Potential revolution world-wide

Quantum Information Processing and Communication in Europe...

Quantum Information Processing and Communication (QIPC) is a new and fast developing scientific field that originated only 20 years ago. It is multidisciplinary by nature, with scientists coming from diverse areas in both theoretical and experimental physics and from other disciplines such as computer science, mathematics, material science and engineering. Its main goal is to understand and to utilise the quantum nature of information – specifically, to learn how to formulate, manipulate, and process information using physical systems that operate on quantum mechanical principles. Quantum physics opens up radically new ways of 'quantum' information processing and communication (QIPC) with no analogue in classical information technology (IT). It could be viewed not as an evolution of current IT, but rather as a revolution of it. QIPC builds in fact upon counterintuitive concepts such as quantum superposition, the ability of a particle to be at two places at once, and quantum entanglement, a direct connection between distant particles that Einstein called 'spooky'. To put it in the words of the 1997 Physics Nobel Laureate William D. Phillips, "Quantum information is a radical departure in information technology, more fundamentally different from current technology than the digital computer is from the abacus."

A particularly relevant example to understand this fundamental difference is the decomposition of a number into prime factors. The security of today's bank transactions over the internet relies crucially on the encryption method known as RSA. RSA is based on the practical observation that it is hard to factor the product of two prime numbers back into the original numbers. If these numbers are both 1024 bits long, it is estimated that the sun will burn out before today's most powerful computers can factor the product. Not quite so for quantum computers: they would solve the problem in a few hours, disclosing our data to potentially malicious eavesdroppers. On the other hand, quantum cryptography already provides the technology for achieving (through quantum encryption schemes) absolute secure communications over several tens of kilometres. The data contained in a quantum encrypted message cannot be read by eavesdroppers even if they are equipped with a quantum computer.

Advances in QIPC have already led and will continuously lead to the discovery of new technologies and devices that hold the promise to radically change the way we compute and communicate. This explains why there is a fast increasing world-wide effort in QIPC research. European researchers have been from the outset prominent in setting the agenda of, and leading, the world-wide efforts in QIPC. The pathfinder role of the Future and Emerging Technologies (FET) part of the Information Society Technologies priority of the Research Programme of the European Commission has been crucial in the development and structuring of this strategic field in Europe. It promoted the early and quick recognition of the potential of QIPC. In particular, QIPC has been a FET proactive initiative in the Fifth (1999-2002) and the Sixth (2003-2006) Framework Programme (FP) for research of the European Commission. The investment has been approximately €50m for each of these four year periods. Some 60 projects have been financed with research groups coming from over 30 countries.

The FET QIPC proactive initiative

The QIPC proactive initiative has significantly enhanced the European Research Area in the field in terms of fostering greater integration between previously disjoint research groups and national programmes. It has become the focal point for all research teams in Europe and for all major activities in the field. An important sense of community and a common European identity has been established among scientists, and a common European research strategy has been elaborated. In the last ten years QIPC has matured and become a well established scientific field. There is critical mass in Europe in the main sub-fields and European scientists are among the best in the world. The FET QIPC proactive initiative is thus a very strong and successful unifying and structuring factor, which allows the European groups to be at the forefront of research in a very competitive international environment and in a very fast developing field that is at the cutting edge of science in general. It is clear that QIPC research has gained an important European dimension, which is crucial for its further development. In order to be able to exploit the full potential of European research and to withstand the challenges of the international competition, it is still necessary to substantially expand and strengthen activities at the European level.

One major outcome of this continued support was the publication by the EU, in October 2005, of a comprehensive overview of the current status, visions and goals of QIPC research in Europe. In a roadmap-type document, a number of top-level European scientists not only present an overview of the state-of-the-art of the entire field, covering the whole range of activities pursued by the European QIPC community, but also go

Eugene Polzik
Professor of Experimental Quantum Optics

© Jacqueline Godany

Anton Zeilinger
Professor of Physics, University of Vienna

Sir Peter Knight FRS
Principal of the Faculty of Natural Sciences, Imperial College

on to define the medium- and long-term goals, as well as visions and challenges for QIPC in Europe. Comprising contributions from 40 of the most prominent European scientists, this document represents an impressive joint effort of the European scientific community, and a good example of how European research can be adequately structured with appropriate help from the respective EU programme. It is also a living document, which is continuously revised and updated to provide a guideline both to scientists and decision makers.

The executive summary of the report stresses the fact that there are no fundamental obstacles to the development of quantum information methodologies in all of its sub-domains (quantum communication, quantum computation and quantum information science). What could slow things down is a lack of EU or regional funding. If activities are maintained at present levels, Europe could start to lag behind the US, not to mention other countries that are coming up fast in this area, such as Australia and Japan. This is why foreseeing a higher funding level for QIPC in FP7, (the EU's Seventh Framework Programme for research), is so essential to maintain European research at the forefront in this area. Also, the document stipulates the need to keep a diversity of experimental realisations and to look for their synergies in order to reach concrete objectives. Integration across different disciplines and different experimental approaches is considered crucial for the further advancement of QIPC in Europe.

The future

On 1st September 2006 a new FP6 co-ordination action programme started under the name of QUROPE (Quantum Information Processing and Communication in Europe). Its main goals are to take over the updates and maintenance of the QIPC roadmap, to centralise dissemination activities across Europe and, generally, to strengthen, structure and unify the European QIPC scientific community. The latter aspect is well illustrated by the fact that 34 legal partners together with an additional 43 affiliated members participate in the QUROPE programme, which therefore incorporates the bulk of European QIPC research institutions. Further activities include the maintenance of centralised databases for QIPC related materials (events, jobs, publications), the organisation of major QIPC related conferences and workshops in Europe, as well as providing a general platform for communication and discussion among its members and with the scientific community overseas. QUROPE will run for three years and will therefore ensure the continuing positive evolution of QIPC research in Europe.

There is something specific that is unusual and sets QIPC apart from most other fields of science and technology – something that makes it so desirable and so interesting, but at the same time so challenging and so elusive. It is the way QIPC connects the most fundamental theory, quantum physics, with cutting-edge experimentation, whilst offering novel, practical and useful applications at the same time. Research in QIPC has led to a deeper and broader understanding of quantum mechanics and of the fundamental laws of the quantum world, the causality principle, the nature of information, information theory and computer science. It has led to the conception of machines and devices able to perform tasks which could not be accomplished before and that have the potential to revolutionise the way we communicate and compute. Its importance for the future European Information Society Technology can hardly be overestimated.

For more information on QIPC projects, see cordis.europa.eu/ist/fet/qipc.htm or contact the QIPC FET Proactive Initiative co-ordinator Antonella Karlson (Antonella.Karlson@ec.europa.eu).

Eugene Polzik
Professor of Experimental Quantum Optics

Danish National Quantum Optics Centre and Niels Bohr Institute
Blegdamsvej 17
DK-2100 Copenhagen
Denmark

polzik@nbi.dk
www.qurope.net

Anton Zeilinger
Professor of Physics

Faculty of Physics
University of Vienna
Boltzmanngasse 5
1090 Vienna
Austria

anton.zeilinger@univie.ac.at
www.quantum.at/zeilinger

Sir Peter Knight FRS
Principal of the Faculty of Natural Sciences

Level 3, Faculty Building
Imperial College
London SW7 2AZ
UK

p.knight@imperial.ac.uk
www.imperial.ac.uk/naturalsciences