Institute for Quantum Information
Activities — 2009–2010

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, Feynman Professor of Theoretical Physics), Alexei Kitaev (co-PI, Professor of Physics and Computer Science), Leonard Schulman (co-PI, Professor of Computer Science), Gil Refael (co-PI, Associate Professor of Theoretical Physics), and Jeff Kimble (Valentine Professor of Physics). Administration of the IQI is supervised by Ann Harvey (IQI Administrative Assistant).

During 2009–10, eleven IQI postdoctoral scholars were in residence: Salman Beigi, Sergio Boixo, Darrick Chang, Lukasz Fidkowski, Liang Jiang, Stephen Jordan, Robert König, Nate Lindner, Yi-Kai Liu, Norbert Schuch, and Stephanie Wehner. Boixo, Fidkowski, Liu, and Wehner were largely supported by NSF, while Chang, Jiang, Schuch, and Jordan were primarily supported by Caltech’s prize postdoctoral fellowship programs, König and Lindner had outside fellowships, and Beigi was mostly supported by another award. In 2010–11, Boixo, Fidkowski, Liu, and Wehner will depart, while Steve Flammia (Perimeter Institute), Alexey Gorshkov (Harvard), and Spiros Michalakis (LANL) will join IQI. About 15 Caltech students (both graduate and undergraduate) also participated in the project.

The IQI has some associate members, faculty at other universities who visit frequently. The current IQI Associates are Todd Brun (USC), Steven van Enk (Oregon), Sandy Irani (UCI), Daniel Lidar (USC), and Kirill Shtengel (UC Riverside). Brun, who was on sabbatical from USC, resided at IQI during much of 2009–10. Peter Love, on sabbatical from Haverford College, also visited the IQI for seven months.

In July 2009, the IQI moved into the Annenberg Center for Information Science and Technology, a newly constructed building on the Caltech campus. This beautiful facility unites Caltech faculty, students, postdocs, visitors, and students under one roof, enhancing our interactions and productivity.
Visiting Scholars and Workshop

The IQI sponsors a vigorous visitor’s program. Thirty-three scholars visited the IQI in 2009–10: Miguel Aguado (MPQ), Mohammad Amin (D-Wave), Joseph Avron (Technion), Erez Berg (Harvard), Robin Blume-Kohout (Perimeter), Paul Fendley (Virginia), Alexey Gorshkov (Harvard), Gus Gutoski (Waterloo), Richard Harris (D-Wave), Mohammad Hafezi (Maryland), Chris Heunen (Oxford), Liza Huijse (Amsterdam), Israel Klich (U. Virginia), Kaveh Khodjasteh (Dartmouth), Christina Kraus (MPQ), John Kubiatowicz (Berkeley), Eric Ladizinsky (D-Wave), Peter Love (Haverford), Keith Lee (Pittsburgh), Debbie Leung (Waterloo), Spiros Michalakis (LANL), Antonello Polosa (INFN), Ben Reichardt (Waterloo), Joe Renes (Darmstadt), Geordie Rose (D-Wave), Terry Rudolph (Imperial), Tony Short (Cambridge), Rolando Somma (LANL), Tom Stace (Queensland), Sarvagya Upadhyah (Waterloo), Jon Walgate (Perimeter), Pawel Wocjan (U. Central Florida), and Shengyu Zhang (Hong Kong). The IQI pays the travel and local expenses for most of our visitors.

In addition to our regular visitors program, in March 2010 the IQI hosted a Workshop on Cryptography from Storage Imperfections. This workshop brought together theorists and experimentalists to explore the promise of cryptographic protocols whose security rests on assumptions about limitations on the size or accuracy of the adversary’s quantum memory. These protocols can achieve secure two-party computation and secure password-based identification. Topics addressed at the workshop included: Can these tasks be performed using low-power portable devices? How should we model the noise in an imperfect quantum memory, and can security proofs be extended to more general types of noise? Can more efficient protocols be constructed? Invited speakers at the workshop included Matthias Christandl (LMU, Munich), Marcos Curty (Vigo), Nilanjana Datta (Cambridge), Serge Fehr (Amsterdam), Mark Godfrey (Bristol), Richard Hughes (LANL), Masato Koashi (Osaka), Martin Kristensen (Aarhus), Christian Kurtsiefer (Singapore), Norbert Lütkenhaus (Waterloo), Joe Renes (Darmstadt), Renato Renner (ETH Zurich), Louis Salvail (Aarhus), Graeme Smith (IBM), Wolfgang Tittel (Calgary), Thomas Vidick (Berkeley), Harald Weinfurter (LMU, Munich), Andreas Winter (Bristol/Singapore), and Juerg Wullschleger (Bristol).

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, and on the manipulation of quantum opto-mechanical systems. Refael’s group studies connections between quantum entanglement theory and condensed matter physics. 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: Matthew Fisher and Lesik Motrunich in quantum many-body theory, Jim Eisenstein in experimental topological quantum computation, Eric Rains in discrete mathematics, Chris Umans in computational complexity, Yanbei Chen in the theory of quantum nondemolition measurement, Kerry Vahala in semiconductor quantum optics, Oskar Painter in nanostructures and photonic crystals, and Keith Schwab in quantum-limited nanomechanical devices.

IQI participants have produced 49 publications since our last annual report in May 2009. 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, Preskill, Refael, and Schulman are training graduate students working on both the theoretical and experimental sides of QIS – a total of over 15 students. Furthermore, students from outside Caltech visit the IQI and collaborate with our researchers. The Caltech students and the visiting students benefit greatly from the interdisciplinary spirit of the IQI. Preskill and Refael also sponsored undergraduate research programs in quantum information science. In 2010, Preskill developed a novel introductory course in quantum physics for Caltech sophomores, emphasizing the information-theoretic aspects of the subject. The IQI also organizes a weekly seminar attended by students, postdocs, and faculty.

**Talks**

IQI participants have presented many invited talks at seminars and conferences during 2009-10. Here is an incomplete list:

- Sergio Boixo: Universidad Autonoma de Barcelona (August 2009), ICFO, Barcelona (August 2009), Universidad Complutense, Madrid (August 2009), Perimeter Institute (August 2009), Workshop on Quantum Information Processing, Zurich (January 2010), Harvard (February 2010).
2010), National University of Singapore (March 2010), USC (March 2010), APS March Meeting, Portland (March 2010).


Lukasz Fidkowski: Dresden MPKS workshop on topological phases (July 2009), Microsoft Station Q seminar (November 2010), Boston College (January 2010), Banff International Research Station Conference: Quantum Computation with Topological Phases of Matter (July 2009).


Stephen Jordan: NIST Mathematical and Computational Sciences Division Seminar Series, Gaithersburg MD (February 2010), Sandia National Laboratories, Albuquerque NM (February 2010), Kavli Institute Program in Quantum Information Science, Santa Barbara CA (September 2009), Workshop on Quantum Computation and Quantum Spin Systems, Erwin Schrodinger Institute, Vienna (August 2009). Conference on Complexity Resources in Quantum Computation, Oxford (August 2009),


Alexei Kitaev: Topological Order: From quantum Hall systems to magnetic materials Dresden (June 2009), Condensed matter physics meets high energy physics, University of Tokyo (February 2010), L.D.Landau Institute for Theoretical Physics, Moscow (April 2010), Cornell University (May 2010).

Robert König: Workshop on Cryptography from Storage Imperfections, Caltech (March 2010), Station Q Seminar, Santa Barbara (February 2010),


Yi-Kai Liu: Quantum information seminar, Berkeley (April 2010), Quantum information seminar, USC (March 2010), Workshop on Complex Quantum Systems, Institute for Mathematical
Sciences, National Univ. of Singapore (March 2010), Quantum information seminar, National Institute of Standards and Technology (January 2010), Workshop on Quantum Marginals and Density Matrices, Fields Institute (July 2009).

Prabha Mandayam: Indian Institute of Technology, Chennai, India (November 2009), Indian Institute of Science, Bangalore, India (November 2009) Institute of Mathematical Sciences, Chennai, India (December 2009).

Nate Lindner: 12th Annual SQuInT Workshop Santa Fe, New Mexico (February 2010).

John Preskill: NSA Workshop, Caltech (September 2009), Annenberg Center Dedication, Caltech (October 2009), Kavli Institute for Theoretical Physics, Santa Barbara (December 2009), IST Lunch Bunch, Caltech (February 2010), QuEST, Washington, DC (April 2010).

Gil Refael: MPIPKS, Dresden (July 2009), PCTP, Princeton University (September 2009), Harvard University (December 2009), U. British Columbia (March 2010), University of Utah (April 2010),


Stephanie Wehner: Workshop on Operator Structures in Quantum Information, Fields Institute, Toronto (June 2009), Workshop on Quantum Cryptography and Non-locality, Singapore (November 2010), DOE Roundtable on Cybersecurity, San Francisco (March 2010), APS March Meeting, Portland (March 2010), University of Bristol (September 2009), Imperial College (October 2009), National University of Singapore (November 2009), ETH Zurich (January 2010), Perimeter Institute (April 2010).