Final Program

3rd International Workshop
ad memoriam of Carlo Novero

"Advances in Foundations of Quantum Mechanics and Quantum Information with atoms and photons"

2-5 May 2006, Torino

Organizers:

M. Genovese, G. Brida, M.L. Rastello, A. Garuccio

Sponsorships:

Istituto Nazionale di Ricerca Metrologica, Torino
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Program

Tuesday 2nd		
09.15-09.30	Welcome to participants of I.N.RI.M. president E. Bava	
Session I - Chairman: S. Kulik		
09.30-10.00	R. Ionicioiu	Entangling spins by measuring charge
10.00-10.30	P. Voss	Recent advances in optical fiber sources of entanglement
10.30-11.00	I. Degiovanni	Analysis of a multiplexed detector system used to increase photon-counting rates by reducing effective deadtime
11.00-11.30	Coffee break	
Session II - Chairman: A. Garuccio		
11.30-12.00	F. Petruccione	Dynamics of two-qubit systems in a spin star environment
12.00-12.30	M. Bondani	Calculation of the 3D interaction geometry for two interlinked chi^2 processes generating entangled triplets
12.30-13.00	I. Marzoli	Towards a quantum computer with trapped electrons
13.00-13.30	G.S. Agarwal	Detector Induced Quantum Entanglement and its Measurement in Radiation from a Collective System
13.30-13.45	A. Gabris	Quantum teleportation with pair coherent states
13.45-15.00	Lunch	
Session III - Chairman J. O'Brien		
15.00-15.30	G. Brida	Dispersion spreading of biphotons and two-photon interference
15.30-16.00	M. Bellini	Quantum tomography of time-delocalized single photons
16.00-16.30	S. Kulik	Polarization ququarts
16.30-17.00	Coffee break	
Session IV - Chairman: Y. Shih		
17.00-17.30	J. Appel	Routing of optical states by atomic media
17.30-18.00	F.Cataliotti	Magnetic microtraps for quantum control

Wednesday 3th		
Session I - Chairman: M. Chekhova		
09.-9.30	P. Mataloni	Hyper-entangled two photon states for quantum communication applications
9.30 - 10	Y. Kim	Recent progress toward "engineered" entangled-photon states
10.00-10.30	M. Genovese	On recostructting photon statistics by on/off detecors: toward multi-partite case
10.30-11.00	C.Monken	Position and momentum entanglement in two-photon states generated by spontaneous parametric down-conversion
11.00-11.30	Coffee break and poster session	
Session II - Chairman: G. Bjork		
11.30-12.00	A. Gatti	Coherent imaging of a pure phase object with classical incoherent light
12.00-12.30	G. DiGiuseppe	Simulation of an Individual Incoherent Eavesdropping on a Two-Way Quantum Communication Protocol
12.30-12.50	P. Walther	Progress towards generation, storage and manipulation of entangled photons in atomic ensembles
12.50-13.10	A. Porzio	Homodyne characterisation of cw bipartite states
13.10-13.30	S. Padua	Generating, distributing and characterizing two-photon entangled spatial qudits
13.30-13.50	R. Migliore	A simple scheme to entangle uncoupled superconducting qubits via an entanglement mediator
13.50-15.00	Lunch	
14:40-15:00	Visit to “Carlo Novero” laboratory	
Session III - Chairman: J. Perina		
15.00-15.15	M. D’Angelo	Is entanglement dispensable in quantum litography?
15.15-15.45	J. Croca	Local Wavelet Analysis versus nonlocal Fourier ontology
15.45-16.15	G. Bjork	Mutually unbiased bases entanglement structures and complementarity relations
16.15-17.00	Coffee break and poster session	
Session IV - Chairman: G.S. Agarwal		
17.00-17.30	K. Banaszek	Characteristic squeezing modes in optical parametric amplification
17.30-18.00	S. Pascazio	Neutron antibunching
18-18.15	K. Yuasa	Projection Operator Method for Open Quantum Systems in the Presence of Initial Correlations
18.15 – 18.30	N. Nayak	Spin squeezing and entanglement in a dispersive cavity
18.30-19.15	Poster session	
20.00	**Social Dinner**	

Thursday 4th		
Session I - Chairman: P. Mataloni		
09.00-09.30	A. Garuccio	One way velocity of light with phase conjugate mirror
09.30-10.00	C. Schmid	Experiments on multi-photon entanglement
10.00-10.30	K. Matsumoto	Hypothesis testing for a Bell pair
10.30-11.00	Y. Shih	Can two-photon correlation of chaotic light be considered as correlation of intensity fluctuations?
11.00-11.30	Coffee break	
Session II - Chairman: M. Rasetti		
11.30-12.00	M. Paris	Distribution of information in the presence of noise
12.00-12.30	M. Palma	Entanglement extraction from condensed matter systems
12.30-12.50	F. Casagrande	Atomic correlations, decoherence of mesoscopic cavity field superposition states, and entanglement in a strongly driven micromaser
12.50-13.20	H. Moya-Cessa	Linearization of the ion-laser interaction micromotion included
13.20 – 13.50	F. Bovino	Spatial Orientation using Quantum Telepathy
13.50-15.00	Lunch	
Session III - Chairman: L. Lugiato		
15.00-15.30	C. Fabre	Quantum information processing in optical images
15.30-16.00	M.Chekhova	Multimode detection and measurement of intensity correlation functions
16.00-16.15	H. Jeong	Schrödinger's cat paradox revisited: Transfer of quantum properties from a microscopic superposition to a macroscopic mixed system
16.15-16.45	R. Okamoto	Tailoring two-photon interference with phase dispersion
16.45-17.10	Coffee break	
Session IV - Chairman: E. Predazzi		
17.10-17.30	V. Giovannetti	Quantum relative positioning in Hilbert space
17.30-17.45	T. Krueger	Entanglement and separability a treatise on different viewpoint
17.45-18.00	N. Nayak	Cavity QED mediated entanglement
18.00-18.30	S. Barrett	Efficient high-fidelity quantum computation using matter qubits and linear optics

Friday 5th		
Session I - Chairman: Chairman: C. Fabre		
09.00-09.30	J. O'Brien	Optical quantum logic gates and their use in quantum information applications
09.30-10.00	D.Goswami	On the practically of adiabatic quantum computing with optical schemes
10.00-10.30	C. Macchiavello	Ideal broadcasting and purification of mixed states
10.30-11.00	J. Rarity	Bright multiphotons for optical quantum logic
11.00-11.30	Coffee break	
Session II - Chairman: A. Andreoni		
11.30-12.00	H.Zbinden	Long distance quantum communication: From practical QKD to unpractical quantum repeaters
12.00-12.30	J. Perina	Direct measurement of photon-number statistics and spatial correlations of photon pairs
12.30-13.00	P. Zanardi	Geometric quantum information processing with semiconductor macroatoms
13.00-13.30	F. Benatti	Tests of Complete Positivity in Fiber Optics
13.30-13.45	T. Elze	Gauge symmetry of the third kind and quantum mechanics as an infrared phenomenon
13.45-15	Lunch	
Session III - Chairman: M. Paris		
15.00-15.30	T.Calarco	Quantum control theory for decoherence suppression in quantum gates
15.30-15.50	L. Maccone	Quantum metrology
15.50-16.20	Coffee break	
Session IV - Chairman: Y. Kim		
16.20-16.50	M. D’Ariano	Quantum mechanics from purely operational axioms
16.50-17.20	A. Marzuoli	The spin network quantum simulator model
17.20-17.40	F. Raffa	Lie algebras and generalized codewords and gate operators
17.40-17.50	S. Mayburov	Information restrictions in quantum measurements
17:50-18.10		Concluding remarks

POSTER SESSION

1	E.A. Anagnostakis	Nanoheterointerface Wave Function Penetration Length Photonic Characterisation
2	N. Antonietti	Atmospheric effects on a quantum communication channel between Earth and Space
3	G.P. Beretta	Mechanics and thermodynamics united by maximal-entropy-generation (steepest-entropy-ascent) nonlinear quantum dynamics
4	A. Cernoch	Several experimental implementations of phase covariant quantum cloner
5	T. Del Rosso	Photon pair production by a PPLN-waveguide for a single-photon source at TELECOM wavelength
6	N.C. Dias	Deformation quantization of confined systems
7	M. Gouanere	Experimental observation compatible with the particle internal clock
8	M. Gramegna	On the realization of controlled decoherence effects on a quantum communication channel.
9	L. Krivistky	Dispersion spreading of biphotons in optical fibre and two-photon interference
10	N.L. Harshman	Dynamical Entanglement in Non-Relativistic, Elastic Scattering
11	S. Hassan	Information entropy of a single-mode cavity QED of a Raman interaction
12	S.P. Maydanyuk	Invisible nuclear system
13	S. Mayburov	Information-Theoretical Restrictions on Quantum Measurements
14	R. Nakhmanson	Evolution, Information and Foundations of Quantum Mechanics
15	A. Napoli	Interpreting concurrence in terms of covariances
16	F. Piacentini	Reconstruction of photon statistics in bi-partite case, experimental details.
17	J.N. Prata	Environment-Induced Decoherence in Noncommutative Quantum Mechanics
18	E.Puddu	Ghost Imaging Protocol with Intense Correlated Fields for Efficient Encryption
19	M. Rajteri	Development of superconducting single-photon detectors at I.N.RI.M.
20	I. Ruo Berchera	On calibration of analog detectors by using PDC correlations.
21	L.G.P. Saavedra	The Spin and Magnetic Moment Unmeasurability of Free Electrons in Quantum Computation and Information
22	G. Scarcelli	Is Entanglement Dispensable in Quantum Lithography?
23	L. Sperandio	New experimental limit on the Pauli exclusion principle violation by electrons (the VIP experiment)
24	P. Traina	Violation of local realism by ququaters
25	G. Zambra	Photon statistics using low resolution thresold photon counters
26	R. Zapatrin	How `hot' are mixed quantum states?
27	A. Zavatta	Remote preparation of single-photon time-encoded ebits and their homodyne tomography characterization

Entangling spins by measuring charge

R. Ionicioiu

What are the resources necessary for quantum computation? In the standard model these consist of one- and two-qubit gates. It has been showed recently (Beenakker etal) that charge parity measurement can act as an efficient spin entangler and hence it can be used as a universal resource (together with single-qubit gates).
The original scheme for entangling two spins using a parity detector involves several steps and the use of an ancilla. After reviewing the recent developments of the field I will present a simplified spin entangler which does not require an ancilla. Finally I will discuss several applications of this scheme.

Recent Advances in Optical Fiber Sources of Entanglement

Paul L. Voss
School of Electrical and Computer Engineering
Georgia Tech Lorraine, Metz, France and Georgia Inst. of Technology, Atlanta, Georgia, USA

Kim Fook Lee, Xiaoying Li*, Jun Chen, Chuang Liang, and Prem Kumar
Center for Photonic Communications and Computing
Department of Electrical and Computer Engineering
Northwestern University, Evanston, Illinois, USA

Recently there has been much interest in producing polarization-entangled photons in optical fibers. Optical fiber sources of entanglement have better potential for integration into real networks and for high rate pair production than do nonlinear crystals. However, because Raman scattering occurs at the same time as four-wave mixing in the fiber, both single photons due to Raman scattering and quantum-correlated pairs of photons due to four-wave mixing are produced. For use in a quantum communications system, it is desirable to obtain the best ratio of quantum-correlated pairs to accidentally coincident pairs. Recent experimental progress in this area will be described. The construction of compact fiber sources of entanglement and their operation in realistic optical network conditions will also be reviewed. Novel potential uses of the $\chi^{(3)}$ nonlinearity of optical fibers as active elements of quantum communications networks will also be discussed.

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Calculation of the 3D interaction geometry for two interlinked $\chi^{(2)}$ processes generating entangled triplets

Maria Bondani[1)] and Alessandra Andreoni[2)]
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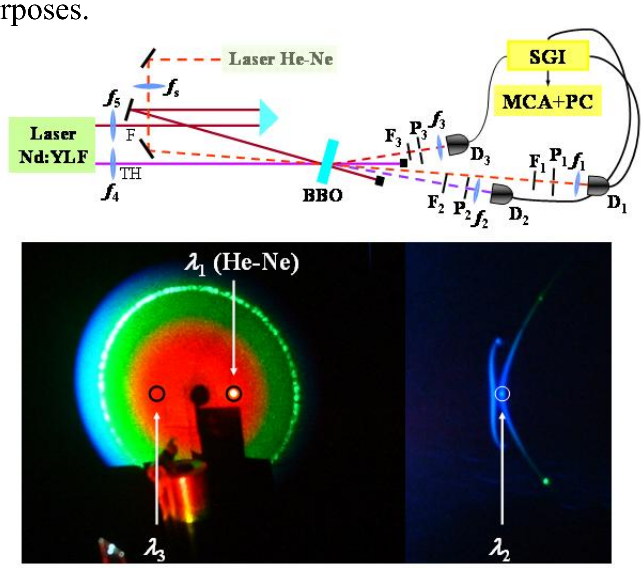
[2)] *Dipartimento di Fisica e Matematica, University of Insubria, and C.N.R.-I.N.F.M., Unita' di Como, Via Valleggio 11 – 22100 Como, Italy*

The geometrical conditions are analytically calculated in which two interlinked second-order nonlinear interactions generating entangled triplets are phase-matched in 3D [1,2]. The

interactions are a spontaneous parametric down-conversion of an intense pump and an up-conversion with a further pump that couples to a continuous of phase matched modes. The calculation applies to type-I interactions occurring in uniaxial crystals and allows to forecast positions and frequencies of the entangled triplets generated in experiments presented in this paper. The calculations show a non-trivial output pattern, whose shape dramatically changes when changing the external control parameters, which, once the frequencies of the pumps have been fixed, reduce to angle between pumps and tuning angle.
For the realization of the interaction the pump fields were provided by a regeneratively amplified mode-locked Nd:YLF laser, namely third harmonics, TH (349 nm, 4.45 ps pulse duration) for the down-conversion process and fundamental, F (1047 nm, 7.7 ps pulse duration) for the up-conversion process. In the figure we show the experimental setup and a photo, taken with a conventional digital camera, of the visible portion of the bright output pattern on a screen located beyond the nonlinear crystal. The localized spots in the figure are those generated if the down-conversion process is seeded by the light emitted by a He-Ne laser for alignment purposes.



As the Hamiltonian description of the interactions admits $N_1 = N_2 + N_3$ as a constant of motion, where 1, 2, and 3 label the triplets, a preliminary way to identify the components of an entangled triplet is to measure the correlations of the charges at the outputs of the photodetectors $D_{1,2,3}$. The existence of strong correlations is necessary but not sufficient to assess entanglement. We performed correlation measurements by inserting pin-holes of suitable diameters ($P_{1,2,3}$ in the figure aligned on the seeded spots) to identify the positions of each party of the triplet. Preliminary measurements performed with p-i-n photodiodes gave correlation values of up to 92% between N_1 and $N_2 + N_3$.

[1] A. Ferraro, M. G. A. Paris, M. Bondani, A. Allevi, E. Puddu, and A. Andreoni, J. Opt. Soc. Am. B **21**, 1241-1249 (2004).
[2] M. Bondani, A. Allevi, A. Andreoni, E. Puddu, A. Ferraro, and M.G.A. Paris, Opt. Letters **29**, 180-182 (2004), and erratum Opt. Letters **29**, 1417 (2004).

Towards a quantum computer with trapped electrons

I. Marzoli

We present a theoretical proposal to implement a quantum processor based on trapped electrons, stored in planar Penning traps. Qubits are encoded in the particle spin, that precesses around the strong homogeneous magnetic field of the trap. The typical precession frequency lies in the microwave range. Hence, the use of long-wavelength radiation for qubit operations requires an additional magnetic field gradient to selectively manipulate the qubits via frequency addressing. The same magnetic gradient, mediated by the Coulomb interaction, realizes an effective coupling between the spin qubits of different particles. The resulting system can be regarded as an artificial molecule, suitable for nuclear magnetic resonance (NMR) quantum computation. Therefore, conditional dynamics is performed by means of well established techniques already successfully demonstrated with NMR quantum computing. The system lends itself to scalability, since the same substrate can accomodate an arbitrary number of traps. Moreover, the spin-spin coupling strength is tunable and under experimental control. To predict the performances of such a quantum processor, we take into account a realistic setting within the reach of present technology.

Detector Induced Quantum Entanglement and its Measurement in Radiation from a Collective System

G. S. Agarwal
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We discuss how the quantum character of the radiation emitted from a collective system can depend on the relative position of the detectors. The successive emission of photons depends on where the detectors are placed and for certain locations only the decay in symmetric (antisymmetric) space is relevant. Further we obtain evidence for spatial bunching and antibunching. Our work also suggests that the arrival time of the second photon depends on location of the detector where the first photon was detected.

We first consider the radiation emitted from independently radiating quantum systems. If the atoms are excited by coherent light then the radiation exhibits the usual interference fringes in the far field as the point of observation is varied [1,2]. By contrast, if the system is incoherently excited no interferences can be seen in the far field intensity pattern, i.e. the first order correlation function. However, if the second order correlation function is considered interferences appear even if the system is incoherently excited, i.e. even if the emitted photons are uncorrelated [3,4]. This can be understood in terms of interferences between multiple pathways for quantum transitions as well as the detection induced entanglement. We show the non-classical nature of these intensity-intensity correlations. Such quantum interferences can be used for range of applications, i.e. for information processing or in applications to quantum search algorithms [5]. We also consider the case when the atoms are close to each other so that the dipole-dipole interaction between them is significant. In this case it is demonstrated that as a function of the detector position we can probe the decay either in the symmetric space or in the antisymmetric space [6].

References:

[1] U. Eichmann et al.,Phys. Rev. Lett. 70, 359 (1993).
[2] W. M. Itano et al., Phys. Rev. A 57, 4176 (1998).
[3] C. Skornia, J. von Zanthier, G. S. Agarwal, E. Werner, H. Walther,
Phys. Rev. A 64, 063801 (2001).
[4] G. S. Agarwal, J. von Zanthier, C. Skornia, H. Walther, Phys. Rev. A 65, 053826 (2002).
[5] G. S. Agarwal, G. O. Ariunbold, J. von Zanthier, H. Walther,
Phys. Rev. A 70, 063816 (2004).
[6] J. von Zanthier, Th. Bastin, G. S. Agarwal, to be published

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Quantum teleportation with pair coherent states

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The pair coherent states are fine examples non-Gaussian entangled states that are also accessible experimentally. These states have long been studied from the point of local realism and Bell inequalities. Recent studies focus on their entanglement properties, and also their applications to quantum key distribution. In this presentation we study the applicability of pair coherent states to
quantum teleportation. We follow the setup originally proposed by Braunstein and Kimble for the quantum teleportation of continuous variables: our Bell analyzer consists of the same homodyne measurement-based apparatus. By calculating the average teleportation fidelity we demonstrate that indeed the same coherent displacement based protocol is natural to the restoration of the state at Bob's side. Using this protocol, we examine which set of states can be teleported with high success rate using a pair coherent state of given average number of photons. We also compare the obtained results with the original scheme of continuous variable quantum teleportation.

Dispersion spreading of biphotons and two-photon interference

G. BRIDA, M. CHEKHOVA, M. GENOVESE, M. GRAMEGNA, L. KRIVITSKY

In this talk we present our recent results [1] on the first observation of two-photon interference structure in the second-order Glauber's correlation function of two-photon light generated via type-II spontaneous parametric down-conversion. In order to obtain this result, two-photon light is transmitted through an optical fibre and the coincidence distribution is analyzed by means of the Time-to-Amplitude Converter method. Beyond the experimental demonstration of an interesting effect in quantum optics, these results also have considerable relevance for quantum
communications.

[1] G. Brida et al., Phys. Rev. Lett. 96 (06) 143601.

Polarization ququarts

S.P. KULIK (SPEAKER), E.V. MOREVA, S.S. STRAUPE

We discuss the concept of polarization states of four-dimensional quantum systems (ququarts) based on frequency non-degenerate biphoton field.
Several quantum tomography protocols were developed and implemented for measurement of an arbitrary state of ququart. A simple method that does not rely on interferometric technique is used to generate and measure the sequence of ququarts that can be used for quantum key distribution purposes.

Routing of Optical States by Atomic Media

J. APPEL, E. FIGUEROA, F. VEWINGER,
K.-P. MARZLIN, A. I. LVOVSKY

Electromagnetically induced transparency (EIT) is a quantum interference effect, in which a weak signal light field and a stronger control field drive atomic transitions with a common excited state. The quantum interference between both light-atom interactions leads to strong dispersion which causes phenomena such as slowdown and stopping of light and can be used for enhanced nonlinear interaction.
We extended the standard quantum theory of EIT to accommodate for multiple excited levels and show experimentally that a transfer of optical quantum states between different signal modes can be implemented by an adiabatic change of the control fields.
Raman adiabatic transfer of optical states resembles stimulated Raman adiabatic passage (STIRAP) but applies to optical rather than atomic states. It can be used to route and distribute optically encoded information in classical and quantum communication.
We performed experiments using the hyperfine levels of Rb87 atoms at the D1 line: First, a signal pulse (resonant to the F=1, F'=1 transition) was placed into the cell under EIT conditions created by a control laser (resonant to F=2, F'=1). Then adiabatically this laser is switched off while another control laser (resonant to F=2, F'=2) is switched on. This procedure transfers the information carried by the state of the original signal pulse to the optical mode resonant with the F=1, F'=2 transition.

Magnetic microtraps for quantum control

FELICE CATALIOTTI

I will review the realization of magnetic microtraps for ultracold atoms. Such devices combine experimental simplicity with unsurpassed versatility in designing confining potentials. I will show how, combining magnetic microtraps with optical lattices one can realize many possible quantum systems of interest in many fields ranging from solid state physics to condensed matter. I will also illustrate new possibilities in the quantum simulation of different systems such as particle accelerators or biological samples.

Analysis of a Multiplexed Detector System Used To Increase Photon-Counting Rates by Reducing Effective Deadtime

S. CASTELLETTO, I. P. DEGIOVANNI, V. SCHETTINI, A. MIGDALL

We present a scheme for a photon-counting detection system that can be operated at incident photon rates that are higher than otherwise possible by suppressing the effects of detector deadtime. The method uses an array of N detectors and a 1-by-N optical switch with a control circuit to direct input light to live detectors. We present calculations and models highlighting the advantages of the technique. We show that using this scheme, a system with N detectors provides an improvement in operation rate that can exceed the improvement that would be obtained by a single detector with deadtime reduced by 1/N, even if it were feasible to produce a single detector with such a large improvement in deadtime. We note that with the advances and increasing availability in photon-counting detector arrays, the feasibility of this type of multiplexed scheme of is becoming more realistic. We model the system for CW and pulsed light sources, both of which are important for quantum metrology and quantum key distribution applications where high detection rates can be an important parameter.

Hyper-entangled two photon states for quantum communication applications

PAOLO MATALONI
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Hyper-entangled two photon states have been experimentally realized by a novel method which has been successfully realized in our laboratory in Rome. It allows to generate bi-partite two photon states simultaneously entangled over the two degrees of freedom of linear momentum and polarization, under excitation of a single, thin Type I, NL crystal in two opposite directions by a UV laser beam.
The adoption of these states may represent a useful control in quantum state engineering and Bell state measurements and. For instance, by using hyper-entangled states, one is able to discriminate the entire set of Bell states, either encoded in polarization or momentum qubits. Moreover, suitable experimental schemes in which a polarizing beam splitter acts as a C-NOT gate, with polarization acting as the control qubit and momentum as the target qubit, may be realized.
Besides their complete characterization, the experimental demonstration of the nonlocal behaviour of these states will be presented.

Realization of a Phase-conjugate mirror by using two-photon thermal light

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We will show that it is possible generate a phase conjugate mirror by using the properties of thermal light correlation.
The result is a novel scheme of imaging which can suggests useful applications.

On reconstructing photon statistics by on/off detectors: toward multi-partite case

M. GENOVESE
I.N.RI.M., Turin, Italy

Reconstructing photon statistics of optical states is necessary for various applications ranging from quantum information to foundations of quantum mechanics. Nevertheless, no detector that can well discriminate the number of incident photons is available nowadays. On the other hand the alternative of reconstructing density matrix by quantum tomography leads to various technical difficulties that are particular severe in the pulsed regime (where mode matching between signal an local oscillator is very challenging).
Even if on/off detectors, as usual avalanche PhotoDiodes operating in Geiger mode, seem useless as photo counters, recently it was shown [1] how reconstruction of photon statistics is possible by considering a variable quantum efficiency.
Recently we have experimentally demonstrated [2] the potentialities of this technique by reconstructing photon statistics for various optical fields both in cw and pulsed regime ranging from heralded photon states to multi-thermal and coherent ones.
In this talk, after a general review of this scheme and of previous results, I will present our recent experimental work addressed on one hand to an accurate estimate of uncertainties on reconstruction of diagonal elements of density matrix and on the other hand to extend this reconstruction to multi-partite case. In particular various experimental data showing the validity of the method also in this last case will be shown and discussed.

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Spatial Orientation using Quantum Telepathy

F. BOVINO

Bizarre effects of quantum entanglement are usually dramatized using Bell’s inequalities. These show that correlations between measurements on two spatially separated systems can be higher than anything allowed by the ”local realistic” (i.e. classical) theories. The way that testing Bell’s inequalities almost invariably proceeds is, in very broad terms, as follows. Alice and Bob share a number of entangled pairs, and Alice measures her systems at the same time as Bob measures his systems. After that, they communicated classically their results to each other and compute various correlation functions. When they combine these correlation functions into a Bell’s inequality, they can then check if the inequality is violated (signifying the existence of correlations stronger than any classical one). It is crucial for this experiment that Alice and Bob classically communicate with each other. Otherwise they would never be able to compute the necessary correlation functions in order to test the inequality. It is absolutely extraordinary, however, that there are applications where Alice and Bob could utilize stronger than classical correlations without any form of classical communication. Suppose that Alice and Bob are far away from each other, but happen to share some entanglement (this could have been established when they met at some earlier time). Can they, using entanglement but without utilizing any classical communication, move in the direction towards each other faster than allowed by any local realistic theories?
Namely can they find each other without communication? Surprisingly, this protocol is possible as shown very recently by Brukner et al. (quant-ph/0509123). The way that this

would proceed is that, depending on the outcomes of their respective measurements, Alice and Bob would move in certain directions, and entanglement would ensure that the directions are such that they (on average) approach each other faster than allowed classically and yet without communicating with each other. This protocol clearly exemplifies why entanglement deserves to be called ”spooky”. The effect could, in fact, be called” spatial orientation using quantum telepathy”. We experimentally demonstrate that quantum entanglement indeed leads to the faster than classical orientation in space.

Progress towards generation, storage and manipulation of entangled photons in atomic ensembles

P. WALTHER

Techniques to facilitate controlled interactions between single photons and atoms are now being actively explored. These techniques are important for the practical realization of quantum networks, in which multiple memory nodes that utilize atoms for generation, storage and processing of quantum states are connected by single-photon transmission in optical fibers. One promising avenue for the realization of quantum networks involves the manipulation of quantum pulses of light in optically dense atomic ensembles using electromagnetically induced transparency (EIT).

We demonstrate the use of electromagnetically induced transparency (EIT) for the controllable generation, transmission, and storage of single photons with tunable frequency, timing and bandwidth. Specifically, we study the interaction of single photons produced in a ’source’ ensemble of rubidium-87 atoms at room temperature with another ’target’ ensemble. This allows

us to simultaneously probe the spectral and quantum statistical properties of narrow-bandwidth single-photon pulses, revealing that their quantum nature is preserved under EIT propagation and storage.

A simple scheme to entangle uncoupled superconducting qubits via an entanglement mediator

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Superconducting quantum circuits with Josephson junctions are currently studied for their potential applications in quantum information processing. Recent experiments demonstrate reasonably long coherence times, and the possibility of state preparation, manipulation, and measurement.
A major challenge is to generate entangled states of two (or more than two) qubits for implementing quantum logic operations.
In this context, we propose a simple scheme to yield entangled states between uncoupled superconducting qubits. In our proposal, a single qubit (entanglement mediator) is repeatedly made to interact locally and consecutively with the qubits to be entangled. The possibility of designing an experimentally realizable circuit where the couplings between different qubits can be selectively switched on and off, and then scaled up to many qubits, will be discussed.

Local analysis by wavelets versus nonlocal fourier analysis

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Orthodox quantum mechanics is commonly supposed to be based on five postulates. Nevertheless a close look at the theory shows that, in reality, deeply rooted at the its very foundations lies another implicit postulate, so important and basic, that without it the whole theoretical building would crash. This implicit postulate never clearly stated is related with the Fourier ontology. This ontology claims the primary importance to the harmonic plane waves, infinite in space and time. In this perspective all other finite waves are mere compositions of these infinite waves. Furthermore it maintains that only harmonic plane waves do have a perfectly well definite frequency, either spatial or temporal. As consequence any finite pulse, any finite wave, being a necessary composition of many infinite harmonic plane waves, has as many frequencies as the waves that compose it.
The bridge with the quantum mechanics is provided by Planck-Einstein and de Broglie formulas, $E = \hbar\omega,\ p = \hbar k$.
From these two assumptions, the first conceptual and the second of experimental nature follows the magnum problem of knowing which is the energy of a single quantum particle described by a finite wave.
To be consistent with the assumptions, it follows necessarily that a single quantum particle, described by a finite wave, has as many energies as the number of harmonic plane waves necessary to build it. Since we are dealing with only one single particle how can this be true? The answer, as we well know, is the orthodox interpretation claiming that before measurement the particle does not really exists. Before the act of measurement all we have is a bunch of potentialities, or probabilities. One of these potentially existent particles can eventually be made real by the act of measurement.
The only way out of this strange situation is to reject Fourier ontology. It is necessary to accept as natural that finite waves may have a very well definite frequency. After all, infinite

in space and time, harmonic plane haves only exist in our imagination. All the true physical waves are finite. These finite waves are, in the common literature, named wavelets. Just as Fourier nonlocal analysis leads directly to Heisenberg relations, finite analysis by wavelets also allows the derivation of a more general set of uncertainty relations.

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Detecting properties incompatible with which slit property without erasure

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In the context of quantum interferometry, typically with regard to double slit experiment, an investigation is performed to find propertiesincompatible with which slit property, which can be detected without erasingthe information about which slit each particle hitting the final screen is passed through. It is found that these properties exist if the dimension of the Hilbert space description of the centre of mass of the particle is at least 4, but they can have a non-trivial character only if such a dimension is at least 6. An ideal experiment is designed which realizes this detection without erasure.

Characteristic squeezing modes in optical parametric amplification

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We describe how the operation of a realistic single-pass parametric amplifier pumped by ultrashort pulses can be understood in terms of characteristic eigenmodes exhibiting plain single-mode squeezing. This approach provides a general framework for analyzing realistic continuous-variable experiments, as well as suggests ways to improve homodyne measurements detecting sub-shot noise fluctuations. In the perturbative limit of low conversion efficiency, the characteristic squeezing modes are closely related to the Schmidt decomposition of the two-photon wave function. In this context, we present our recent measurement of the joint spectrum of photon pairs by means of Fourier-transform spectroscopy.

Neutron antibunching

S. Pascazio

Over the past three decades, the research on the foundations of quantum mechanics has been enriched by many experiments on thermal neutrons, in particular by several enlightening results about the coherence properties and the physical nature of the wave function describing the behavior of a massive particle. A general property of fermions is that of being characterized by an antisymmetric wave function: the second-order correlation function of a fermion gas exhibits an anticorrelation in the intensity fluctuations, in particular interference in the coincidence distributions of identical particles

DISTRIBUTION OF INFORMATION IN THE PRESENCE OF NOISE

M. PARIS

We address the distribution of quantum information to two or more users in the presence of noise both in the transmission and in the detection stages. Two issues are analyzed in details: on one hand we consider how to optimally send to m receivers the information encoded into an unknown coherent state, and show that for a wide range of noise parameters telecloning based on nonlocal quantum correlations is more effective than local cloning followed by direct transmission. On the other hand, we analyze linear cloning schemes for generic Gaussian states taking into account the effect of non-unit quantum efficiency and unbalanced mode-mixing, and evaluate cloning fidelity for classes of Gaussian states with fluctuating covariance matrix.

ENTANGLEMENT EXTRACTION FROM CONDENSED MATTER SYSTEMS

M. PALMA

Some thermodynamical properties of solids, such as heat capacity and magnetic susceptibility, have recently been shown to be linked to the amount of entanglement in a solid. However this entanglement can be a mere mathematical artefact of the typical symmetrization procedure of many-body wave function in solid state physics. Here we show that this entanglement is physical by extracting it from a typical solid state system by scattering two particles off of the system. Moreover we show how to simulate this process using the present-day technology of optical lattices. This demonstrates that entanglement not only exists in solids but can even be used for quantum information processing or to violate Bell's inequalities.

Can Two-photon Correlation of Chaotic Light Be Considered as Correlation of Intensity Fluctuations?

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Two-photon correlation phenomena, including the historical experiment of Hanbury Brown and Twiss, may have to be described quantum mechanically, regardless if the source of radiation is “classical” or quantum. Supporting this point, we present a “ghost” imaging type of second-order spatial correlation experiment of chaotic light to show that the classical understanding based on the concept of statistical intensity fluctuations does not give a correct interpretation for the observation. On the other hand, the quantum model for this experiment provides a perfect solution. From a practical point of view, this experiment demonstrates the possibility of having high contrast lensless two-photon imaging with chaotic light, suggesting imaging applications for radiations for which no effective lens is available.

Quantum Mechanics From Purely Operational Axioms

GIACOMO MAURO D'ARIANO

I show how it is possible to derive the Hilbert space formulation of Quantum Mechanics from a comprehensive definition of "physical experiment" and assuming "experimental

accessibility and simplicity" as specified by five simple Postulates. Pivotal roles are played by the "local observability principle", which reconciles the holism of nonlocality with the reductionism of local observation, and by the postulated existence of "informationally complete observables" and of a "symmetric faithful state". This last notion allows one to introduce an operational definition for the real version of the "adjoint"--i. e. the transposition--from which one can derive a real Hilbert-space structure via either the Mackey-Kakutani or the Gelfand- Naimark-Segal constructions. I will analyze in detail the Gelfand- Naimark-Segal construction, which leads to a real Hilbert space structure analogous to that of (classes of generally unbounded) selfadjoint operators in Quantum Mechanics. For finite dimensions, general dimensionality theorems that can be derived from a local observability principle, allow us to represent the elements of the real Hilbert space as operators over an underlying complex Hilbert space. The route for the present operational axiomatization was suggested by novel ideas originated from Quantum Tomography.

Hypothesis testing for a Bell pair

K. MATSUMOTO

It is important to assess the performance of devices which produce entangled quantum states. We consider a problem to optimize the assessment scheme under the framework of hypothesis testing, a classical problem in quantum information. The optimal testing schemes are derived under some kinds of locality conditions and invariance conditions. In this problem, there is a mathematical difficulties caused by the intractability of LOCC measurement. In order to avoid the difficulty, we consider additional conditions such as invariance associated with the entangled state. Moreover, the measurement is discretized for the sake of convenience in experimental realization.

Atomic correlations, decoherence of mesoscopic cavity field superposition states, and entanglement in a strongly driven micromaser

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One of the most intriguing problems in modern physics is to explain the emergence from the quantum mechanical laws of the classical appearance of the macroscopic world. The fundamental features of quantum mechanics, such as linearity and entanglement, imply the occurrence of interference effects and nonlocal correlations, hence of seemingly paradoxical behaviours that we do not see in the world around us. In macroscopic systems, the unavoidable interaction with the environment induces a decay of quantum coherence, or decoherence, that is practically instantaneous. However, the investigation of systems of mesoscopic size allowed the observation of decoherence in progress by the Haroche group [1]. They generated superpositions of two coherent cavity field states with the same amplitude but different phases, called cat states after the famous Schrödinger paradox, and monitored their decoherence. Besides its deep fundamental importance, the study of decoherence plays a central role in quantum information and communication.

We suggest an alternative scheme [2] for the generation and the decoherence of mesoscopic cavity field superposition states, based on a strongly driven micromaser. In this system a beam of two-level atoms crosses a superconductive microwave cavity where the atomic

transition is resonant with one cavity mode. The atoms cross the cavity one at a time and during the passage they are strongly driven by a classical field.
The dynamics of this quantum open system was analytically solved [3] in spite of the presence of pumping, driving, dissipative, and thermal effects, showing remarkable atom-atom correlations at steady-state. Furthermore [2], in atomic correlation measurements, the detection of the first probe atom prepares a mesoscopic superposition field state, whose decoherence can be described by conditional probabilities for the detection of the second probe atom. The decoherence rate is proportional to the squared interaction time, that rules the separation in phase space between the superposition components, whereas it is independent of the atomic pumping rate. When the cavity is not pumped and the temperature is negligible, the superpositions are just cat states, whose decoherence can be thus monitored by a scheme that may offer some advantages in comparison with [1]. In particular, the atom-photon interaction is resonant rather than dispersive; there is one coherent field driving the atoms in the cavity, instead of two fields acting on the atoms in auxiliary cavities; the cat states are maximally rather than partially separated, i.e., the coherent states have opposite phases.
We also describe the entanglement properties of the system [4]. We show that a strongly driven atom and a resonant cavity mode can be maximally entangled for long enough interaction times, whereas the atom-atom correlations have a classical origin.

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Linearization of the ion-laser interaction micromotion included

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We show that the time dependent Hamiltonian for the ion-laser interaction may be linearized by means of a set of time dependent unitary transformations. We use the method of Ermakov-Lewis invariants to produce Jaynes-Cummings like interactions that may be used in different interaction regimes such as low intensity and high intensity regimes. The method is based on the generalization of a time independent transformation already introduced in [1] to the time dependent case.
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Multi-mode detection and measurement of intensity correlation functions

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For light emitted via parametric down-conversion, normalized intensity correlation functions of different orders are considered. The main problem when measuring such correlation functions is their extremely small time width, which reduces the contrast (the maximal measured value of the correlation function). It is shown that if the radiation under study is modulated by a periodic sequence of pulses that are short compared to the correlation function width, there is no reduction of the contrast. Normalized second-order correlation function is measured in the pulsed regime as a function of mean photon number. It is shown that a simple relation exists between the contrast and the mean number of photons per pulse.

Schrödinger's cat paradox revisited: Transfer of quantum properties from a microscopic superposition to a macroscopic mixed system

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We investigate a more reasonable analogy of Schrödinger's cat paradox [1], where the virtual cat is a significantly mixed thermal state at a high temperature. Our discussion is motivated by the observation that a truly classical system cannot be in a pure state because of its interactions with the environment. We find that non-classical properties of microscopic quantum superpositions can be transferred to thermal states of large average photon numbers. The resulting states show strong quantum coherence and entanglement between severely mixed thermal states. Our examples show that the classical nature of the initial "cat" in Schrödinger's paradox does not preclude the observation of deep quantum phenomena. Remarkably, quantum entanglement can be produced between thermal states with nearly the maximum Bell-inequality violation [2,3] even when the temperatures of the thermal states approach infinity. Our examples are feasible in real physical systems and may be realized for some moderate cases using current technology. A weak cross-Kerr nonlinearity can be used to generate "superpositions" between significantly mixed thermal states in the presence of decoherence with highly visible interference patterns.

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Tailoring two-photon interference with phase dispersion

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When two photons are sent to a 50-50 beam splitter simultaneously, two photon interference bunches them up on one of the output port of the beam splitter. Hong-Ou-Mandel dip (HOM dip), which is the first experimental demonstration of the two photon interference, is observed

when the number of coincidence event is measured while scanning an optical delay added to the one of the input path [1]. Two photon interference has become an important tool in a variety of fields [2-4].
Phase dispersion is given to the photon which passes through the material having frequency-dependent phase shifts. Franson analyzed the effect of dispersion up to the second order and found that the shape of the HOM dip were unchanged [5]. This phenomenon, called dispersion cancellation, was experimentally demonstrated by Steinberg et al. [6]. The dispersion cancellation for photon pairs produced by ultra short pulses were also studied [7]. However, the effect of phase dispersion, including higher-order terms, on the HOM dip has not been analytically formulated.
We show a complete analytical formalism of the effect of phase dispersion on the HOM dip with CW pumping. We found that the HOM dip is strongly modified by the frequency-dependent phase modulation including higher-order terms. We also show that the phase dispersion function can be fully reconstructed via Fourier transformation from the measurement result of the HOM dip when the dispersion function is anti-symmetric. An experimental demonstration of the proposed method using a band pass filter as a test sample is also presented. It means that we can measure the phase dispersion of material with the experimental stability of two photon interference.

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Ideal broadcasting and purification of mixed states

C. MACCHIAVELLO

"Broadcasting", namely distributing information to many users, suffers in-principle limitations when the information is quantum. For pure states ideal broadcasting coincides with "quantum cloning", which is forbidden by the no-cloning theorem for pure states drawn from a non orthogonal set.
For mixed states the no broadcasting theorem says that perfect broadcasting from an input state drawn from a set of two non commuting density operators to two output states cannot be achieved. We prove that this theorem cannot be generalised to more than a single input copy. Moreover, we present the phenomenon of superbroadcasting, where it is possible to purify the input states while broadcasting. We also discuss the relations between optimal broadcasting and other tasks of interest in quantum information.

Bright Multiphotons for Optical Quantum Logic

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The photon is a near ideal carrier of quantum information showing little or no decoherence. The main sources of error become losses and small technical errors due to imperfect components. Although the photon can carry of quantum information the absence of a single photon non-linearity makes optical quantum logic difficult. Linear optical logic has thus been developed exploiting multi-photon interference to make probabilistic gates. These optical quantum logic schemes require high efficiency sources of single and pair photons [1]. We have developed a high brightness pair photon source based on four-wave mixing in micro-structured optical fibre [2]. With this source we are able to demonstrate a bright four photon source producing up to 100 four photon detections per second (two orders of magnitude brighter than alternative sources). Of course to be useful we need this source to produce pure states. This is confirmed in our first four photon interference experiment where we show interference between separate sources of heralded single photons. This is the first step towards building the multi-photon entangled states needed for linear logic schemes.

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Long distance quantum communication: from practical QKD to unpractical quantum repeaters

H. ZBINDEN

On the one hand, we present and demonstrate a new protocol for practical quantum cryptography, tailored for an implementation with weak coherent pulses to obtain a high key generation rate. The key is obtained by a simple time-of-arrival measurement on the data line the presence of an eavesdropper is checked by an interferometer on an additional monitoring line. The setup is experimentally simple; moreover, it is tolerant to reduced interference visibility and to photon number splitting attacks, thus featuring a high efficiency in terms of distilled secret bit per qubit. On the other hand, we present recent results from a quantum teleportation experiment over installed optical fibres and a new source of coherent photon pairs, which allows Bell-state measurements after many kilometers of fibers. These is a necessary but unfortunately insufficient ingredient for a future quantum repeater.

Geometric Quantum Information Processing with Semiconductor Macroatoms

P. ZANARDI

Holonomic Quantum Computing (HQC) is an all-geometric strategy for quantum information processing. HQC is realized by means of adiabatic non-abelian quantum holonomies i.e., generalized Berry phases. In this talk I will introduce the basic ideas of HQC and I will discuss an implementation proposal based on semiconductor nanostructures where quantum hardware consists of coupled semiconductor macroatoms addressed/controlled by ultrafast multicolor laser-pulse sequences and qubits are encoded in excitonic states.

Tests of Complete Positivity in Fiber Optics

F. BENATTI

We consider the propagation of polarized photons in optical fibers under the action of randomly generated noise.
In such situation, the change in time of the photon polarization can be described by a quantum dynamical semigroup.
We show that the hierarchy among the decay constants of the polarization density matrix elements as prescribed by complete positivity can be experimentally probed using standard laboratory setups.

Squeezing oscillations of quantized field interacting with pair of cold atoms via intensity-dependent coupling

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At present great attention is devoted to the cooperative interaction of radiators with quantized electromagnetic field and special attention is devoted to the two-atom systems interacting with radiation field. For example, Tanas and Ficek investigated two-atom entanglement induced by nonclassical two-photon correlations (Tanas and Ficek 2004). In this paper it was demonstrated that the pair of two-level atoms interacting with a squeezed vacuum field can exhibit stationary entanglement associated with nonclassical two-photon correlations characteristic of the squeezed vacuum field. Lately, Chimczak et al proposed a scheme to teleport an entangled state of two Lambda -type atoms via photons (Chimczak et al 2005). It was shown how to manipulate a state of many Lambda -type atoms trapped in a cavity.
On the other hand, with recent rapid development of ion-trapping technology two-slit experiments, requiring the isolation and localization of two atoms are now possible. Thus, a Young two-slit experiment with trapped and laser-cooled ions has been reported (Eichmann et al 1993). In this situation it is desirable to study the interaction of quantized field with pair of cold atoms via intensity-dependent coupling (Buck and Sukumar 1981, 1984). We suppose that two-level atoms in the pair are indistinguishable. It should be noted that the pair of indistinguishable two-level atoms is equivalent to the three-level equidistant model with equal dipole moment matrix transition elements between the adjacent levels (Enaki and Koroli 1999). In this case the states of the atomic pair can be described in the three-level states

representation in the following way: the ground state $|g\rangle$ describes the case when both atoms of the pair are in the ground state, the first excited state $|e_1\rangle$ is equivalent to the case in which the first two-level atom of the pair is in the ground state and the second one is in the excited state and in the second excited state $|e_2\rangle$ both atoms are in the excited state. This problem generalizes the Jaynes-Cummings model with the intensity-dependent coupling interacting with Holstein-Primakoff SU(1,1) coherent state (Buzek 1989). We examine the special case of the Holstein-Primakoff realization of the SU(1,1) Lie algebra (Enaki and Koroli 1998).
We suppose that in the initial moment $t = o$ the field is in the Holstein–Primakoff SU(1,1) coherent state $|\xi\rangle$and the atom is in the first excited state $|e_1\rangle$. In this situation by using Schrodinger equation the exact analytical solution for the state-vector of the coupled atom-field system is found. By using this solution the quantum statistical properties of the radiation field are investigated. It should be noted that the exact periodicity of the physical quantities, particularly of the mean photon number and their fluctuations, that takes place in the single-atom model (Buzek 1989) is violated in our case. Nevertheless, we observe that the mean photon number and their fluctuations exhibit the oscillatory behavior. In this case takes place both Sub- and Super-Poissonian statistics of the field. We have studied the squeezing features of the single-mode electromagnetic field. In this situation we also observe the oscillatory squeezing behavior. It should be emphasized that in the two-atom system the exact periodicity of squeezing is violated in contrast with the single-atom model (Buzek 1989) in which the revivals of squeezing are strictly periodical for any value of initial squeezing.

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Recent progress toward “engineered” entangled-photon states

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Entangled-photon states are one of the most basic resources in photonic quantum information research. Especially, photon pairs that are entangled in their polarization degrees of freedom, generated via the process of spontaneous parametric down-conversion, have played important roles in recent experimental developments in quantum communication as well as photonic quantum computation.
As application possibilities of entangled-photon states grow, demands for engineered entangled-photon states, i.e., entangled-photon states that are engineered for specific purposes, will rise. Such entangled-photon state engineering calls for accurate understanding of all aspects of spontaneous parametric down-conversion; not only polarization properties, but also spectral, temporal, and pump laser properties.
In this talk, we will describe recent progress toward engineered entangled photon states generated by spontaneous parametric down-conversion, with emphases on temporal, spectral, and pump properties.

Quantum control theory for decoherence suppression in quantum gates

T. CALARCO

It can be fairly said that nobody really knows how to build a working quantum computer, with a number of logical qubits such that current classical machines can be outperformed. The path to real implementation for each candidate scheme is full of obstacles, often of a practical nature, like limitations in the way a certain physical system can be bent to behave in an ideally desired way. In this talk the problem is approached at the level of realization of two-qubit gates in a range of atomic systems, exploiting the methods of quantum optimal control theory, and investigating how these techniques allow for overcoming the effect of nonidealities and noise on the gate performance.

Quantum metrology

I. MACCONE

We point out a general framework that encompasses most cases in which quantum effects enable an increase in precision when estimating a parameter (quantum metrology). The typical quantum
precision-enhancement is of the order of the square root of the number of times the system is sampled. We prove that this is optimal and we point out the different strategies (classical and quantum) that permit to attain this bound.

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The spin network quantum simulator model

A. MARZUOLI AND M. RASETTI

The spin network quantum simulator model (A.Marzuoli and M.Rasetti, Annals of Physics 318 (2005),345 quant-ph/0410105) is an ideal playground to discuss both discrete and analogic computational problems involving several, binary coupled SU(2) angular momenta. Relationships between discrete/quantum and continuous/classical models of computation will be
discussed, possibly together with some examples of algorithms.

Stretching the electron as far as it will go

P. SODANO

An exactly solvable model is used to illustrate the idea that Majorana fermions can mediate anomalous transport phenomena in highly correlated electron systems.

Nanoheterointerface Wave Function Penetration Length Photonic Characterisation

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The persistent photoenhancement of the mobility of the two-dimensional electron gas (2DEG) dwelling within a typical functional semiconductor nanoheterointerface (NHI) is processed to yield the energetic separation between the fundamental and first excited conduction subband of the NHI quantum well (QW). By virtue of this, a simulative model rectangular QW is seeked for; thus providing an effective spatial width for the actual NHI QW hosting the 2DEG wave function (WF), along with an estimation for the crucial optoelectronic parametre of the NHI WF penetration length into the QW energetic barrier layer – tantamount with the 2DEG mobility behaviour. The Sturm – Liouville eigenvalue system comprising the quantum mechanical Schroedinger differential equation for the NHI WF and the appropriate asymptotic boundary conditions is treated by a finite difference method, after the employment of an independent variable transformation restricting the integration domain to a universal dimensionless interval. The handling of the problem evolves into the numerical calculation of the eigenvectors and respective eigenvalues of a specific tridiagonal matrix hosting the three successions of coefficients appearing in the kind of finite difference equations selected to convergingly approach the initial Sturm – Liouville differential equation. A careful investigation, then, of the 2DEG WF leakage tail out of the optimised effective NHI QW and into the neighbouring potential energy barrier layer yields the WF penetration length value, permeating the character of 2DEG mobility behaviour versus conduction electron population enhancement in a coherent manner and satisfactorily agreeing with alternatively obtained findings for the parametre.

Atmospheric effects on a single photon in a quantum communication Channel from Earth to Space

N. ANTONIETTI, M. MONDIN, G. BRIDA, M. GENOVESE

Quantum physics can assure secure exchange of information, according to the different quantum communication protocols which exploit single or entangled photons' properties.
Such protocols have been successfully tested in free space for dozens of kilometres.
Next challenge is quantum communication from Earth to Space. Since quantum communications are feasible as long as the chosen properties of the photons hold steady and as the photon has to go right through the atmosphere, before trying any real experiment, a theoretical study of the interactions between a single photon and atmosphere is needed.

In this poster we want to report our introductory study about this topic. A polarization coding is presented, the chosen model of the atmosphere is explained and the first results of different simulations are provided.
Future investigations and results will say whether a quantum communication between Earth and Space is feasible and, eventually, in which way it is possible to achieve best performances.

Photon pair production by a PPLN-waveguide for a single-photon source at TELECOM wavelength

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In this work we measure the efficiency of photon pair production from degenerate parametric downconversion at the photon counting level, generated in a laboratory prototype of PPLN waveguide at 1572 nm. The aim is to enhance the brightness of an heralded single photon source and to improve the compactness for quantum communication applications, namely quantum key distribution. We observed a maximum of the conversion efficiency corresponding to 7.9 10^6 photon pairs/s for a pump power of 28 W. This value is compared with the measured pairs production in a classical experiment of difference frequency generation, realized with the same sample by analogue classical detection. We highlight the advantages of using the waveguide versus a bulk PPLN for such applications and we foresee further possible improvements by adopting waveguide in a single photon level experimental setup.

Deformation quantization of confined systems

N.C. DIAS

A new formulation of quantum systems with boundaries will be presented. This will be used to derive a consistent Wigner-Weyl formulation of confined systems.

Experimental observation compatible with the particle internal clock

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The particle internal clock conjectured by L. de Broglie in 1924 was looked for in a channeling experiment with ~80 MeV electrons traversing a 1-mm thick silicon crystal aligned along the <110> direction. Part of them undergo what is called the rosette motion, in which they interact with a single atomic row. When the electron energy is finely varied, the rate of electron transmission at 0Â° shows an 8% dip within 0.5% of the resonance energy, 80.874 MeV, for which the frequency of atomic collisions matches the internal clock frequency. Our observation is compatible with the de Broglie hypothesis.

On the realization of controlled decoherence effects on a quantum communication channel

M. GRAMEGNA, G. BRIDA, M. GENOVESE

To dispose of controlled decoherence in a quantum communication channel would offer various interesting possibilities ranging from the study of the characterisation of the channel as a CP map to the realisation of a medium where studying how to cope decoherence itself.
In this poster we present preliminary results on the realisation of such a medium by using an acoustic ultrasound bath in which a fiber is immerged.

Dispersion Spreading of Biphotons in Optical Fibres and Two-photon Interference

G. BRIDA, M. CHEKHOVA, M. GENOVESE, M. GRAMEGNA, L. KRIVITSKY

In many quantum communication, quantum computation experiments, entangled states of light are transmitted through optical fibres. For example, quantum key distribution through fibres has already been demonstrated up to 100 km. Because of these applications, a clear understanding of the effect of fibre propagation on the properties of entangled states is highly demanded. In particular, it is known that an entangled two-photon state, a biphoton, spreads in time when propagating through a medium with group velocity dispersion. More specifically, the second-order intensity correlation function of two-photon light gets broadened and at a sufficiently large distance, it takes the shape of the spectrum. It turns out that for biphotons propagating through a dispersion medium, the shape of the correlation function can manifest the effects of two-photon interference. In experiment we generate biphotons from type II nonlinear crystal in collinear frequency degenerate regime. After that we couple biphotons in single mode optical fiber. At the fibers end one place a polarization controller and after that address biphotons to the Brown-Twiss interferometer with polarization selection in diagonal basis. The time coincidence distribution has been analyzed by means of the Time-to-Amplitude converter method. It has been demonstrated clear interference structure in the shape of second-order Glauber correlation function with visibility of about 35%. The problem of non unity visibility achieved in experiment has been explained by influence of a jitter time of the detectors.
Beyond the experimental demonstration of an interesting effect in quantum optics, the achieved results also have considerable relevance for quantum communications. Also, It is worth of mentioning that the measurement of the observed broadening of the second-order Glauber correlation function could eventually be used for the evaluation of the optical fibre chromatic dispersion.

Dynamical Entanglement in Non-Relativistic, Elastic Scattering

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In scattering, it is assumed that the in-coming state is completely uncorrelated and therefore separable. The S-matrix is a global operator that transforms the in-state is transformed into the out-state, which may no longer be separable. This poster presents results on how global Galilean invariance constrains the amount of entanglement that can be dynamically generated in two-body, non-relativistic elastic scattering. Entanglement in both the spin degrees of freedom and momentum degrees of freedom is discussed. The connections to partial wave analysis are also explored.

Information - Theoretical Restrictions in Quantum Measurements Theory

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The restrictions imposed by Information Theory on the possible outcomes of quantum measurements and their efficiency are analyzed. As the example, we regard the measurement of observable Q for some binary state S performed by the information system O which is surrounded by environment E . It's shown that the principal constraints, induced by Heisenberg Commutation Relations, restrict significantly the amount of information J about S state which can be transferred to O in the individual event. Eventually O efficiency of S states discrimination is much weaker than the predictions from quantum dynamical calculations only. In particular, the pure and mixed states with the same <Q> are practically indistinguishable. It temptatively explains the experimentally observed stochasticity of measurement outcomes, i.e. the collapse of quantum state. The influence of E decoherence doesn't change principally obtained restrictions, but can enlarge the information losses additionally. It's argued that the information processing (perception) in the biological systems can be regarded in the same framework. The possible applications to the information transfer and acquisition in Molecular Biology and Bioelectronics are discussed.

Evolution, Information, and Foundations of Quantum Mechanics

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By the end of every year, the editors and news staff of Science (www.sciencemag.org) look back at the big science stories of the past 12 months. As top Breakthrough of 2005 they dub the progress in evolution – "theory in biology postulating that the various types of animals and plants have their origin in other preexisting types and that the distinguishable differences are due to modifications in successive generations" (ENCYCLOPÆDIA BRITANNICA). The evolution does not only select materials and constructions ("hardware") but purposes and laws of behavior ("software") as well. Receiving, using, processing, and spreading of semantic information are the essence of life.

Does semantic information play a role in a world of "inanimate" matter? The theory being applied to microcosm leads to informational interpretation of quantum mechanics. This interpretation is very natural, realistic and local, it explains quantum-mechanical paradoxes and can be proved experimentally. In my talk I will explain schemes of appropriate experiments. In accordance with this interpretation a wave function is not in real 3D space as thought de Broglie, Schrödinger, Heisenberg, and Bohm. It is not in von Neumann's and Wigner's (or his friend's) consciousness. The wave function is in the consciousness of the particle. It is the strategy of a particle's behavior. Each alternation of the wave function, for example because of the choice among alternatives opened by interactions (e.g. with a measurement apparatus) is the so-called collapse of the wave function. The collapse occurs in the consciousness of the particle. In the consciousness of experimenter is only some imagination of particle's wave function. The choice among alternatives occurs using random tactics to search all possible alternatives. The term "Wave packet" belongs to an ensemble, not to a lonely material particle. A lonely photon has a definite frequency ν, energy $\mathbf{h\nu}$, and polarization.

FAQ: Delta ν-spectrum corresponds to an infinite space interval. Where is the photon?
A: If you know the time, point, and direction of the photon after its last interaction you can calculate where and when it is.
All what we know relates to the past. To have a successful strategy we must predict future. Prediction is a very important ability selected by evolution. Consciousness gifted with such an ability is a "hidden variable" missed by Bell. Using fast and random switching of analyzers in performed EPR-like experiments does not exclude prediction.
The noted physician Erasmus Darwin (grandfather of the great naturalist Charles Robert Darwin) played the flute for his flowers. The physicist Charles Galton Darwin (Ch. R. Darwin's grandson) wrote in 1919: "It may be necessary to make ... fundamental changes in our ideas ... .or even ... to endow electrons with free will." The respect to intuition shown by Darwin's clan should encourage us to play music for electrons, photons, and atoms.

More can be found e.g.in http://arXiv.org/pdf/physics/0508143 .

Interpreting concurrence in terms of covariances

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Interacting spin systems have quite recently attracted a growing attention also in view of the fact that they are ideal candidates for the quantum gates needed in quantum computing. We study the dynamics of a system of M Heisenberg coupled one-half spins investigating in particular the time evolution of the entanglement get established within a couple among them. We bring to light the existence of appropriate physical conditions under which we succeed in disclosing a conceptual and quantitative link between the concurrence function and a quantity having a clear physical meaning.

Environment-Induced Decoherence in Noncommutative Quantum Mechanics

J.N. Prata

I derive the Hu-Paz-Zhang equation for a Brownian particle linearly coupled to a bath of harmonic oscillators on the noncommutative plane. In the high-temperature Ohmic regime I study the noncommutative-commutative transition.

Ghost Imaging Protocol with Intense Correlated Fields for Efficient Encryption

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Quantum key distribution (QKD) is a direct application of fundamental quantum mechanics, involving two parties, Alice and Bob, exchanging some information via a classical channel. By QKD Alice and Bob share secret random keys to implement a secure encryption-decryption algorithm (one time pad) without meeting. The security of the distributed keys is based on the laws of quantum physics [1]. However, at variance with classical communication that can be performed at a rate of Gbyte/s, though in insecure way, practical QKD protocols, in their up-to-date best realizations, allow secure quantum key rates below 10 Kbit/s, possibly improved to 100 Kbit/s in the next ten years [2]. Therefore, as the length of the key must necessarily equal the length of the message to guarantee security, for a real-world application quantum keys can be used only for encrypting the most sensitive parts of the messages. In protocols for secure image transmission [3], the problem cannot be easily bypassed since any image must be encrypted as a whole.

As a solution to this problem we propose ghost imaging [4]. In fact ghost imaging allows image retrieval through the computation of the fourth order correlation coefficients of two strongly correlated fields at suitable different positions. Actually we measure photon fluxes in the test and reference arms and compute the correlation coefficients of the intensity fluctuations. Nevertheless, none of the measurements on test/reference arm is sufficient to provide information about the image by itself. This peculiarity suggested us to use the ghost imaging protocol presented here for secure encryption of images. In particular, we realized ghost imaging in the continuous variable regime and, by using classically correlated beams [5] [6], we could easily implement our setup. We obtained the two beams through a seeded parametric down-conversion process at frequency degeneracy, in which we used an intense thermal beam as the seed, thus generating a beam that was strongly correlated to it. We then sent one of the two thermal beams in the test arm to illuminate the object and the other in the reference arm, which contained an imaging lens and a position-sensitive detector (CCD camera). As, in the test arm, we simply measured the pulse energy by means of a bucket detector, the data collected during the experiment were a set of real numbers on this arm representing to the total photon flux and a set of digitized images representing the spatial distribution of the photon flux density of the thermal reference beam. The last set is the one that Alice sends to Bob through a public non-jammable channel, while the first set is encrypted by using the secure quantum key prior to transmission.

With this experiment we demonstrate that the size of the test-arm data that is necessary to encrypt is only 21% the size of the image that Bob can recover by computing the correlations of above.

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Development of superconducting single-photon detectors at I.N.RI.M.

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Among the different kinds of single photon detectors the transition-edge sensors (TES) are the only one with an intrinsic energy resolution and a photon number discrimination capability. This properties account for the interest in developing this type of detector both for metrological and quantum communication applications [1].
TES is a calorimeter using its sharp transition from the normal to the superconducting state as a thermometer. The very high slope of the resistance vs. temperature curve allows to detect a single photon down to infrared wavelengths. The highest energy resolution is obtainable at temperatures below 100 mK, in the electron-phonon decoupling region, where the heat capacity of the detector is reduced only to the contribution of the electronic system of the material C_e, and the thermal conductance is dominated by the conductance between the electronic and the phonon system of the material. g_{e-ph}. The intrinsic response time in the absence of a bias power is $\tau_0 = C_e/g_{e-ph}$.
The voltage bias of the detector [2] provides a convenient mechanism for delivering electrical power directly to the electronic system. Such kind of bias takes advantage of a negative electro-thermal feedback (ETF) that allows to obtain a self-regulation of the bias point without a fine temperature control and to improve the response time up to two or three order of magnitude.
The detector is made with a 50μm x 50μm x 150nm Ti film deposited on a 500μm SiN substrate with g=13.3 nW/K, C=11.2 pJ/K, τ_{etf}~78 μs, T_c in the range of 300-350 mK and R=0.8Ω.
Constant critical current measurements and pulse critical current measurements have been done on the sample finding, with the second method, a three time greater value.
In the visible – near infrared range the main limit to their quantum efficiency (QE) is represented from the reflectivity of the metal surface which can be higher than 50 %. Antireflection coatings can be applied to titanium films in order to reduce the reflectivity both at single wavelengths or in a limited band of wavelengths. To this aim, we have design , by means of genetic algorithms some antireflection coatings based on layers with high and low refraction index [3]. As coating materials we choose hydrogenated amorphous silicon-nitrogen alloys (a-SiNx:Hy) [4] deposited with a R.F. PECVD deposition system.

These materials have a refractive index tuneable up to 4 in the visible range, and allow us to easily obtain the low and high index needed for the multilayer. The simulations are made with the starting layer close to the Ti film. After the deposition of the layers, the reflectivity was measured at room temperature with a spectrophotometer and it was compared with the simulation data.
The computed and measured reflectance at two wavelengths is lower than 0.33%[5] and mean value of the reflectance for a limited band is 7%[5].

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The Spin and Magnetic Moment Unmeasurability of Free Electrons in Quantum Computation and Information

L.G.P. SAAVEDRA

It will be shown with Stern-Gerlach and magnetometer thought experiments that it is impossible to measure and use the spin and magnetic moment of free electrons in quantum information and computation

Is Entanglement Dispensable in Quantum Lithography?

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The working principle of quantum lithography has been demonstrated a few years ago: entangled N-photon system can improve the spatial resolution of an imaging system by a factor of N even beyond its classical limit. Recently, a number of experiments successfully simulated certain features of quantum imaging by using chaotic light. Can classical light simulate the effect of quantum lithography? This paper attempts to provide an answer to this currently debated topic.

The VIP experiment
(VIolation of the Pauli Exclusion Principle)
New experimental limit on the Pauli Exclusion Principle violation by electrons

LAURA SPERANDIO on behalf of the VIP collaboration
1

The Pauli Exclusion Principle (PEP) represents one of the fundamental principles of the modern physics and our comprehension of the surrounding matter is based on it. Even if today there are no compelling reasons to doubt its validity, it still spurs a lively debate on its limits, as testified by the abundant contributions found in the literature and in topical conferences. We present a method of searching for possible small violations of PEP for electrons, through the search for "anomalous" X-ray transitions in copper atoms, produced by "fresh" electrons which can decay in a Pauli-forbidden transition to the 1s level, already occupied by two electrons. The VIP Experiment scientific goal is to improve by four orders of magnitude the present limit on the probability of PEP violation for electrons, bringing it into the 10^{-30} –10^{-31} region, which is of particular interest for all those theories related to possible PEP violation coming from new physics.

Remote preparation of single-photon time-encoded ebits and their homodyne tomography characterization

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We propose and implement a novel method for the remote preparation of entangled bits (ebits) made of a single photon coherently delocalized intwo well-separated temporal modes. The proposed scheme represents a remotely tunable source for tailoring arbitrary ebits, whether maximally or non-maximally entangled, which is highly desirable for applications in quantum information technology. The source is characterized by performing dual-mode homodyne tomography with an ultra-fast time-domain balanced homodyne detection scheme recently developed in our laboratory. A preliminary tomographic test of Bell's inequality is also discussed