

## QUROPE Research Lab and Virtual Institutes

The QUROPE Research Lab and the associated Virtual institutes, represents the QUTE-EUROPE coordination action attempt to set up an ultimately sustainable research architecture specifically designed for the Quantum Information Foundations and Technologies (QIFT) research area. This architecture is lead by a vision for the future sustainability of the field, and ultimately dictated by both the rapid changes that the QIFT community has been and is experiencing, as well as the recent coordination and supporting actions promoted by the Future and Emerging Technologies unit of the European Commission (e.g., the ERA-NET initiative CHIST-ERA, an ERA-NET+ action foreseen in the last part of FP7).

During the last 10-15 years QIFT has matured and become a well established scientific field, that is clearly structured around four complementary sub-fields (identified by the European QIPC roadmap) all sharing equally relevant strategic importance, research challenges and recognized European critical mass and expertise: Quantum Communication, Quantum Computation, Quantum Information Sciences and Quantum Technologies.

To ensure progressive evolution, foster durable integration and cross-fertilization between the different areas, and begin a process possibly leading in the long-term to the sustainability of the whole area, the coordination action QUIE2T has set up the rather unconventional structure of a “European Research Virtual Laboratory” (known as the QUROPE Research Lab) having four (virtual) institutes mapped to the main QIFT areas identified above. Thus from the outside the QUIE2T CA will be seen as a “virtual research lab” with European institutions and groups performing research in the field producing and disseminating its results in a coordinated and coherent way. QUIE2T will be committed to make the Lab internationally recognized and, possibly, sustainable.

It is therefore only in the broader context described above that the QUTE-EUROPE concept can be fully appreciated. In fact, it is not only an initiative that provides coordination measures for the QIFT scientific area; its novel restructuring of the community around the QUROPE Research Lab and its associated Virtual Institutes, together with the integration measures set up among them will complement the CHIST-ERA effort in QIFT, by providing the necessary preparatory work over which a successful ERA-NET+ initiative can be built.

### Description of the Virtual Institutes

- **Topics.** The five VIs -- four initially identified by the QUIE2T consortium and one added by the QUTE-EUROPE project -- are the following:
  - **[Virtual Institute of Quantum Computation.](#)** This institute will integrate all groups which have an effort aiming at building a large scale quantum computer, independently of the physical system used for this purpose. The latter will thus include trapped ions and neutral atoms, cavity QED, solid state devices (such as superconducting qubits, possibly in combination with circuit cavity QED, and spin qubits), all-optical devices, as well as impurity spins in solids, single molecular magnets, and all sort of hybridization between these different implementations.
  - **[Virtual Institute of Quantum Communication.](#)** Quantum Communication can be defined as the art of transferring quantum states from one place to another. The general idea is that quantum states encode quantum information: hence quantum communication also implies transmission of quantum information. Quantum Communication covers aspects of basic physics as well as of practical relevance (e.g., quantum key distribution protocols and quantum cryptography). Additionally, it takes care of the whole “wiring” inside a quantum computer, i.e., contribute to quantum interfaces and repeaters. This institute will incorporate all groups working on the subject.
  - **[Virtual Institute of Quantum Information Sciences.](#)** This Institute will comprise

all theoretical efforts in the field. In fact, the development of QIPC has been driven by theoretical work of scientists working on the boundary between Physics, Computer Science, Mathematics, and Information Theory. In the early stages of this development, theoretical work has often been far ahead of experimental realization of these ideas. At the same time, theory has provided a number of proposals of how to implement basic ideas and concepts from quantum information in specific physical systems. These ideas are now forming the basis for successful experimental work in the laboratory, driving forward the development of tools that will in turn form the basis for all future technologies which employ, control and manipulate matter and radiation at the quantum level.

- **Virtual Institute of Quantum Simulation.** Quantum simulation (QS) of physical and artificial systems is now becoming the focus of many branches of QIPC. Some branches are already mature enough to perform groundbreaking QS experiments and implementations, while for other branches QS constitutes a driver of the development of powerful hardware platforms and protocols. This institute provides a common agenda and a common language for all QIPC groups and projects. It is cross-disciplinary and directly addresses the kind of development that is expected to be the main QIPC road in at least the short term. It embraces transformational aspects in a unified manner, preparing useful applications to profit from progress in hardware, and providing a driver for quantum technologies and the scaling up QIPC platforms. In short, contributing to a sustainable long-term development of QICT.
- **Virtual Institute of Quantum Metrology, Sensing and Imaging (formerly Q. Technologies).** Many branches of QIPC have gone past the proof- of-principle phase, and in the short term the first technological applications of quantum coherence and entanglement will appear. This institute will embrace all groups/industries working on the different aspects of these technologies which can be split into two main categories: either technologies that represent genuine applications of QIPC (e.g., quantum metrology, quantum imaging, quantum random number generators, etc.), or technologies instrumental in developing QIPC devices (e.g., single- and entangled-photon sources and detectors, chips for ion and atom traps, etc.)
- **Structure.** Each institute has a Director and an Executive Secretary. It will be the responsibility of the Director and Executive Secretary to establish any other governing body and/or committee serving the purpose of steering/governing the VI (however the number of these bodies should be kept at a minimum, their scope clearly identified and, finally, some homogeneity between the four VIs should be achieved)
- **Role of the institutes.** Typically, the Directors and Executive Secretary of each VI (or their delegates) will be consulted as the representative of the corresponding QIPC area when decision regarding future initiatives of the whole QIPC field (e.g. the coming CHISTERA QIPC call, and the ERANET+ /Flagship initiatives) are at stake. It will also take care of the updating of the roadmap sections corresponding to the VI area of expertise. The VI Directors and Executive Secretaries will also have the possibility of appointing a task force of experts in order to carry out particular tasks.

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