

Institute for Quantum Information

Activities – 2006-2007

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).

During 2006-07, eight IQI postdoctoral scholars were in residence: Eddy Ardonne, Robin Blume-Kohout, Luc Bouten, Andrew Childs, David Poulin, Ben Reichardt, Jon Yard, and Shengyu Zhang. Blume-Kohout and Yard were fully supported by NSF, Bouten, Reichardt, and Zhang were partially supported by other grants, and Ardonne, Childs, and Poulin were primarily supported by Caltech's prize postdoctoral fellowship programs. In 2007-08, Blume-Kohout, Childs, and Yard will depart, and Lukasz Fidkowski, Robert König, Yi-Kai Liu, and Stephanie Wehner 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. Thirty senior and postdoctoral scholars visited the IQI in 2006-07: Scott Aaronson (Waterloo), Stephen Bartlett (Sydney), Charles Bennett (IBM), Nick Bonesteel (FSU), Yeo-Jin Chung (SMU), Paul Goldbart (Illinois), Jim Harrington (LANL), Aram Harrow (Bristol), Stephen Hsu (Oregon), Lev Ioffe (Rutgers), Dominik Janzing (Karlsruhe), Jordanis Kerenidis (CNRS), Matthew Leifer (Waterloo), Debbie Leung (Waterloo), Peter Love (Haverford), Michael Mueger (Nijmegen U.), Zohar Nussinov (Washington University), Harold Olivier (INRIA), Tobias Osborne (Bristol) Joost Slingerland (Microsoft), Graeme Smith (Bristol), Rolando Somma (LANL), Robert Spalek (UC Berkeley), Rob Spekkens (Cambridge), Jake Taylor (MIT), Frank Verstraete (Vienna), Guifre Vidal (Queensland), Lorenza Viola (Dartmouth),

Andreas Winter (Bristol), and Pawel Wocjan (Central Florida). Twelve students from other institutions also visited us: Jan von Delft (Ludwig Maximilian U.), Bryan Eastin (U. New Mexico), Lara Faoro (Rutgers), Steve Flammia (U. New Mexico), Durdu Guney (UCSD), Stephen Jordan (MIT), Yi-Kai Liu (UCSD), Nicolas Menicucci (Princeton), Markus Mueller (TU Berlin), Gordon Ritter (Harvard University), Stephanie Wehner (CWI), and Andreas Weichselbaum (Ludwig Maximilian U.). 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. Kitaev's group works on quantum complexity, quantum coding, and the interface of quantum information with quantum many-body theory. 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. 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 and Lesik Motrunich 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 46 publications since our last annual report in 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. Seven IQI students will receive Ph.D. degrees in 2007 (Panos Aliferis, John Au, Andrew Berglund, Parsa

Bonderson, John Stockton, Ramon Van Handel, and Michael Zwolak). 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 Kitaev also sponsored undergraduate research programs in quantum information science.

In 2006-07, Preskill and Kitaev co-taught a course on quantum computing offered by Caltech's physics and computer science departments. Lecture notes and homework assignments are posted at the much visited course website: http://www.theory.caltech.edu/~preskill/ph219/ph219_2006-07.

IQI co-hosted at Caltech the 9th annual meeting of SQuInT, the Southwest Quantum Information and Technology Network, on February 16-18, 2007. This workshop brought together over 100 scientists for research presentations and tutorial talks on quantum information science.

Invited Talks

IQI participants have presented many invited talks at seminars and conferences during 2006-07. Here is an incomplete list:

Panos Aliferis: Quantum Information Processing 2007, Brisbane (February 2007), NEC Princeton Labs and Rutgers University (November 2006), University of Waterloo (July 2006).

Robin Blume-Kohout: McGill University (December 2006), Cambridge University (October 2006), University of Alaska-Fairbanks (September 2006), Benasque Center for Science (June 2006).

Parsa Bonderson: Perimeter Institute (January 2007), McMaster University Physics Colloquium (January 2007), Microsoft Station Q (February 2007).

Luc Bouten: Spring School on Quantum Potential Theory (five two-hour lectures), Greifswald, Germany (February – March 2007), Quantum Probability Information and Control symposium, Nottingham UK (July 2006).

Andrew Childs: UC Davis (May 2007), University of Bristol (March 2007), Western States MaQuantum Information Processing 2007, Brisbane (January 2007). Workshop on Quantum Algorithms for Algebraic Problems, Banff International Research Station (September 2006), Los Alamos National Laboratory (July 2006), University of Southern California (April 2007), University of New Mexico (March 2007), University of Oxford (March 2007), University of Washington (March 2007), NEC Labs America (February 2007) University of Waterloo (February 2007), UC San Diego (January 2007).

Kovid Goyal: Workshop on Measurement-Based Quantum Computing, Oxford (March 2007).

Jeff Kimble: 20th International Conference on Atomic Physics Summer School (3 lectures), Innsbruck (July 2006), International Conference on Atomic Physics (ICAP-2006) Innsbruck (July 2006), 2006 US-Japan Workshop on Quantum Information Science, Maui (October 2006), Quantum Optics III Conference, Chile (November 2006), Workshop on Quantum Electromechanical Systems (QEM-2), Morro Bay, CA (December 2006). University of Colorado at Boulder (February 2007). Conference on Lasers and Electro-Optics/Quantum Electronics and Laser Science Conference (CLEO/QELS-07), Baltimore, MD (May 2007).

Alexei Kitaev: Summer School on Quantum Magnetism (3 lectures), Les Houches (June 2006), IPAM workshop on Topological Quantum Computation, UCLA (February 2007), KITP Conference on Strongly Correlated Phases in Condensed Matter and Degenerate Atomic Systems, UCSB (April 2007).

John Preskill: IPAM workshop on Topological Quantum Computation, UCLA (February 2007), Workshop on the Computational Worldview and the Sciences, Caltech (March 2007).

David Poulin: University of Southern California (April 2007), University of Sherbrooke (January 2007), INTRIQ (3 lectures), University of Montreal (January 2007), Perimeter Institute, Waterloo (October 2006), IQC, University of Waterloo (October 2006), University of New Mexico (October 2006), Los Alamos National Laboratory (October 2006).

Ben Reichardt: University of New Mexico (September 2006), FOCS 2006, Berkeley, (October 2006), MIT (November 2006), Quantum Information Processing 2007, Brisbane (February 2007).

Leonard Schulman: Banff International Research Station (September 2006).

Graeme Smith: University of Waterloo (September 2006), IBM T. J. Watson Research Center (August 2006).

Ben Toner: University of Queensland (September 2006).

Frank Verstraete: Stanford University (June 2006). Gordon Research Conference on quantum information, Il Ciocco (October 2006).

Pawel Wocjan: IBM T. J. Research Center (July 2006).

Shengyu Zhang: Microsoft Research Asia, Tsinghua University (April 2007), NEC Laboratories America (April 2007).

Michael Zwolak: University of Karlsruhe (2007), Los Alamos National Laboratory (2007).