http://qurope.eu/projects/farquest

Summary of the 2nd ESF Forward Look workshop: FARQUEST CHALLENGES

UCL, London, 4-6 May 2012

PREPARED BY
Dirk Holste, Dana Wasserbacher (AIT)

CONTRIBUTING WORKING GROUP CO-CHAIRS
Rienk van Grondelle (U Amsterdam), Gerardo Adesso (U Nottingham), Yossi Paltiel (U Jerusalem)

2011 – 2012

1. Proposal
2. Scoping workshop
3. Workshop I
4. Workshop WG2
5. Meeting WG3
6. **Workshop II**
7. Workshop III
8. Outreach
9. Consensus meeting

Draft report
Final conference (ESF)
Final report (ESF)

- **QUANTUM EFFECTS IN BIOLOGICAL AND BIOCHEMICAL SYSTEMS**
  Working Group 1 (WG1)
  CONTEXT: FROM LIVING MATTER TO BIO-INSPIRED ENERGY HARVESTING
- **QUANTUM MANY-BODY SYSTEMS AND COMPLEXITY**
  Working Group 2 (WG2)
  CONTEXT: FROM QUANTUM SIMULATIONS TO CONDENSED-MATTER PHYSICS AND MATERIAL SCIENCE

Workshop Agenda

The workshop is embedded in the project FARQUEST, which is taking a *forward look* on science, technology and society relevant, plausible future developments in cross-disciplinary research areas of quantum information science and technology to derive science policy recommendations.

- **Overall 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 either inspired and "spilling over" into other research fields and applicative areas through past and current advances or anticipated to be further advancing quantum information theory and technology; and (II) addressing needs and deriving recommendations for specific stakeholder groups. Working-groups are coordinated by co-chairs for each group. The workshop series is followed by a "**Consensus Meeting**" among the Science Committee and working-group co-chairs 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.

Guiding questions for SWOT analysis

- **What we want to do.** Research directions (Topics & Targets)
- **What can we do?** Internal factors driving and factors hindering the realization of research topics
- **What should we do?** External factors affecting the realization of research topics
- **What are we expected to do**? What advancements, newness, benefit, usability do we anticipate

- **Workshop structure**

Previous workshops resp. meetings identified future research directions and goals for all three working-groups. This workshop focused on the preparedness and challenges to conduct the research and work toward realizing the set research goals. The workshop format followed sequentially the four steps of strategic analysis of internal strength and weaknesses as well as external opportunities and threats (SWOT). It included different working formats such as group discussions, world-café and plenary style sessions, short presentations, as well as delegate conference and open chair sessions. The 2nd workshop marks the first event where working groups (WG1 and WG2) established after the 1st workshop were informing each other and working collaboratively. Participants of WG3 could not take part due to time conflicts, yet the main outcome of WG3 were presented at this workshop, feedback was provided and gathered, and later delivered to the co-chairs for WG3.

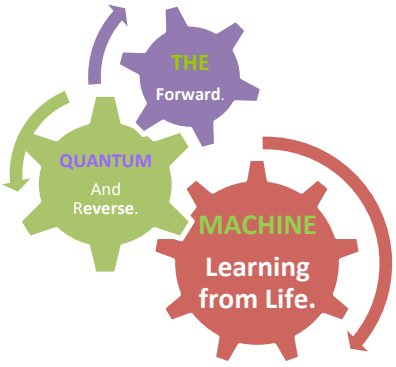
Main Results

Search for an overarching research direction that can captures significant across all three working-groups and that aligns the research topics and targets of WG1, WG2 and WG3 to one theme with focus, novelty, innovation, and condensed thematic representation of FARQUEST:

- **OVERARCHING RESEARCH GOAL**

The quantum Machine

LEARNING FROM LIFE › FORWARD AND REVERSE ‹



a) Suggestion 1: "Building the quantum machine and learning from life" (cf. Exhibit IV)

- *The* quantum machine has a fundamental flavour, hints at basic principles for building it, implicates uniqueness and indicates an inherent level of complexity
- Integrates nature and (man-made quantum) mechanics
- Compatibility between machine and life: The machine to explore life – Life to develop the machine
- Involves new Quantum Mechanics or hints at something entirely new

- **Discussion**
  - Real-world conditions seem as a critical factor / distinctive criterion
  - Context dependence: "*The (real-world) quantum machine: Learning from life"* as a proper title for politicians or the general public; may be problematic within the different communities as a distinctive criterion
  - Bio-inspired is redundant

- Quantum machine is seen as attractive for policy makers, something that can be sold, i.e. *the machine*
- The quantum machine is not a very short-term vision, maybe a problem when selling it to stakeholders (e.g. funders, policy makers)
- The Quantum machine, subtitle: learning from life and for life: *We learned from life, that we could have a real-world quantum machine*
- Difference between quantum machine, quantum computer, quantum sensors, etc.: the quantum machine is a broader term including all other concepts and things
- Quantum biologists – reverse engineers / Quantum mechanists – forward engineers; Forward and reverse engineering, forward and reverse design; Learning from life – forward and reverse

b) Suggestion 2: "From quantum to information to life" " (cf. Exhibit IV)

c) Suggestion 3: "Bio-inspired quantum machines" " (cf. Exhibit IV)

- **CROSS-LINKING**

Guiding questions for "cross-linking" between working-groups: Common Goals–What interlinks the individual goals of working-groups? Common strategic issues–What frames the individual topics in an overall FARQUEST setting? Key research questions–What joins our scientific activities?

a) Common research goals (cf. Exhibit I):

- Photobiology
- Identification of quantum signatures
- Dynamic meets noise / collective behaviour
  - Insulating from noise
  - Use noise productively
- Identify / "tame" genuine quantum signatures
- Biological evolution – Quantum behaviour
  - Tune to influence variables (i.e. is quantum physics involved?)
- Opposite of the correspondence principle: Define a "non-corresponding principle"
- Quantum phenomena on a higher level: Time-length scales of paradigmatic systems as examples
- Quantum dynamics – Noise – Disorder: Does it matter for emergence?
- Links between 1) biological systems and quantumness, 2) quantum many-body systems and complexity, and 3) quantum-enabled technology
  - Forward (›): Bio-inspired quantum technology
  - Reverse (‹): Quantum-inspired biotechnology
- Open search for "revolutionary" quantum behaviour (i.e. unexpected quantum behaviour)
- Tuning of quantum behaviour to influence behaviour on microscopic level of systems

b) Common strategic issues (cf. Exhibit I):

- Quantum matter, quantum diagnostic tools, quantum-enhanced devices and technologies
- Quantum vs. classical: In which context?
  - Emergence of new properties
- Think "more than sensors": What else is there (still unnoticed, unrevealed, untapped) between the areas Cryptography and Simulation?
- Quantum mechanics to "inspire" biological systems (e.g. life-death or apoptosis decision making)
- Suitable funding schemes promoting high-risk research with prospect of high benefit
- Cross-departmental appointments for Professors (cross-fertilisation)
- Structural funding and professional development in a cross-scenario action

c) Common research questions (cf. Exhibit I):

- Emergence: Quantum Mechanics – Noise – Disorder
- Quantum Mechanics systems and scale-up
  - Tune the degree of quantumness
  - How far can you scale a quantum system and it still "stays quantum"?
- Learning from nature for man-made systems: Dead matter – Living matter – Life
- Role of Quantum Mechanics with respect to robustness of photosynthesis
  - Complex adaptive to environment
  - Robustness(role of quantum mechanics) in photosynthesis (quantum efficiency)
- General principles when Biology meets Quantum Mechanics (Is there a particular pattern or a particular signature?)
- Cellular dynamics & quantum aspect
- Is there a guiding principle for when Biology adapts Quantum Mechanics?
- Learning from Biology: Things that nature does really well – Can we reverse engineer it, can we even make it better (than nature?)
- Bio and non-bio: The debate about what distinguishes living systems from non-living systems? (Manmade systems: What we want is our own devices.)
- More work on non-equilibrium quantum dynamics (applicable to real world systems)
- Quantum control:
  - Of the dynamics
  - Of the degree of quantumness (from dead to living matter)
- L earning by building up complexity: Export quantumness to manipulated vertical complex systems
- Change of how we look at systems, i.e. not necessarily bound to existing knowledge
- Spill-over effect: Exploiting discussed tools for other systems (than complex ones)

- **FIRST JOINT PROJECTS**

Guiding question for "cross-linking" between working-groups: First collaborative project ideas–What builds upon our diverse competences? (Cf. Exhibit XXX).

a) Initial project ideas (cf. Exhibit I):

- Emergence and Quantum Mechanics – Noise – Disorder
- Define / determine the degree of quantumness
- Effectively explore systems to scale up quantumness
- Quantumness in hybrid systems
- Derive effective Hamiltonians: What is the effective Hamiltonian for a system? Verify it!
- Bio-inspired quantum technology / Quantum-inspired biotechnology
- Research targeted on the explanatory power of Quantum Mechanics: Discoveries which are explained by but are itself not Quantum Mechanics
- Use the methodology of Quantum Mechanics in a system which is not quantum in nature

b) Project management (cf. Exhibit II):

- **General aspects:**
  - Adopt "best practice" project management (resources, results, timeline)
  - Right people, right funding, right course of action
  - Proper preparedness for timely arising opportunities (to help your "good luck")
- **Team building**
  - Team members with interest to work with one other in synergistic ways
  - Interdisciplinary core complementing in expertise
  - Sufficient size for both critical mass and being able to collaborate
  - Big consortium needs big consensus (in terms of people, funding, course of action) and steering committee with clear roles and responsibilities
- **Research topics**
  - Clear focus on simple challenges (limited set of challenges)
  - Develop a spectrum of research activities to address the challenges
- **Optimizing leverage**
  - High potentials, experienced people, recognising and growing strengths in people
  - Setting of proper incentives (e.g. results-oriented, rewards, career perspectives)
  - Educating your neighbouring, collaborating with interdisciplinary communities, embed in the right community, foster the understanding and support of the society
- **Interdisciplinarity**
  - Spotting opportunities to transfer / bridge expertise across fields
  - Seek multi-facet approaches
  - Establish (interdisciplinary, across departments) fellowships for physicists, computer scientists, informatics, etc.

- **Evaluation of research**
  - Critical revision at interim project points (show flexibility, open-mindedness)
  - Perseverance ("Do believe in your work")
  - Be aware of current science politics
- **Public relations**
  - Public awareness: The image of your research field (e.g. the relevant problem solver, the future created and tested in the lab, etc.), the public communication and political debate
  - Have an eye for economic success (Bohr vs. Edison vs. Pasteur types of research)
- **Methods and tools**
  - Standardisation (e.g. tools, materials, software, rules, procedures, etc.) within a project and between (parallel or follow-up) projects to share between labs in same resp. different organizations resp. countries (→ Some sort of common Wiki)
  - Adaption of tools or methods from other fields
  - Tool development: Potential and need for high-technology SMEs and their funding

c) Project management (cf. Exhibit III):

- **Working-group 1 (WG1)**
  - **Programmes**
    - No specific programmes
    - ERC, FET Flagships?
    - Quantum Biology: Only DARPA programmes with no EU counterpart
    - EPSR: Physics of life, quantum technology for practical [purposes]
  - **Bridging disciplines brings money**
    - Biomedical impact, e.g., cell life and death
    - Energy – Solar
    - At present no wide relevance
  - **Education: *Dr. Universales***
    - Albertus Magnus Program
    - Long-duration PhD for cross-disciplinary training (3-4 years)
    - Similar to the DSC (GB) or *Docteur de Science* (F)
    - Short-term (e.g. 1 year) contracts for post-docs have negative impact
    - Implications on how we evaluate research and researchers (performance)
- **Working-group 2 (WG2)**
  - **R&D funding programs**
    - FET Open and Proactive; FET Flagships
    - ERC
    - Marie Curie – ITN, etc.
    - COST programme

- **Additional programs for cross-disciplinary research**
  - DFG
  - UK: Doctoral training centres; FQXI – UK / Templeton
  - (ERA Net)
- **Arguments for funding agencies**
  - Added value
  - Science-based approach to novelty and understandings of biology / materials
  - Quantum communication, other specific technological advances
- **Education**
  - Inspire people to take up physics → Quantum mechanics at room temperature
- **How legitimate engagement to public authorities?**
  - Training / bio-inspired technologies (specifically quantum mechanics)
  - Quantum mechanics as technologically most fertile science to date
  - Unexplored potential of fundamental quantum features
- **More visibility /attractiveness with respect to R&D**
  - Complex quantum transport in photovoltaic applications
  - Team up with R&D in industry / R&D funding for industry

- **Participants of 2nd Workshop**

Participant; e-mail contact	
Gerardo ADESSO	University Nottingham; gerardo.adesso@nottingham.ac.uk
Andreas BUCHLEITNER	University Freiburg; abu@uni-freiburg.de
Aigars EKERS	European Science Foundation; aekers@esf.org
Juan GARRAHAN	University Nottingham; juan.garrahan@nottingham.ac.uk
Winfried HENSINGER	University Sussex; w.k.hensinger@sussex.ac.uk
Dirk HOLSTE (chair)	Austrian Institute of Technology; dirk.holste@ait.ac.at
Jonathan HOME	ETHZ; jhome@phys.ethz.ch
Eric LUTZ	University Augsburg; eric.lutz@physik.uni-augsburg.de
Günther MAHLER	University Stuttgart; guenter.mahler@itp1.uni-stuttgart.de
Sabrina MANISCALCO	Heriot-Watt University; smanis@utu.fi
Zeeya MERALI	merali@cantab.net
Alexandra OLAYA-CASTRO	University College London; a.olaya@ucl.ac.uk
Jonathan OPPENHEIM	University College London; j.oppenheim@ucl.ac.uk
Yossi PALTIEL	Hebrew University Jerusalem; paltiel@cc.huji.ac.il
Bruno ROBERT	French Alternative Energies and Atomic Energy Commission; bruno.robert@cea.fr
Peter RUSSER	Technical University of Munich; p.russer@gmail.com
Karlheinz STEINMÜLLER	Z Punkt GmbH; steinmueller@z-punkt.de
Luca TURIN	Biomedical Sciences Research Centre Alexander Fleming; lucaturin@me.com
Mark THOMPSON	University Bristol; mark.thompson@bristol.ac.uk
Rienk VAN GRONDELLE	University Amsterdam; r.van.grondelle@vu.nl
Alipasha VAZIRI	Institute for Molecular Pathology and Max-F.-Perutz Laboratories; alipasha.vaziri@mfpl.ac.at
Petra WAGNER-LUPTACIK	Austrian Institute of Technology; petra.wagner-luptacik@ait.ac.at
Dana WASSERBACHER	Austrian Institute of Technology; dana.wasserbacher.fl@ait.ac.at
Hans WESTERHOFF	University Manchester; hans.westerhoff@manchester.ac.uk
Karoline WIESNER	University Bristol; k.wiesner@bristol.ac.uk
Doris WILHELMER	Austrian Institute of Technology; doris.wilhelmer@ait.ac.at