PROGRAMME



MONT AUX SOURCES HOTEL

Northern Drakensberg (South Africa)

3-7 September 2012

Supported by

Dear Colleagues,

welcome to South Africa.

We are pleased and honoured to host the Quantum Africa 2 conference on Quantum Science and Technology at the Mont-aux-Sources Hotel.

The goal of the conference is to bring together African and International scientists and engineers working in the interdisciplinary field of of quantum information science and technology. Without any doubt the Quantum Africa 2 conference will give a new impetus to Quantum Science and Technology in Africa. For this reason, we would like to thank you in advance for your active contribution to make the Quantum Africa 2 conference a success.

Also, we would like to encourage you to enjoy the natural beauty of the uKhahlamba Drakensberg Park UNESCO World Heritage Site and its diversity of habitats that protects many endemic species, especially birds and plants.

With best wishes,

Francesco Petruccione

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Important Information

Conference Venue

Mont aux Sources Hotel
Mont Aux Sources: Northern Drakensburg, KZN.

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Emergency Phone Numbers

Police: 10111
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Mountain Rescue Service: 080 000 5133

About Quantum Africa 2

History

The Centre for Quantum Technology of the University of KwaZulu-Natal has organised a first international conference in 2006 on Theoretical and Experimental Foundations of Recent Quantum Technologies. The local and international positive resonance to this conference motivated the organization of a new series of conferences: Quantum Africa. The new series of conferences intends to provide a knowledge base for research in quantum science and technology in Africa.

Topics of the Conference

- Controlling quantum dynamics
- Open quantum systems
- Quantum computing and communication
- Quantum cryptography
- Quantum metrology
- Quantum biology
- Quantum foundations
- Quantum information theory
- Quantum materials
- Quantum optics
- Spintronics
- Ultrafast phenomena

Previous Conferences

- Theoretical and Experimental Foundations of Recent Quantum Technologies, Protea Hotel Edwards, Durban, South Africa (10-14 July 2006)
- Quantum Africa 2010, Oyster Box Hotel, Durban, South Africa (20-23 September 2010)

Quantum Africa Steering Committee

- Andreas Buchleitner
- Artur Ekert
- Sir Peter Knight
- Francesco Petruccione
- Barry Sanders

Quantum Africa Programme Committee

The Programme Committee of the Quantum Africa 2 Conference is chaired by Prof. Barry Sanders (University of Calgary) and is formed by the following members:

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- Markus Aspelmeyer, University of Vienna
- Alàn Aspuru-Guzik, Harvard University
- Konrad Banaszek, Warsaw University
- Raymond Beausoleil, HP Labs, Palo Alto
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- Dr. I. Sinayskiy (NIThePKZN)
- Dr. H. Uys (CSIR)
- Dr S. Roux (CSIR)

Programme

Sunday, 2 September 2012

16:00 - 18:00 **Registration**

18:00 - 21:00 **Welcome Braai**

Monday, 3 September 2012

8:30 - 8:45	**Opening addresses**	
8:45 - 9:45	Luiz Davidovich	Quantum metrology: Reaching the ultimate precision limits
9:45 - 10:15	Hermann Uys	Quantum thermometry: Using entanglement to measure the temperature of trapped Ions
10:15 - 10:30	Abdul Mirza	Recent findings in QKD at UKZN
10:30 - 11:00	**Coffee break**	
11:00 - 12:00	Paolo Villoresi	Quantum communications over free-space and space channels
12:00 - 12:30	Thomas Busch	Quantum bit embedding in an ultra-cold Fermi sea
12:30 - 13:00	Habatwa Mweene	The Landau Problem with an Added Linear Potential for Various Geometries
13:00 - 14:30	**Lunch**	
14:30 - 15:30	Beatrix Hiesmayr	Testing Foundations of Quantum Mechanics in High Energy Physics
15:30 - 16:00	Filippo Giraldi	Critical frequency control in open quantum systems
16:00 - 16:30	**Coffee break**	
16:30 - 17:30	Wolfgang Löffler	Phase-only modulation of spatially entangled photons
17:30 - 17:45	Melanie McLaren	Entangled Bessel beams
17:45- 18:00	Mary J. Romero	Orbital angular momentum and angular position correlations of entangled photons
18:00 - 19:00	**Free time**	
19:00 - 20:30	**Dinner**	
20:30 - 21:15	Ndumiso Cingo	The African Laser Centre: Past, present and future of Africa through light

Tuesday, 4 September 2012

8:45 - 9:45	Miles Padgett	Measuring Light's Twist
9:45 - 10:15	Kavan Modi	Operational approach to quantum dynamics
10:15 - 10:30	Giovanni Vacanti	When Casimir meets Kibble-Zurek
10:30 - 11:00	**Coffee break**	
11:00 - 12:00	Juan Pablo Paz	Dynamics and thermodynamics of linear quantum open systems
12:00 - 12:30	Mark Williamson	Quantum correlations can be twisted
12:30 - 13:00	Vitalii Semin	Approximation techniques for the dynamics of open spin systems
13:00 - 14:30	**Lunch**	
14:30 - 15:30	Tim Ralph	Quantum optics in space-time
15:30 - 16:00	Thomas Konrad	Emergence of classicality from continuous observation?
16:00 - 16:30	**Coffee break**	
16:30 - 17:30	Stephan Sponar	Foundations of quantum mechanics explored with neutrons
17:30 - 17:45	Attie Hendriks	Process optimization utilizing an adaptive algorithm in a closed loop feedback system
17:45- 18:00	Alpha Ibrahim	A numerical study of the orbital angular momentum entanglement in atmospheric turbulence
18:00 - 18:15	Malehohonolo Semonyo	Orbital angular momentum and angular position correlations of entangled photons
18:30 - 19:00	**Free time**	
19:00 - 20:30	**Dinner**	
20:30 - 21:15	Caroline Zunckel	The Square Kilometer Array: An African Legacy

Wednesday, 5 September 2012

8:45 - 9:45	Nicolas Gisin	Quantum memories for quantum networks and device independent QKD
9:45 - 10:15	Ilya Sinayskiy	Dissipative Preparation of large W states in Optical Cavities
10:15 - 10:30	Anne Ghesquiere	Thermalisation in a two-particle system
10:30 - 11:00	**Coffee break**	
11:00 - 12:00	Luis L Sanchez Soto	Complete characterization of quantum polarization
12:00 - 12:30	Claudia Zander	Entropic entanglement criteria for fermion systems
12:30 - 13:00	Angela Dudley	Implementation of a quantum walk using the orbital angular momentum states of light
13:00 - 14:30	**Lunch**	
14:30 - 18:30	**Excursion**	Royal Natal National Park
18:30 - 19:00	Free time	
19:00 - 20:30	Dinner	
20:30 - 21:15	Sahal Yacoob	The discovery of a new fundamental particle

Thursday, 6 September 2012

8:45 - 9:45	Michele Mosca	Bridging quantum algorithms to quantum architectures
9:45 - 10:15	Francesco Petruccione	Open quantum walks and dissipative quantum computing
10:15 - 10:30	Adriana Marais	Decoherence-assisted transport in quantum networks
10:30 - 11:00	**Coffee break**	
11:00 - 12:00	Norbert Lütkenhaus	Directions in optical implementations of quantum key distribution
12:00 - 12:30	Alessandro Ferraro	Continuous-variables graph state generation and reconstruction
12:30 - 13:00	Teodora Kirova	Manifestation of dark state formation in Na hyperfine level system
13:00 - 14:30	**Lunch**	
14:30 - 15:30	Mahmoud Abdel-Aty	Information aspects of quantum systems
15:30 - 16:00	Alessio Avella	Engineering of spectral properties of two-photon states
16:00 - 16:30	**Coffee break**	
16:30 - 17:30	Thomas Wellens	Optimal networks for for excitonic energy transport
17:30 - 17:45	Laura Russell	Optical nanofibres as probes for bright and dark cold atoms
• **17:45- 18:00**	Makhamisa 2 Senekane	Realization of the B92 QKD protocol using id3100 Clavis system quantum key distribution system
18:00 - 19:00	**Free time**	
19:00 - 21:00	**Conference Dinner**	

Friday, 7 September 2012

8:45 - 9:45	Fedor Jelezko	Quantum control of single spins in diamond
9:45 - 10:15	John Goold	Emergent thermodynamics in a quenched quantum many-body system
10:15 - 10:30	Emmanuel Olotu	Influence of Oxygen Flow Rate on the Optical Properties of Nb-Doped TiO2 (NTO) Thin Films Deposited on Glass Sub strate from Ti (0.99)Nb (0.01) Alloy Target by DC Reactive Magnetron Sputtering.
10:30 - 11:00	**Coffee break**	
11:00 - 12:00	Sile Nic Chormaic	Tapered Optical Fibres for Particle Trapping and Manipula tion
12:00 - 12:30	Michael Morrissey	A novel magnetic trap configuration for Bose Einstein con densates with large atom numbers
12:30 - 13:00	Ameneh Sheikhan	Numerical and analytical study of a charge qubit interacting with a semi-infinite 1D wire
13:00 - 14:30	**Lunch**	
14:30	**Departure**	

Evening Lectures

Monday, 3 September 2012

The African Laser Centre: Past, present and future of Africa through light

Ndumiso Cingo and Paul Motalane

African Laser Centre

Tuesday, 4 September 2012

The Square Kilometer Array: An African Legacy

Caroline Zunckel

School of Chemistry and Physics, University of KwaZulu-Natal, Durban, South Africa

Abstract

On Friday 25 May 2012, the Square Kilometer Array Organization announced that South Africa will host the Square Kilometer Array (SKA) telescope project jointly with Australia. South Africa will be the majority partner and is set to host two out of the three antennae sites in collaboration with 8 other African countries. This project will involve the construction of 3,000 dishes, which will operate in unison to become the most sensitive radio telescope in the world by 100-fold. In this talk, I will focus on the motivation behind a radio astronomy project of this scale, the scientific objectives of the SKA and how, through innovative design, these goals will be achieved. I will also discuss South Africa's bid to host the SKA, what we stand to gain as a country from leading this international endeavor and the challenges that lie ahead.

Wednesday, 4 September 2012

The Discovery of a New Fundamental Particle

Sahal Yacoob

School of Chemistry and Physics, University of KwaZulu-Natal, Durban, South Africa

Abstract

On the 4th of July 2012, two experiments at the European Centre for Nuclear Research (CERN) captured the attention of the world's media with the announcement of the discovery of the Higgs Boson, which verified our understanding of the origins of elementary particle mass. These experiments (CMS and ATLAS) are large multinational endeavours with thousands of physicists, and engineers, working on complex unique detectors (approximately 5 stories high and 100m underground). This lecture aims to give a better understanding of the result, clarifying what is meant by the 'origin of mass', placing the discovery in the context of our current understanding of the subatomic world, and touching on the complexity and effort behind this discovery.

Abstracts: Monday, 3 September 2012

Quantum metrology: Reaching the ultimate precision limits

Luiz Davidovich

Federal University of Rio de Janeiro

Keywords: Quantum metrology, quantum information, Fisher information, parameter estimation.

Abstract

The estimation of parameters plays a central role in science and technology. It is based on measurements made on probe systems undergoing a parameter-dependent process. Quantum metrology deals with the ultimate precision limits in estimation procedures, taking into account the constraints imposed by quantum mechanics. The parameters of interest could be for instance a phase displacement in an optical interferometer, the time duration of a physical process, a tiny force acting on a mesoscopic object, or the frequency of an atomic transition. The estimation error decreases with the number N of resources employed in the measurement (number of probes, probe energy). Quantum mechanics imposes restrictions on the precision of the estimation, since two outgoing states corresponding to two different values of the parameter are not necessarily distinguishable, and furthermore measurements must conform to quantum constraints. On the other hand, quantum features, like entanglement and squeezing, help to increase the estimation accuracy beyond the standard limit, yielding better precision for the same amount of resources. However, the precision of recent experiments, while beginning to reach the limits imposed by quantum mechanics, is spoiled by the unavoidable influence of noise. Evaluating this effect is a difficult task. While exact results and analytical solutions are known for noiseless situations, the determination of the ultimate precision limit in the presence of noise is still a challenging problem in quantum mechanics. This talk will review some of the achievements and difficulties of quantum metrology, and will present a recently proposed method [1,2] that transforms the noisy evolution into a unitary one in an extended Hilbert space that describes both the system and the environment. This method is applied to obtain an exact solution for the precision limit in the measurement of a weak force acting on a noisy harmonic oscillator [3], and very good bounds for the precision in optical interferometry and atomic spectroscopy.

[1] B. M. Escher, R. L. de Matos Filho, and L. Davidovich, General framework for estimating the ultimate precision limit in noisy quantum-enhanced metrology, Nature Physics 7, 406 (2011).

[2] B. M. Escher, R. L. de Matos Filho, and L. Davidovich, Quantum metrology for noisy systems, Braz. J. Phys. 41, 229 (2011).

[3] C. L. Latune, B. M. Escher, R. L. de Matos Filho, and L. Davidovich, Quantum limit for measurement of weak forces with noisy harmonic oscillators, submitted (2012).

Quantum thermometry: Using entanglement to measure the temperature of trapped ions

Hermann Uys[1], Brian C. Saewyer[2], Joseph W. Britton[2], Adam C. Keith[3], C. C. Joseph Wang[3],

Michael J. Beircuk[4], John J, Bollinger[2]

[1]*National Laser Centre, Council for Scientific and Industrial Research, Pretoria, RSA*

[2]*Time and Frequency Division, National Institute of Standards and Technology, Boulder, CO, USA*

[3]*Department of Physics, Georgetown University, Washington, DC, USA*

[4]*Centre for Engineering Quantum Systems, School of physics, The University of Sydney, NSW, Australia*

Keywords: Quantum metrology, ion traps, thermometry, entanglement.

Abstract

The narrow spacing of motional mode frequencies of crystals of many $(N \gtrsim 10)$ trapped ions, prevents temperature measurements through conventional techniques, e.g. sideband detection of motional state distributions. Here we demonstrate that the decay in hyperfine coherence due to entanglement between hyperfine states and motional excitations, can be used to measure temperature (Phys. Rev. Lett. 108, 213003 (2012)). The measurements are carried out by exciting drumhead motional modes of a planar crystal of several hundred $^9Be^+$ ions with a spin-dependent optical dipole force. Center-of-mass displacements below $\sim$1 nm are detected in the process.

Recent findings in QKD at UKZN

Abdul Mirza, Sharmini Pillay, Yaseera Ismail, Marco Mariola, Makhamisa Senekane,

Mhlambululi Mafu, Francesco Petruccione

CQT, School of Chemistry and Physics, UKZN, Durban, South Africa

Keywords: Quantum communications, quantum cryptography, free-space optics.

Abstract

Quantum Key Distribution has matured from a fundamental science to the engineering of products. The feasibility of integrating QKD systems into conventional communications, however, remains an active filed of research. There are various bottlenecks related to QKD systems that limit the transparency and robustness of this technology within a conventional network. Investigations towards overcoming these constraints will promote the uptake of QKD as a mainstream technology.

While the European Telecommunication Standards Institute (ETSI) currently drives the standardization (ETSI ISG-QKD) of QKD systems, there is a need for the development of supporting technologies. The aim of the various projects at the CQT is to develop a hybrid QKD solution which integrates various established QKD technologies in order to optimally utilise conventional communications networks. To this end, the CQT is investigating the applications of quantum entanglement, polarization-encoded QKD in freespace and fibre and quantum networking and protocol development and implementation.

Quantum communication over free-space and space channels

Paolo Villoresi

DEI - University of Padova, Italy

Keywords: Quantum communications, quantum cryptography, free-space optics.

Abstract

Quantum Communications represent a clear paradigm shift with respect to the classical counterpart. Indeed, it allows envisaging the application of global cryptographic key distribution as well as of other quantum technologies.

The sharing of quantum states among ground and orbiting terminal may be considered as feasible according to present optical technologies. However, the extension of the Quantum Communications and Technologies to long distances, on the surface of the Earth as well as from the Earth to an orbiting terminal in Space, is influenced by difficulties, among which the moving terminals, the large losses, the effects on the optical propagation of the turbulent medium. Indeed, the quantum state that is prepared and sent at the transmitter side experiences a transformation in the spatial spectrum in addition to the vacuum diffraction, that requires strategies to be compensated. We addressed a series of experiments and modelling to address the relevant issues for the demonstration of the space quantum communica**tions.**

The study of optimal design of transmitter optics has been tested on very long links, including the 144 km path between Tenerife and La Palma Islands, and schemes for the aiming and the stabilization of transmission through turbulence has been devised.
The modelling of the quantum communications for the ground-to space and the intersatellite links has been analysed on the base of extensive calculations and the previous experience on the single-photon exchange with orbiting retroreflectors.

References

[1] A. Tomaello et al. Link budget and background noise for satellite quantum key distribution, Advances in Space Research, 47, 802 (2011).
[2] P. Villoresi et al. Experimental verification of the feasibility of a quantum channel between space and earth. New J. Phys. 10 033038 (2008).

Quantum bit embedding in an ultra-cold Fermi sea

John Goold[1], Thomas Fogarty[1], Nicola Lo Gullo[1], Mauro Paternostro[2], and **Thomas Busch[1]**

[1]University College Cork, Ireland

[2]Queen's University Belfast, UK

Keywords: quantum bits, ultracold atomic gases, devcoherence.

Abstract

Single spin impurities embedded in Fermi gases or single atoms or ions combined with Bose-Einstein condensates are examples of a new class of quantum-hybrid systems. They offer the possibility for detailed investigations into the theory of quantum interactions and decoherence and the controlled simulation of different system-environment models synonymous with condensed matter physics and non-equilibrium statistical physics**.**

Here we will present a realistic and exactly solvable model for a single quantum bit which is coupled to a low-dimensional, ultra-cold Fermi gas. We will show that any initial coherence in the qubit is quickly lost, which is related to the presence of Anderson's orthogonality catastrophe, and which has effects on the entropy of the system and the Loschmidt echo. The latter is closely related to the retarded Green's function, from which the spectral function of the gas can be calculated, so that the results can be compared to classic solid state experiments. We will show that the expected broadening in the orthogonality regime can be observed using Ramsey spectroscopy on the qubit.

The Landau problem with an added linear potential for various geometries

Habatwa Mweene[1], Jan Govaerts[2] and Norbert Hounkonnou[3]

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[2]*Universite Catholique de Louvin, Belgium*

[3]*University of Abomey-Calavi, Benin*

Keywords: Landau problem, additional linear potential, various geometries.

Abstract

The classical Landau problem treats the motion of a charged particle in two dimensions under the effect of a uniform magnetic field at right angles to the plane of motion. Since its first advent, many different aspects of this problem have been studied by many authors. In this presentation, we discuss the problem under the effect of an added linear potential in the direction of one of the coordinates. The problem is treated for the case of unconstrained motion, motion in the half plane and motion on a strip. We first clear up an ambiguity about the choice of gauge for the problem, and prescribe the correct method for imposing a gauge on the system. We are able to solve the problem analytically by means of algebraic methods for the unconstrained-motion case, and thereby to give the energy spectrum exactly. For the other two geomentries, this is not possible and numerical methods are ultimately needed for the computation of the energies. The spectra for both cases present a rich structure which has yet to be properly explicated.

Testing foundations of quantum mechanics in high energy physics

Beatrix C. Hiesmayr

Masayrk University, Czech Republic

Keywords: foundations of quantum mechanics, high energy physics, Bell's inequality, collapse models, quantum marking and quantum erasure.

Abstract

I give an overview over various fundamental tests of the quantum theory, such as e.g. superposition or Bell's nonlocality, for systems in the realm of High Energy Physics. I focus on the basic theoretical ideas and report on experiments that have been and will be performed to tackle fundamental issues of quantum information theory and particle physics.

Critical frequency control in open quantum systems

Filippo Giraldi and Francesco Petruccione

Quantum Research Group and National Institute for Theoretical Physics, School of Chemistry and Physics, University of KwaZulu-Natal, Durban

Keywords: open quantum systems, decoherence.

Abstract

The study of the exact dynamics of qubit interacting with structured reservoirs [1], reveals the existence of critical configurations giving discontinuities in the long time inverse power law relaxations of the elements of the reduced density matrix [2]. As matter of facts, arbitrarily slow decoherence processes of the qubit, can be obtained either manipulating the sub and superohmic regimes of a general dissipative environment, or in correspondence of critical values of the qubit transition frequency. Similar effects appear in the boson-boson interaction [3], both in weak and strong coupling regimes. This scenario encourages to build up a general theory for the control of the dynamics in arbitrary open quantum systems.

[1] F. Giraldi and F. Petruccione, Phys. Rev. A 83, 012107 (2011); F. Giraldi and F. Petruccione, Open Systems & Information Dynamics Vol. 18 No. 3 289-299 (2011).
[2] F. Giraldi and F. Petruccione, Phys. Rev. A 85, 062107 (2012).
[3] F. Giraldi and F. Petruccione, "Discontinuities in a damped quantum harmonic oscillator", J. Phys. A (2012) in press.

Phase-only modulation of spatially entangled photons

Wolfgang Löffler

Leiden University, Netherlands

Keywords: quantum optics, spatial entanglement, photon entanglement, phase-only modulation of spatially entangled photons.

Abstract

The spatial degree of freedom of entangled photons is a resource that turns out to be one of the most promising systems for the investigation of high dimensional quantum entanglement. Such systems are also interesting in quantum cryptography. A key challenge is the ability to perform high fidelity and high efficiency projective measurements on the spatial part of the photon wave function. Spatial light modulators are the method of choice, however, they are limited to phase-only modulation if efficiency is relevant, which makes finding suitable orthogonal Schmidt modes hard. We present a novel approach by combining the traditional concept of 'analogue' transverse optical modes with methods known from coding of binary data. This turns out to be very intuitive and simple. We discuss wether we can get get access to the full amount of entanglement as provided by spontaneous parametric downconversion and address issues such as equalizing the detection efficiency for all detection states, which is key for high-dimensional Bell tests. We show experimental results that this approach is promising and demonstrate control over very high dimensional entangled Hilbert spaces.

Entangled Bessel beams

Melanie McLaren, F. S. Roux, Andrew Forbes

CSIR, Pretoria, South Africa

Keywords: entanglement, orbital angular momentum.

Abstract

The Bessel-Gauss (BG) basis is used to investigate oribital angular momentum (OAM) entanglement. The radial index associated with Laguerre-Gaussian (LG) modes is replaced by a continuous scaling parameter for the radial part of the BG modes. The relative ease and accuracy with which one can manipulate the azimuthal and radial dependencies of BG modes make them a favourable choice for high-fidelity quantum information systems. We observe an increase when measuring the full-width-half-maximum width of the OAM spectrum from LG modes to BG modes, indicating the availability of more states for quantum information processing. We demonstrate photon entanglement in terms of BG modes by performing an EPR experiment for OAM and a d-dimensional quantum state tomography on the photon pair, generated by spontaneous parametric down-conversion.

Orbital angular momentum and angular position correlations of entangled photons

Marie Jacquline Romero[1], Daniele Giovannini[1], Melanie McLaren[2], Enrique Galvez[3], Sonja Franke-Arnold[1], Andrew Forbes[2], Stephen M. Barnett[4], Miles John Padgett[1]

[1]*University of Glasgow, United Kingdom*

[2]*CSIR, National Laser Centre, Pretoria, and University of Stellenbosch, South Africa*

[3]*Colgate University, United States ofAmerica*

[4]*University of Strathclyde, United Kingdom*

Keywords: high-dimensional entanglement,, orbital angular momentum, spontaneous parametric down-conversion.

Abstract

Orbital angular momentum(OAM) and its conjugate variable, angular position, have been steadily gaining ground as degrees of freedom in which to observe quantum correlations. The infinite-dimensional state-space of photon OAM makes it an attractive playground in which to explore high-dimensional entanglement. We explore how observed OAM and angular position correlations between entangled photons can be modified.

We use a beta barium borate (BBO) crystal cut for type 1 collinear spontaneous parametric down-conversion to produce our photon pairs. The entangled photons are incident on a beamsplitter to direct them to two separate measuring arms. The output face of the crystal is imaged onto two separate spatial light modulators (SLM), and the SLMs are then imaged onto single mode fibres connected to avalanche photodiodes for single photon detection. The SLMs are used to display holograms—either a forked diffraction grating to measure OAM, or an angular mask to measure angular position. The coincidence count is recorded as a function of the hologram being displayed.

By changing the phase-matching conditions, we demonstrate a factor of 2 increase on the half-width of the OAM-correlation spectrum, from 10 to 20. By changing the mode of the pump to a first order Hermite-Gaussian-like beam, we show the redistribution of OAM correlations consistent with OAM conservation. In addition, we measure angular position correlations and show a consistent Fourier relationship between OAM and angle.

Abstracts: Tuesday, 4 September 2012

Measuring light's twist

Miles J. Padgett

University of Glasgow, United Kingdom

Keywords: orbital angular momentum, multistate measurement, optical momentum.

Abstract

In addition to photon spin, light carries an orbital angular momentum (OAM). Whereas the spin (polarization) has two orthogonal states, the OAM has an unbounded number of states. To use this extra information we present a multi-way sorter to separate photons according to their OAM.

Operational approach to open dynamics

Kavan Modi

University of Oxford, United Kingdom

Keywords: complete positivity, non-Markovian, initial correlations, dynamics.

Abstract

In recent years, there has been a great deal of activity to classify dynamics of quantum systems that are initially correlated with their environments. The dynamics of such systems can be nonpositive and leads to interpretational issues. Simultaneous to this, many are seeking to differentiate between Markovian and non-Markovian dynamics using the techniques of quantum information theory. We will show that both of these problems have a simultaneous solution when the determination of quantum process in done in an operational way. By operational, we mean that quantum dynamics should only be concerned with connecting preparation to measurements, without worrying about the structure of states. We will finally discuss the difficulties with our approach.

When Casimir meets Kibble-Zurek

Giovanni Vacanti

Centre for Quantum Technologies, National University of Singapore, Singapore

Keywords: Casimir, Kibble-Zurek, quantum phase transition.

Abstract

The dynamical Casimir effect (DCE) predicts the generation of photons from the vacuum due to the parametric amplification of the quantum fluctuations of an electromagnetic field. The verification of such an effect is still elusive in optical systems due to the very demanding requirements of its experimental implementation. We show that an ensemble of two-level atoms collectively coupled to the electromagnetic field of a cavity, driven at low frequencies and close to a quantum phase transition, stimulates the production of photons from the vacuum. This paves the way to an effective simulation of the DCE through a mechanism that has recently found experimental demonstration. The spectral properties of the emitted radiation reflect the critical nature of the system and allow us to link the detection of the DCE to the Kibble-Zurek mechanism for the production of defects when crossing a continuous phase transition.

Dynamics and thermodynamics of linear quantum open systems

Juan Pablo Paz

Department of Physics, FCEyN, University of Buenos Aires, Argentina

Keywords: quantum foundations, quantum thermodynamics, quantum information.

Abstract

I will analyze the behavior of the most general network of quantum oscillators coupled with a number of arbitrary external environments. I will present four main original results: 1) I will show that the dynamics is such that the quantum state of the network always obeys a local master equation and 2) that such equation always has a simple analytical solution. I will use this to study the emergence of thermodynamical laws in the stationary regime, achieved for sufficiently long times if the environments are dissipative. I will show that the validity of the second law implies the impossibility of building a quantum refrigerator without moving parts (therefore, a quantum absorption refrigerators requires non-linearity as an crucial ingredient, as recently proposed by Kosloff and others). I will also show that the third law imposes strong constraints on the low frequency behavior of the environmental spectral densities.

Quantum correlations can be twisted

Mark Williamson

National University of Singapore, Singapore and University of Oxford, United Kingdom

Keywords: correlation, geometric phase, Lorentz group, quantum gravity

Abstract

We show how to associate the 'twistedness' of the bipartite correlations in a general, static, multi-qubit state to an element of the Lorentz group, familiar from the theory of relativity. One can interpret this Lorentz element in operationally as a SLOCC protocol familiar from quantum information theory as the general local operation needed to symmetrize the bipartite correlations in the global quantum state. This Lorentz element mathematically is a holonomy and allows one to build a Lorentz group gauge theory from bipartite qubit correlations. We show that one can find a different quantum state representing every element of the Lorentz group. The mathematics here is very similar to loop quantum gravity although the interpretation is very different. We speculate whether one can find a quantum state that has the same properties as a simple curved spacetime.

Approximation techniques for the dynamics of non-Markovian spin systems

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Keywords: spin star system, correlated projection operators, exact dynamics.

Abstract

We test different versions of the projection operator techniques for the describtion of the dynamics of non-Markovian spin systems. In particular, we consider two exactly solvable models.

Quantum optics on earth and in space

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Keywords: quantum communication, noiseless linear amplification, quantum optics, general relativity.

Abstract

In the first part of this talk I will discuss new techniques for improving quantum communication protocols based on noiseless linear amplification. In the second part of my talk I will discuss proposed space-based quantum optics experiments designed to probe the interface between quantum mechanics and general relativity.

The noiseless linear amplifier (NLA) is a probabilistic, but heralded device that can take small coherent states to larger ones without imposing a noise penalty – an operation that is prohibited deterministically. Such a device can also be used to enhance the transmission efficiency of single photon qubits through a lossy channel. Here we demonstrate this latter effect experimentally. We show that, given an input mode containing a mixture of vacuum plus a single photon in an unknown polarization state, we can produce a heralded, free propagating optical mode in which the probability of finding the single photon has been increased over the input.

To date, experiments that test quantum mechanics in the presence of gravity can be explained in terms of Newtonian gravity. Experiments in which genuine general relativistic effects appear can be explained with classical mechanics. Here we propose space-based quantum optical experiments in which both quantum and relativistic effects would appear simultaneously. We discuss why such tests are interesting and what we might learn from them.

Emergence of classicality from continuous observation?

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Keywords: Bose-Einstein condensate, continuous unsharp measurement, classical states.

Abstract

We study the monitoring of the evolution of a BEC in a double-well potential via an unsharp continuous measurement of the number of atoms in one site of the well. In the presence of interatomic interactions a continuously updated state estimate converges to the initially unknown state of the BEC and, subsequently, the quantum dynamics –modified by the measurement– are monitored with unit fidelity. We argue that in this case the measurement induces classical properties in the system: The BEC approximately assumes a stable coherent state and evolves on classical trajectories given by the mean-field dynamics of the Gross-Pitaevskii equation, in contrast to the quantum evolution of the unmeasured BEC.

Foundations of quantum mechanics explored with neutrons

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Keywords: entanglement, uncertainty, neutron, spin, interferometry, polarimetry.

Abstract

Neutron interferometry, where an interference effects of matter waves passing through a perfect silicon-crystal interferometer is observed, and neutron polarimetry, also referred to as spin-interferometry, have established as a powerful tool for investigation of fundamental quantum mechanical concepts with massive particles. Utilizing neutron interferometry tests of non-contextual realistic theories, by means of Bell inequalities or the Kochen-specker theorem, have been performed successfully. Furthermore, we investigated the influence of geometric phases on Bell measurements, and achieved preparation of a Greenberger-Horne-Zeilinger entanglement consisting different degree of freedom, in a single neutron system. Tests of contextual realistic models require a significantly higher contrast and are therefore not feasible with neutron interferometry. Falsification of a contextual realistic model, analogous to Leggett's non-local realistic model for entangled pairs of particles, has been accomplished using neutron polarimetry. Our experimental data rule out classes of contextual, as well as non-contextual realistic theories and are fully in favor of quantum mechanics. In a more recent experiment a fundamental principle of quantum mechanics, i.e., Heisenberg's uncertainty principle is studied, demonstrating validity of a new universally valid error-disturbance uncertainty relation. In the neutron optical experiment the error of a spin-component measurement and the disturbance caused on another spin-measurement are recorded, clearly confirming that both error and disturbance obey this universally valid uncertainty relation but violate the original one in a wide range of experimental parameters.

Process optimization utilizing an adaptive algorithm in a closed loop feedback system

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Keywords: genetic algorithm, quantum control, process optimization.

Abstract

We present arbitrary process optimization through the use of a combined optical and electronic closed loop feedback system. Shaped pulses are sent through a time-of-flight setup causing light-matter interaction followed by post-ionization. Signal strengths for different fragments are evaluated and success determined for optimizing a desired process. By now using an adaptive algorithm new pulse shapes are determined and generated using an acousto-optic programmable dispersive filter. Process optimization is acquired by iteratively applying this scheme.

In this work we will benchmark our learning algorithm towards optimizing pulse compression as well as show some techniques for speeding up conversion to an optimal solution. We will also show for certain processes optimization will not necessary be that of a transform limited pulse, but can be some non-trivial solution. This implies the process is not directly correlated to the pulse energy density, but rather some other dynamic.

Future experiments will also be discussed which can lead to bond forming between different species. Finally we will show using a different basis within our learning algorithm can be beneficial towards optimization depending on the solution space one would like to traverse.

A numerical study of the orbital angular momentum entanglement in atmospheric turbulence

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Keywords: quantum communication, free-space optical communication, orbital angular momentum entanglement.

Abstract

The orbital angular momentum (OAM) state of light has been the object of much interest within the quantum information community lately mainly because it can be used to implement higher dimensional entanglement. Unfortunately, the OAM cannot be used for quantum communication through optical fibers in use today because these fibers support only modes with zero OAM values. One can alternatively use free-space communication. However, one needs to understand how atmospheric turbulence affects quantum entanglement. Here, we present a numerical study of the evolution of quantum entanglement between a pair of qubits. The qubits consist of photons entangled in the OAM basis. The photons propagate in a turbulent atmosphere modeled by a series of consecutive phase screens based on the Kolmogorov theory of turbulence. Maximally entangled initial states are considered, and the concurrence is used as a measure of entanglement. We investigate both Laguerre-Gaussian modes and Bessel modes and we compare the results.

A numerical study of the orbital angular momentum entanglement in atmospheric turbulence

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Keywords: 2D MOT, Bose-Einstein condensate.

Abstract

The first demonstration of three-dimensional laser cooling and trapping of neutral atoms in the form of a magneto-optical trapping (MOT) was a major breakthrough in the advancement of experimental physics. These experimental techniques facilitated the routine production of a cold atomic sample, of various different atom species, in many laboratories around the world. This has also enabled further advancements in the creation of a Bose-Einstein Condensate (BEC). In order to create a large BEC, it is highly advantageous to create a double-MOT system. In such a configuration, the first MOT (usually a 2-D MOT) pre-cools atoms in a vacuum system where there is an adequate atomic background pressure (10-8 mbar). The atoms are then transported via differential pumping; to the second MOT (a 3-D MOT) where the atoms are recaptured in a vacuum system whose pressure is much lower (10-11 mbar). This allows a large number of cooled atoms as a starting point for a creation of the BEC.

Here we describe a novel magnetic coils design which generates a magnetic field suitable for a 2-D MOT. This coil design has the unprecedented advantage of being both compact and robust in a system that is typically much larger, while also outperforming the standard techniques. The process of transferring pre-cooled atoms from the 2-D MOT to the 3-D MOT will also be described in detail. In addition to this, the vacuum chamber, laser system, magnetic field production, necessary for such an experiment will also be described.

Abstracts: Wednesday, 5 September 2012

Quantum memories for quantum networks and device-independent QKD

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Keywords: quantum communication, quantum networks, device independent QKD.

Abstract

There are two main Grand Challenges for academic research in quantum communication. The first one aims at futuristic continental scale quantum networks. The second one concerns "device independent QKD", that is an implementation of Quantum Key Distribution that exploits the nonlocal correlation observed in violations of Bell's inequality to realize "self testing QKD apparatuses".

Direct point-to-point fiber optic based quantum communication is limited by losses. For example, even with a perfect 10 GHz single-photon source and 100% efficient single-photon detectors, the expected time for a photon to be detected after 1000 km of optical fibers is ridiculously low: more than 3 centuries! The only way to overcome this severe distance limitation is the use of quantum repeaters based on multimode quantum memories. We present a protocol for a solid-state multimode quantum memory and illustrate its potential with experimental results, including two crystal entanglement and violation of Bell inequality between a single-photon and a crystal. The European project QuRep gathers groups from Switzerland, France, Germany and Sweden to explore this technology with the aim of clearing the road for a future industrial project.

QKD is the most advanced application of quantum communication. Its principle has been proven to be secure, contrary to complexity based cryptography that rests on unproven assumptions. However, any implementation of the principle of QKD is necessarily only an approximation to the ideal protocol. Hence, one has to thoroughly test QKD system for possible loopholes or side channels. A very elegant solution, that would greatly simplify the testing, exploits nonlocal correlations. Intuitively, if the correlation between Alice and Bob is nonlocal (i.e. violates Bell's inequality), then there are no local variables and, a fortiori, no adversary could hold a copy of the nonexisting local variables. This intuition has recently been put on solid ground, the security could be proven against all possible collective attacks. However, it is well known that all optical violation of Bell's inequality so far suffered from the detection loophole. Interestingly, this has turned the detection loophole problem from a philosophical question to an applied physics problem. We present a realistic, though challenging, way of realizing a laboratory demonstration of Device Independent QKD free of the detection loophole.

Dissipative preparation of large W states in optical cavities

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Keywords: quantum communication, quantum networks, device independent QKD.

Abstract

We propose a novel scheme for the dissipative preparation of large W states in a bimodal optical cavity. By utilizing a generalized angular momentum approach, based on irreducible representations of su(3), we are able to construct a relevant invariant subspace of the full Hilbert space in which it is possible to employ adiabatic elimination, via the effective operator formalism, to identify and engineer effective decay processes. In the proposed scheme, the natural decay processes of spontaneous emission and photon leakage are no longer undesirable, but essential to the required dynamics. We explore all aspects of our scheme, relevant to implementation in currently available bimodal cavities, especially with respect to increasing system size.

Thermalisation in a two-level system

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Keywords: entanglement, open quantum systems.

Abstract

We study an initially entangled two-particle system, where each particle is coupled to an independent environment. The two particles are interacting with each other and we study the evolution of the entanglement between them. We study the approach to equilibrium by deriving an expression for the steady state of the system. We present results in the case when the steady state exists. We derive an expression for the short time dynamics of the entanglement. We study the effect of varying the bath's parameters, as well as the coupling and the system's parameters. We examine the thermalisation of the system.

Complete characterization of quantum polarization

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Keywords: Stokes vector, coherence theory, higher order correlations.

Abstract

Classical polarization is almost exclusively restricted to first-order moments of the Stokes vector. This may be sufficient for most classical problems, but for subtle quantum fields higher-order correlations turn out to play a crucial role. We claim that a complete characterization must involve an order-by-order study, much as it happens in coherence theory. We address these problems and sketch possible solutions.

Entropic entanglement criteria for fermion systems

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Keywords: entanglement, fermions, entropic criteria.

Abstract

The entanglement features exhibited by systems consisting of identical fermions are important for the study of different physical systems and they also have implications for the development of quantum information technology. If the concept of entanglement in systems of indistinguishable particles is compared to the corresponding concept for systems consisting of distinguishable subsystems, some differences are observed.

The aim of this contribution is to investigate entanglement criteria in the case of general (pure or mixed) states of systems consisting of two identical fermions and to extend these criteria to systems of N identical fermions [1].

The criteria introduced are based on appropriate inequalities involving the entropy of the global density matrix describing the total system and the entropy of the one-particle reduced density matrix. A majorization-related relation between these two density matrices is obtained, leading to a family of entanglement criteria based on Renyi's entropic measure. These criteria are applied to various illustrative examples of parameterized families of mixed states.

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Implementation of a quantum walk using the orbital angular momentum states of light

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Keywords: quantum walk, orbital angular momentum, resonator.

Abstract

We outline a theoretical model and a proposed experimental scheme for implementing a qudit, quantum walk by exploiting the angular momentum states of light. Our proposed experimental system is based on a standard laser resonator. Internal to the resonator, a polarization rotator (which utilizes the spin angular momentum (SAM) states) and a q-plate (which utilizes both the SAM states and orbital angular momentum (OAM) states) are used as a 'ladder' operator on the OAM states of the transmitted beam. After N rounds, the beam is coupled out of the resonator, where its OAM spectrum is measured and expected to resemble that of a quantum walk. Apart from a theoretical and experimental description of our quantum walk scheme, initial tests on the three major components (the polarization grating (PG), q-plate and mode-sorter) will be presented. Physical realizations of quantum walks are beneficial as quantum algorithms (based on quantum walks) have shown a quadratic decrease in computation time as opposed to classical algorithms (based on classical walks).

Abstracts: Thursday, 5 September 2012

Bridging quantum algorithms with quantum architectures

Michele Mosca

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Keywords: Clifford gate, T gate, optimal decomposition of logical operations.

Abstract

Quantum computer algorithms are typically described at a high level of abstraction, using logical operations that can be quite complex. On a realistic scalable quantum computer, these logical operations would have to be compiled down to a small set of elementary gates which then have to be performed in a fault-tolerant manner. The efficiency of this compilation can have a significant impact on the practical usefulness of a quantum computer of a given size.

In this talk, I will discuss some of the tools we have been developing for optimizing the mapping from abstract algorithms to actual devices. For example, we characterize the one-qubit gates that may be exactly synthesized using Clifford gates and the T gate, and we have an efficient exact synthesis algorithm with exact optimality guarantee on the number of Hadamard gates used. We also present an algorithm for computing depth-optimal decompositions of logical operations, leveraging the meet-in-the-middle technique to provide roughly a quadratic speed-up over simple brute force algorithms. As an illustration of our method, we present a decomposition of the Toffoli gate over the set of Clifford and T gates. Our decomposition achieves a total T-depth of 3, thereby providing a 40% reduction over the previously best known decomposition for the Toffoli gate with T-depth 5.

Open quantum walks for dissipative quantum information processing

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Keywords: quantum computing, quantum state engineering, open quantum systems.

Abstract

Open quantum walks (OQWs) are introduced as a novel type of quantum walk, exclusively based on dissipative dynamics. OQWs are formulated in terms of quantum Markov chains on graphs and are demonstrated to be an efficient tool for dissipative quantum computing and state engineering. The approach is illustrated with several dissipative implementations of quantum algorithms. It is explicitly demonstrated that OKW based algorithms are more efficient than the traditional dissipative quantum computing approach. In particular, the open quantum walks can be designed to converge faster to the desired steady state and to increase the probability of detection of the outcome of the computation. Finally, applications of OQW to problems in quantum biology are sketched.

Decoherence-assisted transport in quantum networks

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Keywords: quantum biology, open quantum systems, photosynthesis.

Abstract

The dynamics of a quantum network under the influence of decoherence are studied. The model under investigation consists of a homogenous fully connected quantum network in contact with environmental spins. Analytic expressions for the transfer probabilities are obtained. It is shown that decoherent interaction with the environment assists energy transfer in the quantum network. This model of decoherence-assisted energy transfer is applied to energy transfer in the Fenna-Matthews-Olson complex.

Directions in optical implementations of quantum key distribution

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Keywords: quantum communication, quantum cryptography, quantum optics.

Abstract

In practical QKD, we design point-to-point QKD devices and then connect these links to global or local trusted repeater networks. We will highlight two recent results in each of these steps.

Phase-encoding for the BB84 protocol has been practiced since very early on in optical implementations as this encoding is very robust for transmission over fiber optics cables. Effectively, this scheme corresponds to a Mach-Zehnder interferometer that prepares two light pulses of equal amplitude. The signals are then encoded in the relative optical phase of the pulses. These signal states are equivalent to the states used in polarization encoding. However, in practical implementations the amplitudes of the two pulses become asymmetric as the phase modulators that set the phase have about 3 dB insertion loss. In practice this does not lead to observed problems, as the losses of the phase modulator in the receiver re-establishes the symmetry in the interfering pulses. For the security analysis, though, it is crucial that the signal states have a relative structure that differs from the BB84 protocol. We analyze the new signal structure and give a security proof that covers for this deviation. [1] Note that the resulting key rate is lower than the one for the BB84 protocol, so that this readjustment cannot be ignored for phase encoded BB84.

Trusted Repeater Networks have been implemented in several major QKD network demonstrations. They allow establishing a multi-user framework for QKD that addresses the distance and key rate performance of individual QKD links. The traditional paradigm is to establish secret keys between connected neighbors in these networks and then to propagate a secret key between two parties along a chain of nodes, using the respective nearest neighbor keys. We propose a different approach which reduces the amount of computational and communication resources that are required by the intermediate nodes. Intermediate nodes establish quantum correlated classical data with their neighbors. Instead of completing secret keys out of these classical data with their neighbors doing error correction and privacy amplification and then to propagate the final key, we propose that the nodes directly propagate the quantum correlated data using simple public announcements, thereby establishing quantum correlated classical data between the distant parties. Then only these distance parties need to complete the steps of error correction and privacy amplification to establish directly their secret key. We analyze the performance of this arrangement in-

cluding implementations using weak coherent laser pulses. Note that our method not only reduces the work load for intermediate nodes, a reduction that scales with the number of intermediate nodes, but also offers additional protection of the final secret key against passive eavesdropping attacks by breach of trust in intermediate nodes, as the communication required to establish the secret key between the distant users no longer needs to pass through the intermediate (trusted) nodes.

[1] A. Ferenczi, V. Narasimhachar, N. Lütkenhaus, Security proof of the unbalanced phase-encoded BB84 protocol, arXiv:1206.6668.

Continuous-variables graph state generation and reconstruction

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Keywords: quantum computation with continuous variables, quantum state reconstruction, continuous-variables graph state.

Abstract

Gaussian graph states represent the basic resource for measurement-based quantum computation with continuous variables. I will present two approaches for obtaining them. The first [1] involves a family of Hamiltonians whose ground states are Gaussian graph states, thus opening the way for their adiabatic preparation in physical settings beyond the standard optical ones. Regarding the second approach [2] I will present a general scheme, applying both to discrete- and continuous-variable systems, for sequential one-way quantum computation, where both the generation of the graph state and its consumption by measurements are carried out simultaneously. Finally, I will introduce a scheme to reconstruct those states (and any arbitrary state) in the case of quantum networks composed of interacting continuous variables [3]. The scheme uses minimal resources, in the sense that it i) requires only the interaction between one-qubit probe and one constituent of the network; ii) provides the reconstructed state directly from the data, avoiding any tomographic transformation; iii) involves the tuning of only one coupling parameter. ous proposals and mention possible implementations using atom-photon interfaces.

[1] Leandro Aolita, Augusto J. Roncaglia, Alessandro Ferraro, and Antonio Acín Phys. Rev. Lett. 106, 090501 (2011).

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[3] Tommaso Tufarelli, Alessandro Ferraro, M. S. Kim, and Sougato Bose, Phys. Rev. A 85, 032334 (2012).

Manifestation of dark state formation in Na hyperfine level system

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Keywords: dark state, hyperfine structure, laser-dressed state.

Abstract

We demonstrate experimentally the formation of a dark state in atomic Na hyperfine energy levels upon the action of a strong coupling filed. The 3S1/2,F''=1,2 and the 3P1/2,F'=1,2 hyperfine levels are coupled by a strong laser field S with Rabi frequency Omega_S, leading to the formation of laser-dressed states. The dressed states are monitored by recording the excitation spectrum while scanning a weak probe field P across the 3P1/2,F=1,2 to 7D3/2 transition.

The experiment is performed in a supersonic atomic beam with counter-propagating S and P laser fields while fluorescence from the 7D3/2 state is registered by a photon counter. The excitation spectrum of the 7D3/2 state exhibits an intense main peak and side peaks with much smaller intensities.

The increase of Omega_S leads to no change in the position of the main peak, while the side peaks are shifted further apart. These results are confirmed by our theoretical model based on the density matrix equations of motion and the numerical simulations show a good agreement with the experimental data.

Our observations are explained in the dressed-states picture of the three level system consisting of Na ground state hyperfine levels F''=1 or F''=2 with the 3P1/2(F'=1,2) levels which are coupled by the strong field. We show that such system exhibits a visible "gray" state whose eigenvalue is weakly affected by the magnitude of Omega_S. This gray state evolves into a dark state at high coupling field intensities.

We acknowledge support by the EU FP7 Centre of Excellence project FOTONIKA-LV as well as IRSES Project COLIMA.

Information aspects of quantum systems

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Center for Scientific Publication, University of Bahrain, Bahrain

Keywords: multilevel atoms, phonon bath, decay, entanglement, entropy.

Abstract

Information dynamics of different quantum systems under influence of both a phonon bath in contact with the resonator and irreversible decay of the qubits is considered. The focus of our analysis is devoted to multi-level atoms and the effects arising from the coupling to the reservoir. Even in the presence of the reservoirs, the inherent entanglement is found to be rather robust. Due to this fact, together with control of system parameters, the system may therefore be especially suited for quantum information processing. Information entropy, entropy squeezing and Wehrl entropy are discussed as indicators of entanglement. Our findings also shed light on the evolution of open quantum many-body systems.

Engineering of spectral properties of two-photon states

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Keywords: two-photon state, spectral properties, engineering.

Abstract

We present an experimental implementation of spectral properties engineering on biphoton light,emitted via ultrafast type II spontaneous parametric down conversion (SPDC), based on the shaping of the pump pulse spectrum and propagation of the emitted correlated photons through dispersive media [1, 2].
Spectral properties of a biphoton state are fully characterized by the two-photon spectral amplitude (TPSA) [3-7]. Exploiting the group velocity dispersion (GVD) induced by the passage of optical fields through dispersive media, an energy to time two dimensional Fourier transform of the TPSA is operated [8-10]: this returns a technique to reconstruct TPSA through a temporal measurement among the delay between the laser pulse emission (trigger) and the detection times of the two
correlated photons. Exploiting this kind of measurement it is possible to deeply resolve the interference pattern in the shape of TPSA. In this research we report on the conditions under which subtle structure on TPSA spectra can be deliberately engineered via modulation of the pump beam spectrum.

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Optical networks for excitonic energy transfer

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Keywords: quantum transport, quantum networks, optimal configuration.

Abstract

We investigate coherent transport of a single excitation on finite-size, disordered quantum networks. In the first part of the talk, we will argue that, in general, the phenomenon of quantum interference tends to suppress transport on average, i.e., for typical realizations of the random network. However, as shown in the second part, there also exist certain optimal network realizations where, in contrast, transport is enhanced by constructive quantum interference. We discuss important properties of these optimal networks, and show how the transport efficiency behaves when suppressing coherent effects by adding noise to the system.

Optical nanofibres as probes for bright and dark cold atoms

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Tyndall National Institute, University College Cork and Okinawa Institute of Science and Technology

Keywords: laser cooling, optical nanofibre, spectroscopy.

Abstract

The optical nanofibre (ONF) is a narrow glass waveguide fabricated from commercially-available optical fibre. With high transmission and a sub-micron waist diameter, the ONF has been used extensively as a tool in cold atom technologies. We have measured temperatures above and below the Doppler Limit of 143 micro-Kelvin for rubidium-85 using the ONF, thereby paving the way for nanofibres to be integrated with ultracold atoms for hybrid quantum devices. In this work, we will discuss the use of the ONF as a probe for 1- and 2-photon absorption in a dark magneto-optical trap (DMOT) for rubidium-85: a frequency-scanned probe is launched through the nanofibre and interacts with the cold atoms via the evanescent field at the nanofibre waist.

Realization of the B92 QKD protocol using id3100 Clavis 2 system

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Keywords: B92, BB84, SARG04, pug-and-play, prepare-and-measure.

Abstract

Quantum key distribution is an encryption technique for securely exchanging a bit string (known as a key) between two communicating parties, traditionally known as Alice, the sender and Bob, the receiver, in the presence of an eavesdropper, Eve. This technique is based on two laws of quantum mechanics, namely Uncertainty Principle and no-cloning theorem. The first operational quantum key distribution protocol was developed by Charles Bennett and Gilles Brassard (BB84). Since then, various QKD protocols have been developed. Examples include a B92, SARG04 and six state protocols. Currently, BB84 forms the most established protocol and widely used protocol. However, since the B92 protocol uses two quantum states, as opposed to BB84's four, it is easier to implement. Despite the advantage of the B92 protocol being easily implementable, this advantage has not been fully exploited. Therefore, we investigate the feasibility of implementing the B92 protocol by using the id3100 Clavis2 system from id Quantique.

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Quantum control of single spins in diamond

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Keywords: defects in diamond, NMR and ESR techniques, entangled quantum states, sensing.

Abstract

Owing to permanent miniaturization of electronic components the control of quantum state of individual quantum systems become crucial. On the other hand, ability to manipulate the state of matter at the nanoscale is important for building new quantum based devices like magnetic and electric field sensors. Here we show how defects in diamond can be used to new quantum technologies based on quantum coherence. Such optically active impurities (colour centers) show unique coherence properties under ambient conditions. Their quantum state can be manipulated using well established NMR and ESR techniques. We show how engineered arrays of defects can be used for creation of non-classical (entangled) quantum states. We also demonstrate the potential of single atom technique of spin manipulation in diamond for sensing at nanoscale.

Emergent thermodynamics in a quenched quantum many-body system

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Keywords: statistical mechanics, fluctuation theorems, dynamical phase transition, many-body physics.

Abstract

Owing to permanent miniaturization of electronic components the control of quantum state of individual quantum systems become crucial. On the other hand, ability to manipulate the state of matter at the nanoscale is important for building new quantum based devices like magnetic and electric field sensors. Here we show how defects in diamond can be used to new quantum technologies based on quantum coherence. Such optically active impurities (colour centers) show unique coherence properties under ambient conditions. Their quantum state can be manipulated using well established NMR and ESR techniques. We show how engineered arrays of defects can be used for creation of non-classical (entangled) quantum states. We also demonstrate the potential of single atom technique of spin manipulation in diamond for sensing at nanoscale.

Influence of oxygen flow rate on the optical properties of Nb doped TiO2 (NTO) thin films deposited on glass substrate from Ti (0.99)Nb(0.01) alloy target by DC reactive magnetron sputtering

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Keywords: transparent conducting oxides, sputtering, thin films technology.

Abstract

Transparent conducting oxide (TCO) thin films, particularly sputter-deposited Sn doped In2O3 (ITO) have a wide application on optical coatings and optoelectronics. However,due to the scarcity and increasing cost of indium, efforts have been to research indium-free materials which must be abundant and non-toxic. Sputter-deposited Nb-doped TiO2 (NTO) is among recent material which has shown great potential for TCO applications. In this study we report and discuss influence of oxygen flow rate on the optical properties of Nb-doped TiO2(NTO) thin films deposited on glass substrate from alloy target of Ti (0.99) Nb (0.01) by DC reactive
magnetron sputtering for low emissivity (Low-e) optical coatings on architectural windows glasses. Analysis indicated a decrease of sputtering rate with increased oxygen flow rate while SHIMADZU SolidSpec-3700 DUV determined an increase of solar transmittance (Tsol) with the same. The band gap energy (Eg) and refractive index (n) were observed to increase while optical constants (k) decreased with increased oxygen flow rate. PERKIN ELMER Bx FTIR determined that the IR reflectance of the films decreased as oxygen flow rate increased. Average Tsol of above 70% and IR reflectance 20% were achieved. The results implied a possibility for Low-e with the material upon improving the IR reflectance by raising the Nb-doping level.

Tapered optical fibres for particle trapping and manipulation

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Keywords: particle manipulation, optical tweezers, atom trapping.

Abstract

In this paper we will discuss the use of tapered optical fibres for the trapping and manipulation of colloidal microparticles in an aqueous solution. In particular, we will present recent experimental work on the propagation of higher modes through a tapered optical fibre and the challenges this presents in comparison to fundamental mode propagation. Higher mode propagation has a distinct advantage since mode interference can lead to position-controllable trapping sites around the fibre, and can be extended to cold atom trapping in novel geometries. We will also discuss how a tapered fibre could be integrated into an optical tweezers configuration for improved deterministic selection of particles, whether they be colloidal or atomic.

A novel magnetic trap configuration for Bose Einstein condensates with large atom numbers

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Keywords: laser cooling, quantum optics, cold atoms, magnetic trapping.

Abstract

The experimental demonstration of Bose-Einstein condensation (BEC) is one of the most exciting developments of recent decades and has allowed researchers to study quantum effects on the macroscopic scale with well controllable parameters. This has sparked a flurry of experiments making many contributions to our understanding of solid state physics, quantum optics, atomic physics and precision metrology.

For many BEC experiments it is highly advantageous to have a high number of atoms. This means that all the stages previous to a BEC must also be sufficient to generate and trap a large number of atoms. One of the major challenges in performing such an experiment is to design an adequate and easy-to-use magnetic trapping system with appropriate trapping parameter to maintain large number of atoms. The focus of this presentation will be on a novel configuration Ioffe-Pritchard magnetic trap which is designed to trap a large number of atoms. Also presented will an overview of the entire BEC experiment, as well as the proposed first African BEC machine.

Numerical and analytical study of a charge qubit interacting with a semi-infinite 1D wire

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Keywords: many-body system, electron gas, Fermi edge singularity, DMRG.

Abstract

We study the system consists of an electron gas interacting with a two level system (charge qubit). The system displays the physics of the Fermi edge singularity, i.e. a singularity in the qubit tunneling rate due to a proliferation of long wavelength excitations in the wire. We confine our attention to the equilibrium situation but consider a setup in which the spectral function has interesting features at energies away from the singularity. The quantity of interest in our study is the qubit tunneling rate, which can be calculated analytically. There are also several numerical algorithms to study one-dimensional strongly correlated system such as non-perturbative treatments via density matrix renormalization group (DMRG). DMRG is a tool that we use to study the statics and dynamics of our system with high accuracy. Parameters such as ground state energy, ground state wave function and electron density in each level of the qubit can be calculated by DMRG. The DMRG studies have lead to results that agree with analytics.