) molecule. In thought-experiments we sometimes assume that we do; this invariably entails ridiculous consequences.... »
2nd quantum revolution

When reaching the level of individual quantum objects, the most surprising and far-reaching quantum properties, such as superpositions and entanglement, become experimental evidences.

These quantum properties open the way to revolutionary methods to process and manipulate the information carried by such objects.

source of individual photons

Quantum bit (qubit) in superconductors
The superposition principle

\[ |\psi\rangle = \alpha |\psi_A\rangle + \beta |\psi_B\rangle \]
Quantum key distribution with a single photon

Coding a bit (0 or 1) on the polarization of one photon

Deterministic result

A useful information is extracted if and only if the basis used by the emitter (coding) and by the receiver (detecting) are the same!

Random result

Deterministic result
Entanglement

\[ |\psi\rangle = |\uparrow_A \downarrow_B\rangle + |\downarrow_A \uparrow_B\rangle \]

Also a resource for QKD
Quantum technologies in France and in Europe

Companies:
- AtoS
- ASML
- Safran
- IBM
- Intel
- Bosch
- Huawei
- e2v
- TOSIBA
- imec
- Thales
- Siemens
- Nokia
- Single Quantum
- Microsoft
QT in France
Network in the Ile de France Region

SIRTEQ

Some numbers:

* 300 CNRS, CEA or Univ. staff,
* 250 doctoral students
* 100 post-doctoral students,
* 650 researchers total
* >100 teams, 30 laboratories
* gathers computer scientists and physicists from condensed matter, cold atoms, quantum optics, metrology, material science...
National and regional initiatives for Quantum Technologies

• 2 GDR National networks concerning quantum science and technology
  Ingénierie Quantique, des aspects Fondamentaux aux Applications

• Paris Center for Quantum Computing (PCQC)
• 6 national fabrication platforms
• 4 Excellence Initiative (IDEX)
• 5 LABEX (Laboratory of Excellence) coordinated in the framework of the national network IQFA
• Several regional Initiatives
ANR: National Research Agency

- Specific budgets for Quantum Technologies defined by the Ministry, starting in 2018: 10M€/year
- Direct participation to European financing: 3 M€ contribution to the QuanERA (Eranet Cofund) call
- Next QuantERA call (not Cofund) 2 M€ end 2018 or beginning 2019
QuantERA Co-funded Call

QuantERA: FET ERA-NET Cofund Action in Quantum Technologies

- Broad Scope: Quantum (« Q ») communication, Q simulation, Q computation, Q information sciences, Q metrology sensing and imaging, Novel ideas and applications in quantum science and technologies
- Low TRLs targeted, FET-like: Long-term vision, Breakthrough S&T target, Novelty, Foundational, High-risk, Interdisciplinary
- Project size: 1 to 2 M€, at least 3 partners from 3 countries, 2 to 3 years
QuantERA Consortium
QuantERA Consortium coordinated by NCN (Poland)

26 countries, 31 organizations

- Poland – NCN, NCBR
- Austria – FWF, FFG
- Belgium – FNRS, FWO
- Bulgaria – NBSF
- Czech Republic – MSMT
- Denmark – IFD
- Finland – AKA
- France – ANR
- Germany, BMBF, VDI-TZ
- Greece – GSRT
- Hungary – NKFIH
- Ireland – SFI
- Israel - MATIMOP
- Italy – MIUR, CNR
- Latvia – VIAA
- Netherlands – FOM
- Norway - RCN
- Portugal – FCT
- Romania – UEFISCDI
- Slovakia – SAS
- Slovenia – MIZS
- Spain – MINECO
- Sweden – VR
- Switzerland – SNSF
- Turkey – TUBITAK
- United Kingdom – EPSRC, IUK

Contributions of the Member States and associated countries, together with the EC : 38 M€

Call budget 34 M€
QuantERA Co-funded Call

- Launch of the call: **January 2017**
- Deadline for pre-proposals: **15 March 2017**

**220 pre-proposals submitted**
- Notification of accepted pre-proposals: **May 2017**

**92 pre-proposals accepted**
- Deadline for full proposals: **10 July 2017**
- Rebuttal stage: **September 2017**
- Notification of accepted proposals: **October 2017**

**26 proposals accepted**
- Projects start: **early 2018**
European Quantum Technologies Flagship
Amsterdam 17 May 2016
Presentation of Quantum Manifesto
European Quantum Technologies Flagship

Report handed over to the European Commission Nov 2017

1 billion euros over 10 years
1st call for proposals is open (dead line end of February): 148 M€

### Quantum Manifesto

#### 1. Communication
- **A** Core technology of quantum repeaters
- **B** Secure point-to-point quantum links
- **C** Quantum networks between distant cities
- **D** Quantum credit cards
- **E** Quantum repeaters with cryptography and eavesdropping detection
- **F** Secure Europe-wide internet merging quantum and classical communication

#### 2. Simulators
- **A** Simulator of motion of electrons in materials
- **B** New algorithms for quantum simulators and networks
- **C** Development and design of new complex materials
- **D** Versatile simulator of quantum magnetism and electricity
- **E** Simulators of quantum dynamics and chemical reaction mechanisms to support drug design

#### 3. Sensors
- **A** Quantum sensors for niche applications (incl. gravity and magnetic sensors for health care, geosurvey and security)
- **B** More precise atomic clocks for synchronisation of future smart networks, incl. energy grids
- **C** Quantum sensors for larger volume applications including automotive, construction
- **D** Handheld quantum navigation devices
- **E** Gravity imaging devices based on gravity sensors
- **F** Integrate quantum sensors with consumer applications including mobile devices

#### 4. Computers
- **A** Operation of a logical qubit protected by error correction or topologically
- **B** New algorithms for quantum computers
- **C** Small quantum processor executing technologically relevant algorithms
- **D** Solving chemistry and materials science problems with special purpose quantum computer > 100 physical qubit
- **E** Integration of quantum circuit and cryogenic classical control hardware
- **F** General purpose quantum computers exceed computational power of classical computers
Members of the High Level Steering Committee

Academic Members

- Prof. Dr. Jürgen Mlynek, *Chairman*
- Prof. Dr. Rainer Blatt, *Academic Member (AM)*
- Prof. Dr. Vladimir Buzek, *AM*
- Prof. Dr. Tommaso Calarco, *AM*
- Prof. Dr. Per Delsing, *AM*
- Prof. Dr. Elisabeth Giacobino, *AM*
- Prof. Dr. hab. Marek Kus, *AM*
- Prof. Dr. Eugene Simon Polzik, *AM*
- Dr. Maria Luisa Rastello, *AM*
- Prof. Dr. ir. Wim Van Saarloos, *AM*
- Prof. Dr. Lluis Torner, *AM*
- Prof. Ian Walmsley, *AM*

- Prof. Dr. Maria Chiara Carrozza, Observer
- Dr. Gustav Kalbe, European Commission (EC)
- Beatrice Marquez-Garrido, EC
- Matyas Kovacs, Assistant to the Chairman
- Dr. Marco Wedel, Assistant to the Chairman
## Industrial members

<table>
<thead>
<tr>
<th>Name</th>
<th>Company/Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr. Paolo Bianco</td>
<td>Airbus Defense &amp; Space UK</td>
</tr>
<tr>
<td>Dr. Markus Matthes</td>
<td>ASML</td>
</tr>
<tr>
<td>Dr. Cyril Allouche</td>
<td>Atos SE</td>
</tr>
<tr>
<td>Dr. Fabio Cavaliere</td>
<td>Ericsson</td>
</tr>
<tr>
<td>Dr. Grégoire Ribordy</td>
<td>ID Quantique</td>
</tr>
<tr>
<td>Ms. Jaya Baloo</td>
<td>KPN</td>
</tr>
<tr>
<td>Dr. Graeme Malcolm</td>
<td>M2 Lasers</td>
</tr>
<tr>
<td>Dr. Michael Bolle</td>
<td>Robert Bosch</td>
</tr>
<tr>
<td>Dr. Norbert Lütke-Entrup</td>
<td>Siemens AG</td>
</tr>
<tr>
<td>Dr. Guido Chiaretti</td>
<td>ST Micro</td>
</tr>
<tr>
<td>Mr. Daniel Dolfi</td>
<td>Thales</td>
</tr>
<tr>
<td>Dr. Iñigo Artundo Martinez</td>
<td>VLC Photonics</td>
</tr>
</tbody>
</table>
Tasks of the High Level Steering Committee
to deliver advice to the DG CONNECT on

(1) a Strategic Research Agenda, taking into account industrial aspects, with
• a long term roadmap for the flagship and
• a detailed agenda for the H2020 ramp-up phase that should start in 2018

(2) an Implementation Model, it should propose a concrete implementation
approach both for the short term ramp-up phase within H2020 as well as for
the longer term beyond H2020;

(3) a Governance Model,
• internal governance of the flagship
• relations with Member States, with the Commission and with the
relevant funding agencies.

The group should consolidate contributions from the wider community of
relevant stakeholders from academia, industry and Member States.
Strategic research agenda

• **four QT pillars**: Simulation; Communication; Computing; Metrology and Sensing and Enabling Science

• and a **transverse cross-cutting domain**

• Inclusiveness should be rooted on excellence, together with industrial perspective

• Breakthroughs resulting in **disruptive technologies** are expected. For this high-risk projects should be supported

• Place Europe at the forefront of second quantum revolution
Governance model for the QT Flagship
QT Flagship Governance

Intelligence gathering

Decision making

Implementation

Stakeholders (QT community)

European Commission

QT Flagship Projects

QuantERA Projects

National activities,…

QT FLAGSHIP STRATEGIC ADVISORY BOARD (SAB)

QT Flagship Coordination and Support Action

SCIENCE AND ENGINEERING BOARD

European Commission

BOARD OF FUNDERS (EC + MS/AC)
Strategic level

**Decision making by public authorities**

- **Board of Funders:**
  - Discussion forum
  - Alignment of initiatives
  - Overall follow-up

- **European Commission:**
  - Planning of financial support
  - Project selection and funding decision
  - Project follow-up

**Strategic advice by quantum community**

- **Strategic Advisory Board:**
  - Monitors the progress of the Flagship towards its goals
  - Proposes updates of Strategic Research Agenda
  - Works with the EC and reports progress to the BoF
  - Gets inputs from networking & coordination level (CSA, SEB)
Composition:
- 6-8 academic members (including RTOs)
- 6-8 industrial members (including SMEs)
- from MS/AC
- appointed by the EC
- 1 chairperson + 1 vice-chair
- not involved in activities funded by the QT Flagship

Rules of procedure:
- Meeting up to 4x/year
- 2-year mandate

Transition from QT-HLSC:
~10 former QT-HLSC members appointed with an initial 1-year mandate
QT Flagship
Science & Engineering Board

Composition:
• QT Flagship project coordinators
• Representatives of QuantERA projects

Tasks:
• Coordination of QT Flagship R&I activities
• Identify collaboration opportunities, joint developments, sharing of infrastructures among projects
• Interacts with the Strategic Advisory Board and reports to the EC
QT Flagship
Coordination and Support Action

- Networking of stakeholders
- Liaison with QT initiatives at national/regional level
- Management the information repository (databases,...)
- Organisation of workshops, conferences
- Organisation of the benchmarking of QT projects
- Promotes, disseminates, maximises outreach
- Facilitates International cooperation
- Collects progress indicators
- Identifies education and training offers/needs
- Identifies standardisation needs
- Supports the SEB and SAB
Present coordination action  
(16 months, 2018-2019) :
Quantum Coordination and Support Action  
QSA

Partners

1 Universität Ulm  DE
2 Robert Bosch GmbH  DE
3 Thales SA  FR
4 Université de Genève  CH
5 Universität des Saarlandes  DE

Contact (French partner): Thierry Debuisschert (Thalès)
Submitted (20 February 2018) Coordination Action
36 months, 2018-2021
Quantum Flagship Coordination and Support Action (QFlag)

Partners

<table>
<thead>
<tr>
<th></th>
<th>Partners</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VDI Technologiezentrum GmbH</td>
<td>DE</td>
</tr>
<tr>
<td>2</td>
<td>Université de Genève</td>
<td>CH</td>
</tr>
<tr>
<td>3</td>
<td>Nederlandse Organisatie voor Toegepast natuurweten-schappelijk onderzoek TNO</td>
<td>NL</td>
</tr>
<tr>
<td>4</td>
<td>Commissariat à l'energie atomique et aux energies alternatives</td>
<td>FR</td>
</tr>
<tr>
<td>5</td>
<td>Robert Bosch GmbH</td>
<td>DE</td>
</tr>
<tr>
<td>6</td>
<td>Consiglio Nazionale delle Ricerche</td>
<td>IT</td>
</tr>
<tr>
<td>7</td>
<td>Fundació Institut de Ciències Fotòniques</td>
<td>ES</td>
</tr>
</tbody>
</table>

Contacts (French partners): Philippe Chomaz, Yves Samson (CEA)
Coordination and Support Actions

QSA and proposed CSA work packages and partners

QSA (2018)
- WP 1: Strategy and Structuring
  - Uni Geneva
- WP 2: Innovation and Exploitation
  - Thales
- WP 3: Education and Outreach
  - Uni Saarland
- WP 4: Org., Structures and Processes
  - Bosch
- WP 5: Management
  - Uni Ulm

QFlag (19-21)
- WP 1: Strategy and Structuring
- WP 2: Innovation & Infrastructure
- WP 3: Exploitation & Outreach
- WP 4: Education & Training
- WP 5: Governance & Nat’l QT program coord.
- WP 6: Management

CSA consortium partners:
- Bosch
- CEA
- Uni Geneva
- Uni Saarland
- Uni Ulm
- TNO
- VDI Technologiezentrum
Work Programme 2018-2020

QT Flagship = 10+ year duration

QT Flagship ramp-up phase in H2020 (2017-2020)

- QuantERA (33 M€) in 2017 (started)
- CSA in 2017 (WP update)

Transition period + MS initiatives (?)

- RIA in 2018
- CSA in 2018
- ERANET 2020

WP18-20

=> Project start: 1/1/2019

130 M€

QT Flagship "full" deployment in FP9 (2020 & beyond)
WP 2018-2010 : funding

• a. Quantum Communication
• b. Quantum Computing Systems
• c. Quantum Simulation
• d. Quantum Metrology and Sensing
• e. Fundamental science

• For areas a. to d., proposals should be based on a close cooperation between academia and industry
• The Commission considers that proposals for Research and Innovation Actions requesting a contribution from the EU up to EUR 10 million would allow the areas a. to d. to be addressed appropriately;
• proposals requesting a contribution from the EU between EUR 2 and 3 million would allow the area e. to be addressed appropriately.
Timeline: 1st Flagship Call
Opening: 31 Oct 2017, Deadline: 20 Feb 2018

First Flagship calls
Evaluation
Flagship projects

Second QuantERA call

QuantERA call
St 1 Stage 2 Evaluation
QuantERA projects

HLSC final report
HLSC intermediate report

Call and applications Evaluation Flagship projects


2021
Quantum Computing milestones

• **In 3 years**, fault tolerant routes will be demonstrated for making quantum processors with eventually more than 50 qubits

• **In 6 years**, quantum processor fitted with quantum error correction or robust qubits will be realized, outperforming physical qubits;

• **In 10 years**, quantum algorithms demonstrating quantum speed-up and outperforming classical computers will be operated.
Thank you for your attention