Quantum Communication Workshop 2010

Quantum Communication: State and Perspectives

Theoretical Approaches and Experimental Implementations

February 1st – 2nd, 2010

UNIK - University Graduate Center, Gunnar Randers vei 19, 2027 Kjeller, Norway

QCW2010 is a two-day **workshop** on **theoretical** and **experimental** aspects of **quantum communication** and **quantum cryptography**.
This event is organized by **UNIK - University Graduate Center of Kjeller**, at the **Kjeller Technology Cluster**, located half-way between the Oslo Airport and downtown Oslo in Norway.

QCW2010 will focus on practical **advanced solutions** for quantum **communication** and **cryptography** currently under development in **European** and **world-wide** partnerships involving **academic research centers**, **commercial companies** and **public consortia.**

Quantum communication technologies developed in the trusted environment of **experimental laboratories** have recently addressed **industrialization** and **commercialization**, thus facing expected and unexpected **challenges**: from **security** vs. **business requirements** and conformity to **standardization** and **legal specifications**, to field **operational tests** under **malevolent attacks**.

Aiming to provide **network security** for communications, **quantum fiber-based** and **free-space technologies** are both becoming a reality across optical networks, and will thus be discussed at **QCW2010** by experts in the field within a global perspective.

UNIK UNIVERSITETSSENTERET PÅ KJELLER

NISNet

Quantum Hacking Group

Quantum Communication Workshop 2010

Technical Program

February 1st, 2010

9.30 Registration
9.45 Welcome and Opening

Keynote Lecture Session 1
10.00 Renato Renner – Why should cryptographers care about quantum physics?
10.40 Sebastién Kunz-Jacques – Quantum Key Distribution at SeQureNet

11.20 Coffee Break

Keynote Lecture Session 2
11.40 Vicente Martín – Integrating QKD in telecommunication networks
12.20 Jesús Martínez – Hints for QKD industrialization

13.00 Lunch

14.40 Gaby Lenhart – QKD standardization at ETSI

Contributed Lecture Session 1
15.20 Francesco Petruccione – Durban-QuantumCity
15.45 Nino Walenta – QKD and 1Gbit/s data encryption over a single 50km fiber

16.10 Coffee Break

Quantum Hacking Session
16.30 Sara Felloni – Quantum errors in quantum communication and computation
17.10 Lars Lydersen – Practical security of QKD and quantum hacking
17.50 Vadim Makarov – Equipment demo: control of passively-quenched single-photon detector

18.45 Social Dinner

February 2nd, 2010

9.45 Welcome and Opening

Keynote Lecture Session 3
10.00 Rupert Ursin – Quantum communication using satellite infrastructure
10.40 Josep Perdigues Armengol – ESA developments on quantum communications

11.20 Coffee Break

Keynote Lecture Session 4
11.40 Simon Devitt – The Long Road ahead: Fusiliers, Fusilades and the pathway to worldwide quantum networks
12.20 Mohamed Bourennan – Single-qubit secure quantum communication

13.00 Lunch

Contributed Lecture Session 2
14.40 Marco Lucamarini – Compensating the phase-drift of a communication channel through asymmetric encoding of quantum information
15.05 Dominique Elser – Atmospheric quantum communication using continuous polarization variables

15.30 *Informal Session*

16.10 Coffee Break

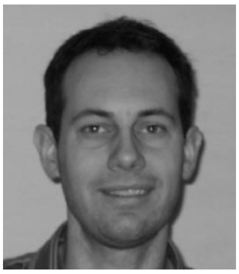
17.00 Closing of the Workshop

Keynote Lectures – Session 1

Why should cryptographers care about quantum physics?

Renato Renner – ETH Zürich

It is well known that an attacker equipped with the capability to process quantum information can break public-key cryptosystems such as RSA. It is, however, less well known (and somewhat surprising) that cryptographic schemes that are proved information-theoretically secure against any classical attacker are susceptible to such “quantum attacks”, even if the scheme only involves the processing of purely classical data. In my talk, I will explain and illustrate this threat.



Renato Renner is Professor at the ETH Institute for Theoretical Physics and head of the Quantum Information Theory (QIT) Group. His research area may be described as "physics of information". The concept of information is indeed intrinsically tied to physics: Any representation of information is necessarily physical and, conversely, the very process of doing physics ultimately involves the acquisition and processing of information. The study of these connections is a central objective of Renner's research.

Quantum Key Distribution at SeQureNet

Sébastien Kunz-Jacques – SeQureNet

SeQureNet is a startup that was created at Telecom ParisTech in a research team focused on quantum information theory. We are associated with industrial and academic partners to develop IP around quantum key distribution. In my talk, I will discuss the common criteria evaluation of QKD devices, and the use of keys obtained through QKD. As we will see, there are challenges ahead in these two areas to foster QKD adoption. Then I will present some of the projects we are involved in, and in particular, the way we hope to make advances in practical aspects of QKD security.

Sébastien Kunz-Jacques is the CTO of SeQureNet. He previously worked for four years at the crypto laboratory of the French national body for IT security, the ANSSI, whose missions include the evaluation of the security of IT products. There, he achieved a PhD in cryptology under the direction of David Pointcheval, head of the cryptography team at the Ecole Normale Supérieure.

Keynote Lectures – Session 2

Integrating QKD in telecommunication networks

Vicente Martín – Technical University of Madrid

To date, QKD development has mostly focused in non-shared point-to-point links. Despite its limitations, this is the only technology commercially available today, and this makes it even more expensive and not easily deployable. The integration of QKD with the commercial network infrastructure would open the possibility of a scalable deployment and without requiring a massive initial investment QKD could reach a broader market. Current metro area networks are evolving towards optical, passive infrastructures and this opens up a good window of opportunity for QKD integration, since an all-optical clear path among two points in the network is no longer unfeasible or extremely expensive. However, the simultaneous propagation of quantum and classical signals over a shared link poses important problems due to the spilling of photons coming from classical signals. In this talk I'll present current architectures for all optical metro networks and discuss our results in the integration of QKD in commercial networks.

Vicente Martín is Associated Professor of Computational Science at the Technical University of Madrid (UPM), Ph. D. Physics at the U. Autónoma de Madrid on the numerical simulation of quantum systems. He is member of the foundational committee of the "Specialised Group in Quantum Information and Computation" of the Spanish Royal Society of Physics. He currently leads the "Quantum Information and Computation Group" at UPM and the effort to build the QKD network prototype together with Telefónica Research and Development (TID). He is also a member of the European Telecommunications Standards Institute (ETSI) Industry Specification Group (ISG) on QKD and rapporteur on QKD Integration with Standard Networks.

Hints for QKD industrialization

Jesús Martínez – Technical University of Madrid

Today, 25 years after the publication of the first quantum protocol, the first commercial Quantum Key Distribution Systems are a reality. Even though a lot of progress has been done, these systems are still far from reaching their full potential. In order to broaden markets, QKD community has to adapt the traditional claims and objectives to make them compatible with those from the conventional security market. The talk will revise some of the security issues and market requirements that QKD has to overcome in order to become a successful and marketable technology, and the efforts to develop security standards for QKD systems.

Jesús Martínez is Assistant Professor at the Applied Mathematics Department of the Technical University of Madrid (UPM). He has been working in security applications under contracts with defense-related organizations (Border Control Program) and also in SW development of network protocols, especially in embedded systems, for public broadcasting companies. He is now a member of the "Quantum Information and Computation Group" at UPM and has developed part of the QKDS SW now running at the UPM, the UPM-TID QKD network and the new algorithms for key distillation.

Keynote Lectures – Session 2

QKD standardization at ETSI

Gaby Lenhart – European Technology and Standardization Institute

The ETSI QKD ISG is only open to those ETSI members and non-members who sign the special ISG Agreement, which describes confidentiality issues, ISG budget, voting weights, and related issues. This standardization group brings together experts from industry, research and academia from different continents, who are specifying all relevant issues of QKD networks, such as use cases, security requirements and proofs, components, interfaces.

Gaby Lenhart is Senior Research Officer at the Strategy & New Initiatives department at ETSI and responsible for all aspects of quantum technologies. She studied electrical engineering with emphasis on communications electronics at the Technical University Vienna and ICSS (Intelligent Communication Systems and Services) at the Technikum Vienna. She has been Project Leader in the division 'Network Building & Infrastructure at Max-Mobil Austria (now T-Mobile Austria). Afterwards, she joined the division International Standardization at T-Mobile International as Standardization Expert, Head of Delegation and Chairman of OMA POC. Recently, she has been Project Leader for Smart Cards and eHealth at ETSI.

Keynote Lectures – Session 3

Quantum communication using satellite infrastructure

Rupert Ursin – Institute for Quantum Optics and Quantum Information

I will report on recent theoretical studies on the feasibility of single-photons and entangled-photons experiments in space using state-of-the-art satellite based infrastructure and optical space-proofed technology. Experimental demonstration performed using a 144 km long horizontal free-space channel will be presented together with an emulation of a single photon downlink from a satellite.

Rupert Ursin is Senior Scientist at the IQOQI, Institute for Quantum Optics and Quantum Information. His main field of research is to develop quantum communications and quantum information processing technologies mainly for free-space but also for fiber-based systems. The scope will range from near term engineering solutions for secure key sharing (quantum cryptography) to more speculative research. Experiments on quantum communication and teleportation using entangled photon pairs. He has published more than 25 papers in scientific journals such as Science and Nature. He is experimentally active in several international collaborations in Germany, Italy, Spain, USA as well as Japan.

ESA developments on quantum communications

Josep Perdigues Armengol – European Space Agency

The European Space Agency (ESA) has supported since 2002, in the frame of its General Studies Programme, several studies in the field of quantum communications for space systems. As a result of these studies, a European research consortium led by Prof. Zeilinger (Vienna University) submitted the mission proposal Space-QUEST ("QUantum Entanglement for Space ExperimenTs") to the European Life and Physical Sciences in Space Programme of ESA, aiming at a quantum communications space-to-ground experiment from the International Space Station. This talk will present the main achievements of the ESA studies and the on-going technology developments on the area of quantum communications to pave the way towards an in-orbit demonstration of quantum communications in space.

Josep Maria Perdigues Armengol is working at ESA/ESTEC in the Optics Section in the Directorate of Technical and Quality Management since 2001. He is involved in the definition and development on new optical technologies in different areas like Telecommunications, Science and Earth Observation. Currently, his major area of work is the engineering and development of optical technologies and optical payloads for free space laser communications, on-board optical processing and quantum communications. He is a Telecommunications (BSc) and Electrical (MSc) engineer from the Ramon Llull University in Barcelona, in 1995 and 1997 respectively.

Keynote Lectures – Session 4

The Long Road ahead: Fusiliers, Fusillades and the pathway to worldwide quantum networks

Simon Devitt – National Institute for Informatics of Tokyo

The study of quantum repeaters and large scale quantum networks has reached an interesting crossroad. The basic building blocks of such networks have been well established and in some cases experimentally tested. These traditional techniques, based on the distribution of Bell states over small scale repeater nodes, purification protocols and entanglement swapping, can, in principal, lead to a large scale quantum communications network spanning buildings, cities and possibly continents. However, the practical implementation of these ideas soon forces us to realize that these primitive ideas are simply not appropriate for a large-scale and fast communication networks. This talk will discuss several more advanced techniques for constructing (and operating) a large quantum network, showing that significant differences will occur between city-wide and continent-wide networks.

Simon Devitt is a Fellow at the National Institute for Informatics in Tokyo, Japan. His research has been heavily focused on the architectural construction of both quantum computing systems and communication networks, and delving into what could be called "Quantum Engineering". He believes that the quantum field has matured to the stage where serious works needs to be performed, adapting abstract theoretical techniques in quantum information processing, error correction, algorithms and related areas to the physical restrictions of device manufacturing and control, well beyond the 1000-qubit level. He received his Ph.D from the Centre for Quantum Computing Technology in Australia in 2007.

Single-qubit secure quantum communication

Mohamed Bourennane – Stockholm University

Quantum information science overcomes a number of barriers for conventional information transfer, cryptography and computation. In quantum cryptography, and in particular in secret sharing protocol, a protocol where a secret message is split among several parties in a way that its reconstruction require the collaboration of the participating parties. It has been proven that assisted multipartite entanglement secret sharing protocol is secure. It has been also shown that quantum multiparty communication complexity protocols assisted with multi-partite entanglement were clearly superior with respect to classical ones. However, so far the only quantum scheme that reached the stage of commercial application is quantum key distribution. Here we experimentally realize multiparty communication complexity and secret sharing protocols by using single-qubit communication.

Mohamed Bourennane is Associate Professor at the Physics Department, Stockholm University, and head of the Quantum Information and Quantum Optics Group. His research area is quantum cryptography, quantum communication, and linear optics quantum computation. Recent research achievements are the observation of six-partite entanglement, bound entanglement and the experimental realization of multiparty quantum secret sharing.

QHG Lectures

Quantum errors in quantum communication and computation

Sara Felloni – UNIK & NTNU

Decoherence, noise and experimental imperfections threaten the correctness of quantum computations as well as the intended functioning of quantum communication protocols, and different imperfections can affect quantum protocols very differently. Error models capable of describing all physically possible single-qubit and two-qubit errors could offer a complete and realistic description of the most general experimental framework in quantum computation or communication, thus allowing the investigation of the qualitative behavior and noise tolerance of quantum protocols. The developing of a theoretical single-qubit error model and the study of two-qubit experimentally realistic imperfections will be reviewed in this talk.

Sara Felloni is a postdoctoral fellow at NTNU - the Norwegian University of Science and Technology, and UNIK - University graduate center of Kjeller, supported by ERCIM - the European Research Consortium for Informatics and Mathematics. Working in Quantum Information Processing, she graduated in Mathematics and achieved a PhD degree in Informatics. Her current research interests concern quantum noise models, quantum computation and communication protocols in experimentally realistic conditions, and quantum information representations.

Practical security of QKD and quantum hacking

Lars Lydersen – UNIK & NTNU

Experimental quantum key distribution has evolved from a 30cm tabletop experiment to several commercial suppliers of QKD systems. However, the question arises whether the QKD implementations can be proved unconditionally secure with the current security proofs, or conversely, if the current security proofs are sufficiently general to incorporate the imperfections of the commercial QKD systems. The latter has been attempted with the so called device-independent security proofs. Lately, an effort has been made to eavesdrop on QKD systems exploiting implementation-caused loopholes, originating the so-called quantum hacking. The Quantum Hacking group progress on practical security proofs, as well as the hacking of implemented QKD systems, will be reviewed in this talk.

Lars Lydersen is a PhD-student in the Quantum Hacking group at NTNU - the Norwegian University of Science and Technology, and UNIK - University graduate center of Kjeller. His research activities and interests include theoretical and experimental security of QKD systems and quantum hacking.

QHG Demonstration

Equipment demo: Control of passively-quenched single-photon detector

Vadim Makarov – NTNU

During an experiment at the National University of Singapore in the summer 2009, we have demonstrated a full intercept-resend attack on a quantum key distribution line. Under realistic conditions, Eve has eavesdropped 100% of the secure key information without alerting the legitimate users. We have on display our eavesdropping equipment: Eve's faked-state generator. We will demonstrate the key component of the attack, taking control of one channel of Bob's passively-quenched detector.

Vadim Makarov is a postdoctoral fellow at NTNU. His research interests are quantum hacking, hack-proof experimental quantum key distribution and single-photon detectors.

Durban-QuantumCity

Abdul Mirza [1] and Francesco Petruccione [1,2]

[1] School of Physics, University of KwaZulu-Natal, Durban, South Africa

[2] National Institute of Theoretical Physics, South Africa

We present an update on QuantumCity initiative in Durban, South Africa. Many QKD experimental setups have failed to provide a long-term analysis of QKD systems in commercial environments. Long-term analysis of the stability and performance of these systems are an imperative step towards the market acceptance of QKD technology.

The Durban - QuantumCity project intends to develop a multi-user quantum communication network currently being hosted on the fibre infrastructure of the eThekwini Municipality. The first phase of this project includes the deployment of a four-node star-network within a radius of 25 km. The network currently secures Municipal buildings including Civic Centers, clinics and administrative offices of the municipality. We intend to extend this network to further building within Durban with the final intention of providing quantum-secured communication to corporations using the municipal fiber network.

The systems have been running continuously since September 2009 and have been encrypting live data since then. The quantum-secured solution provides encryption to all communication between the network nodes. This includes telephone calls/VoIP, internet usage, emails and file transfers. We present results on the essential quantum key distribution parameters measured on these links.

We further intend to use this test-bed network for investigating both passive routing methods as well as software implementations of key management protocols.

Contributed Talks – Session 1

QKD and 1Gbit/s data encryption over a single 50km fiber

Nino Walenta

Group of Applied Physics-Optique, University of Geneva, Switzerland

Since the initial proposal of quantum key distribution (QKD) in 1984 [1] and its first experimental demonstration [2], major progresses in long-distance, fiber-based point-to-point QKD have been achieved. Today, QKD is mature enough to be an integral part of commercially available network security systems which rely on the exchange of secret encryption keys based on the security of QKD [3].

Until recently, one of the specifics of such systems was the need for multiple optical fibers, with one of the fibers exclusively reserved for the quantum channel. Signals of classical strength, assigned to perform key distillation and encrypted communication between the end users, were sent through separate fibers to not compromise the weak quantum signal. With the aim for scalable and cost effective deployment of security systems based on QKD in mind, without the costly need for multiple fibers, we have investigated the feasibility to integrate such systems into commercial network infrastructures where only one fiber is accessible.

This objective necessitates the wavelength multiplexing of all system relevant channels on a single fiber. In our experiment [4] we use a standard 8 channel C-band dense-wavelength-division multiplexer (DWDM) with 100 GHz spacing. We simultaneously multiplex 4 classical channels (one bidirectional channel for key distillation and one bidirectional encrypted 1 Gbps communication channel, respectively) along with the quantum channel, which is separated from the nearest classical channel by only 200 GHz.

In my presentation I discuss the most severe effects (e.g. channel crosstalk, Raman scattering, four-wave-mixing) which can degrade QKD system operation in such configuration, and present the countermeasures implemented in our setup. I present the performance results in terms of QBER and secret key rate provided to the encryptors to establish an encrypted link between two end users which were separated by up to 50 km fiber. In this context I also address the question whether or not it might be advantageous to place the quantum channel in the O-band around 1310 nm while keeping the classical communication channels in the C-band around 1550 nm.

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[4] arXiv:0912.1798v1 [quant-ph]

Compensating the phase-drift of a communication channel through asymmetric encoding of quantum information

Marco Lucamarini*, Rupesh Kumar, Giovanni Di Giuseppe, David Vitali and Paolo Tombesi

Physics Department, University of Camerino, Italy

It has been recently shown that nonlinear effects related to the propagation of intense light pulses in an optical fiber can generate noise in the sensitive single-photon detectors, thus limiting in practice the maximum distance of a secure fiber-based Quantum Key Distribution (QKD) [1]. Furthermore, the co-existence of dim and intense light pulses in the same channel can be exploited by an eavesdropper to hack a QKD-based cryptosystem [2]. This suggests that it would be worth developing QKD systems based entirely on quantum signals, together with devices capable of detecting the "quantumness" of the employed signals.

There are two main obstacles against this program: one is the synchronization of the two distant users' QKD boxes; the other is the compensation of the noise present on the communication channel connecting the users. Both of these tasks are usually tackled by resorting to classical means like intense light pulses and PIN detectors. However both of them can be undertaken by quantum means as well. The synchronization at the quantum level has been already performed efficiently in some QKD setups [3]. On the contrary, the noise-compensation at the quantum level has been performed so far by sacrificing some useful quantum resources [4,5], thus resulting in a decrease of the overall efficiency of the QKD process.

Our contribution aims at showing how an asymmetric preparation of the quantum states carrying the information can enable a new way to monitor and actively compensate the noise of a communication channel [6]. The paradigm of such an asymmetric treatment of the quantum information is given by the Bennett 1992 protocol [7-9], in which the ratio between conclusive and inconclusive counts is in direct connection with the channel noise. Using this protocol as a guiding example, we show how to correct the phase drift of a communication channel through the same signal states employed for the distillation of the quantum key. The technique does not require intense light pulses to work [10,11] and entails no waste of quantum resources. We provide theoretical, numerical and preliminary experimental results to support our claims.

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Contributed Talks – Session 2

Atmospheric quantum communication using continuous polarization variables

D. Elser*, B. Heim, T. Bartley, M. Sabuncu, Ch. Wittmann, D. Sych, Ch. Marquardt and G. Leuchs

Physics Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, Germany

Max Planck Institute for the Science of Light, Erlangen, Germany

We present a continuous-variable quantum communication protocol which is particularly suitable for atmospheric transmission. We employ a local oscillator to perform optical homodyne detection of weak coherent signal states. Alice utilizes coherent polarization states to combine signal and local oscillator in a single beam. As a consequence, Bob's detection is very efficient and perfectly shielded against any stray light. We have experimentally demonstrated the feasibility of quantum key distribution over a distance of 100 m on the roof of the Max Planck Institute in Erlangen [1].

Our measurements indicate that the atmosphere does not corrupt our quantum states in a fundamental way. In practice, however, atmospheric beam wander can be an issue: a spatially fluctuating beam translates to quickly varying losses if the light beam is clipped by a finite detection aperture. Since such effects might limit the performance of our protocol, we characterized them precisely [2]. Furthermore we analyzed the mitigation of beam wander effects by using optical tapers at the receiver [3]. The knowledge gained from these studies will contribute to the optimization of a 1.6 km link between two buildings.

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Quantum Communication Workshop 2010

QCW2010 Committee

Sara Felloni (UNIK & NTNU) *organizer and chair*

Lars Lydersen (UNIK & NTNU) *contributed program*
Vadim Makarov (NTNU) *contributed program*
Giuliano Strini (University of Milan) *contributed program*

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