

# Institute for Quantum Information

## Activities — 2008–2009

### 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 Gil Refael (Associate Professor of Theoretical Physics). Administration of the IQI is supervised by Ann Harvey (IQI Administrative Assistant).

During 2008–09, eight IQI postdoctoral scholars were in residence: Sergio Boixo, Darrick Chang, Lukasz Fidkowski, Stephen Jordan, Robert König, Liang Kong, Yi-Kai Liu, Stephanie Wehner. Boixo, Fidkowski, König, Liu, and Wehner were primarily supported by NSF (in Liu's case, by an NSF postdoctoral fellowship that was not funded by IQI), while Chang, Jordan, and Kong were primarily supported by Caltech's prize postdoctoral fellowship programs. In 2008–09, Kong will depart, while Salman Beigi (MIT), Liang Jiang (Harvard), Nate Lindner (Technion), and Norbert Schuch (MPQ) will join IQI. About 20 Caltech students (both graduate and undergraduate) also participated in the project.

The IQI also 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). Irani and Lidar, who were both on sabbatical from their home universities, resided at IQI full time during 2008–09.

In 2009 IQI established an external advisory committee. The current members are Carlton Caves (UNM), Michael Freedman (Microsoft), Umesh Vazirani (Berkeley), and Peter Zoller (Innsbruck).

### Visiting Scholars and Students

The IQI sponsors a vigorous visitor's program. Twenty-five senior and postdoctoral scholars visited the IQI in 2008–09: Miguel Aguado (MPQ), Andris Ambainis (Latvia), Mohammad Amin (D-

Wave), Dave Bacon (U. Washington), Stephen Bartlett (Sydney), Sergey Bravyi (IBM), Andrew Daley (Innsbruck), Luming Duan (Michigan), Matthew Elliott (U. Southern Indiana), Steve Flammia (Perimeter), Daniel Gottesman (Perimeter), Klemens Hammerer (Innsbruck), Avinandan Hassidim (MIT), Stefan Kehrein (Munich), Roderich Moessner (Dresden), Jonathan Oppenheim (Cambridge), Christian Schaffner (CWI), Norbert Schuch (MPQ), Tony Short (Cambridge), Frank Verstraete (Vienna), Guifre Vidal (Queensland), Margareta Wallquist (Innsbruck), Joerg Wullschleger (Bristol), Shoucheng Zhang (Stanford), Peter Zoller (Innsbruck). Nine students from other institutions also visited us: Hamed Ahmadi (U. Central Florida), Salman Beigi (MIT), Hector Bombin (Madrid), Glen Evenbly (Queensland), Zhengcheng Gu (MIT), Netanel Lindner (Technion), Volkher Scholz (Hannover), Thomas Vidick (Berkeley), Yi Zhao (Toronto). 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. 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: Lesik Motrunich in quantum many-body theory, Jim Eisenstein in experimental topological quantum computation, Eric Rains in discrete mathematics, John Doyle in control theory, Yanbei Chen and Kip Thorne in the theory of quantum nondemolition measurement, Kerry Vahala in semiconductor quantum optics, Oskar Painter and Axel Scherer in nanostructures and photonic crystals, and Michael Roukes and Keith Schwab in quantum-limited nanomechanical devices.

IQI participants have produced 37 publications since our last annual report in May 2008. 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 20 students. As already noted, 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. Preskill and Refael also sponsored undergraduate research programs in quantum information science. The IQI organizes a weekly seminar attended by students, postdocs, and faculty.

## Invited Talks

IQI participants have presented many invited talks at seminars and conferences during 2008-09. Here is an incomplete list:

Sergio Boixo: SQuInT 2009: Southwest Quantum Information and Technology Eleventh Annual Meeting, Seattle WA (February 2009), Universidad Autonoma de Barcelona (March 2009).

Darrick Chang: Workshop on Open Quantum Systems: Decoherence and Control, Harvard ITAMP (November 2008), National Taiwan University (February 2009).

Bill Fefferman: NEC Labs Quantum IT group, Princeton NJ (October 2008).

Lukasz Fidkowski: Banff International Research Station Conference: Quantum Computation with Topological Phases of Matter (July 2009), UC Santa Barbara (March 2009).

Stephen Jordan: MIT (May 2009), UC Berkeley (April 2009), Perimeter Institute (April 2009).

Alexei Kitaev: L.D.Landau Memorial Conference: Advances in Theoretical Physics, Chernogolovka, Russia (June 2008), 24th Solvay Conference in Physics: Quantum Theory of Condensed Matter, Brussels, Belgium (October 2008), Quantum Spin Hall Effect and Topological Insulators, KITP Santa Barbara (December 2008), Modular Categories and Applications, Indiana University (March 2009), 2008 Les Houches Summer School: Exact methods in low-dimensional physics and quantum computing (July 2008).

Liang Kong: Conference on Topological Field Theory, Northwestern University (May 2009), Univ. of Michigan (April 2009), Univ. of Utah (April 2009).

Robert König: QIP 2009: Twelfth Workshop on Quantum Information Processing, Santa Fe NM (January 2009), CIFAR quantum information processing program, Caledon, Ontario (May 2009), SQuInT 2009: Southwest Quantum Information and Technology Eleventh Annual Meeting, Seattle WA (February 2009).

Yi-Kai Liu:

XQIT Conference on Difficult Problems in Quantum Information Theory, MIT (November 2008), QIP 2009: Twelfth Workshop on Quantum Information Processing, Santa Fe NM (January 2009), University of Waterloo (June 2008), UC San Diego (July 2008), Institute for Advanced Study (November 2008).

Hui Khoon Ng: Centre for Quantum Technologies Seminar, National University of Singapore (two talks, September 2008).

John Preskill: Physics Colloquium UC Riverside (June 2008), Caltech Frosh Camp Keynote Address, Ventura CA (September 2008), QUINCE: QUantum INformation conferenCE 2008, Annapolis, MD (September 2008), Categorically Not Public Lecture, Santa Monica CA (October 2008), Workshop on Quantum Information Science, Vienna VA (April 2009), 2009 H. L. Welsh Lectures in Physics, University of Toronto (two lectures, May 2009), TQC 2009: 4th workshop on theory of quantum computation, communication, and cryptography, Waterloo, Canada (May 2009), Caltech Alumni Seminar Day (May 2009).

Stephanie Wehner: TQC 2009: 4th workshop on theory of quantum computation, communication, and cryptography, Waterloo, Canada (May 2009), WQACT 2008: Workshop on quantum algorithms and complexity theory, Singapore (November 2008), CIFAR quantum information processing program, Kelowna, Canada (November 2008), Workshop on information primitives and laws of nature, Zurich (November 2008), Perimeter Institute (May 2009), University of Queensland (September 2008), University of Toronto (July 2008).