

Institute for Quantum Information

Activities – 2005-2006

Personnel

The primary goal of the Institute for Quantum Information (IQI) is to carry out and facilitate research in Quantum Information Science (QIS). The IQI is an NSF-supported collaboration of Caltech's Divisions of Engineering and Applied Science and of Physics, Mathematics, and Astronomy. It is led by five Caltech faculty members: John Preskill (Director and PI, MacArthur Professor of Theoretical Physics), Alexei Kitaev (co-PI, Professor of Physics and Computer Science), Leonard Schulman (co-PI, Professor of Computer Science), Jeff Kimble (Valentine Professor of Physics), and Hideo Mabuchi (Associate Professor of Physics and Control and Dynamical Systems). Administration of the IQI is supervised by Ann Harvey (IQI Administrative Assistant).

In 2005-06, six IQI postdoctoral scholars were in residence: Robin Blume-Kohout, Luc Bouten, Andrew Childs, Frank Verstraete, Pawel Wocjan, and Jon Yard. In addition, Robert Raussendorf departed in March 2006, and David Poulin arrived in April 2006. Blume-Kohout and Yard were fully supported by NSF, Bouten, Raussendorf, and Wocjan were partially supported by other grants, and Childs, Verstraete, and Poulin were primarily supported by Caltech's prize postdoctoral fellowship programs. In fall of 2006, Verstraete and Wocjan will depart for faculty positions elsewhere (making a total of 15 former IQI postdoctoral fellows who now hold faculty positions or the equivalent), and Shengyu Zhang and Ben Reichardt will join IQI. About 25 Caltech students (both graduate and undergraduate) also participated in the project.

Visiting Scholars and Students

The IQI sponsors a vigorous visitor's program. Our long-term visitor for 2005-06 was Scott Parkins (Auckland), whose visit was partially sponsored by Caltech's Center for the Physics of Information (CPI). Twenty-four other senior and postdoctoral scholars visited the IQI for one week or longer in 2005-06: Dorit Aharonov (Hebrew U.), Sergey Bravyi (IBM), Matthias Christandl (Cambridge), Daniel Gottesman (Perimeter), Jim Harrington (LANL), Aram Harrow (Bristol), Matthew Hastings (LANL), Patrick Hayden (McGill), Debbie Leung (Waterloo), Serge Massar (Brussels),

Carlos Mochon (Perimeter), David Perez-Garcia (MPI), Alex Russell (UConn), Lawrence Schulman (Clarkson), Renato Renner (Cambridge), Petra Scudo (Technion), Yaoyun Shi (Michigan), Joost Slingerland (Microsoft), John Smolin (IBM), Joseph Traub (Columbia), Martin Van Den Nest (KU Leuven), Guifre Vidal (Queensland), Karl Vollbrecht (MPI), and Jonathan Walgate (Calgary). In addition there were seven visiting graduate students: Jürg Buehler (Karlsruhe), Andrew Cross (MIT), Mike Levin (MIT), Yi-Kai Liu (UCSD), Ben Reichardt (Berkeley), Krysta Svore (Columbia), and Shengyu Zhang (Princeton). There were many shorter-term visitors as well. The IQI pays the travel and local expenses for most of our visitors.

Research Activities

IQI researchers are among the world leaders on both the theoretical and experimental sides of QIS. Preskill's group studies quantum information theory, quantum cryptography, and the theory of fault-tolerant control of quantum systems. Schulman's group develops new quantum algorithms that could outperform classical algorithms, and derives limits on the power of quantum computers. Kimble's group works on both the theory and practice of manipulating quantum information encoded in single atoms and in photons. Mabuchi's group is involved in both theoretical and experimental aspects of quantum control, quantum measurement, and quantum coding. Kitaev's group works on quantum complexity, quantum coding, and the interface of quantum information with quantum many-body theory. Our postdoctoral scholars and students are also very active in all of these areas of QIS. In addition affiliated faculty are active in adjacent areas: Gil Refael in quantum many-body theory, John Doyle in control theory, Kip Thorne in the theory of quantum nondemolition measurement, Axel Scherer in nanostructures and photonic crystals, and Michael Roukes in quantum-limited nanomechanical devices.

IQI participants have produced 35 publications during the nine-month period from 1 September 2005 to 31 May 2006. More details about these research accomplishments can be found in the Findings section of this Annual Report.

It is important to emphasize that the IQI is more than the sum of the research groups it includes. By providing a hub for the widespread research efforts at Caltech in quantum information science, and by facilitating interaction with the broader QIS community beyond Caltech, the IQI has created a unique research environment that strongly encourages work straddling the traditional boundaries between academic disciplines. This interdisciplinary attitude has many manifestations in the discussion of our Findings.

Education and Training

IQI participants Kimble, Kitaev, Mabuchi, Preskill, and Schulman are training graduate students working on both the theoretical and experimental sides of QIS – a total of over 20 students. Five IQI students will receive Ph.D. degrees in 2006. As already noted, many students from outside Caltech have visited the IQI and collaborated with our researchers. The Caltech students and the visiting students benefit greatly from the interdisciplinary spirit of the IQI. Mabuchi, Preskill, and Schulman also sponsor undergraduate research programs in quantum information science.

In December 2005, IQI sponsored a one-day workshop on *Numerical Renormalization Group Methods: New Perspectives from Entanglement Theory*. This event brought together researchers who share an interest in how recent insights regarding quantum entanglement can be applied to quantum many-body theory. Also in December, we co-sponsored (with Caltech's Center for the Physics of Information) a $3\frac{1}{2}$ day workshop on *Classical and Quantum Information Security*. This meeting brought together researchers from a variety of backgrounds who work on different aspects of classical and quantum information security, to identify issues and problems of common interest that can be effectively addressed by pooling their expertise.