THE QUANTUM TIMES

APS TOPICAL GROUP ON QUANTUM INFORMATION, CONCEPTS, AND COMPUTATION

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Advances & Challenges in Quantum Key Distribution

Quantum Key Distribution (QKD) is the flagship success of quantum communication. Since Bennett and Brassard's 1984 publication [2] it has given a new direction to the field. (For a review see e.g. [3].) Up to then in quantum communication, the properties of quantum mechanics were used, for example, to improve on the through-put of optical channels. With the arrival of QKD an application has been created that achieves what cannot be achieved with classical communication alone: provably secure protocols with no assumption about the computational power of an adversary. (This scenario is referred to as unconditional security, a technical term in cryptography. Still, the devices of sender and receiver are assumed to be perfect and out of bound of the adversary, an assumption without which no cryptography is possible at all.) It is sufficient to prepare non-orthogonal states as signals and to measure them at the receiver's end. Then, using an authenticated public channel, both parties can distill a secret key from the data. The procedure needs to be kick-started with some secret key in order to authenticate the first round of key generation. However, the resulting key is composable, that is, it can be used in any cryptographic application like a perfect random secret key, and so a newly generated key can be used to authenticate the public channel in the next round.

In a ground-breaking work, Dominic Mayers [9, 10] provided a first complete security proof for this scheme in its ideal implementation, and since then proofs have appeared that are either more accessible or work with different levels of assumptions on signals and detection devices. The first experiments used weak laser pulses to prepare the signal states. This resulted in a wide gap between the experiments and the security proofs, which assumed a signal structure as arising from single photons. However, it was possible to close this gap and to provide security proofs that take the new signal structure into account and deliver unconditional security.

Everything has its price: using weak laser pulses means that some of the signals carry more photons in them, all in the same state as the intended single photon. In the BB84 protocol this enables the adversary to learn perfectly all those multi-photon signals. As long as the number of these events is under control, this still leads to a secret key, but it costs secret key *rate* since controlling the multi-photon pulses means reducing the mean photon number with increasing loss in the overall quantum channel. As a result of this mechanism and the brutal reality of life in the form of detector dark counts, the key rate drops to zero, typically, at around 30 km.

To overcome this problem, one needs to change the hardware (a software update through the SARG protocol [12] has

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Inside…

… you will find a little bit of everything. We begin with an article from Norbert Lütkenhaus on quantum key distribution (QKD) that grew out of a news article from our last issue. Norbert speaks from the standpoint of someone at the forefront of quantum cryptography and his article should be read by anyone interested in the current state and future direction of QKD.

David Guerra and I have included an article on some overlooked points in the history of the laser that grew out of some research David has been working on for a few years. It seemed appropriate in light of the recent passing of Ted Maiman and the importance of laser technology to everything quantum physicists do.

Günther Greindl, a philosopher of science – eek! – brings us a report on the first (and hopefully not the last) Vienna Symposium while Ken Wharton reports on this year's Växjo conference.

Finally, along with the usual news and announcements (including important March Meeting information) is an editorial that will probably produce an FBI file with my name on it, but you be the judge.

I sincerely hope everyone had a great summer! Oh, and read *The Lighter Side* on the last page…

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already given some limited improvement). One option would be to develop single-photon sources, but they are not readily available and have problems of their own. Another option developed beginning with the work of Hwang [4], Lo et al. [7], and Wang [13], who made a small change to the BB84 protocol, known as the so-called decoy-state QKD protocol: instead of a single intensity for the signal, this protocol randomly changes the intensity from pulse to pulse thereby testing the quantum channel in greater detail. With a refined analysis of the data from this protocol, the provably secure performance was improved to resemble that of an ideal single-photon source, simply by inserting an intensity modulator into existing BB84 set-ups with weak laser pulses, something that is relatively easy to do. As a result, the coverable distances grew to more than 100 km. Other protocols emerged, all comparable in performance to the ideal BB84 with single-photon sources, which are expected to cover distances of up to 200 km and use standard optical telecommunication equipment and advanced detector technology (e.g. including superconducting detector technology).

So does this mean that all is well for QKD? After all, there are already two companies offering QKD as a commercial application (IdQuantique and MagiQ Technologies). The closer one comes to the market, the more critical one has to be about the devices. It is one thing to have a provably secure protocol but it is another thing entirely to sell a device claiming that it is unconditionally secure. Is there a difference between the protocol and the implementation and, if so, what is it? The QKD protocol with BB84 and the decoy states is proven to be unconditionally secure, but that does not mean that any *implementation* of this protocol is secure. The list of possible problems is long: does the device prepare the correct signals, or is there a classical side-channel (e.g. slightly different optical frequencies for each of the four possible signals, or a slight time lag), is the detection efficiency of the devices indeed independent of the signal basis as required in most security proofs? Worldwide, only a few research groups have attacked this question. One of them is the Trondheim Group in Norway with Vadim Makarov [8]. Other groups include Harald Weinfurter's group in Munich [5], Hoi-Kwong Lo's group in Toronto [11] and Christian Kurtsiefer and Antia Lamas-Linares' group in Singapore [6].

Searching for all possible deviations between device models assumed for proofs and actual devices used in implementations is, of course, fundamental to the success of QKD. After all, in building up QKD demonstrations we leave the typical world of experiments behind. In QKD we have to assume that the adversary conspires against us and we have to brace for the worst case scenario. Additionally, security cannot be proven experimentally; one can demonstrate that, to the best of our knowledge, a given apparatus conforms to the device assumptions made in a theoretical security proof. It is an important direction in QKD research to understand how we can make these proofs watertight. After all, the general rule is that once one knows the problem and can quantify it (and the hole is not too big), then one can take it into account during the so-called privacy amplification step in QKD, in which initial correlations to an eavesdropper are cut at the cost of the resulting key rate. Interestingly, the use of entangled systems as sources together with active choices of measurement bases may open up some possibilities for stronger claims of security. The approach is similar to those that investigate the violation of Bell's inequality, though the usual high-loss regime in experiments will be a problem for these approaches [1].

These investigations should be distinguished from another effort: implementing optimal eavesdropping attacks for given scenarios is a neat experimental accomplishment, but it doesn't tell us anything about the security of our QKD systems. After all, these attacks are exactly what is covered in the security proofs since they manipulate only the signals as they fly from sender to receiver without exploiting any device imperfections. Of course, it's always good to show that these experiments might not be as unfeasible as some people might think!

So in what direction is QKD research heading these days? One is the development of protocols better adapted to an optical communication infrastructure in order to get the key rate up. Then, we need to assess the problem of side-channels and other security loopholes in implementations of QKD protocols. Finally, we need to be able to adapt QKD to a network structure with multi-user scenarios. This can be done in the short term via trusted repeater networks, which are collections of point-to-point QKD links connecting trusted classical repeater stations. In the long term, we would like to see *quantum* repeater technologies in their place allowing secure routing of QKD without having to trust the routing procedure.

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Bits, Bytes, & Qubits

QUANTUM NEWS AND NOTES

$|0\rangle$ **Two qubit C-NOT calculation achieved.** Researchers at Delft University of Technology (TU Delft) successfully carried out a 'controlled-NOT' or C-NOT calculation using two qubits realized with superconducting rings. The research actually tackled two problems. In addition to successfully carrying out a calculation with two qubits, the work also represented a step toward understanding how actual quantum computers might be manufactured using existing techniques from the computer chip industry. The Delft group has been studying both superconducting rings as well as quantum dots. The two-qubit realization project was led by PhD student Jelle Plantenberg who is part of the team led by Kees Harmans and Hans Mooij. The work appeared in *Nature* in June.

$\langle 1|0\rangle$ **Potential quantum computing interface.** While the Delft group successfully completed a two-qubit calculation, simultaneously testing potential manufacturing issues of quantum computers, a group in Germany led by Gerhard Rempe, Director of the Max Planck Institute for Quantum Optics, has taken a step toward the realization of a possible quantum computing interface. In this case the answer might turn out to be the creation of a distributed network of 'quantum memories' that can communicate with each other. In this case the 'quantum memory' was a 'stationary' atom excited by a laser that was entangled with the photon it emitted. The photon then can transfer information elsewhere over long distances. Thus, a network of such excited atoms could potentially act as a quantum computing version of memory – a sort of quantum access memory, or QAM, if you will, though the analogy is tenuous since it is difficult to compare quantum and classical computers in such terms since quantum computers are in their infancy. The work by Rempe and his group appeared in *Science* (via *Science Express*) in June.

$\langle 1|0\rangle$ **Um… maybe we won't need it after all?** One of the arguments for the creation of quantum computers is that certain problems appear to be too difficult to solve for ordinary classical computers. Researchers at the University of Queensland (UQ) in Australia and the Van der Waals Zeeman Institute (WZI) of the University of Amsterdam in the Netherlands have successfully eliminated one of those problems from the list. The group, led by Peter Drummond (UQ) and Piotr Deuar (WZI), successfully simulated a collision between two beams from atom lasers using an ordinary desktop computer (no word on whether it was a Mac or a PC). The key was actually *not* in the details. Instead the calculations were carried out using a modified random walk to randomly sample the complexity of moving between two adjacent points in time. While the randomness did eventually swamp the system bringing an end to the simulation, this was not before enough time had elapsed to learn how a large number of atoms interact at ultra-low temperatures. The resulting predictions are soon to be put to the test by researchers in Paris and at the Australian National University. Drummond and Deuer's work appeared in *Physical Review Letters* last spring.

$\langle 1|0\rangle$ **Long, long, long distance entanglement.** For most people interested in entanglement in general, this bit of news likely did not escape your attention. But, on the off chance it has, a large group of researchers from a consortium of universities and agencies throughout Europe, used the European Space Agency's (ESA) Optical Ground Station (OGS) in the Canary Islands to achieve quantum key distribution over a distance of 144 km (that's 89.5 miles to Americans or 77.8 nautical miles to pirates). This result, which exceeds the previous record by an entire order of magnitude, appeared in *Nature: Physics* in June. The groups involved in the research included the Institute for Experimental Physics at the University of Vienna, the Institute for Quantum Optics and Quantum Communication at the Austrian Academy of Sciences, the Max Planck Institute for Quantum Optics, Ludwig-Maximilians University, the University of Bristol, the University of Padova, ARC Seibersdorf Research GmbH, and the ESA.

$\langle 1|0\rangle$ **Physicists in *Forbes*? Are you serious?** Yes, we are serious. *Forbes* recently profiled ten people it says could change the world, from an economist wrestling with the problems of poverty to a filmmaker attempting to create 'open-source' cinema. The fact that the list was not limited to those in science and technology makes the inclusion of *two* physicists even more amazing. Ignacio Cirac of the Max Planck Institute for Quantum Optics made the list. Cirac was recognized for an experiment he and his group, that included Eugene Polzik of the Niels Bohr Institute in Copenhagen, recently carried out that was groundbreaking in *two* ways. In the experiment a quantum state was teleported from a photon to an ensemble of cesium atoms over a distance of half a meter. Quantum states have been teleported before, but always between matter and matter or light and light. This is the first instance of quantum teleportation between matter and light. In addition, quantum teleportation prior to this experiment had only been achieved over distances of a few millimeters. The idea for the experiment originated with Cirac and his former Max Planck colleague (and current University of Innsbruck researcher) Klemens Hammerer. In addition to Cirac's inclusion in *Forbes'* list, MIT's Max Tegmark, a cosmologist who occasionally dabbles in quantum information theory, was recognized. While he is considered one of the top cosmologists in the world, he is also well-known across several sub-disciplines for his involvement in the Foundational Questions Institute that began disbursing grant money for research in foundational questions just this year. A number of quantum information-related researchers received awards under the first round of funding. The fact that not just one, but *two* physicists made such a list seems truly momentous. Physics is apparently cool again!

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Note: A list of recent prizes and awards in quantum information and quantum foundations can be found on page 13.

An excellent way to stay up-to-date on the quantum world is via the main page of Quantiki, one of two quantum information wikis. Quantiki, which can be found at http://www.quantiki.org, is back online after a severe hardware failure.

The FBI in Academe

An Editorial on Academic and Personal Freedom

Recently it was reported [1] that the FBI has been visiting some of this nation's premier universities, purportedly requesting that graduate students curtail their overseas travel and report any so-called 'suspicious' activities that their fellow graduate students or even faculty mentors might be involved in. Those along with additional rules appear in a set of guidelines published by the FBI and distributed to administrators [2]. Certain details within the document and statements made by the FBI in relation to their courting of school administrators raises some serious concerns about both academic and personal liberty.

On the one hand, certain rumors circulating on the Internet regarding the FBI's actions do *not* seem to be true. Specifically, while many bloggers were reporting that the FBI was attempting to cease overseas travel by graduate students entirely, this is *not* contained in their list of guidelines nor was it reported as being conveyed to administrators in any major news source that I could find.

Nonetheless, the guidelines do contain certain troubling points. For instance, in the rather lengthy list of examples of so-called "suspicious behaviors" is the rather vague statement "personal possession and use of a foreign passport," listed under the sub-heading "Divided Loyalty and Allegiance to the US." According to a 2004 report by the American Institute of Physics (of which the APS is a member organization), non-US citizens make up nearly 50% of physics graduate students in this country, all of whom must possess a foreign passport and most of whom likely engage in some amount of overseas or foreign travel (not to mention those with dual citizenship which is still possible to obtain). The document also lists "unreported close continuing contact with foreign nationals, including intimate encounters, shared living quarters or marriage" as a suspicious behavior (as is *any association with* such individuals). Considering the aforementioned statistic about non-US citizens in the nation's physics programs, nearly all of us might qualify as suspicious.

While the document also – and rightly so –

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The LASER

A Closer Look at its Development

While it is no longer common nor perhaps even 'officially' *correct* to do so, the choice of capital letters in the title of this article is not a mistake. Though most physicists can likely still tell you that LASER is really an acronym that has slowly morphed into a word in the colloquial, the same is probably not true of the general public. Even some physicists may have forgotten that the laser actually owes its name to another lesser-known technology, the MASER (where the 'M' stands for microwave).

The development of the laser has been well documented by many authors [1], including accounts by some of the key figures in the creation of this important and ubiquitous technology [2-4]. These accounts, that highlight the path from Einstein's concept of stimulated emission [5] to Townes' maser [6], Townes and Schawlow's subsequent proposal for an optical maser [7], and the eventual success of Maiman [8] (whose obituary appeared in the last issue of *The Quantum Times*) in producing the first operating laser, are all interesting and enlightening. As often happens with history, however, details are frequently forgotten and subsequent events have a tendency color preceding ones. For instance, does anyone (American) remember the names of the *other* riders who set out with Paul Revere to spread the word that the British were coming in 1775? Most Americans primarily remember Revere thanks to Henry Wadsworth Longfellow's poem *The Midnight Ride of Paul Revere* written in 1860 that became required reading in schools around the country in the succeeding century.

In the case of the development of the laser, the ensuing patent war put the spotlight squarely on certain parties and a few crucial steps between the Townes and Schawlow proposal and Maiman's success are almost always glossed over. Indeed, some seem *never* to have been mentioned while others, as crucial as they were, seem to have actually missed citation in certain papers.

The standard history usually begins by describing the first device to employ stimulated emission in the amplification of radiation, the MASER (Microwave Amplification by Stimulated Emission of Radiation), created by Gordon, Zeiger, and Townes [6] in 1953. This maser achieved stimulated emission by passing microwaves, generated in a klystron, through a cylindrical copper cavity filled with excited ammonia (NH_3) molecules. The excited ammonia molecules were separated from the molecules in the lower state by an external *(continued from box on previous page)* lists advocacy of violent or forceful acts against the US government (though note it says nothing about such acts against US *citizens*), it also includes the ever ambiguous “association” with those who advocate such acts as a suspicious behavior. The trouble with that statement is that it *could* be interpreted by zealous officials to include association *without knowledge*. What’s to stop a repeat of the Duke University lacrosse team case, this time under the guise of the “war on terror?” While the likelihood of this happening is probably slim, the fact that the possibility exists should be a cause for some concern. History has shown that loopholes in such laws almost always lead to some innocent prosecutions. And yet it is the beauty of the American legal system that one is (theoretically) innocent until proven guilty. Defending this time-honored tradition is as worthy a goal as defending open research.

While the list of suspicious behaviors included in the guidelines has been in use by the intelligence community since the 1970s (i.e. it was likely recycled from guidelines targeted at employees of the FBI, CIA, and NSA), its inclusion in a document targeted at academic institutions is inappropriate and troubling. But perhaps even more troubling are statements made by Warren T. Bramford of the FBI’s Boston Office to the *Boston Globe*: “[w]hat we're most concerned about are those things that are not classified being developed by MIT, Worcester Polytech, and other universities." [2] But if they’re not classified, how is it the FBI’s business (or anyone else’s for that matter) how such research is accessed and distributed? Academia is traditionally an open environment. Research is performed with results being published, usually in a peer-reviewed journal, though with the advent of the arXiv (originally developed at Los Alamos, I might add) research results and intellectual ideas are now more accessible than ever.

Now, clearly, as a reasonable person, if a university was indeed developing a technology that had the potential to cause serious harm if found in the wrong hands, then it ought to be classified, but only after a full review of the merits of classification by *both the FBI and the institution involved*.

In any case, what conclusion (if any) can we infer from this? What possible interest can

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electric field before they were injected into the cavity. In 1958, Schawlow and Townes [7] proposed the development of infrared and optical masers opening the doors to the development of the laser. The eventual winner of the technological race to build the first laser was won by Ted Maiman [8] in 1959. It is clear that Schawlow and Townes’ paper stimulated the research efforts that eventually lead to Maiman’s ruby laser and it is also clear that Schawlow and Townes were careful to site the work of N. Bloembergen [9] on solid state masers in their work. In his 1956 paper, Bloembergen suggested that the structure of the energy levels in a solid could be used to store the excited molecules and thus separate them from the lower level molecules to create a population inversion, where more of the molecules in the crystal are in an excited state than in the ground state. This proposal was not only important to Maiman’s success, but to the entire modern laser industry. This is because, unlike the first maser, which actively separated out the excited molecules, the energy level structure of a laser material is used to store energy for the eventual stimulated emission. Although this is a fair representation of the critical steps in the development of the laser a few important steps which are commonly omitted may help shed light on some of the details.

The first of these key steps was the first operation of a solid state Maser, originally proposed by Bloembergen [9] and achieved by Scovil, Feher, and Seidel [10] in 1956. In their paper the authors report on achieving success in implementing the proposal of Bloembergen using a magnetically dilute paramagnetic salt. This system consisted of a paramagnetic salt in which a Gd++ ion is pumped into an excited state with a magnetic field and amplification is achieved for the microwave radiation at 9 GHz ($\lambda = 3.33$ cm). This achievement is the first account of a solid-state, stimulated-emission amplification system that did not rely on an external separation of the excited molecules, but instead utilized the energy level structure to store the energy eventually used in the amplification process.

A second key step that may have had a direct impact on Maiman’s choice of material (though there is no direct citation in Maiman’s papers) was the work of Makhov, Kikuchi, Lambe, and Terhune. In two papers [11, 12], these authors report on masers developed using ruby (Al_2O_3:Cr) crystals. The authors make a point of explaining the role of the trivalent chromium ion, Cr+++, as the maser ion in the crystal. This is suggestive of the language used today for common laser material such as Nd:YAG, where the Neodymium (Nd+++) is the laser ion in the crystal of Yttrium Aluminum Garnet ($Y_3Al_5O_{12}$).

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the FBI have with unclassified research? Do they simply not understand the open nature of academic research (which, incidentally, naturally leads to extensive contact with foreign nationals)? Or do they fully understand the world of academic research? If so, the only motive for their statements regarding unclassified research that makes any sense is protecting future corporate interests that might benefit from such research remaining in American hands. Either way, the prospect of the FBI influencing academic research is frightening particularly since it sets a precedent for government manipulation of what is supposed to be free inquiry.

Aside from the philosophical arguments, though, creating an environment of suspicion and fear could have other consequences. Academia is already intensely competitive and nowhere is that intensity felt more acutely than in graduate school. A 1997 study of Big Ten universities showed that graduate students were at the greatest risk for suicide among campus-based populations, comprising 32% of all campus suicides [3]. Injecting fear and suspicion into such an environment is like adding fuel to a fire. Yes, we must be vigilant to potential threats, but suspicion, fear, and paranoia are only counter-productive (terrorists feed off insecurity and fear – that's why they're called terrorists). Is the FBI really concerned with our welfare or are they using the "war on terror" as a front for less altruistic purposes?

Though increased security in this day and age is clearly a necessity, it is puzzling that we are often asked to give up certain freedoms in order to protect those very same freedoms. If we have given them up we no longer have anything to protect. Traditionally academics have always strived to be as open and objective as possible. While we may never achieve the ideal, striving for it is a worthy goal – a freedom – we should never relinquish.

-ITD

[1] Document link: http://www.ncix.gov/archives/docs/Your_Role_in_Combating_the_Insider_Threat.pdf

[2] Murphy, S. and Bombardieri, M., "FBI Warns Colleges of Terror Threat," *Boston Globe*, June 12, 2007.

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In their papers the authors explain that forbidden transitions in the chromium ions are pumped via specific transitions with a magnetic field. The crystal is oriented in a cylindrical cavity designed to excite specific modes of oscillation. This language is also suggestive of that which might be used in a modern paper on the development of new laser materials.

The are a few additional historical points worth mentioning. The first and perhaps the most crucial was Joseph Weber's 1952 realization that stimulated emission was even possible [13]. The realization was likely spurred by Weber's PhD research on the microwave inversion spectrum of ammonia, work that also plays a crucial role in the history of extra-galactic astronomy. Indeed, the early development of both lasers and telecommunications is intimately linked to astronomy (as anyone who is familiar with the Bells Labs/Cosmic Microwave Background story knows). Few people remember that it was Robert Dicke at Princeton and his then *undergraduate* student Bob Griffiths (author of the lead article in the last issue of *The Quantum Times*) who first realized that a simple set of mirrors open to the air would work just as well as the old 'coffee can' model for cavities, particularly optical [14, 15]. Dicke, of course, is often remembered as an astrophysicist.

Townes (1964), Schawlow (1981), and Bloembergen (1981) all won Nobel prizes. One could probably argue that Maiman deserved one, but, regardless, he is well-remembered as the first to successfully build a working laser. Townes and Schawlow are also 'household names' in regards to the history of the laser. Bloembergen, on the other hand, is often forgotten in popular accounts of this period. In fact he is not even cited in Maiman's papers.

Even less known is the work of Scovil, Feher, and Seidel, as well as that of Makhov, Kikuchi, Lambe, and Terhune, both of which helped bridge the gap between the laser proposal of Schawlow and Townes and the successful operation of the first laser by Maiman. The choice of ruby as the material in Maiman's case was critical to his success and the work of these two groups seems to have contributed to that, though Maiman, again, was sparse in his citation list. Historically, however, there is clearly a natural progression beginning with Weber in 1952 and leading finally to Maiman less than a decade later.

The development of the laser, one of the most ubiquitous quantum-electronic devices on earth these days (take a quick glance around your house), is an astounding achievement, progressing from a mere idea to full fruition in less than a decade. It invites comparison to the space race of the 1960s. Perhaps colored by subsequent events, crucial steps have long been relegated to the dustbin of history. Clearly the work of Weber, Dicke, Griffiths, Bloembergen, Scovil, Feher, Seidel, Makhov, Kikuchi, Lambe, and Terhune is worth more than a simple footnote (or less). This also clearly shows the importance of taking the occasional look back upon historical events, ensuring that the details aren't forgotten.

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Session Proposal Deadline

2008 March Meeting, New Orleans

The web site for proposing invited sessions for the APS March Meeting (New Orleans, March 10-14, 2008) is now open and can be found at http://www.aps.org/units/gqi/invited.

The TGQI Program Committee will be organizing two invited sessions at the March Meeting, which can only be selected from among those submitted through the above web-based procedure. The deadline for submitting nominations is **September 7, 2007**. Proposed sessions will also be considered for inclusion in the program of the DAMOP Annual Meeting (Penn State, May 27-31, 2008).

In making proposals, please keep in mind the following guidelines: (i) no individual may receive an invitation two years in a row (unless [s]he is a winner of a Prize in the second year); (ii) a single invited session is not permitted to have two speakers from the same institution (i.e., same university or laboratory). A chair and a speaker from the same institution is acceptable.

To make a nomination, you will need to create an account at the above web site and fill out the nomination form, which asks for reasonably detailed information about the proposed topic of the session and the proposed invited speakers. The more information you provide, the better the chance the session you propose will be selected. Feel free to indicate your preference for inclusion in the invited program of either the March Meeting or the DAMOP Meeting, by paying special attention to the fact that a full session includes 5 speakers for the March Meeting and 4 for DAMOP.

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Morbid Trivia (i.e. space filler)

That could save your life

It is possible to fatally injure yourself with a simple 9V battery. It is the high resistance of your skin that normally protects you but human tissue has a low enough resistance that the resulting current can be fatal (100 mA is enough to stop your heart).

Summer in Sweden…

A REPORT FROM VÄXJO

Given the century-long, ongoing debate about how best to interpret quantum phenomena, it's surprising that there are few conferences that specifically address this topic in the United States. Instead, Europe – including Växjö, Sweden and Vienna, Austria – has become the central location where such fundamental questions are now being raised. My first visit to Växjö in June 2007 was for the fourth Växjö conference titled "Quantum Theory: Reconsideration of Foundations", alternating every other year since 2000 with the similarly-themed "Foundations of Probability and Physics".

I highly recommend Växjö for any scientist interested in the foundations of quantum mechanics. It's only a 2-hour train from Copenhagen – fitting, considering that this year, the conference was purportedly devoted to "80 years of the Copenhagen Interpretation". The bulk of each day was taken up with a single track speakers, each given 45-minutes. Three of the six days also had 3-way parallel afternoon sessions for non-invited speakers, each given 30-minutes. The parallel sessions were frustrating (the 3-way aspect meant that everyone missed at least two-thirds of the non-invited speakers), but I certainly appreciated the generous speaking time. One evening, instead of the parallel sessions, a 2-hour conference-wide "round table" discussion was held.

I took notes on what interested me, so what follows is strongly biased toward the presentations that I felt offered the newest and most plausible insights into 1) possible fallacies of current conventional wisdom, and 2) novel interpretations of quantum mechanics.

The first talk fell in category #1, with Timothy Boyer (CUNY) pointing out that the standard interpretation of the Aharonov-Bohm phase shift might be wrong. He made a convincing case that this is not a quantum effect without classical analogue, but rather is caused by fields generated in the solenoid (induced by the moving charge). If he's right, a new prediction implies the usual interference pattern would disappear for charged particles with a sufficiently short coherence length; Boyer claims this is now being tested.

Leslie Ballentine (SFU, Canada) also had a very interesting talk, pointing out the differences between subjective probability (caused by incomplete information) and objective probability (which I interpreted as corresponding to complete preparation/measurement pairs). I thought his most important point was that different observers, with different information, could come up with the same density matrix and yet make different probabilistic interpretations of the same experiment – implying that the density matrix is neither a complete nor a purely objective description of a quantum system.

On day 2, I really enjoyed the talk by Andrei Khrennikov (Växjö U.), arguing that quantum statistics have a form that one would expect as a linear approximation of a more general, non-linear theory. He raised the question of how these non-linear effects might reveal themselves experimentally – tough to answer without an actual model – but speculated that they might be unnoticeable, on the order of experimental measurement times divided by the Planck time. (Afterward, I suggested that a more promising time-scale for electrons would be the Compton period, ~ 0.01 attoseconds).

Hrvoje Nikolic (RBI, Croatia) also had an interesting talk, pointing out that there is a solvable non-linear version of the Schrödinger equation – one that corresponds to the classical mechanics of a statistical ensemble. This in turn implies that there are two interpretations of classical mechanics: a realistic interpretation (analogous to a Bohmian interpretation) and a probabilistic interpretation. The implication was that if one rejects the Bohmian interpretation of QM, then a consistent thinker would also prefer a probabilistic interpretation (with a non-local collapse!) of classical mechanics.

Jose Pereira (UNESP, Brazil) pointed out that if the cause of our accelerating universe is a cosmological constant, Λ, the non-translational invariance of the de Sitter group would change quantum mechanics – for example deforming the momentum operator by a term proportional to Λ. The resulting model is similar to Doubly Special Relativity, except that Lorentz invariance is unaffected, so DSR's so-called "soccer-ball problem" is automatically solved.

There were hardly any experimentalists presenting results, but Thilo Bauch (CUT, Sweden) was a notable exception. He gave evidence of macroscopic quantum tunneling and energy level quantization in a superconducting d-wave Josephson junction – in contradiction with the expected suppression of quantum effects for this dissipative system. The mostly-theorist audience was quite interested in how these measurements are actually made.

Other invited speakers included Guillaume Adenier (Växjö U.), who gave a very clear talk on how the detection loophole makes experimental claims of non-locality less than a slam-dunk; Geoffrey Sewell (QMU London) who is modeling the quantum dynamics of a macroscopic measurement device to explain the quantum measurement problem; Karl Gustafson (UC Boulder) who discussed some unresolved mathematical issues with various quantum topics, including the quantum zeno effect; and Chandrasekhar Roychoudhuri (U. Conn.) who made a general call for a radical rethinking of standard wave/particle interpretations.

In the parallel sessions, my own presentation (Ken Wharton, SJSU) concerned the idea that perhaps the fundamental QM wave equation should be the full Klein-Gordon equation (not dropping half the solutions to reduce to the Schrödinger equation.) But this second-order in time differential equation needs twice the boundary conditions, which aren't experimentally accessible (at the same time) thanks to Heisenberg. My path forward is to impose half the boundary conditions at one time (a preparation), and half at another time (a subsequent measurement), then solving for the solution between the two boundaries. The result is a time-symmetric, no-collapse picture that nearly (but not exactly) recovers ordinary quantum probabilities.

Philip Goyal (Cambridge) showed how one can systematically derive the mathematical operators that represent physical measurements from a straightforward axiom he calls the "average-value correspondence principle". It also generates the appropriate symmetry transformations as well as the standard commutation relations. This is part of his program to derive the quantum formalism from information-theoretic principles.

Andrey Akhmeteli (IOS) showed that if a Klein-Gordon field was coupled to an electromagnetic 4-potential, then in a gauge where the KG field is real, one can exactly solve the wave equations knowing only the EM 4-potential and its first time derivative. It wasn't clear that you could actually measure both of these at the same time, but one proposed implication was that the EM potential could be the Bohmian guiding field.

Gianni Garbarino (U. Torino) had one of the few explicit experimental proposals – pointing out that entangled neutral kaons might allow for an interesting quantum eraser experiment. (The key is the strangeness oscillations between two kaon eigenstates with different lifetimes.)

I was surprised by the number of parallel-session talks that (effectively) argued for a local hidden-variable interpretation without a convincing argument to get around Bell's theorem. This meant that there was a contingent in the audience with a surprisingly negative attitude towards Bell's conclusions. When Eric Cavalcanti (UQ, Australia) carefully restated some basic EPR- and Bell-type arguments when presenting how EPR relates to Wiseman's "steering", he was (in my view) unfairly attacked for simply standing by well-established logical propositions.

Still, the anti-Bell contingent was in the minority, as shown during the "round table" when everyone voted to see who thought that "Bell was right". Bell won by a 2:1 ratio. Another vote concerned whether quantum mechanics was complete; that result was another 2:1 ratio, with the majority of attendants saying that QM is currently not complete.

Andrei Khrennikov, who moderated the round table, expressed surprise that any individual could consistently side with both incompleteness and Bell. I discussed this issue with him later in the conference, and he agreed with me that if one thought that there were non-local hidden variables (at least, non-local as defined by Bell) then both majorities were consistent. That, at least, is my personal view, and the fact that at least a third of the attendants must have voted in the majority for both questions gives me some hope that there is a sizable group of physicists ready for a radically new interpretation of quantum mechanics – once we stumble upon the right one.

–Ken Wharton
Department of Physics
San Jose State University

…and Austria

A REPORT FROM VIENNA

From the 7th to the 10th of June, Vienna was – if such is still possible in the internet age – the center of the physics world. The "Vienna Symposium on the Foundations of Modern Physics" was organized by the working group of Quantum Optics and Quantum Information of the Faculty of Physics of the University of Vienna. Caslav Brukner, Markus Arndt, Markus Aspelmeyer and Anton Zeilinger were among the local organizers.

Approximately 165 people from over 25 countries attended the conference, among them well-known physicists including Claude Cohen-

Tannoudji, William Unruh, Charles Bennett and too many others to list here.

Each of the four days of the conference that was largely held in the Main Lecture Hall at Strudlhofgasse 4 was devoted to a certain topic. The material was dense, in large parts mathematical, and not easily compressible without irresponsible abbreviation. I can only give here a highly idiosyncratic view of the conference, through the lens of a philosopher of science. A physicist may have taken note of very different things.

The idea of the conference was to explicitly discuss the foundational questions – not simply to "shut up and calculate", as the great Richard Feynman would have put it, but to discuss the very philosophical and metaphysical underpinnings of the world as we know it. Indeed, I think that this is of the utmost importance: the goal of science is not only to measure and predict, but to explain. To this end it is vital to think deeply about results of experiments and their philosophical implications. It is very beneficial that a conference was held with such a process in mind.

The first day was firmly in the hand of experimentalists who reported impressive progress on the manipulation of matter on the ultra-small level. Whereas quantum weirdness stood at the beginning of quantum mechanics in the 1930s and has confounded philosophers and physicists ever since, the possible effects that can be reaped from the quantum world are only gradually being explored. The increased precision and imaginativeness of these experiments promise not only further experimental data but also new insights to support further theoretical and philosophical excursions.

The second day witnessed the discussion of quantum gravity and cosmological problems. This is the area which probably raises the most expectations for the future, but also reveals the deep trouble physics is in at the moment. The two most successful theories of contemporary physics – Einstein's general relativity theory and quantum mechanics (or quantum field theory, which includes relativistic effects) are in contradiction when one assumes large gravitational effects at the quantum scale – as would occur in a black hole or at the Big Bang. This reveals that something is not yet right with the fundamental way we theorize about our universe, and I suspect that a successful unification of the two theories will change our view of the nature of our universe in a way similar to the changes witnessed at the beginning of the last century. While a solution is not yet in sight, the talks showed that thoughtful work is being done on this subject that will form the cornerstone of any future solutions. The approaches in this field are very diverse.

The day ended with a public lecture by Paul Davies in the "Festsaal" of the Austrian Academy of Sciences on the possibility of time travel. Whereas time travel into the future is a trivial effect of special relativity, the problem is getting back again. Here things get very speculative, and it seems to me that a lot of assumptions have to be made to somehow save the concept of time travel into the past. As it stands, you better not count on it right now.

On the third day, quantum information was at the center of attention which I suspect will provide the most important contribution to the future of the field. Quantum Mechanics will grow on our intuitions when we use it at a technological as opposed to research level. We should expect a lot of innovation in this field in the next few years.

After the talks there was a plenum discussion about recommendations the accomplished physicists would give to young people venturing into this field. The recommendations where quite diverse: they ranged from "be willing to take risks" and "do what you believe in" to "stay away from the hard problems in physics so you won't ruin your thesis.” The general consensus view was that the "low-hanging fruit" have been taken – astonishing results will necessarily have to be preceded by hard work - but the knowledge of physics in twenty years will be very different from that of today – logically entailing that there is much to be discovered and a lot to be gained from original work.

On the last day Anton Zeilinger talked about the current research being done at the University of Vienna concerning decoherence – the phenomenon that all the possibilities of the wave function "collapse" into a definite measurement in a seemingly random way. A very intriguing notion, which was also presented at the poster session and which is being performed under the auspices of Zeilinger's colleague Caslav Brukner is the attempt to unite quantum randomness with concepts from mathematical logic – especially Gödel's famous incompleteness theorems. The basic idea is that quantum states embody a finite amount of information, and when queried in such a way as to force an answer about information not contained in the quantum state, the result is necessarily random – because, in fact, no sensible answer can be given. This is somewhat analogous to an undecidable statement in mathematics.

Another topic raised by Zeilinger is that of giving up physical realism. Does this mean that the last safe haven from post-modernistic and relativistic fuzziness – physics – has fallen? Fortunately not: "physical realism" is a technical term meaning that certain physical attributes are properties of physical systems independent of measurement. Giving up this kind of realism would only mean that certain properties emerge during the measurement process (or, more neutrally: "interaction process" – to make clear that no human being is needed to measure, as some mystical interpretations of quantum mechanics would have it).

The existence of an external world per se is, however, not at stake. I would certainly suggest naming this differently – maybe "Einsteinian realism" or "attribute-realism". Using the term "physical realism" and then proclaiming to give it up creates the wrong impression – and rather quickly at that – as soon as one moves out of the domain of physics and thus may add to the confusion rather than ease it.

The atmosphere at the conference was very amicable, and the well-spaced breaks led to interesting discussions and an informal exchange of ideas. The amenable atmosphere was reflected by the well attended social event Saturday evening at a "Heuriger" in Döbling, which saw further physical discussions.

All in all, the state of physics seems vigorous and full of cautious optimism. I was very impressed with the amount of self-reflection, self-criticism, methodological criticism and cooperative interest shown at this conference – from the point of view of the philosophy of science I couldn't be happier. I think the next ten to twenty years will see breakthrough discoveries and increased efficacy at the handling of quantum phenomena. Quantum Computation and Cryptography will certainly be the driving forces and much can be gained – indeed, will and must be gained – by the mastery of the ultra-small, the very fabric of the universe. The conference was, so much as can be said, a definite success – Anton Zeilinger proclaimed at the end of the conference that it should be renamed the "*First* Symposium of Foundations of Modern Physics" – the second being envisaged in two or three years. I am looking forward very much to attending again and observing the progress that will have been made.

–Günther Greindl
Department of Philosophy of Science
University of Vienna

Resources (including a list of speakers):
http://www.quantum.at/talksevents/vienna-symposium.html

Ninth International Conference on Quantum Communication, Measurement and Computing (QCMC)

UNIVERSITY OF CALGARY, CANADA, AUGUST 19 TO 24, 2008

The scope of the conference will be similar to that of previous meetings in the series and include the following topics:

Quantum Cryptography and Quantum Communications

Quantum Measurement and Quantum Metrology

Quantum Computing and Quantum Information Theory

Implementations of Quantum Information Processing

Quantum Control

The abstract submission deadline for contributed papers is April 15, 2008, and the early registration deadline is June 30, 2008. Further details about the meeting can be found on the website http://www.qcmc2008.org/.

Calgary is a city of one million inhabitants in the foothills of the magnificent Canadian Rocky Mountains. Calgary is close to Banff National Park and offers many summertime recreational activities including hiking, whitewater rafting and kayaking, climbing, caving, mountain-lake scuba diving, mountain biking, glacier trips, hang gliding, and horseback riding. August is an excellent month for recreation due to its clement warm and usually dry weather.

We look forward to welcoming you in Calgary in August 2008. On behalf of the organizing and program committees,

–Alex Lvovsky, Principal Organizer
Institute for Quantum Information Science
& Department of Physics and Astronomy
University of Calgary

Kudos & Salutations

RECENT PRIZES & AWARDS

⊗ Markus Aspelmeyer received the 2007 Fresnel prize for fundamental aspects on June 19. The prize is awarded by the European Physical Society (EPS) for outstanding contributions to quantum electronics and optics made by young scientists before the age of 35. Aspelmeyer was awarded for his outstanding achievement in the fields of entanglement, quantum communication and the quantum physics of nano-mechanical devices.

⊗ The International Advisory Committee of the International Conferences Series on Recent Progress in Many-Body Theories awarded the 2007 Hermann Kümmel Early Achievement Award in Many-Body Physics to Professor Frank Verstraete. This award honors Prof. K's long and distinguished career as a leader in the field of many-body physics and as a mentor to younger generations of many-body physicists. Prof. Verstraete receives the award "for his pioneering work on the use of quantum information and entanglement theory in formulating new and powerful numerical simulation methods for use in strongly correlated systems, stochastic nonequilibrium systems, and strongly coupled quantum field theories." The inaugural award will be presented to Prof. Verstraete at the 14th International Conference on Recent Progress in Many-Body Theories, to be held in Barcelona, Spain, 16-20 July 2007.

⊗ The 2007 EPS Quantum Electronics Prize was awarded to Anton Zeilinger. Zeilinger received the senior EPS/QEOD prize 2007 for fundamental aspects on June 19. The prize is awarded for outstanding contributions to quantum electronics and optics. Zeilinger was awarded for his many seminal contributions to the foundations of quantum optics and quantum information science. The EPS awards two scientists (one for fundamental aspects and one for applied aspects) on a biennial basis.

⊗ On 4 June, the Netherlands Organisation for Scientific Research (NWO) announced which four researchers will receive the NWO Spinoza prize ('Dutch Nobel prize') for 2007. The prize is the biggest Dutch award in science. Each researcher receives one-and-a-half million euros to freely devote to his or her research. The researchers receive the prestigious prize for their outstanding, pioneering and inspiring scientific work. One of the winners of the NWO Spinoza prize 2007 is Prof. L.P. (Leo) Kouwenhoven, a physicist at the Delft University of Technology (TU Delft). Professor Kouwenhoven was honored for his groundbreaking work on spin qubits.

–Thanks to Barry Sanders for organizing this list.–

QIPC 2007 International Conference on Quantum Information Processing and Communication

BARCELONA, SPAIN
OCTOBER 15 TO 19, 2007

This meeting is organized by the coordination action project QUROPE in collaboration with the QIPC Proactive Initiative of the Future and Emerging Technologies (FET - Proactive) part of the ICT Research Program of the European Commission. Locally, the meeting is organized mostly by ICFO-The Institute of Photonic Sciences, together with other QI groups of Barcelona.

The conference aims at covering all scientific activity in Quantum Information Science, with a clear inter-disciplinary approach. This ranges from theoretical aspects on Computer Science and Theoretical Physics to Experimental activity, as well as the connection between Quantum Information Science and other scientific fields, such as Quantum Optics or Condensed Matter. The target audience is any researcher interested in Quantum Information Science.

Apart from standards talks and posters, several events will take place during the same week: an "Industrial Perspective Session" organized by Prof. Gisin, with the participation ok keynote speakers from industry, a "Strategy and planning of the FET QIPC Proactive Initiative" session, and a series of plenary talks for a general audience by Profs. Glauber, Aspect and Cirac.

For more information see: http://icfo.pulse.com

From APS HQ

CONCERNS OVER ELECTION BALLOTING

Concerns over the recently circulated election ballot prompted a response from the APS that was sent to Unit Chairs and Secretary/Treasurers. Some specific concerns included the seeming imbalance in representation of the so-called "March Meeting People (MMP)" and "April Meeting People (AMP)." While this division is not the best indicator of the physics community, it simplifies the explanation of what transpired.

While the only MMP on the ballot were the two for International Councilor, it should be noted that the slate of candidates was prepared by the Nominating Committee that actually included more MMP than AMP this year. The committee set the slate based on their observation that all four members of the current Presidential Line are MMP and six of the eight councilors are MMP (one is a mixture of both). In addition, the Chair, Chair Elect, and the Past Chair of the Nominating Committee itself are all MMP.

The APS is stressing that this is not a new idea and that past Nominating Committees have done similar things to balance the slate (e.g. increase representation for some group such as industrial physicists, women & minorities, etc.). Regardless of the outcome this year, MMP will still have a large majority in elected positions.

As Judy Franz noted, "It is very hard for people from small areas of physics to get elected if they run against people from large areas. Unfortunately, the physics community seems to have fewer overarching heroes, so many people just vote for people in their own field."

The Nominating Committee's decision grew out of a recent Executive Board meeting where this issue was discussed and the general feeling was that the APS (specifically the Nominating Committee) should work toward a balanced *end result*, not just a balanced slate. The intention of the committee was to increase representation of some of the smaller areas of physics. However, as always, the APS welcomes other suggestions.

–Thanks to Judy Franz for bringing this to everyone's attention and supplying the appropriate background information.

THE LIGHTER SIDE

The March Meeting witnessed repeated use of the word *ancilla* (just one example being Bryan Eastin's paper "Making Moderately Large Ancillae.") Just what *is* an ancilla and how do you pronounce *ancillae*? The following is from various dictionaries. I did *not* make any of it up.

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an·cil·la [*pr.* an·sil·*uh*] noun, *plural*: ancillas, **ancillae (*pr.* an·sil·*ai*)** 1. an accessory, auxiliary, or adjunct; **2. *Latin*: a maidservent [Nuns often refer to themselves as *ancillae*.]**

GQI Executive Committee

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GQI Website

http://units.aps.org/units/gqi/

Newsletter information

Submissions, including letters, should be in Word, RTF, or PDF. In particular, all TeX or related formatting (especially for equations) should be converted to one of the above formats. All submissions must be sent electronically to the editor at idurham@anselm.edu.

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