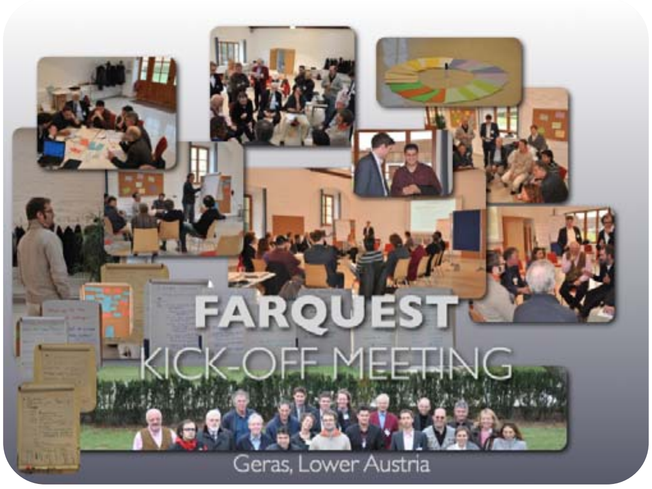
EUROPEAN SCIENCE FOUNDATION

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY TOMORROW TODAY

2011 – 2012

Proposal
Scoping workshop
1. Workshop
2. Workshop
3. Workshop
Outreach
Consensus meeting
Draft report
Final conference

http://qurope.eu/projects/farquest



FARQUEST is a **prospective analysis** of quantum information science and technology. The goal is to synthesise **scenarios of future developments** for collaborative significant problem-solving with answers and ideas **outside the core disciplines of quantum information and inspired by cross-disciplinary** fields.

Related goals are to **raise the awareness** of the current and future potential of quantum information and its technologies, and to **shed light on present needs** in terms of matching research questions, societal needs, research programmes, infrastructures, science policy, and education.

Summary of the ESF Forward Look workshop

FARQUEST VISIONS

December 9 – 11, 2011
Kunst und Kultur Hotel Geras, Geras, Austria

PREPARED BY
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CONTRIBUTING WORKING GROUP CO-CHAIRS
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Workshop Agenda

Based on the outcome of the Scoping Workshop (2011), the first workshop was kicking-off with a creative exploration and the authentic strategic conversations of research topics that are witnessed at the interface of quantum information science and technology (QIST) to cross-disciplinary fields in 1) physics and engineering, or 2) the life-sciences.

Starting from the participant's own expertise, research areas and related open questions that require collaborative problem-solving, it was **aimed at identifying promising research topics** where added-value can be expected from multi- and interdisciplinary approaches that show significant contributions from the knowledge base of quantum information theory and technology.

To this end, the plausible development of such topics was to be explored, in order to see where the research topic could be going in the future – and to gather the positive "drivers" of the development along a certain part: new scientific advances, instrumentation and lab tools, model systems, materials, computation capacities, etc.

» What are our key research and development challenges?
» What would we like to contribute to future science, technology and society?
» What are the topics we like to continue exploring together?
» What is it that we want to create together?
» Where do we need complementary knowledge?
» What are supportive structures, processes, actors, frameworks which may bring our topic further forward?

- **Project structure**

Working-groups work in series of three **workshops**. The task of the groups is to work toward (I) creating scenarios of plausible future developments (cross-disciplinary topics, targets, means, challenges, needs, societal contributions) that are inspired and anticipated by advances in quantum information theory and technology "spilling over" into other research fields; and (II) and deriving recommendations addressing specific stakeholder groups (science policy makers, national funding organizations, the larger public). Working-groups are coordinated by a team of two coordinators for each group. The workshop series is followed by a "**Consensus Meeting**" among the Science Committee and working-group coordinators which serves to discuss the draft report on activities, scenarios and recommendations. A "**Final Conference**" will be organized by the ESF to launch dissemination and is summoned after a time window for community feedback ("**Outreach**"). It serves to disseminate the finalized report on activities, scenarios and recommendations.

- **Workshop structure**

Day-1 introduced the FARQUEST project in terms aims, goals and expected impact, and gave the workshop agenda and approach. Christian Monyk (AIT, Quantum Technology) summarized the main results of the Scoping Workshop in terms of broadly identified cross-disciplinary research areas; the ESF's perspective was highlighted Aigars Ekers (ESF); and Tommaso Calarco (U Ulm, Chair of the Scientific Committee) put the workshop in context with the latest European science-political decision making and identified the recent developments regarding the institutionalisation of research funding. The participant's perspectives expectations on the 1st Workshop were gathered to continuously fine-tune the agenda and reflect at the end of the workshop. Speculative perspectives from a public document survey summarizing different levels and time horizons of futures of quantum information were presented by Petra Schaper-Rinkel (AIT), which were discussed in the context of the predictability of the future and a critical assessment of public documents covering results, ideas, and visions related to quantum theory.

After summarizing the first day, **Day-2** started off with the introduction of the open-space format and "social laws" for self-organization of working-groups, delivered by Petra Wagner-Luptacik (AIT), which was practiced throughout the remainder of the day. The last session was reserved for the keynote *How to think about a quantum future?* given by Hannu Rajaniemi (ThinkTank Maths), after which Christopher Coenen (ITAS) and Ralf Bülow facilitated a discussion on *What science can learn from fiction and vice versa?* **Day-3** anticipated dimensions of change and corresponding time horizons to "unfold" the research topics addressed during the previous days. The workshop was closed by two sessions for presenting the obtained results and addressing questions of own and other group members, as well as planned next steps and the reflection and feedback on days 1-3.

> Hannu Rajaniemi is the author of the recent book "*The Quantum Thief*". He shared his experience, approach and insight on the construction of interesting futures and on the interaction of science-fiction with scientific research and the development of technology.

Main Results

- **QUANTUM BIOLOGY**

Working Group 1 (WG1): Quantum effects in biological and biochemical systems

CONTEXT: FROM LIVING MATTER TO BIO-INSPIRED ENERGY HARVESTING.

Quantum biology is an emerging research area that has been pursuing questions and open theoretical as well as real-world problems characterized by growing insight into the "biological quantumness". It follows the notion of quantum effects as being a key analytical concept that is relevant to fully grasp, control and exploit biological processes and evolution (mutation, selection). To this end, it marries concepts from biophysics resp. physics, biochemistry, and cellular and molecular biology in theory and means for quantification..

a) **Topics, targets, and potential impacts (cf. Exhibit 4)**

Four research topics (1-4) suitable and profitable through added-value for a quantum biology approach:

(1) **Photobiology**
(2) **Ligand – receptor interaction**
(3) **Metals in life**
(4) **Molecular motors and pumps**

Research topics and concepts	**Photobiology:** charge separation and energy transfer, shaping environment and optimizing systems	**Ligand-receptor interaction:** SARS, multiple receptor states, "key turns in lock"	**Metals in life:** quantum electrochemistry, hydrogenase, water splitting enzyme/oxygen evolving complex	**Molecular motors and pumps:** reversibility, function
Socio-economic sector	**Energy**	**Health**	**Chemistry/ Processing**	**Manufacturing**
Societal impact	Conversion and storage of solar energy, higher crop yield	New and better drugs and drug delivery systems	New and more efficient catalysis	nano-mechanical devices

b) Methods resp. tools and instrumentation

<u>Seven initial enabling methods</u> (1-7) for a quantum biology approach:

(1) Spin spectroscopy / Single molecule spin sensing
(2) Electronic spectroscopy
(3) Phonons / Vibrational spectroscopy
(4) Control: External by technology / Use of quantum mechanics and information for efficient control of bio-systems
(5) Characterization of structures
(6) Single molecules resp. particles
(7) Computation and simulation.

c) Dimensions of change

<u>Five changes</u> (1-5) anticipated through accumulated and lateral insight from quantum biology:

(1) Quantum dynamics of biological functions, *10 years* (Physics)
(2) Quantumness and biological control / engineering, *10 years*
(3) Quantumness and biological evolution, *10-20 years*
(4) Quantum computation / Quantum thermodynamics and quantum dynamics in biology, *10 years*
(5) Quantum biology: superposition states at the basis of a biological process, determinism.

- **QUANTUM TECHNOLOGY IN NOISY ENVIRONMENTS**

Working Group 2 (WG2): Complex quantum systems & computation; quantum-enabled technologies

CONTEXT: FROM QUANTUM SIMULATIONS TO CONDENSED-MATTER PHYSICS AND MATERIAL SCIENCE; PHOTONICS AND METROLOGY TO POSITIONING AND SENSING

Quantum information technology is both a fundamental and applied research area with significant advances and breakthroughs accumulated over the last two decade, even gathering velocity during the last few years. Still the targeted knowledge transfer and spill-over effects from academic to industrial research and development (R&D) are limited to very few QIST-based business models in Europe.

a) Quantum science and technology applicable under real-world conditions (cf. Exhibit III)

One reason is in the difference between theory and experiments under laboratory conditions *vs.* to real-world and noisy environments, and so the discussion of the working-groups centred on the development of theory, relevant model systems, tools and devices for real-world applications: (cf. Exhibit III)

(1) Noise-assisted quantum information processes
(2) Quantum computation driven by dissipation

The issue is to determine, from a fundamental and technologically applicative perspective, what resource makes quantum information processing more efficient than classical one, even in the presence of a noisy environment. Identifying the conditions under which mixed-state quantum computation and, more generally, quantum dynamics cannot be simulated classically is relevant to provide enabling capabilities for quantum devices operating at room-temperatures and used in metrology and quantum simulation. Here, a general need of the field was seen in seeking interactions with end-users of QIST, e.g., in areas of satellite applications (e.g. GALILEO+).

Feedback on 1st Workshop

(1) The open-space resp. self-organized approach of this workshop was generally found positive and stimulating to engage in strategic conversations and find consensus regarding the importance of QIST to identified topics and targets. (2) At the same time, a perceived lack of structure (resulting from the balance between self-organization and order) was partly perceived sub-optimal for efficient discussions of potential applications. (3) Specific pointers to key information amongst all available project documents were expressed for making efficiency gains when time is short. (4) On occasion the methodology was perceived as "over-representative", which was one consequence of the "crystallization" at this early stage of the project. (5) Some participants expressed the desire for a more central location for next workshops, while others noted that 2hrs Airport-to-Geras (organized bus transport from the airport, back+forth) does not offer more than +1 hr to save when compared to the alternative of getting into the city. (6) Geras was found a stimulating environment. Notable a central location in Vienna could not match the conditions met in Geras. (7) The duration was partly considered too long, particularly for experts with tight schedules, while at the same time the time for entering and having strategic discussions as well as the development of topics and targets, etc. was seen as a key factor of the 1st workshop – and rarely experienced in other events.

b) Topics of relevance for complex quantum systems (cf. Exhibit III)

Five topics (1-5) relevant to complex quantum systems across research in biology, chemistry, solid state physics, high-end technology, modelling, computer science, complex networks, material science, and mathematics:

(1) Complex noisy systems
(2) Develop simulation capability
(3) Novel quantum materials
(4) Technological breakthroughs
(5) System architecture and expertise.

c) Topics of relevance for quantum technology (cf. Exhibit II)

Four topics (1-4) relevant to quantum technology across applications in communication, sensing, space science including gravitometry, biomedical science, and industrial applications:

(1) Existing knowledge
(2) Develop applications
(3) Address real-world problems
(4) Societal relevance.

- **Participants of 1st Workshop**

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