

# Overview and strategy of the FET Proactive Initiative

## *Quantum Information processing and Communication*

**1999 – 2006**

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### **What makes QIPC so different and so fascinating?**

Quantum Information Processing and Communication (QIPC) is a new scientific field with origins in the late 80's and early 90's. It is multidisciplinary by nature, with scientists coming from diverse areas in both theoretical and experimental physics (atomic physics, quantum optics and laser physics, high energy and mathematical physics, condensed matter, etc.) and from other disciplines such as computer science, mathematics, material science and engineering. QIPC exploits fundamentally new modes of computation and communication, namely the quantum nature of information. The most fundamental properties of quantum mechanical systems like the coherent manipulation and control of individual or entangled quantum degrees of freedom are used to encode, process and transfer information. 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 evasive. It is the way QIPC connects the most fundamental theory with fundamental experimentation in the quantum world, whilst offering novel, practical and revolutionary applications at the same time. Today, there is a significant world-wide effort to advance research in QIPC, which 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 also led to the conception of machines and devices able to perform tasks which could not be accomplished before and have the potential to radically change the way we communicate and compute. QIPC represents a long-term investment with new results both in technological applications and fundamental quantum physics emerging continuously and new avenues opening up. One could evoke the symbolic image of a strong and elegant plant that is continuously growing, new leaves are going sideward leading to strategic new applications, while the top is growing upward discovering new physical phenomena....

QIPC has three closely interconnected sub-domains:

- **Quantum Computing:** The long-term goal is to develop a general-purpose quantum processor. A medium-term goal is a few-qubit processor including error correction, as a model system to demonstrate quantum algorithms and various quantum computing architectures, and with emphasis on potential scalability. It is essential to pursue this goal on a broad basis of competing physical systems and approaches, allowing hybridization and cross-fertilization between different implementations. A crucial issue is to overcome decoherence, both via technological advances and via novel theoretical approaches. In parallel, special purpose quantum computers should be developed to act as programmable quantum simulators, whose dynamics can be engineered to reproduce other many body quantum systems.

- **Quantum Communication:** The goal is to transfer quantum states from one place to another using entanglement and other non-local characteristics of quantum physics. A major objective is to develop long distance quantum communication both in optical fiber and in free space increasing significantly the distance and the qubit transfer rate. This entails a number of serious scientific challenges like developing quantum repeaters, quantum memories and quantum interfaces (faithful transfer of quantum states between light and matter). In parallel, building quantum networks and quantum processor interconnects is a major priority and has to complement the development of computer architectures in order to build entire working quantum systems. This could mean on a small scale, to transport information within different quantum computer architecture components; and over larger distances, to interconnect several quantum processors in networks.

- **Quantum Information Science:** One hand it must continue to play a leading role in guiding and supporting experimental developments. On the other hand, a major goal is its comprehensive formulation as a quantum counterpart to the classical theory of information, computation and communication. This implies the search for new quantum algorithms, new computational models and architectures, as well as for new quantum communication and entanglement manipulation protocols. A key element is a deeper understanding of entanglement and decoherence, which is necessary for elaborating quantum error correction and purification schemes.

These three sub-domains are closely interrelated and strongly influence each other. Integration between them, as well as between different experimental approaches is needed for building complete integrated quantum systems. This is a key issue for developing QIPC as the basis of a future technology.

## The FET QIPC Proactive Initiative - Projects

European scientists have been at the forefront of QIPC research since the beginning. FET has been very successful in attracting to the IST Program the best research teams in Europe, which are also among the best ones in the world.

During 1998 the QCEPP working group (the so-called *Pathfinder* project) laid the basis for the research field of QIPC at European level and was the first endeavor explicitly to address this area of research. In FP5 (1999 – 2002) FET launched QIPC as a proactive initiative. Two calls for proposals and 25 projects were launched with an EU funding of 31 M€. The contracts of the last group of FP5 projects finished at the end of 2005. QIPC is also funded via the FET-Open continuous submission scheme. In FP5 ten QIPC projects with total cost of 7 M€ and EU funding of 5.6 M€ were launched. Integrate the projects arising from the Open scheme with those supported through the proactive initiative and coordinate the work of all these projects is a main priority of the proactive initiative. The **QUIPROCONE** Thematic Network successfully supported FET in this endeavor.

In FP6 (2003 – 2006) QIPC continued as a FET proactive initiative. There was one dedicated call for proposals in 2004. Three Integrated Projects started in November 2005 with a contract for four years and total EU funding of 25 M€:

**SCALA** - *Scalable Quantum Computing with Light and Atoms* (9.36 M€): The focus is on the realization of a scalable quantum computer, by using individually controlled atoms, ions and photons. This long-term goal is divided into two specific objectives, achievable during the project duration: A) Realization of interconnected quantum gates and quantum wiring elements. B) Realization of first approaches of "operational" quantum computing, which include (i) systems able to perform small-scale quantum algorithms, such as error correction (ii) special-purpose quantum processors, such as quantum simulators, and (iii) entanglement-assisted metrology.

**QAP** - *Qubit Applications* (9.9 M€): The focus is on qubit applications that are based on photonic, atomic and solid state systems. One of the project objectives is to design, build and operate quantum memories. It also aims to developing scalable quantum networks and operational prototypes of quantum repeaters that would allow to transmit quantum entanglement over large distances (both in fiber and free space). The ultimate goal is to design prototypes for satellite communications based on quantum entanglement. The project also strives to developing operational demonstrations of efficient control of dynamics of few-qubit quantum systems that will be employed for performing quantum simulations.

**EuroSQIP** - *European Superconducting Quantum Information Processor* (6 M€): The focus is to develop a 3-5-qubit quantum information processor capable to: - run elementary algorithms; - demonstrate quantum state control of a macroscopic multi-partite system - demonstrate entanglement and entanglement transfer - provide storage of quantum information - provide quantum communication interfaces - run simple quantum error correction schemes for suppression of decoherence. This will be implemented on platforms based on Josephson junction technology for i) charge-phase and ii) flux qubits.

Coverage: All three IPs deal with central topics of quantum computing, two of them (QAP and SCALA) address quantum information and one of them (QAP) covers also central topics of quantum communication. In SCALA and QAP the accent on integration across different disciplines and approaches is very strong and it is considered crucial for the further advancement of QIPC in Europe. All three consortia involve leading European scientists in their respective domains. In all projects the European dimension is a clear added value. The start of the three integrated projects marks a new more mature stage of development in European science.

Eight smaller projects (STREPs) were contracted in FP6 via FET Open: **COVAQIAL** - Continuous Variable Quantum Information with Atoms and Light, **QUELE** - Quantum Computing with Trapped Electrons, **RSFQUBIT** - RSFQ Control of Josephson Junctions Qubits, **OLAQUI** - Optical lattices and quantum information, **ACDET** - Acoustoelectronic single photon detector, **MICROTRAP** - Development of pan-European micro-trap technology capability for trapped ion quantum information science, **QICS** - Foundational Structures of Quantum Information and Computation, **EQUIND** - Engineered Quantum Information in Nanostructured Diamond. The total European funding is of 13.582M€.

At the end of 2006 there are two active Coordination Action Projects. These are not research projects, but rather their goal is to collaborate with the QIPC FET proactive initiative in developing a strategy and in carrying out common activities.

**ERA-Pilot QIST** (850 K€) - *Structuring the ERA with quantum information science and technology*. Its goal is to promote QIPC research in Europe and to give recommendations to

European and national authorities on policy, structuring, coordination and funding. Its work includes: • Contribute to the updates of the QIPC Roadmap • Develop a map of European QIPC centres of excellence • Develop a QIPC classification scheme according to the roadmap. The so-called QICS codes were accepted in the Fall of 2006 by Physical Review in the US to be included in the universal PACS classification codes for physics. • Compile information about national QIPC programs. • Compile information on international QIPC programmes. The Description of Work of the project went through a major update and restructuring in order to meet the fast changing needs of the field. The last two tasks above were substantially updated and expanded and new expertise was added to the consortium. The contract is extended till the end of 2007 and cooperation with the CA QUROPE is established.

**QUROPE** (1 M€): It aims at structuring the European QIPC research community around the FET QIPC proactive initiative and covers a large spectrum of activities like: •Develop a common European vision, strategy and goals for QIPC research by developing and updating the QIPC roadmap • Increase the public visibility and aim at broad dissemination activities • Develop and support an Electronic Information Infrastructure and Information Exchange (with a feedback channel) • Organize scientific meetings • Create links with industry • Develop international collaboration outside of Europe. It is important to note that the consortium consists of 34 research groups, among the best from all over Europe. These play the role of regional focal points for other 43 research groups who are defined as affiliated members. In this way a considerable part of the scientific community can participate in the actions undertaken by the project. The decision making process is in the power of the Governing Board which consists of 19 well known scientists. Therefore the project is central to the entire QIPC scientific community and plays the role of its collective representative. It has reached a higher level of maturity and integration than all other similar actions in the past.

It is necessary to mention that there is one project in the field of QIPC which is not funded by FET but rather by the *Security* strategic objective of the IST Research Program. It is called **SECOQC** - *Development of a Global Network for Secure Communication based on Quantum Cryptography*. This FP6 integrated project started on 01/04/2004. It will last four years with a total cost of 16.82 M€ and EU funding of 11.35 M€. The project emerged naturally from the FP5 FET QIPC projects in the field of applied quantum cryptography. The consortium comprises 40 research groups which are the best ones in Europe in this field. They have all been or still are partners in the FET QIPC projects and are active participants in the actions undertaken by the QIPC proactive initiative. SECOQC has very ambitious goals in the practical realizations of quantum cryptography: specify, design, and validate the feasibility of an open, Quantum Key Distribution infrastructure dedicated to secure quantum communication, as well as fully develop the basic enabling technology. A network will be designed for dependable and secure long-range quantum communication building upon a Quantum Key Distribution (QKD) technology. The functionality of the developed architecture will be demonstrated. The design will be based on a comprehensive analysis of requirements of potential users. For more information please see the project web site: <http://www.secoqc.net/index.html> or the short article: [http://cordis.europa.eu/austria/showcases4\\_en.html](http://cordis.europa.eu/austria/showcases4_en.html)

In order to complete the picture of the projects in the area of QIPC funded by the European Commission research program in general, it is important to include the existing two Marie Curie research training networks funded by the Marie Curie program of DG RTD. They are CONQUEST: Controlled Quantum Coherence and Entanglement is Sets of Trapped Particles and ATOMCHIPS.

## Main objectives of the QIPC Proactive Initiative

The QIPC research community in Europe is very active and is working at the forefront of QIPC research. On the other hand this is relatively a small community. There are 158 academic research groups or laboratories who have registered in the database created by the roadmap work package of the project ERA Pilot QIST. An estimate is that about 120 have their central activities in QIPC. They are spread over more than 30 countries with very different research management structure, policy and financing in the field of QIPC. All these countries have also very different traditions and history in quantum physics or in natural sciences in general. The only unifying and structuring factor is the EU research program - the FET QIPC proactive initiative. As already mentioned several times, most of these researchers are scientifically the best ones in the world. They are solicited or challenged by colleagues and programs outside the EU. In order to withstand the challenges and stay at the edge of research in this very competitive international environment and in this very fast developing field, they need to stay together and to form a well structured and collaborative community. In this sense the FET QIPC proactive initiative fulfils a natural leading role and is the focal point for all QIPC researchers in Europe.

In this respect, the main objectives of the proactive initiative can be divided into two groups. The first one is quite obvious and most of the time straightforward, though not at all easy to carry out: define calls for proposals, organize evaluations of proposals, negotiate project contracts, manage and monitor projects throughout their complete lifetime. The second group is less evident and much more sophisticated. But most importantly, in order to have any chances of success, it has to be carried out every step of the way in close collaboration with the entire research community and with its active participation. Bottom-up approach, exchange of ideas and an open dialogue, mutual respect and common understanding, comprehensive and no-nonsense feedback channels are all key elements of this very difficult but stimulating and rewarding journey. Some of the objectives in the second group are:

- Promote information exchange and collaboration between research groups and projects
- Plan pan-European events and activities
- Maintain pan-European dissemination activities and a comprehensive public image of the field
- Create and maintain a dialogue with the research management in member states and at European level
- Coordinate efforts between national and local programs on one hand and the EU initiative on the other hand
- Structure and strengthen the research community, unify it around the QIPC initiative
- Create a sense of community and a *common European identity*, develop a pan-European strategy for the future development of the community
- Develop and maintain an European QIPC web portal with a comprehensive feedback channel
- Define a common vision and objectives for research, a pan-European strategy for research and therefore continuously maintain and update the European QIPC roadmap
- Support emerging new areas, research topics and applications
- Create international alliances and a common strategy for international collaboration at pan-European level
- Maintain a dialogue and create a common strategy to attract industrial partners
- Create and maintain a common strategy and unified standards for the education of young researchers

- Maintain a global overview at European level

All these elements need to be in dynamic equilibrium between each other and it is very important to respond on time and proactively to:

- the changing needs of the community
- the fast research developments
- changes at EU and Commission level
- changes in the international scene

Keeping all these objectives in mind, it is very beneficial to maintain *continuity* and to build on what has been already achieved. Part of it is to *keep the traditions* already established over the years. There are two major annual events organized within the framework of the QIPC proactive initiative since 2000: The first one is a ‘cluster review’ with a conference. Its goals are to review and evaluate the work of each project and how its objectives fit within the common objectives of the initiative, to revise priorities if necessary and to evaluate the progress of the initiative as a whole. In 2005 and 2006, a detailed cluster review report was written after every review. The second event is the annual European QIPC workshop where projects and individual research groups present their work. Both events are the focal point for the scientific community and serve as a platform for information exchange and an open forum for scientific discussions. Since 2004, at each of these events it was also organized a ‘special session’ to discuss the strategy and planning of the QIPC proactive initiative and to launch new actions. A list of all the events with some comments is available at the end of this article.

## **Preparation for FP7 and a Common European strategy for research in QIPC**

While the field has now reached a certain degree of maturity and there is critical mass in Europe in the main sub-domains, it is necessary to substantially expand and strengthen activities at European level. In view of the forthcoming FP7, FET and the European QIPC research community have been actively working during 2005 and 2006 towards the elaboration of a common European research strategy. These efforts have culminated in the scientific and technological roadmap “**Quantum Information Processing and Communication: Strategic report on current status, visions and goals for research in Europe**”. This was really a community effort, as it can be seen from the substantial list of 40 contributors, who are among the most prominent scientists in Europe. The editing author is Prof. Peter Zoller from the University of Innsbruck. The document is an impressive joint effort of the European scientific community and a good example how European research can be adequately structured with the help from the respective EU program. After an initial consultation within the research community, in April 2005 the first version of the strategic report was published on the FET and on the ERA Pilot – QIST project web sites. The goal was to initiate a broader discussion and receive feedback in order to make appropriate corrections. The report presents in a comprehensive way the state-of-the-art, the medium and long term goals, the visions and challenges in a general roadmap-type document. It includes a Foreword by Director Mr. Ulf Dahlsten, an executive summary, an overview of the general scientific and technological context of the field, an overview of the activities of the FET QIPC proactive initiative, a description of national research programs and the worldwide research position of Europe in QIPC. The main bulk of the document is devoted to a scientific assessment of current results and an outlook for future efforts. It covers the three main research sub-domains: quantum communication, quantum computation and quantum information science, as well as the interactions and interdependences between them. The document stipulates the need for further support in these three research directions, as well as to keep a diversity of experimental realizations and to look for synergies between them in

order to reach concrete objectives. Integration across different disciplines and between different experimental approaches is considered crucial for the further advancement of QIPC in Europe. Prospects for applications and commercial exploitation are equally discussed.

The initial version of the roadmap was extensively discussed within the scientific community and subsequently at a series of special sessions organized by FET at the traditional events (Feb. 2005 Innsbruck, May 2005 Vienna, Feb. 2006 Paris, October 2006 London). One new version was published as an official publication of the European Communities in October 2005 and another one in *The European Physical Journal D - Atomic, Molecular and Optical Physics* (Vol. 36 No. 2 November 2005; <http://www.edpsciences.org/journal/index.cfm?edpsname=epjd>). The roadmap is a living document, which is updated every six months. This is done in the context of the project ERA Pilot QIST by the team of WP1 (Prof. Peter Zoller, Dr. Tommaso Calarco and Dr. Daniele Binosi). After the end of the project this activity will be continued by the same team in the context of QUROPE WP2. Each update is subject to a wide consultation. The objective is that the QIPC roadmap serves as a guideline both to scientists and to decision makers in order to shape the future of QIPC in Europe. It will determine the strategic research agenda for the next decade.

In the period January – March 2006 there was a general FP7 consultation process called BTH (Beyond-the-Horizon) in 7 FET domains. In parallel and independently of this action, the QIPC proactive initiative carried out a consultation forum on the web site of the project ERA Pilot QIST (<http://qist.ect.it/>). The QIPC roadmap was subject to discussion and there were 84 comments submitted.

A summary of the research goals of the QIPC roadmap were elaborated in the period March - May 2006, after the roadmap was published and updated several times. These pages reflect in a nutshell the entire scientific part of the roadmap and are the result of a long and careful reflection by the entire team of contributing authors and at a second stage by the entire scientific community. It is written in "Scientific American style" and therefore is understandable by a wider audience. For each of the main sub-domains (quantum communication, computation and information) the research goals and priorities divided in short-term (up to 5 years) and long-term (up to 10 years) were clearly and comprehensively defined. The summary includes a fourth section on integration and synergies between the three main sub-domains. The idea was to present in a comprehensive and accessible way the main scientific challenges which would serve as a starting point in FP7.

Another major effort for preparation of FP7 is a second official publication of the European Communities "*QIPC in Europe*". This is a booklet of about 250 pages which contains 30 articles written by 58 of the most prominent scientists in Europe. Each article gives a comprehensive overview of one specific area of QIPC and refers to work accomplished within the framework of EC and nationally funded projects. The publication as a whole gives a balanced overview of QIPC research activities and achievements in Europe. The booklet includes a Foreword by Commissioner Ms Viviane Reding. The entire text is available on the FET web site and is printed as EC publication. The QIPC roadmap and the collection of articles complement each other and are important milestones along the way towards elaborating a common European strategy in QIPC.

The QIPC classification scheme is a logical continuation of the roadmap. It was elaborated by Tommaso Calarco and Daniele Binosi within the framework of ERA Pilot QIST WP1. Profiting from their experience gained while writing the roadmap, they have scanned through thousands of QIPC publications in recent years in order to give a systematic overview of the research subjects treated therein. A concise version of the QICS classification scheme will be integrated in the PACS codes (universal classification scheme for physics). This is a

major achievement not only for the authors but most of all for QIPC which is accepted as a physical science in its own right.

Issue 233 of the Parliament Magazine (<http://www.parliamentmag.com>) of November 13, 2006 published an article on QIPC (page 81). It reflects the work of the coordination action project QUROPE, the QIPC roadmap and the QIPC FET proactive initiative. The entire issue is dedicated to IST in FP7 and the Helsinki IST Event 2006 (21 – 23 October) [http://ec.europa.eu/information\\_society/istevent/2006/index\\_en.htm](http://ec.europa.eu/information_society/istevent/2006/index_en.htm). There are articles from the Commissioner Ms Reding, from the Director General Fabio Colasanti and from a number of Parliamentarians.

At the plenary session of the IST Conference in Helsinki entitled "*Opportunities for ICT Research & Development Beyond 2007*" one of the four invited speakers was Prof. Anton Zeilinger from the University of Vienna. He gave a talk on "*Quantum Information Processing and Quantum Communication: A Crucial Opportunity for European Collaborative Research*".

FP7 is starting in January 2007. The intention is to continue the QIPC proactive initiative and the support for QIPC research at European level. A call for proposals is planned for January 2009. It is important that the research community in collaboration with FET gets ready for this call by developing the research goals and priorities according to the roadmap, research collaborations and new challenging projects.

## **Forging Collaborations and Alliances**

In order to keep the momentum of the European progress in QIPC and the competitiveness of our scientists, it is in Europe's interest to develop a common strategy for international collaboration at pan-European level in a concerted and structured way. Some European countries have strong national programs in QIPC, but the efforts are fragmented and none of them by itself can be a counterpart to the QIPC programs in the developed countries, as research and investment in QIPC have grown tremendously in recent years. On the other hand it is very important to establish and maintain research collaborations with good teams outside Europe. This stimulates scientific excellence and cross fertilization between different research cultures and traditions. Therefore the QIPC initiative needs to create the best possible conditions for European scientists to excel in the field in this global environment.

In May 2005 the *QUPON Conference (Quantum Physics of Nature)* was organized at the University of Vienna. It was a major international event with more than 350 of the best scientists in the world taking part.

The *Gordon research Conference on Quantum Information Science* makes part of the series of high level research events organized by the institution with the same name in the US. In 2006 it took place 7-12 May in Il Ciocco (Italy) and was organized by Peter Zoller (University of Innsbruck) and Ignacio Cirac (Max Planck Institute in Garching, Germany). There were representatives from US funding agencies and also the coordinator of the FET QIPC PI. In 2007 this conference is organized in the same place in April. It is an important recognition for European research that the GRC on Quantum Information is organized in Europe.

The US – Japan Workshop on Quantum Information Science took place on 16 – 20 October in Hawaii. Europe was represented by six scientists (Anton Zeilinger, Hans Briegel, John Rarity, Philippe Grangier, Rainer Blatt, Serge Haroche) and the coordinator of the FET QIPC proactive initiative. The opening session was dedicated to invited talks given by Quantum Information Science program managers from funding agencies in the US, Japan and Europe.

Cooperation with ESA (European Space Agency) is also important. ESA has several ongoing projects related to quantum communication in free space. The main partner is the group at the University of Vienna (Prof. Zeilinger) with several other well established scientists and active participants in the FET initiative. There is an ongoing dialogue and search for collaboration opportunities on joint activities between ESA and the QIPC proactive initiative.

## **Conclusions and Outlook**

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 programs. It is an excellent example that the whole is worth much more than its individual parts. The proactive initiative 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 among scientists are in the process of development. A common European research strategy has been elaborated in the QIPC roadmap. All these activities have naturally led to a greater awareness and prominence of QIPC research in Europe. It is now a well established scientific field which has matured in the last ten years. There is critical mass in Europe in the main sub-fields and European science is competitive at world level. Some applications are already fit for real-world deployment. The FET QIPC proactive initiative is thus a very strong and successful unifying and structuring factor, which allowed the European groups to be at the forefront of research in a very competitive international environment and in a very fast developing field which 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 future.

Considering all these developments, it is therefore necessary to substantially expand and strengthen activities at European level in order to be able to exploit the full potential of European research and to withstand the challenges of the international competition. That could be followed in different ways:

- increase funding at European level
- expand activities to support the main objectives of the QIPC proactive initiative as given above
- support and maintain research in all the main sub-domains of QIPC: quantum communication, computation and information theory
- keep a diversity of experimental realizations and approaches, and yet actively to look for synergies and integration between them in order to reach concrete objectives
- ensure timely and appropriate concentration of efforts and coordination of activities

Breakthroughs of the type needed to make QIPC a reality cannot be expected to follow a precise timetable. It is however imperative that at each point in time we have a clear understanding of the results obtained, an assessment of the strengths and weaknesses in present research, as well as a clear definition of the challenges and the objectives.

## List of the annual events organized by the FET QIPC proactive initiative in collaboration with the European QIPC Scientific Community

### The QIPC Cluster Review with Conference:

**2007:** The event will be held on 28 Feb. - 2 March at the University of Oxford, UK. Subject to the review are the integrated projects: SCALA, QAP, EuroSQIP. The first day is dedicated to a conference open to the entire QIPC research community. On the program are presentations from the three IPs and the special session on strategy and planning of the FET QIPC proactive initiative.

**2006:** The event took place on 13-15 February at the Institut Henri Poincaré in Paris, France. <http://www.quantware.ups-tlse.fr/IHP2006/>.) The contracts of the last group of 10 FP5 projects, which finished at the end of 2005, were subject to the review. An extensive cluster review report was written which evaluates the achievements of the FP5 proactive initiative as a whole. The event was organized in the context of the “Trimester on Quantum Information, Computation and Complexity” (January 4th – April 7th, 2006). <http://www.ihp.jussieu.fr/ceb/Trimestres/T06-1/C2/index.html>. At the special session organized by FET there was an extensive discussion on the updates of the QIPC roadmap and on the activities of the project ERA Pilot QIST.

**2005:** The event took place on 14-16 February at the Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences in Innsbruck, Austria. Thirteen FP5 projects were subject to the review. A detailed cluster review report was written after the event. The first draft of the QIPC roadmap was presented and discussed in detail by all participants at the special session organized by FET.

<ftp://ftp.cordis.europa.eu/pub/ist/docs/fet/qip2-18.pdf>

**2004:** The event took place 16 – 18 February in Bratislava, Slovakia.

<http://www.quiprocone.org/Bratislava/Review04.htm>

**2003:** The event took place on 9 – 12 March in Bad Nauheim, Germany.

[http://www.quiprocone.org/Frankfurt/open\\_info\\_workshop.htm](http://www.quiprocone.org/Frankfurt/open_info_workshop.htm)

<http://www.quiprocone.org/Frankfurt/review.htm>

**2002:** The event took place on 27th February - 1st March in Dolce Chantilly (near Paris), France.

<http://www.quiprocone.org/chantilly/chantillyagenda.htm>

**2001:** The event took place on 14 – 16 March in Seefeld, Austria.

<http://www.quiprocone.org/seefeld/default.htm>

## **The annual European QIPC Workshop:**

**2007:** The 8th European QIPC Workshop will take place in October in Barcelona, Spain. It will be organized by QUROPE.

**2006:** The 7th European QIPC Workshop took place Oct. 13-14, 2006 at The Royal Society London, UK. This year the title was "Physicists and Computer Scientists Unite!" The format was very original: the program was divided in pairs of speakers, each treating the same subject from two different points of view. There was a special session on strategy and planning and the kick-off meeting of the CA QUROPE. Sponsoring and logistics organization was provided by the project ERA Pilot QIST.

<http://www.qist-europe.net/QIPC-Workshop/>

**2005:** The 6th European QIPC Workshop was organized within the framework of the major international conference QUPON (Quantum Physics of Nature) on May 20 – 26 at the University of Vienna, Austria. At the special session on the strategy and planning of the proactive initiative, several issues were discussed: detailed structure of the QIPC roadmap and the proposal of QUROPE.

<http://www.quantum.univie.ac.at/QUPON/>

**2004:** The 5th European QIPC Workshop, took place 20 – 22 September at the University Roma La Sapienza, Rome, Italy. At the special session it was discussed and decided to start work on the QIPC roadmap. Prof. Peter Zoller from the University of Innsbruck was elected as the editor of the roadmap. A draft list of contributing authors was made. The actual work started immediately afterwards.

<http://cordis.europa.eu/ist/fet/qipc-7fp.htm>

[http://quantumoptics.phys.uniroma1.it/Conference\\_QIPC/conf.htm](http://quantumoptics.phys.uniroma1.it/Conference_QIPC/conf.htm)

**2003:** The 4<sup>th</sup> European QIPC Workshop took place on 13 – 17 July in Clarendon Laboratory, Oxford University, UK.

[http://www.quiprocone.org/Oxford/4th\\_Keble.htm](http://www.quiprocone.org/Oxford/4th_Keble.htm)

**2002:** The 3<sup>rd</sup> European QIPC Workshop took place on 15 – 18 September at Trinity College, The University of Dublin, Ireland.

<http://www.quiprocone.org/Dublin/dublinworkshop.htm>

**2001:** The 2<sup>nd</sup> European QIPC Workshop took place on 28 – 31 October at the Institute for Scientific Interchange Foundation (ISI) at Villa Gualino in Torino, Italy.

<http://www.quiprocone.org/Torino/index.htm>

**2000:** The 1<sup>st</sup> European QIPC Workshop took place 27 – 29 September at the University of Potsdam, Germany.

<http://www.qipc.org/workshop/>

## Prizes and awards given to members of the QIPC scientific community in recent years

→ **2006 International Quantum Communications Award** - 28 November 2006, Japan

For theoretical research:

- **Ignacio Cirac** (Max-Planck-Institut für Quantenoptik, Garching, DE)
- **Peter Zoller** (University of Innsbruck and the Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences)

Projects: ERA Pilot QIST, QUROPE, SCALA, RESQ

For experimental research:

- **Philippe Grangier** (Institut d'Optique, France)

Projects: QUROPE, QAP, COVAQIAL, QUICOV, SECOQC

International Conference on Quantum Communication, Measurement and Computing (QCMC) <http://www.qcmc2006.org/index.html>

Past QCMC Awards to scientists from the EU QIPC community:

- 2004: **Richard Jozsa** (University of Bristol, UK)
- 2002: **David Deutsch** (University of Oxford, UK) and S. Haroche (ENS, Paris, FR)

→ **Nicolas Cerf** (Universite Libre de Bruxelles, BE) won the **Marie Curie Excellence Award** – Nov. 16, 2006. Projects: ERA Pilot QIST, QUROPE, QAP, COVAQIAL, QUICOV, SECOQC

[http://cordis.europa.eu/fetch?CALLER=EN\\_NEWS&ACTION=D&SESSION=&RCN=26670](http://cordis.europa.eu/fetch?CALLER=EN_NEWS&ACTION=D&SESSION=&RCN=26670)

→ **Rainer Blatt** (University of Innsbruck and the Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, A) won the **Schrodinger Prize of the Austrian Academy of Sciences** – Oct. 13, 2006. Projects: ERA Pilot QIST, QUROPE, SCALA, MICROTRAP, QGATES, QUEST, CONQUEST, QUBITS.

<http://www.igogqi.at/news/2006/396460.html>

<http://www.oeaw.ac.at/stipref/forscherpreise/>

→ **Peter Zoller** won the **Dirac Medal of the International Centre for Theoretical Physics (ICTP)** in Trieste, Italy - 8th August, 2006

<http://physicsweb.org/articles/news/10/8/6/1>

→ **Ignacio Cirac** has been given the **2006 Prince of Asturias Award for Scientific and Technical Research**.

<http://www.fundacionprincipedeasturias.org/servlet/buscadorGalardonadosIng>

<http://www.fundacionprincipedeasturias.org/ing/index.html>

→ **Joerg Schmiedmayer** (University of Technology, Vienna, AT) won the **Wittgenstein Prize 2006**. FET Projects: ACQUIRE, ACQP, SCALA, QUROPE

→ **Julia Kempe** (Laboratoire de Recherche en Informatique at Orsay, Univ. Paris-Sud, FR):

- **Médaille de bronze CNRS 2006** (prize for young researchers)  
<http://www.cnrs.fr/fr/presentation/prix/medaillesbronze.htm>
- **Prix Irène Joliot-Curie 2006** (prize for women)  
<http://www.recherche.gouv.fr/discours/2006/remiseprixijc06.htm>  
<http://www.recherche.gouv.fr/discours/2006/dpprixijc2006.pdf>

→ **Peter Zoller** has been given the **Niels Bohr Gold Medal of UNESCO** - Copenhagen, November 15, 2005.

→ On October 4 the Nobel Committee announced the **Nobel Prize in Physics 2005**. It went to research in the field of quantum optics, the science describing the nature of light and its interactions with matter particles according to the principles of quantum mechanics. One of the three winners is **Prof. Theodor Hänsch** from Max-Planck-Institut für Quantenoptik, Garching and Ludwig-Maximilians-Universität, Munich, DE.

FET Projects: ACQUIRE, ACQP

[http://www.kva.se/KVA\\_Root/eng/\\_press/detail.asp?NewsId=693](http://www.kva.se/KVA_Root/eng/_press/detail.asp?NewsId=693)

→ **Alain Aspect** (Laboratoire Charles Fabry de l'Institut d'optique, FR) won **the Medaille d'Or of the CNRS**, FR - 9 November 2005. FET projects: SCALA, QUROPE

[http://sciences.nouvelobs.com/sci\\_20051109.OBS4730.html](http://sciences.nouvelobs.com/sci_20051109.OBS4730.html)

<http://www2.cnrs.fr/presse/communique/781.htm>

<http://www.lemonde.fr/web/article/0,1-0@2-3244,36-708342@51-699012,0.html>

→ **Rudolf Grimm** of the Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, Innsbruck, AT received the **Wittgenstein Prize in 2005**.

→ **Immanuel Bloch** (Johannes Gutenberg University, DE) won the **Gottfried Wilhelm Leibniz-Prize 2005** of the Deutschen Forschungsgemeinschaft. FET projects: QGates, QUASICOMBS, OLAQUI

→ **Alain Aspect** (Laboratoire Charles Fabry de l'Institut d'optique, FR) was awarded **Chevalier de la Légion d'Honneur (2004)**.

→ **Jakob Reichel** (Laboratoire Kastler Brossel of E.N.S., FR) won the **2004 European Young Investigators Award (EURYI)** for the project "Integrated quantum devices". FET Projects: SCALA, ACQUIRE, ACQP

[http://www.dfg.de/aktuelles\\_presse/preise/euryi\\_preis/2004/download/awardeereichel.pdf](http://www.dfg.de/aktuelles_presse/preise/euryi_preis/2004/download/awardeereichel.pdf)

→ **Jens Eisert** (University of Postdam, DE) won the **2004 European Young Investigators Award (EURYI)** for the project "Multi-particle entanglement in critical and distributed quantum systems". FET projects: QAP

[http://www.dfg.de/aktuelles\\_presse/preise/euryi\\_preis/2004/download/awardeeeisert.pdf](http://www.dfg.de/aktuelles_presse/preise/euryi_preis/2004/download/awardeeeisert.pdf)

→ The project **QUCOMM – Long distance Photonic Quantum Communication** won the **2004 Descartes Prize**.

Project details:

Start date: 01/01/2000

End date: 30/04/2004

Contact Person: Prof. A. Karlsson, KTH, Sweden

Project web site <http://www.imit.kth.se/QEO/qucomm/>