

Institute for Quantum Information

Activities — 2007-2008

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 (Assistant Professor of Theoretical Physics). Previously, Hideo Mabuchi (Associate Professor of Physics and Control and Dynamical Systems) had also been a co-PI, but Mabuchi has departed Caltech; meanwhile, Refael has arrived at Caltech and he has joined the IQI team. Administration of the IQI is supervised by Ann Harvey (IQI Administrative Assistant).

During 2007–08, nine IQI postdoctoral scholars were in residence for at least part of the year: Eddy Ardonne, Luc Bouten, Lukasz Fidkowski, Robert König, Yi-Kai Liu, David Poulin, Ben Reichardt, Stephanie Wehner, and Shengyu Zhang. Fidkowski, König, Liu, and Wehner were fully supported by NSF (in Liu's case, by an NSF postdoctoral fellowship that was not funded by IQI), Bouten, Reichardt, and Zhang were partially supported by grants from other agencies, and Ardonne and Poulin were primarily supported by Caltech's prize postdoctoral fellowship programs. In 2008–09, Ardonne, Bouten, Poulin, Reichardt, and Zhang will depart, while Sergio Boixo, Derek Chang, and Stephen Jordan will join IQI. About 25 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), Kirill Shtengel (UC Riverside). Two new IQI Associates, Daniel Lidar (USC) and Sandy Irani (UC Irvine) will be in residence during 2008–09.

Visiting Scholars and Students

The IQI sponsors a vigorous visitor's program. Twenty-nine senior and postdoctoral scholars visited the IQI in 2007–08: Panos Aliferis (IBM), Charles Bennett (IBM), Robin Blume-Kohout (Perimeter), Jean Christian Boileau (Toronto), Parsa Bonderson (Microsoft), Nicolas Cerf (Brussels), Wim van Dam (UCSB), Berge Englert (Singapore), Daniel Gottesman (Perimeter), Aram Harrow (Bristol), Matthew Hastings (LANL), Rahul Jain (Waterloo), Raymond Laflamme (Waterloo), Debbie Leung (Waterloo), Peter Love (Haverford), Carlos Mochon (Perimeter), Joel Moore (Berkeley), Eduardo Novais (Duke), Jonathan Oppenheim (Cambridge), Apoorva Patel (Indian Institute of Science), Frank Pollmann (Berkeley), Alex Russell (U. Conn.), Ulrich Schollwöck (Aachen), Graeme Smith (IBM), Frank Verstraete (Vienna), Guifre Vidal (Queensland), Pawel Wocjan (U. Central Florida), William Wootters (Williams), Shoucheng Zhang (Stanford). Seven students from other institutions also visited us: Sergio Boixo (UNM), Darrick Chang (Harvard), Lara Faoro (Rutgers), Liang Jiang (Harvard), Nicolas Menicucci (Princeton), Falk Unger (CWI), Lucy Zhang (Perimeter). 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 in quantum-limited nanomechanical devices.

IQI participants have produced 41 publications since our last annual report in May 2007. 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 Kitaev also sponsored undergraduate research programs in quantum information science.

The IQI organizes a weekly seminar attended by students, postdocs, and faculty. We also co-sponsored the First International Conference on Quantum Error Correction (QEC07), held at USC December 17–21, 2007.

Budget Discussion

The IQI budget for the three year period from September 2005 to August 2008 is \$1.8 million, of which \$600K is budgeted for the current year. Over the three-year period of this award, these funds have been allocated as follows (amounts are approximate):

Postdoctoral scholars	46%
Students	13%
Faculty salaries	12%
Visitor support	15%
Support Staff	7%
Travel	3%
Equipment and miscellaneous	4%

Invited Talks

IQI participants have presented many invited talks at seminars and conferences during 2007-08. Here is an incomplete list:

Kovid Goyal: First International Conference on Quantum Error Correction, QEC07, USC (December 2007).

Jeff Kimble: International Conference on Quantum Information, ICQI (June 2007), Photons, Atoms, and Qubits Conference, PAQ07 (September 2007).

Robert König: ETH Zurich (December 2007), Quantum Information Technology Symposium (QIT18), Tokyo (May 2008).

Alexei Kitaev: First International Conference on Quantum Error Correction, QEC07, USC (December 2007).

David Poulin: Quantum Information Processing and Communication, Barcelona, (October 2007), First international conference on quantum error correction, QEC07, USC (December 2007), The University of Queensland, St-Lucia, Australia (January 2008), Sydney quantum information theory workshop, Coogee, Australia (January 2008), Southwest quantum information and technology, Santa Fe (February 2008), Classical and quantum information theory, Santa Fe (March 2008).

John Preskill: Fault-Tolerant Quantum Computation II, Perimeter Institute (June 2007), When Matter Meets Information, Perimeter Institute (June 2007), UC Santa Barbara (September 2007), First International Conference on Quantum Error Correction, QEC07, USC (December 2007), APS March Meeting, New Orleans (March 2008), Classical and Quantum Information Theory, Santa Fe (March 2008), UC Berkeley (April 2008), Microsoft Station Q, Santa Barbara (April 2008), Frontiers in Quantum Computation, Princeton Institute for Theoretical Physics (April 2008).

Ben Reichardt: Conference on Quantum Information Science, AQIS, (September 2007), Foundations of Computer Science (FOCS) (October 2007), NEC/Rutgers joint seminar (October 2007), Quantum information processing (QIP) 2008 (December 2007), UC Berkeley (February 2008, March 2008), U. Waterloo (February 2008), UC Davis (March 2008), USC (April 2008).

Shengyu Zhang: Chinese University of Hong Kong (February 2008), U. Michigan (April 2008).