The Quantum Times

Volume 5, Number 4
First Quarter, 2011

Newsletter of the Topical Group on Quantum Information

American Physical Society

Inside this issue

Quantum Information: the crossroads of modern science

Ian T. Durham

Quantum information is an interesting field for many reasons, not the least of which is because it brings together a menagerie of disciplines (including physicists, computer scientists, mathematicians, chemists, engineers, and even a few philosophers) in a single field of endeavor. What is particularly exciting is that the addition of the information paradigm ('it' from 'bit') to quantum theory has helped to broaden its explanatory power and range of applicability. For example, while it is highly likely that the relatively new sub-discipline of quantum biology would have matured irrespective of any influence from quantum information, there is no arguing that quantum information has influenced its recent development.

Within the discipline of quantum information itself, as in most of the empirical sciences, any division tends to ignore the disciplinary differences in favor of a division into experimentalist and theorist groupings. In certain cases (e.g. Anton Zeilinger) the line between experimentalist and theorist remains blurred. It is often at this interface that the field realizes some of its most profound results. This is where game-changing discoveries are often made. What is additionally interesting about this is that it also often marks the meeting point of two very different kinds of science – formal and empirical†.

The formal sciences, which include computer science as well as mathematics and logic, are those sciences concerned with formal systems. Formal systems, sometimes called axiomatic systems, generally consist of a formal language and a set of rules of inference that are used to derive an expression from one or more premises. Such premises are either supposed (and thus known as axioms) or derived (and thus known as theorems). By their very nature, formal sciences and systems should (in principle) be entirely self-consistent; no branch of mathematics is inconsistent with any other branch of mathematics. As it was put to me by a mathematician, mathematics is about as close as one can get to the Platonic ideal.

The empirical sciences, on the other hand, which include physics and chemistry, are those sciences that chiefly employ the scientific method in the investigation of physical (i.e. natural) phenomena. As such, while they do adhere to specific principles of reasoning, they also rely heavily on observable, empirical, and measurable evidence. As the foundation for all other natural sciences, physics is sometimes taken as being a pure, unadulterated application of the scientific method, breaking phenomena down into their smallest constituent explanatory 'chunks' before reassembling the larger picture.

Nevertheless, attempts have been made throughout history to axiomatize physics. To some extent, this has helped fuel the mutual development of mathematics and physics. Indeed, it is difficult to find two disciplines whose

Continued on next page

†I use the term 'empirical' in place of the usual 'natural' as a way to emphasize the methodological differences.

histories are so intertwined. But, thus far, all attempts to axiomatize physics have failed. In addition, unlike mathematics which is entirely self-consistent, arguably the two greatest achievements in twentieth-century physics - quantum mechanics and general relativity - are seemingly incompatible (at least in their present forms) and yet both match experiment to a high degree. Since mathematics *is* entirely self-consistent, one might expect that the way to reconcile these two theories is by reconciling the mathematics of each. But we can't forget that, when modeling something physical, the mathematics *must* be grounded in physical arguments. The fact is that there are mathematical results that simply *can't* correspond to reality§. This then raises the intriguing question, what *is* the descriptive limit of the formal sciences such as mathematics? Of course, quantum information science is one of many fields capable of probing this limit (one might argue that any attempt to experimentally realize quantum computation does so).

Testing the descriptive limit of mathematics and logic is more than merely experimentally testing theories, however. Every well-developed theory in physics has a mathematical foundation and all will end up being tested at some point since physics is ultimately a *physical* science. What makes quantum information unique is that in order to bring quantum information technology to fruition, we have no choice but to probe the limits of quantum physics. Indeed, quantum information itself essentially exists on the 'edge' of quantum phenomena, as it were, while simultaneously being at a cross-roads of sorts, between the formal and the empirical. Consider that all classical computers ultimately rely on quantum processes (semiconductors are quantum devices) but hardly push any serious boundaries within the quantum realm. Quantum information, on the other hand, has both theoretically and experimentally pushed the boundaries of quantum physics. For example, consider that quantum information has introduced us to quantum teleportation and the no cloning theorem. In fact, let's take a closer look at the no cloning theorem in order to get a better sense of just how quantum information can be used to probe the descriptive limits of formal systems.

A quantum cloning machine, if it were to exist, would allow us to create multiple-copy states that can more easily be distinguished than single-copy states [1]. The no-cloning theorem essentially says such machines cannot exist. More specifically, suppose we have three subsystems representing the input system (system to be copied), A, the output system, B, and the cloning machine, C. The no-cloning theorem states that no unitary cloning machine exists that works on arbitrary initial states of input A. This theorem was first proved by Wootters and Zurek [2], and independently by Dieks [3], in 1982. In theory every step of these proofs has an underlying physical assumption. The question is, how many of these physical assumptions are *necessary* for the proof? In Dieks' proof, for example (see [1] for a nice comparison of the two), inner product states are preserved because the time evolution is unitary. Our only rationale for assuming that the time evolution is unitary is based on our empirical observation that nature works this way. In other words, the contradiction used to show the impossibility of cloning only arises because we have empirical evidence that time evolution in quantum mechanics is a unitary process. One could argue that the additional assumption that the initial state of the combined subsystem BC does not depend on the initial state of A is also a physical argument, but that is a more tenuous claim; i.e. it is entirely plausible to imagine the same assumption being made on mathematical grounds. Thus, if we deconstruct Dieks' proof, we find that only one physical assumption is *necessary* for completion of the proof. While mathematics dominates - and very nearly does it all - *mathematics alone simply doesn't work.*

No-cloning is an example of mathematics going not quite far enough. By itself, mathematics leaves us at a proverbial fork-in-the-road and we need physical guidance on which route to take. Conversely, sometimes mathematics can lead us a bit *too* far and we need physical guidance on where to stop. As a very simple example of this, consider that the Pauli matrices when generalized to describe spin-1 particles, have eigenvalues of 1, 0, and -1. These eigenvalues represent the possible outcomes for a measurement of spin in a given direction and so we discard the 0 eigenvalue as being unphysical since we're describing spin-1 particles.

These are very simple examples merely meant to convey the subtle sense of interplay between the formal and empirical aspects of quantum information. As the field matures and the breadth of our implementations increases, we will undoubtedly witness further refinements to this interplay.

With that said, there are still subtler divisions within the field, all a clear sign of a vibrant and healthy scientific community. One interesting division gets at the heart of the entire field of endeavor: what constitutes a quantum computer. We are all familiar with D-Wave's efforts to implement an adiabatic quantum computer. Though Google

§As a simple example, consider the mathematical notion of a four-vector. Mathematically, it is entirely possible for the square of the magnitude of such a vector to be negative. In special relativity, four-momentum is a four-vector whose magnitude is the mass of the object possessing that four-momentum. On purely physical grounds, we assume that the square of the magnitude of the four-momentum can't be negative since that would imply a complex value for the mass (more accurately, particles whose mass is complex in this sense, are said to be 'off mass-shell' and are thus considered to be virtual particles).

As a second even simpler (and actually related) example, also from special relativity, consider how we mathematically treat time as simply another dimension. Mathematically, nothing should prevent objects from moving backward in time (since they can move backward in any other dimension). But we never experience time running backward and so we add a *physical* caveat to our mathematical results.

now employs D-Wave's chip noting that, whatever it is, it is better than anything they've seen, the jury is still out within the community as to whether or not this truly constitutes quantum computing. At last year's (2010) QIP meeting in Zürich, one physicist noted that, to him, a quantum computer must be coherent, i.e. that it must be capable of maintaining and manipulating coherent superpositions of quantum states. Several groups have made strides toward the goal of realizing such a system. Most recently researchers at the National Institute of Standards and Technology (NIST) in Boulder, Colorado developed a programmable two-qubit quantum computer. But it is safe to say that the question is not entirely closed. Given the tremendous theoretical predictions of quantum information science, suffice it to say that, at some point or another, we'll *all* be able to look at a particular piece of technology and say "*That* is a quantum computer!" In other words, we'll know it when we see it.

Nevertheless, the debate itself is healthy and, whatever one thinks of D-Wave's claims, they have clearly built a product that someone (namely Google) finds commercially useful. Since that product is a result of work in the field of quantum information, it can be added to the growing list of technologies the field has spawned (others include commercially available quantum cryptography devices, for instance). All of this is good for the field since it not only ties quantum information to marketable technologies (which is a good way to convince the general public that the field is worth funding) but also because it generates discussion and debate which are the hallmarks of good science.

It's an exciting time to be a quantum information scientist, whether your interests lie in experiment or theory, whether you are a lab rat or an esoteric foundationalist (or both, if you're Anton Zeilinger), or whether you're a physicist, computer scientist, chemist, or mathematician. One can't help but feel that we are on the edge of something really big. To quote Hall of Fame (American) football coach Marv Levy [4], "Where else would you rather be than right here, right now?"

References

1. B. Schumacher and M. Westmoreland. *Quantum Processes, Systems, & Information*. Cambridge University Press, Cambridge, 2010.
2. W.K. Wootters and W.H. Zurek. A single quantum cannot be cloned. *Nature*, 299:802-803, 1982.
3. D. Dieks. Communication by EPR devices. *Phys. Lett. A*, 92(6):271-272, 1982.
4. Levy famously said this before nearly every game he coached and so its exact form varied. Levy later published his memoir with the title *Where Else Would You Rather Be?* (Sports Publishing, LLC, 2004).

Ian Durham *is the founding editor of The Quantum Times. When not writing and editing The Times, he is Associate Professor and Chair of the Department of Physics and Director of the Computational Physical Sciences Program at Saint Anselm College in Manchester, New Hampshire. He lives on the coast of Maine with his family and is originally from just outside of Buffalo, New York. As such, he is a lifelong fan of Buffalo sports and often pines for the good-old-days when Marv Levy served as head coach of the Buffalo Bills.*

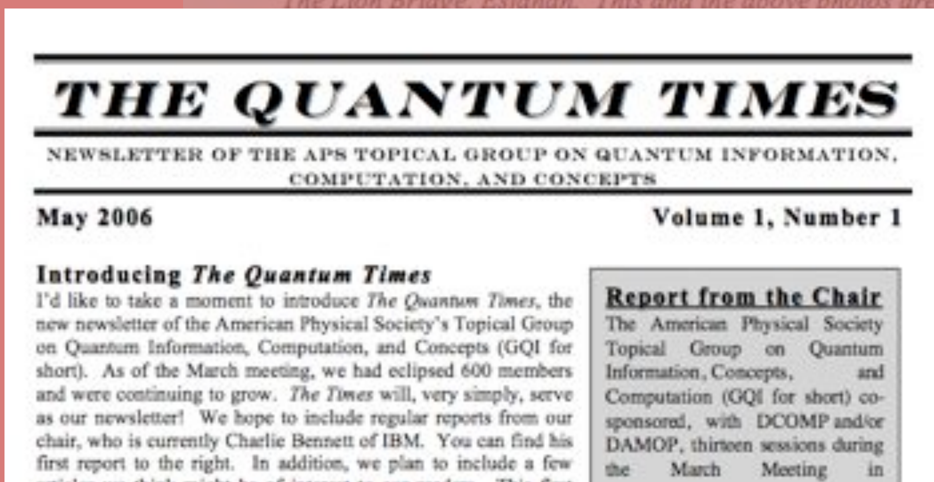
Quantum mascots

Courtesy Lídia del Rio

See pages 10 & 11 for associated conference announcements

Celebrating Five Years of GQI and *The Quantum Times*

The Lion Bridge, Esfahan. This and the above photos are courtesy Lorenzo Maccone, ...erg as well as others at



THE QUANTUM TIMES

NEWSLETTER OF THE APS TOPICAL GROUP ON QUANTUM INFORMATION, COMPUTATION, AND CONCEPTS

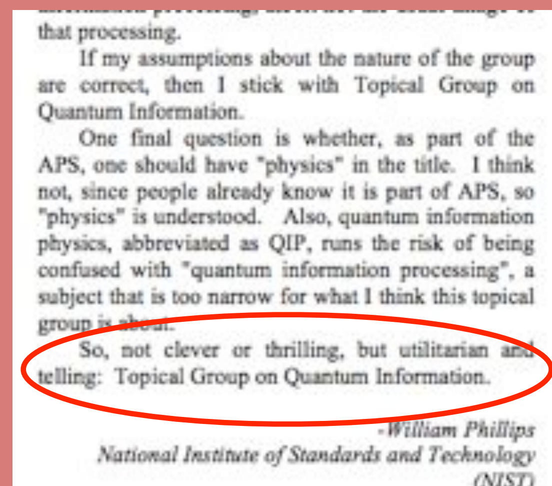
May 2006 Volume 1, Number 1

Introducing *The Quantum Times*

I'd like to take a moment to introduce *The Quantum Times*, the new newsletter of the American Physical Society's Topical Group on Quantum Information, Computation, and Concepts (GQI for short). As of the March meeting, we had eclipsed 600 members and were continuing to grow. *The Times* will, very simply, serve as our newsletter! We hope to include regular reports from our chair, who is currently Charlie Bennett of IBM. You can find his first report to the right. In addition, we plan to include a few

Report from the Chair

The American Physical Society Topical Group on Quantum Information, Concepts, and Computation (GQI for short) co-sponsored, with DCOMP and/or DAMOP, thirteen sessions during the March Meeting in



that processing.

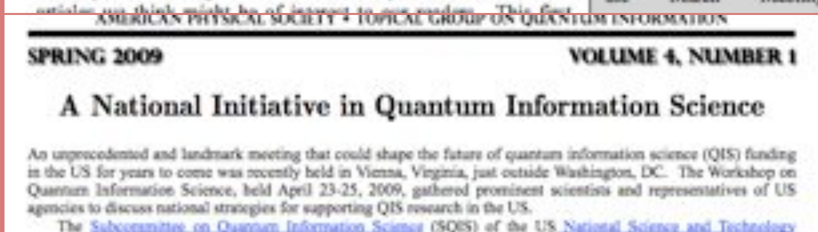
If my assumptions about the nature of the group are correct, then I stick with Topical Group on Quantum Information.

One final question is whether, as part of the APS, one should have "physics" in the title. I think not, since people already know it is part of APS, so "physics" is understood. Also, quantum information physics, abbreviated as QIP, runs the risk of being confused with "quantum information processing", a subject that is too narrow for what I think this topical group is about.

So, not clever or thrilling, but utilitarian and telling: Topical Group on Quantum Information.

-William Phillips
National Institute of Standards and Technology (NIST)

From Volume 1, Number 3



AMERICAN PHYSICAL SOCIETY • TOPICAL GROUP ON QUANTUM INFORMATION

SPRING 2009 VOLUME 4, NUMBER 1

A National Initiative in Quantum Information Science

An unprecedented and landmark meeting that could shape the future of quantum information science (QIS) funding in the US for years to come was recently held in Vienna, Virginia, just outside Washington, DC. The Workshop on Quantum Information Science, held April 23-25, 2009, gathered prominent scientists and representatives of US agencies to discuss national strategies for supporting QIS research in the US.

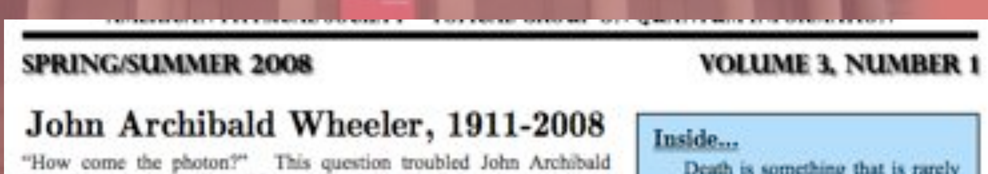
The Subcommittee on Quantum Information Science (SQIS) of the US National Science and Technology

Back issues

All back issues of *The Quantum Times* are available on the APS GQI website: http://www.aps.org/units/gqi/newsletters/index.cfm

Quantum information all-stars gather in Dallas

By nearly every measure, the recent March Meeting in Dallas, which marked the fifth anniversary of the Topical Group, was an unqualified success. GQI sponsored 30 sessions and hosted 21 invited speakers, sponsored a business meeting that drew a standing-room-only crowd, and welcomed a remarkable number of pioneers in the field. Notably, GQI co-founders **Danny Greenberger** and **Anton Zeilinger** were both in attendance as was GQI's first official Chair, **Charlie Bennett**. Other notable attendees included **Dave DiVincenzo**, **Artur Ekert**, **Jim Franson**, **Richard Hughes**, **John Preskill**, **Wolfgang Schleich**, **Rob Schoelkopf**, **Ben Schumacher**, and **Bill Wootters** among many others. As of the meeting, GQI membership had exceeded 1100 putting Division status within reach.



SPRING/SUMMER 2008 VOLUME 3, NUMBER 1

John Archibald Wheeler, 1911-2008

"How come the photon?" This question troubled John Archibald Wheeler during his whole life as a physicist. He frequently mentioned

Inside...

Death is something that is rarely

Bits, BYTES, *and Qubits*

QUANTUM NEWS & NOTES

Josephson junctions as a QC architecture

Josephson junctions have been explored as the basis for a quantum computing architecture for many years. Numerous presentations on the subject at the recent March Meeting in Dallas attest to the robustness of the research in this area. One group, led by John Martinis of the University of California - Santa Barbara (UCSB), has developed a 6 cm by 6 cm chip (not quite 'micro,' but getting there!) holding four completely decoupled Josephson junction qubits. The group expects to be able to scale this up to ten qubits by the end of the year.

The breakthrough with this work involved the ability to completely decouple the qubits, i.e. eliminate any interactions between them. In the process the team has essentially created an architecture for a quantum computer. Referred to as RezQu, it appears to have the advantage of scalability, though we'll have to wait a bit for something on a larger scale. Nevertheless, the team remains confident it can be accomplished. Their implementation also includes custom electronics based on simple cellphone technology that has the potential to also drive the cost down. Could this finally be 'the one?' Only time will tell. Regardless, it should induce a bit of unease in those who have persistently doubted that quantum computers could be made.

Group creates anti-laser

Yes, that's correct. If you haven't heard the news (well, that's why we're here!), a group at Yale University has created an *anti*-laser. The device *absorbs* coherent light with near perfect (99.4%) efficiency. In fact, the group argues that perfect (100%) efficiency should be possible to achieve.

The idea was first hatched theoretically by Yale's Douglas Stone about a year ago. He then teamed up with a few colleagues on the experimental side in order to build the device. The idea is actually fairly simple. A beam of light is split into two new beams which are then sent into opposite sides of a silicon wafer. The two beams are tuned in such a way as to create an interference pattern inside the wafer that essentially stalls the light, trapping it inside the wafer. That is, once the light enters the wafer from either side, it essentially gets stuck and bounces back-and-forth inside, turning to heat in the process. Thus the efficiency not only represents how much of the light is absorbed, it also represents how much is converted to heat. This means that no energy gets syphoned off by a phase change or by some non-heat-related dynamical mode.

So what could an anti-laser be used for aside from melting toy soldiers in your back yard? Stone hypothesizes that applications could include filters for laser-based sensors at terahertz frequencies for detecting biological agents or pollutants (which requires detecting a small backscattered laser signal against a large background of thermal noise), shields in laser-based surgeries (to prevent unwanted destruction of unrelated tissue), or, with a third beam, an optical switch. The latter setup allows the device to toggle between near complete absorption and 1% absorption. Hey, that's sounds like a binary operation. Hmm...

Extracting time-like entanglement

In a paper that took almost a year to go from submission to publication, Jay Olson and Tim Ralph of the University of Queensland demonstrated that states of the quantum vacuum could be entangled in time, i.e. between the past and the future. The process amounts to a teleportation in time. This is subtly different than the usual cause and effect we experience every day in that it implies the ability for something (in this case a qubit) to be present at a certain time, call it $t_0 = 0$, and at a certain later time, $t > t_0$ *without experiencing any of the intermediate time between* t_0 *and* t! Note that this is *not* the same thing as the Twin Paradox in special relativity. In that example each twin actually *is* present at all times intermediate to the departure and arrival of the space-faring twin even though it might appear as if one managed to 'skip' some intervening years.

In a recent follow-up preprint, Olson and Ralph have discovered how to actually *extract* this entanglement. In other words, they show that the time-like entanglement can be extracted from the vacuum and converted into 'ordinary' space-like entanglement. The space-like entanglement takes place between two inertial, two-state detectors that are at the same spatial location with one coupled to the field in the past and the other coupled to the field in the future. It is not yet clear how far this idea can be taken experimentally, but it certainly offers up a fresh set of intriguing ideas for theorists to chew on.

Another record is broken

A group from Universität Innsbruck, IQC/Waterloo, McGill University, and Österreichische Akademie der Wissenschaften led by Thomas Monz (Innsbruck) has just announced in the April 1st (and, no, it wasn't an April Fool's joke) issue of *Physical Review Letters* that they have created GHZ states with a record-breaking fourteen qubits using trapped calcium ions. Measured coherence times showed a decay proportional to the square of the number of qubits, which agrees with theoretical models of systems affected by correlated, Gaussian phase noise.

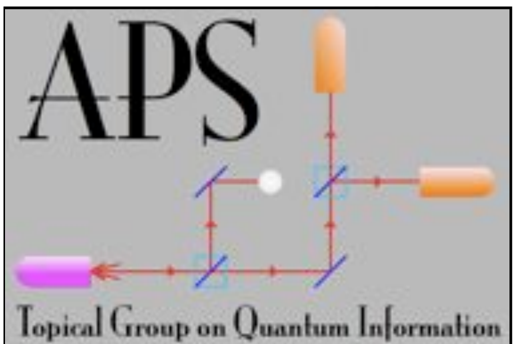
Continued on next page

News, continued

News shorts

- A group from ICFO-Institut de Ciencies Fotoniques in Barcelona and Université Paris Diderot et CNRS has demonstrated 'super-Heisenberg' scaling (breaking the Heisenberg limit) in a nonlinear, non-destructive measurement of the magnetization of an atomic ensemble. The work appeared the March 23rd issue of *Nature*.
- Researchers at the Universität Wien in Austria and Technische Universität München in Germany have developed a finite-element-based numerical solver capable of predicting the design-limited damping of almost arbitrary mechanical resonators to resolve a long-standing problem in the design of micro- and nano-electromechanical resonators. In the process they studied the minimization of the energy dissipation in an effort to observe the intrinsic quantum fluctuations of these resonators. The work appeared in a recent issue of *Nature Communications*.

-ITD



The Quantum Times is a publication of the Topical Group on Quantum Information of the American Physical Society. It is published four times per year, usually in March, June, September, and December, though times may vary slightly.

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Contributions
Contributions from readers for any and all portions of the newsletter are welcome and encouraged. We are particularly keen to receive

- **op-ed pieces and letters** (the APS is *strongly* encouraging inclusion of such items in unit newsletters)
- **books reviews**
- **review articles**
- **articles describing individual research** that are aimed at a broad audience
- **humor** of a nature appropriate for this publication

Submissions are accepted at any time. They must be in electronic format and may be sent to the editor at idurham@anselm.edu. Acceptable forms for electronic files (other than images) include LaTeX, Word, Pages (iWork), RTF, PDF, and plain text.

Editorial policy
All opinions expressed in *The Quantum Times* are those of the individual authors and do not represent those of the Topical Group on Quantum Information or the American Physical Society in general.

Seeking news items!!!

Don't see your work mentioned in "Bits, Bytes, and Qubits?" Think we've forgotten about you? Send us **a one-to-three paragraph summary of your recent research** and we will include it in our news items. This is a great way to get your work noticed not just by others in the field, but also by some outside the field. At least once (possibly more) an item in *The Quantum Times* has directly led to an item appearing in *Physics Today*!

Unfortunately, the editor only has a finite amount of time he can dedicate to the actual writing process. As such, it would be *immensely helpful* if short submissions similar to what appears in "Bits, Bytes, and Qubits" were submitted for inclusion.

Submissions should be e-mailed in LaTeX, Word, Pages (iWork), RTF, PDF, or plain text to the editor at idurham@anselm.edu.

University of Southern California

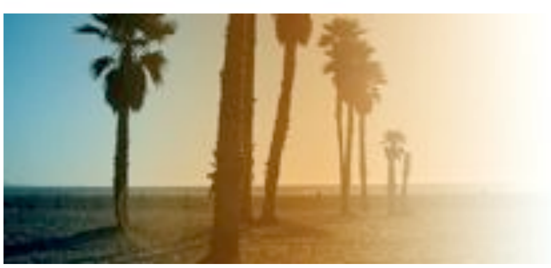
Quantum Error Correction 2011

University of Southern California, Los Angeles, USA
Dec. 5-9, 2011

Quantum error correction of decoherence and faulty control operations forms the backbone of all of quantum information processing. In spite of remarkable progress on this front ever since the discovery of quantum error correcting codes more than a decade ago, there remain important open problems in both theory and applications to real physical systems. In short, a theory of quantum error correction that is at the same time comprehensive and realistically applicable has not yet been discovered. Therefore the subject remains a very active area of research with a continuing stream of progress and breakthroughs.

The Second International Conference on Quantum Error Correction, hosted by the USC Center for Quantum Information Science & Technology (CQIST), will bring together a wide group of experts to discuss all aspects of decoherence control and fault tolerance. The subject is at this point in time of a mostly theoretical nature, but the conference will include talks surveying the latest experimental progress, and will seek to promote an interaction between theoreticians and experimentalists.

Topics of interest include, in random order: fault tolerance and thresholds, pulse control methods (dynamical decoupling), hybrid methods, applications to cryptography, decoherence-free subspaces and noiseless subsystems, operator quantum error correction, advanced codes (convolutional codes, catalytic, entanglement assisted, ...), topological codes, fault tolerance in the cluster model, fault tolerance in linear optics QC, fault tolerance in condensed matter systems, unification of error correction paradigms, self-correcting systems, error correction/avoidance via energy gaps, error correction in adiabatic QC, composite pulses, continuous-time QEC, error correction for specific errors (e.g., spontaneous emission), etc.



Website: http://qserver.usc.edu/qec11/

Registration: http://qserver.usc.edu/qec11/reg.html

Conceptual Foundations and Foils for Quantum Information Processing

May 9 - 13, 2011

Perimeter Institute for Theoretical Physics, Waterloo, Ontario, Canada

The interplay between information-processing protocols and basic physical principles has attracted increasing interest in the past few years and has been the subject of many new and exciting results. Such investigations offer a new perspective on the foundations of quantum theory, a deeper understanding of the origin of quantum advantages for information-processing, and a framework for exploring the nature of information-processing within alternatives to quantum theory (foil theories).

Invited Speakers

Scott Aaronson, MIT
Antonio Acín, ICFO Barcelona
Howard Barnum, University of New Mexico
Jon Barrett, Royal Holloway*
Gilles Brassard, Université de Montréal
Nicolas Brunner, University of Bristol
Dan Browne, University College London*
Caslav Brukner, University of Vienna
Bob Coecke, University of Oxford
Roger Colbeck, Perimeter Institute
Mauro D'Ariano, University of Pavia
Chris Fuchs, Perimeter Institute
Lucien Hardy, Perimeter Institute
Marc Kaplan, Université de Montréal
Gen Kimura, Shibaura Institute of Technology*
Tsuyoshi Ito, Institute for Quantum Computing
Lluis Masanes, ICFO
Markus Mueller, Perimeter Institute
Jonathan Oppenheim, University of Cambridge
Paolo Perinotti, University of Pavia
Sandu Popescu, University of Bristol
Renato Renner, ETH Zurich
Valerio Scarani, National University of Singapore
Ben Schumacher, Kenyon College
Anthony Short, University of Cambridge
Stephanie Wehner, National University of Singapore
Alex Wilce, Susquehanna University
Andreas Winter, University of Bristol

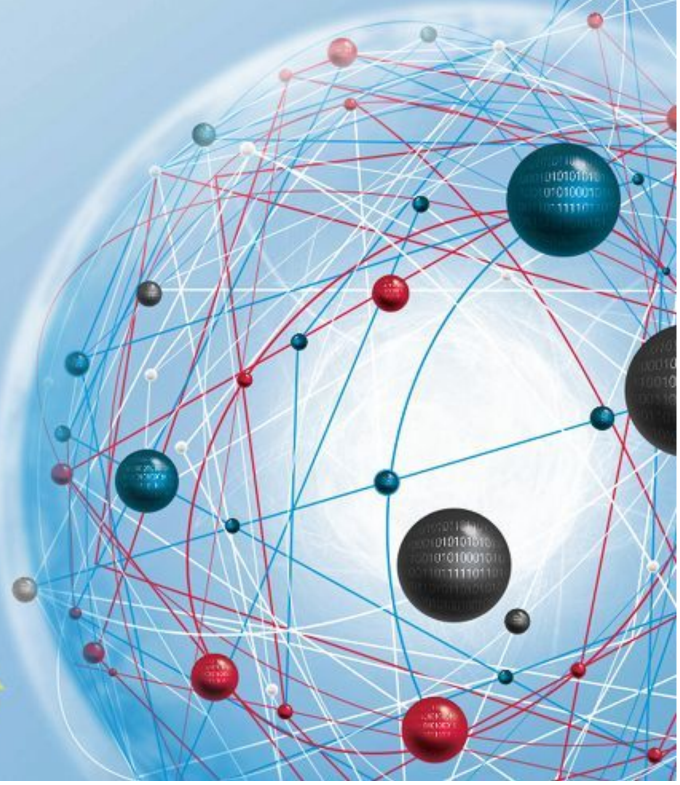
*to be confirmed

Scientific Organizers

Giulio Chiribella, Perimeter Institute (main organizer)
Anne Broadbent, Institute for Quantum Computing
Robert Spekkens, Perimeter Institute

Deadline for registration is May 3, 2011

www.perimeterinstitute.ca/Conceptual_Foundations_and_Foils_for_QIP



PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

IQC Institute for Quantum Computing

Industry Canada Industrie Canada

Canada

ACTION PLAN D'ACTION

Quantum Physics meets TARK

Groningen, the Netherlands, Friday 15 July 2011
http://www.ai.rug.nl/conf/quantumTARK/

The aim of this workshop is to explore the connections between traditional Theoretical Aspects of Rationality and Knowledge (TARK) topics and Quantum Physics. While TARK traditionally focuses on the theoretical aspects of rationality and knowledge, quantum mechanics and quantum computation focus on the fundamental link between physical reality and informational (knowledge-acquiring) actions, such as observations and measurements. We think one can gain new insights from combining methods and concepts coming from these two lines of research. On the one hand, we are interested in how techniques from quantum physics can help us reason about knowledge or rational decision making. On the other hand, we are interested in how the logical and game-theoretical techniques traditionally associated with TARK can be used to formalize physical theories, reason about their concepts or their applications, and provide some principled understanding of their foundations.

Topics of interest include but are not limited to:

classical correlations versus quantum correlations;
classical games versus quantum games;
classical information flow versus quantum information flow;
logical methods for quantum computation;
quantum logic and its relation to logics of knowledge and action;
the use of quantum methods and concepts in decision theory, game theory and logic;
game-theoretical logical semantics and foundations of quantum mechanics.

Invited Speakers :

Samson Abramsky (Oxford University)
Adam Brandenburger (Stern School of Business, New York)

Deadline CfP: Please send your submission in PDF format, not exceeding 10 double-spaced pages (4,000 words) by Wednesday May 4, 2011. The PDF - files have to be uploaded online via the workshop's submission website: https://www.easychair.org/account/signin.cgi?conf=quantumtark2011

Authors will be notified of acceptance by Friday, May 27.
Authors of accepted papers will be expected to upload their paper in an online workshop proceedings collection that we are currently setting up. Further details about the proceedings will be made available on the conference website soon.

Program Committee:
- Sonja Smets (University of Groningen, Chair)
- Samson Abramsky (Oxford University)
- Alexandru Baltag (Oxford University)
- Adam Brandenburger (Stern School of Business, New York)
- Jerome Busemeyer (Indiana University)
- Pierfrancesco La Mura (Leipzig Graduate School of Management)
- Daniel Lehmann (The Hebrew University of Jerusalem)
- Alessandra Palmigiano (University of Amsterdam)
- Prakash Panangaden (McGill University)
- Alex Wilce (Susquehanna University)

TARK Local Organizers at the University of Groningen:
Rineke Verbrugge and Sonja Smets (chairs), Virginie Fiutek, Sujata Ghosh, Barteld Kooi, Ben Meijering, Bryan Renne, Ben Rodenhäuser, Olivier Roy, Allard Tamminga, Bart Verheij.

Sponsors: The Netherlands Organization for Scientific Research, The VIDI Project: 'Reasoning about quantum interaction: Logical modelling and verification of multi-agent quantum protocols'

The workshop follows one day after TARK XIII, The Thirteenth conference on Theoretical Aspects of Rationality and Knowledge (http://www.philos.rug.nl/TARK2011/)

quantum information
and foundations of thermodynamics

The idea of studying thermodynamics from the viewpoint of information theory has always attracted considerable attention. An early example is the paradox of Maxwell's demon, which, as pointed out by Szilárd and Bennett, can be related to information principles:

> A demon operates the trapdoor between two boxes filled with a gas at the same temperature. He lets fast particles fly to the right box, cooling the left container and heating the right one. The apparent violation of the second law is clarified if we look at the demon's memory, where he stores the information about the particles. Eventually he will have to erase his memory, an irreversible operation that costs him work.

Now, a new generation of researchers is committed to use quantum information theory to explore the foundations of thermodynamics. Join us in a four-day workshop in Zurich to share knowledge and discuss future directions for the field.

We will cover topics like thermalization, heat engines, entropy measures in thermodynamics, the information-work relation, state preparation, and thermodynamics of small systems.

organization

Renato Renner
Tony Short
Johan Åberg
Lídia del Rio

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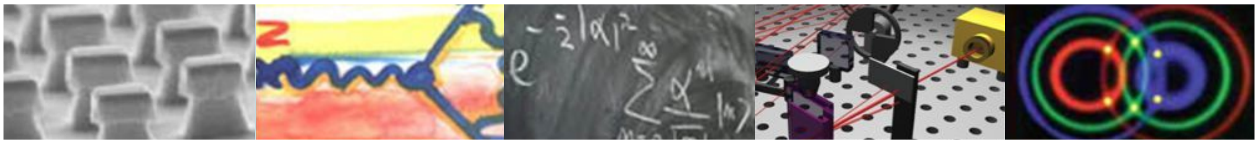
ETH Zurich

12th-16th September 2011

deadline for submission: 12th May

Conference on Quantum Information and Quantum Control IV

8 – 12 August 2011 at the Fields Institute, Toronto, Canada



Quantum Information (QI) and Quantum Control (QC) are both hot topics with promising overlap. This conference will bring together physicists, chemists, computer scientists, and mathematicians to discuss the current status of the two fields and present important recent developments.

CQIQC

FIELDS

The second biennial John Stewart Bell Prize will be awarded to **Sandu Popescu** (Bristol University).

Invited Speakers Include

Shigeki Takeuchi (Hokkaido) Junde Wu (Zhejiang) Gershon Kurizki (Weizmann)
Adrian Lupascu (Waterloo) Tomas Mancal (Charles U., Prague)
Vladimir Buzek (Bratislava) Alexandra Olaya-Castro (UCL)
Christine Silberhorn (Paderborn) Ben Buchler (ANU) Jianshu Cao (MIT)
Tzu-Chieh Wei (UBC) Alexander Lvovsky (Calgary)
Vladimir Korepin (SUNY, Stony Brook)
David Kribs (Guelph)
Alexandre Blais (Sherbrooke)
John Howell (Rochester)
Marco Bellini (LENS)

http://www.fields.utoronto.ca/programs/scientific/11-12/CQIQCIV/
Abstract Submission Deadline: May 20, 2011
Online Registration Deadline: July 29, 2011