QUANTUM TECHNOLOGY:
PREPARING THE NEW EUROPEAN FLAGSHIP

Prof. Dr. Jürgen Mlynek

Chairman of the High-Level Steering Committee
Commission Expert Group on Quantum Technology

Imperial College London, UK
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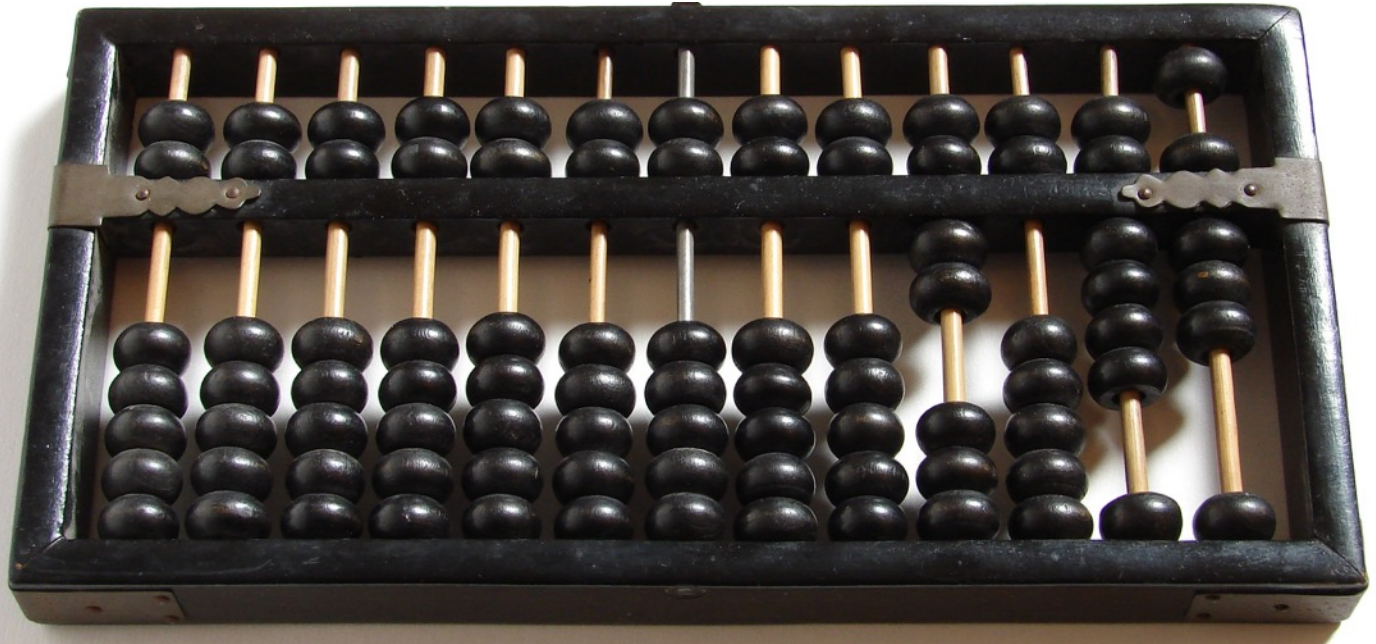
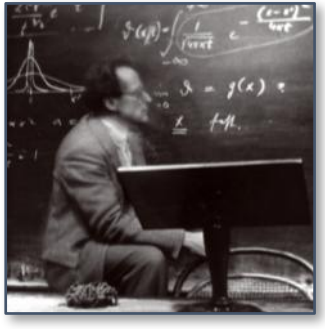
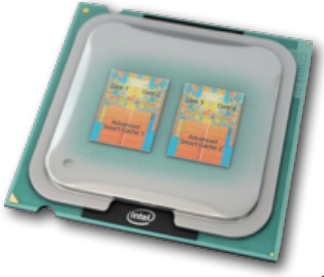
„Quantum information is a radical departure in information technology, more fundamentally different from current technology than the digital computer is from the abacus.“

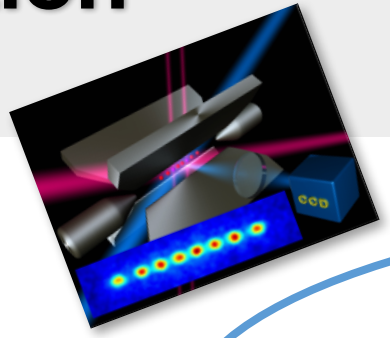
W. D. Phillips
Nobel laureate 1997

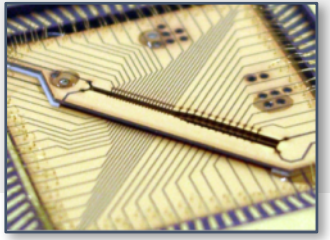


The second quantum revolution
is unfolding globally...









First quantum revolution

- Discovery of fundamental laws of the microscopic realm
- Formulation of quantum mechanics

‘Bulk’ quantum technologies

- Based on bulk effects, where many quantum degrees of freedom are manipulated at once
- Development of ground-breaking technologies such as transistor and laser

Second quantum revolution

- Technologies based on the manipulation of individual quantum states
- Make use of “strange” quantum properties, such as superposition and entanglement
- Secure communications, ultimate computing power, ultraprecise sensors

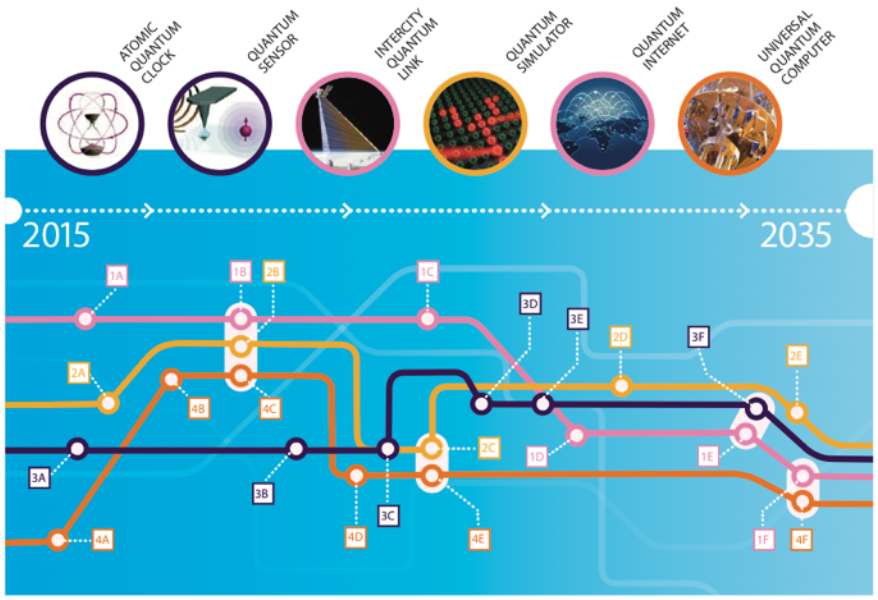
Quantum Technology

Europe‘s position in the world

- Europe is the global leader in QT, roughly half of the world‘s publications in the field come from EU-based groups
- EU Roadmap already in place: constant progress, milestones reached, gaps and challenges identified
- Europe‘s competitors around the world (USA, China, Japan, Russia, Singapore, Australia) are developing their own quantum research programs
- overall many branches of QT have gone past the proof-of-principle phase, but further progress can only be achieved through the leap in resources and the long-term commitments coming with it
- strong QT Community: Quantum Manifesto with overwhelming support

Quantum Manifesto

- an initiative of the European Quantum Community
- published in May 2016, supported by over 3500 scientists, research institutions and companies
- main goal: aid the selection of QT as the new European flagship project



	1. Communication	2. Simulators	3. Sensors	4. Computers
0 – 5 years	A Core technology of quantum repeaters B Secure point-to-point quantum links	A Simulator of motion of electrons in materials B New algorithms for quantum simulators and networks	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	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
5 – 10 years	C Quantum networks between distant cities D Quantum credit cards	C Development and design of new complex materials D Versatile simulator of quantum magnetism and electricity	C Quantum sensors for larger volume applications including automotive, construction D Handheld quantum navigation devices	D Solving chemistry and materials science problems with special purpose quantum computer > 100 physical qubit
> 10 years	E Quantum repeaters with cryptography and eavesdropping detection F Secure Europe-wide internet merging quantum and classical communication	E Simulators of quantum dynamics and chemical reaction mechanisms to support drug design	E Gravity imaging devices based on gravity sensors F Integrate quantum sensors with consumer applications including mobile devices	E Integration of quantum circuit and cryogenic classical control hardware F General purpose quantum computers exceed computational power of classical computers

Quantum Technology
the new European Flagship Project

Timeframe

- May 2016: Commissioner Günther H. Oettinger announces the project
- Sept-Oct 2016: High-Level Steering Committee appointed with a 1-year mandate
- flagship project cycle: ramp-up phase from 2019, full project phase from 2021

Goals

- Europe has to become the leading force of the second quantum revolution
- consolidate and expand European scientific leadership and excellence in quantum research, including training the relevant skills
- kick-start a competitive European quantum industry to position Europe as a leader in the future global industrial landscape
- make Europe a dynamic and attractive region for innovative business and investments in quantum technologies, thus accelerating their development and take-up by the market
- make the transformative technologies accessible for the entire society

Quantum Technology
the new European Flagship Project

Priorities

- national programs and commitments have to become part of the agenda, but there has to be an overarching added European value
- inclusiveness should be rooted in excellence, not necessarily the broadest reach
- education, young innovators and innovators need to be a prime focus of the programs, in great part building on Europe‘s world-leading academic background

Added value

- combine the strength and flexibility of a broad, decentralized programme with the clustering and coordination of focused initiatives
- promote cross-border collaboration and networking of people and information between different centres across academia and industry, foster mobility and knowledge exchange
- integrate and enhance collaboration between education, science, engineering and innovation

High-Level Steering Committee
of the QT Flagship Project

collectively represents the diversity of stakeholders in Europe:
12 Academic and 12 Industry Members, appointed by the European Commission

Prof. Dr. Jürgen Mlynek, Chairman, Humboldt University of Berlin
Prof. Dr. Rainer Blatt, University of Innsbruck
Prof. Dr. Vladimir Bužek, Slovak Academy of Sciences Bratislava
Prof. Dr. Tommaso Calarco, University of Ulm
Prof. Dr. Per Delsing, Chalmers University Gothenburg
Prof. Dr. Elisabeth Giacobino, CNRS Lab Kastler-Brossel Paris
Prof. Dr. Marek Kuś, Polish Academy of Sciences Warsaw
Prof. Dr. Eugene Simon Polzik, Niels Bohr Institute Copenhagen
Dr. Maria Luisa Rastello, INRIM Torino
Prof. Dr. ir. Wim Van Saarloos, KNAW Amsterdam
Prof. Dr. Lluis Torner, Institute of Photonic Sciences Barcelona
Prof. Dr. Ian Walmsley, University of Oxford

Dr. Cyril Allouche, Atos SE
Jaya Baloo, KPN
Dr. Paolo Bianco, Airbus D&S UK
Dr. Michael Bolle, Bosch GmbH
Dr. Fabio Cavaliere, Ericsson
Dr. Guido Chiaretti, ST Micro
Dr. Daniel Dolfi, Thales
Dr. Norbert Lütke-Entrup, Siemens AG
Dr. Graeme Malcolm, M2 Lasers
Dr. Iñigo A. Martinez, VLC Photonics
Dr. Markus Matthes, ASML
Dr. Grégoire Ribordy, ID Quantique

Observer: **Prof. Dr. Maria Chiara Carrozza**, Sant'Anna School Pisa

High-Level Steering Committee
of the QT Flagship Project

Mandate

- work in an open and transparent way, together with the wider community of stakeholders from academia and industry, in close collaboration with the EC and Member States
- deliver an Intermediate Report by February 2017, and a Final Report by Q3 2017, preparing the framework of the flagship initiative
- advise the European Commission in the launch of the QT Flagship by delivering

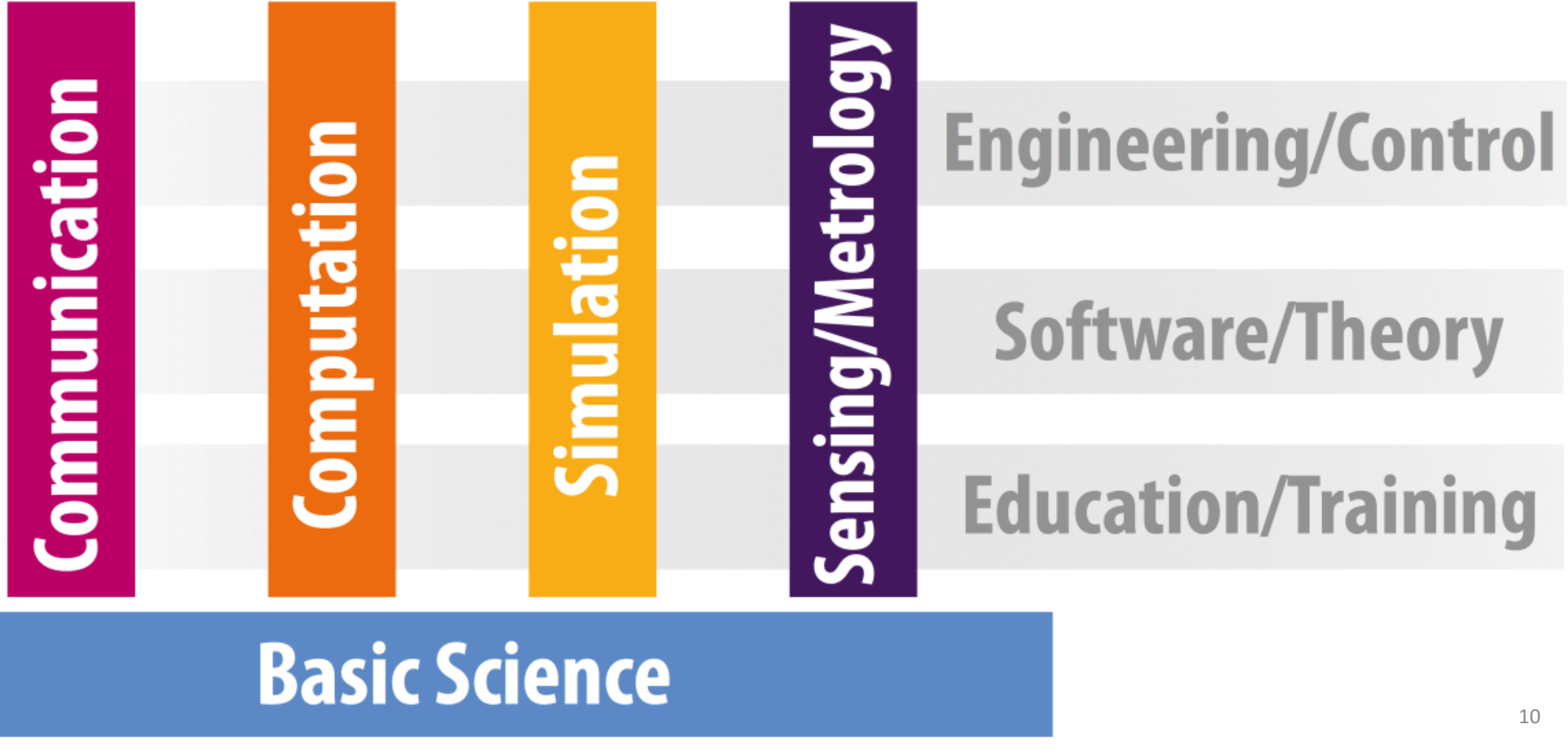
  - a **Strategic Research Agenda**, taking into account industrial aspects. It should include a long-term roadmap for the flagship as well as a more detailed agenda for the H2020 ramp-up phase that should start with the first projects in Q1 2019

  - an **Implementation Model**, proposing a concrete implementation approach both for the ramp-up phase within H2020 as well as for the longer term beyond H2020

  - a **Governance Structure**, including the internal governance of the flagship as well as the relations with the EC, the Member States and the relevant funding agencies

Strategic Research Agenda: Structure

outlined in the Intermediate Report of the QT Flagship Project



Strategic Research Agenda
outlined in the Intermediate Report of the QT Flagship Project

Vertical domains

The flagship program should be structured into five domains, of which four vertical domains address vital application areas of a future knowledge-driven industry:

- **Communication**: guarantee secure data transmission and long-term security for the information society by using quantum resources for communication protocols
- **Computation**: solve problems beyond the reach of current or conceivable classical processors by using programmable quantum machines
- **Simulation**: understand and solve important problems, by mapping them onto controlled quantum systems in an analogue or digital way
- **Sensing and metrology**: achieve unprecedented sensitivity, accuracy and resolution in measurement and diagnostics, by coherently manipulating quantum objects

Strategic Research Agenda
outlined in the Intermediate Report of the QT Flagship Project

Horizontal domain: Basic science

The aim of the fifth domain is to develop novel ideas and concepts that can have a major impact on the vertical domains, ranging from theoretical and experimental science to proof-of-principle experiments, capable of delivering concepts, tools, materials and processes.

Cross-cutting activities

Support the domains' mission-driven objectives and provide a structure to identify common concepts, capabilities and opportunities:

- **Engineering and Control**: advance the understanding, design, control, construction and use of new technologies and driving their transition from concepts, theories, one-off and proof-of-principle experiments to high-yield and scalable devices and systems
- **Software and Theory**: develop quantum algorithms, protocols, and applications, and connect to tools for control and certification and understanding the quantum advantage
- **Education and Training**: tutor a new generation of skilled technicians, engineers, scientists and application developers in QT and foster ecosystems for them to work on shared mission-driven technologies and to develop tools and software

Implementation model

outlined in the Final Report of the QT Flagship Project

HOW?	▪ realize the highest level of transparency in the development process ▪ show openness to involving emerging actors and attract the best talent ▪ fair evaluation of proposals with top priority to excellence and impact ▪ sustainability over a timescale also beyond the 10-year flagship program ▪ align national efforts with the overarching EU-level flagship goals
WHAT?	▪ aim at societal impact and commercial exploitation ▪ set demanding but achievable goals, measurable KPIs and project milestones ▪ include high-risk/high-reward research and developments
WHO?	▪ include academic and industrial partners from different European countries ▪ focus on the impact and strategic benefit in the global race for QT leadership
WHEN?	▪ Member States are expected to start national support as early as possible ▪ Q1 2019: start of the first flagship projects in the ramp-up phase

Governance model

outlined in the Final Report of the QT Flagship Project

Principles

- to be based on the priorities of the Strategic Research Agenda
- set up governing bodies and implement productive workflows on the stakeholder, executive and program management levels
- simple and effective structures on all program levels, including efficient feedback loops
- ensure that the overall strategy will have the broadest scientific, industrial and societal impact
- provide strong links to the European Commission and the Member States

Priorities

- flexibility and agility is needed to follow changes in the European and global research, market and political agendas
- provide a continuous consultative forum for the QT community
- ensure transparency of operational and decision-making processes

Governance model

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Innovation Mindset

in the QT Flagship Project

the project shouldn‘t only support the next European generation in science, it should prove to be appealing on a global talent level

subsidies for science-based startups, high-risk/high-gain investments and young researchers

aim: turn scientific discoveries into industrial innovation

The European QT industry

SIEMENS

THALES

Alcatel·Lucent

IBM

BOSCH

ASML

Microsoft

AIRBUS DEFENCE & SPACE

e2v Bringing life to technology

imec

HUAWEI

SINGLE QUANTUM

IDQ FROM VISION TO TECHNOLOGY

NOKIA

TOSHIBA

SAFRAN AEROSPACE · DEFENCE · SECURITY

Atos

intel

µQUANS PRECISION QUANTUM SENSORS

Thank you for your attention!

juergen.mlynek@physik.hu-berlin.de
juergen.mlynek@falling-walls.com