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Organizers: M. Genovese, G. Brida, M.L. Rastello

Digest

Monday 26th

Welcome by IEN former president E. Bava

Tuesday 27th

Wednesday 28th

Posters

Engineered Entanglement: From Quantum Cryptography to Quantum “Bio-Photonics"

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We discuss novel quantum-optical measurement techniques in bio-medical engineering based on specially engineered entangled-photon states. The power and high information capacity of entangled states has been so far demonstrated in several areas of quantum communication and quantum computing. We recently developed new techniques for precise optical measurement in life sciences and optoelectronics that take advantage of quantum entanglement and exceed traditional approaches both in resolution and in the amount of obtained information about the system under evaluation. We review our latest results when the engineering of specialty entangled-photon states with particular spatial, spectral, and polarization characteristics enabled us to demonstrate such novel technologies as quantum optical coherence tomography and quantum ellipsometry.
We discuss potential benefits our new quantum approaches can provide in bio-photonics and optoelectronics.

Entanglement and cosmology

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In these years there is a very strong symbiotic relationship between particle physics and cosmology. The Einstein-Podolsy-Rosen (EPR) paradox has become one of the most controversial problems of QM. In particular and generally speaking, we define EPR effect as a correlated character of quantum processes in regions separated by a space-like interval though referring to a single (coherent) quantum state of the system.
Following EPR paradox and its generalization in the last years it is emerging a sort of correlation between cosmology and EPR quantum systems.
One of the most important problems in cosmology is the study on the primordial Universe is connected with the electroweak phase transition, at t=10^{-12} sec from the Big Bang.
During this phase transistion we have the appearance of topological defects (domain walls, cosmic strings...), in particular the domain walls occur at the boundaries between regions of space with values of the field phi that interpolates the wall.
In this context our work is addressed to study the probability of formation of domain wall taking into account the EPR effects and the presence of a primordial magnetic field that may be originated at the electroweak phase transition.

Scalable quantum computer with trapped electrons in vacuum (*)

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In recent years we proposed the use of a trapped electron in a Penning trap as a toy-model to implement quantum logic operations. The trapped electron in vacuum is indeed a great resource because with that single particle one could operate with up to three qubits, respectively given by the two external degrees of freedom, i.e. the cyclotron motion and the axial motion, and the natural qubit: its spin.
.However, the real challenge is to devise a scalable quantum computer where the number of qubits is, in principle, unlimited. This can be achieved only using more than one particle. It is, therefore, fundamental to extend the existing schemes to trap and manipulate an electron to several particles. Hence, we need a completely new trap design to hold and manipulate each particle and, at the same time, to guarantee its single addressability. On the other side, we require the possibility to perform two-particle operations.
We thus present a scheme for the implementation of a scalable quantum processor consisting of a linear array of electrons.

(*)This work has been done in collaboration with G. Ciaramicoli and I. Marzoli.

A continuous variable, shift resistant stabilizer quantum code: the role of non-linearity in Josephson-coupled systems

M. Rasetti, Politecnico di Torino, Italy

The implementation of quantum information processing devices in physical systems exhibiting Josephson coupling, such has SQUID and/or superconductive Josephson junction based devices, or weakly coupled Bose condensates, is more and more promising. The non-linearity of the interaction characteristic of such systems leads to a number of novel subtle features, some of which may be efficiently exploited in the QIP applications. After concisely surveying the most relevant ones, the realization of a continuous variable, shift-resistant stabilizer quantum code is discussed.

Optimal phase covariant cloning, phase estimation and spin networks

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We present optimal phase covariant cloning transformations for equatorial d-dimensional systems, highlighting their connections to quantum cryptographicprotocols. We relate these results to the problem of optimal estimation of multiplephases for systems with arbitrary finite dimension. We finally show how to realise phase covariant cloning in spin networks.

Experiments with time-frequency entangled photon pairs

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We will review recent experiments performed by the group of the National Institute of Applied Optics (INOA) in Florence on the time-frequency entangled photons generated by pulsed SPDC. In particular, we will concentrate on: i) the non-local temporal/spectral shaping mechanisms which led to the observation of "ghost" interferences in the spectrum of one photon conditioned by the crossing of a temporal double-slit by the entangled twin; ii) the appearance of controllable recurrent Hong-Ou-Mandel interferences when a "comb-like" two-photon state is created by placing an etalon optical cavity in the path of one of the two photons.

Informationally complete quantum measurements

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A quantum measurement is "informationally complete" when it can be used to determine any desired ensemble average by only changing the processing of the measurement outcomes. Such novel kind of measurement is of relevance both at the foundational level, and for applications to the Quantum Information technology. Methods for optimizing the data processing are presented, along with strategies for designing "universal detectors".

Continuous-variable experiments with qubits

Alexander Lvovsky
Univ. Konstanz, Germany

I will report on some of our recent experiments involving field quadrature measurements of highly nonclassical optical states. Special attention will be paid to nonlocal properties of a dual-rail qubit – a single photon split over two spatially separated optical modes.

Experimental Evidence for Bounds on Quantum Correlations

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We implemented the experiment proposed by Cabello in the preceding Letter to test the bounds of quantum correlation. As expected from the theory we found that, for certain choices of local observables, Tsirelson's bound of the Clauser-Horne-Shimony-Holt inequality is not reached by any quantum states.

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Towards quantum information processing with multiphoton states

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Generation and manipulation of entangled multiphoton states is a prerequisite for more complex long-haul quantum communications protocols, with the prospects of leading to fully scalable photonic quantum computation. We report here the development of a down-conversion source based on a non-linear KTP waveguide that delivers photons in controlled spatio-temporal modes with ultrahigh production rates. As the first test of this source, we discuss a verification of non-classical character of down-converted radiation using inequalities that take into account limitations of avalanche photodiodes, namely their incapability to resolve multiphoton detection events. We also present a general method to overcome this limitation of avalanche photodiodes by splitting the input light pulse into a large number of output modes that can be expected to contain no more than one photon. Finally, we discuss theoretically how the development of tools for manipulating multiphoton states can be used for conditional generation of maximally entangled photon pairs without the usual strong vacuum contribution.

Light pulses on Bose-Einstein condensates: from Rabi oscillations to superradiance

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When laser light is elastically scattered from a Bose-Einstein condensate two atomic wavepackets with different momenta are created. By applying a strong laser beam and varying the intensity of a weak counterpropagating laser beam we observe the transition from the Rabi oscillation regime in a two-level system to the pure superradiant regime. The process is limited by the decoherence between the two atomic wavepackets. In the superradiant regime the experiment gives evidence of a contribution to decoherence which depends on the square of the energy difference between the two wavepackets.

Orthogonality of single-mode biphotons

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We consider polarization state for two-photon light in one frequency and wavevector mode. Such single-mode two-photon states, often called biphotons, represent three-state quantum systems, or qutrits. To implement ternary quantum communication protocols for such biphotons, one should find an operational (experimental) criterion for their orthogonality, which allows one to distinguish between three mutually orthogonal biphoton states. In this work, we formulate such a criterion theoretically and verify it in an experiment where single-mode biphotons with arbitrary polarization degree are produced through spontaneous parametric down-conversion in collinear frequency-degenerate regime.

Quantum states engineering: qutrits based on biphotons.

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We consider experimental methods for generation, transformation and measurement of particular three-state system. This quantum object (qutrit) is realized on polarization states of degenerate collinear two-photon field (biphoton).
For qutrits generation the interferometric technique is used which allows to combine biphotons emitted from three nonlinear crystals separated in space. All parameters determining the state are controlled using appropriate phase plates and phase shifters. For transforming the state different phase plates are applied to qutrits as well but such type of transformation does not allow one to realize complete untiray transformation of arbitrary qutrits. For the state measuring the quantum tomography method was developed and tested.
Also we report about preparation and measurement of 12 particular quantum states, which might be used in quantum key distribution based on three-state systems

A conclusive experiment to throw more light on “light”

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We report on the realization of Ghose, Agarwal and Home experiment about the precise nature of wave particle duality at single photon state regime, performed taking Unnikrishnan and Murthy's advices to overcome empirical and statistical limitation growth up in the experimental set-up and anticoincidence measurement of Mizobuchi and Ohtaké realization. Our result is obtained by the valuation of the parameter *alfa* that discriminate the thermal, coherent or quantum nature of the source, and highlights the urge of weaken the sharp interpretation of the mutual wave-particle exclusiveness expressed in the actual formulation of the Bohr's principle versus a smooth disappearing of coherence at the increasing of “whelcher weg” information, all in agreement with the formalism of quantum mechanics.

Entangled and correlated imaging in the macroscopic regime

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The technique of Entangled Imaging, first formulated by Klyshko, has attracted a lot of attention in the recent years. It allows to obtain for example the image of an object or the intensity distribution of its Fourier transform (diffraction pattern), with a degree of flexibility superior to the standard imaging techniques.
The basis of this technique is to have two spatially entangled beams. We focus on the case in

which they have a large number of photons per pulse, and we show both analytically and numerically that in this regime the imaging performances of the entangled source can be emulated by classically correlated beams. These are created by utilizing thermal (or thermal-like) radiation with appropriate properties, injecting it onto a beam splitter and treating the two outgoing beams in the same way as the signal and idler beams in entangled imaging. The two cases of entangled beams and classically correlated thermal beams are treated in parallel.

Experimental quantum communication complexity

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Quantum communication complexity is one of the promising applications in quantum information processing. It tackles the problem of communication reduction during distributed computation tasks by the utilization of quantum effects. It was theoretically proven that entanglement or qubit communication can help to solve a range of such tasks with even exponential gain over optimal classical protocols.

We report on the experimental realization of one-qubit communication complexity protocol, in which five parties must determine in common the correct value of a specific Boolean function with the highest possible probability of success. This function depends on personal random data distributed initially to each party. To accomplish the task the parties can communicate sequentially only one qubit.

The protocol is implemented using single photon passing through all parties and the last one performs an analysis of a photon polarization state. The personal information of each party is encoded via a phase transformation to the photon state. For a fair comparison with classical one-bit protocol, no experimental runs are discarded, even if the detection of photon fails. The obtained results enabled us to demonstrate for the first time the superiority of quantum communication over its classical counterpart for a broad class of distributed computation tasks.

Optomechanical network for the manipulation of quantum information

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We present an optomechanical system as a paradigm of three-mode teleportation network. Quantum state transfer among optical and vibrational modes becomes possible by exploiting correlations established by radiation pressure.

Convergence properties of quantum random walks

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Although quantum random walks cannot be considered as stochastic processes in the usual sense, it is possible to define and study their convergence properties in terms of the sequence of probability measures induced by the quantum dynamical evolution. Here we present a new convergence theorem for general quantum walks on D-dimensional lattices. In particular, we show that the position distribution of the quantum walker converges weakly, after a large number of steps, to a limit distribution which is absolutely continuous and with bounded support. This weak convergence generalizes to the quantum case the central limit theorem for classical random walks.
The proof is rigorous and allows to compute in a simple way the asymptotic distribution in terms of the spectrum of the evolution operator of the process.

Numerical simulations of Entangled Imaging with direct and with homodyne detection

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We illustrate the results for entangled imaging in the macroscopic regime with extended, realistic numerical simulations and animations for the case of quantum correlated beams generated by parametric down-conversion. In particular, by using a special technique we demonstrate how the object diffraction pattern can be obtained by a vastly reduced number of pulse-repetitions, and also that this method greatly improves the imaging bandwidth with respect to the natural spatial bandwidth in parametric down-conversion.
An advantage of the quantum configuration is that one can perform homodyne detection instead of direct intensity detection. We show that in addition to the amplitude information that is also available to the latter scheme, the homodyne scheme allows to obtain also the phase information. Moreover, the special technique mentionad above works particularly well for the homodyne scheme in the far field, allowing for a complete retrieval of even highly complex images.

Conditioned unitary gate on biphotons and application to photodetectors calibration

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We describe the realization of a conditioned unitary transformation (90 degrees polarization rotation) at single photon level. The transformation is realized by rotating the polarization of a photon belonging to a biphoton state by means of a Pockel cell triggered by the detection of the other photon of the pair after polarization selection. This result is relevant to practical realization of various quantum information schemes.
Furthermore, we propose, as an application of this set-up, a new scheme for measuring the quantum efficiency of a single photon detection apparatus. We present experimental results obtained with this scheme(QE = 0.449 ±0.031) compared with traditional biphoton calibration (QE=0.4812 ±0.0015). Various corrections to be introduced for the two schemes are discussed. An uncertainty budget for the two cases is presented. Our results show the interesting potentiality of the suggested scheme.

Generation and characterization of bipartite entangled mixed states with tunable degree of mixedness

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Maximally entangled mixed states (MEMS), including entangled pure states and Werner states, are created by a universal parametric source of entanglement which has been developed in Rome. Several kinds of mixed states, spanning a 2x2 Hilbert space may be created by this source. The results concerning the detection of entanglement by the entanglement witness method as well the characterization and investigation of the nonlocal properties of all these states are presented.

Quantum computations with atoms in optical lattices: marker atoms and molecular interactions

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We develop a scheme for quantum computation with neutral atoms, based on the concept of "marker" atoms, i.e., auxiliary atoms that can be efficiently transported in state-independent periodic external traps to operate quantum gates between physically distant qubits. This allows for relaxing a number of experimental constraints for quantum computation with neutral atoms in microscopic potential, including single-atom laser addressability. We discuss the advantages of this approach in a concrete physical scenario involving molecular interactions.

Refocusing schemes for holonomic quantum computation in presence of dissipation

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The effects of dissipation on a holonomic quantum computation scheme are analyzed within the quantum-jump approach. We extend to the non-Abelian case the refocusing strategies formerly introduced for (Abelian) geometric computation. We show how double loop symmetrization schemes allow one to get rid of the unwanted influence of dissipation in the no-jump trajectory.

Three-mode entanglement in continuous variable systems

Matteo Paris
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We address the generation of entanglement by bilinear Hamiltonian in cv systems, analyze its characterization and robustness against noise, and discuss its application to telecloning and conditional generation of two-mode entanglement.

An All Linear Optical Quantum Memories and Repeaters Based on Quantum Error Correction

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When photons are sent through a fiber as part of a quantum communication protocol, the error that is most difficult to correct is photon loss. Here, we propose and analyze a two-to-four qubit encoding scheme, which can recover the loss of one qubit in the transmission. This device acts as a repeater when it is placed in series to cover a distance larger than the attenuation length of the fiber, and it acts as an optical quantum memory when it is inserted in a fiber loop. We call this dual-purpose device a ``quantum transponder."

Beyond the Heisenberg uncertainty principle

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Quantum entanglement is one of the most surprising consequences of quantum mechanics. Based on EPR's criteria, the presence of the ä-functions ä(p_1+p_2) and ä(x_1-x_2) in the idealized entangled two-particle system considered by EPR, seems to represent a violation of the uncertainty principle. It is indeed true, from a statistical point of view, that correlation measurements realized on two independent particles must obey the inequalities: Ä(p_1+p_2) > Max(Äp_1, Äp_2) and Ä(x_1-x_2) > Max(Äx_1, Äx_2). The apparent contradiction between these classical inequalities and the EPR inequalities: Ä(p_1+p_2) < min(Äp_1, Äp_2) and Ä(x_1-x_2) < min(Äx_1, Äx_2) has deeply troubled EPR and many other physicists. Our recent experiments have demonstrated that entangled two-photon systems satisfy the EPR inequalities. These experimental demonstrations also highlighted a number of novel practical protocols for high-precision timing and positioning applications. The accuracy in these measurements could overcome, in principle, the limitations imposed by the uncertainty principle. However, we show that this is not a violation of the uncertainty principle.

On the Measurement of Two-Photon Single Mode Coupling Efficiency in PDC Photon Sources

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The advent of photon-based quantum cryptography, communication, and computation schemes [1–10] has increased the need for light sources that produce individual photons [11]. An ideal single-photon source would produce completely characterized single photons on demand. Because all of the currently available sources fall significantly short of this ideal (that is they do not produce photons 100% of the time and/or they do not produce only single photons), much efforts has been focused on creating improved single photon on demand sources (SPOD). Some of these schemes [12, 13] rely on optical parametric downconversion (PDC), because it produces photons two at a time, allowing one photon to herald the existence of the other. In a previous work, we proposed one such scheme where a multiplexed PDC array is used to make an improved SPOD source with increased probability of single photon emission, while suppressing the probability of multi-photon generation [13]. Most PDC-based schemes (including ours) require that the PDC output be collected into a single spatial mode defined by an optical fiber. For these PDC schemes to reliably produce single photons, it is essential that the optical collection system efficiently gathers and detects the herald photon, and with minimal loss, sends its twin to the output of the system.

Various theoretical models have been developed to predict how the collection efficiency of PDC light in a "two-photon single mode" can be improved [14–17], and in some cases these models have been used to improve coupling efficiency. In particular, it has been shown that the size of the pump beam focus affects the shape of the PDC output [14] and hence the coupling efficiency of the PDC light into a given spatial mode. In addition, a more detailed work [16] recently showed how increasing the crystal length and walk-off reduces the coupling efficiency for a pulsed broadband pump. However, in these last works, the attempts to increase the single mode fiber coupling efficiency were limited to a thin crystal and a tightly focused pump beam, which reduces the overall source brightness. This restriction is forced on the calculations because the approximations used for the phase mismatch function in terms of longitudinal wavevector mismatch are not valid in the long crystal case. Moreover these works deal only with either type I or II exclusively, they do not include the non-collinearity and walk-off of the emitted photons and the pump beam. The work done to date does however give some partial guidance for increasing coupling efficiency in certain experimental situations. For instance, the most practical results to date generally show that the collection efficiency for long crystals is optimized for properly matched large pump and collection waists. However the maximum efficiency is limited by walk-off in type II [16] phase-matching and by excessive crystal length in type I phase-matching [17]. Furthermore, the approximations done in the previous theory limited the validity of the results to a narrow range of crystal lengths and collection/pump waists.

A more general approach to the problem is needed to clarify open issues such as those mentioned above (i.e. overcoming the calculations limits and extending the theory), and to determine how we can best test the collection efficiency modelling. Here we present two models describing the coupling of the PDC source into single spatial modes, which lead to two different results, even in the thin crystal limit. One method is intensity-based, where an intensity projector operator represents the effect of a spatial filtering, as suggested in refs.[14, 18]. The second method uses a field-based model to describe the coupling of the PDC field with single mode fiber defined fields, as has been partially presented in other works [16, 17]. We calculate the intensity-based and field-based collection efficiencies between both type I and II PDC output and two single modes defined by optical fibers, accounting for effects due to the crystal length, walk-off of extraordinary fields, non collinear phase-matching, and pump transverse field distribution. We then evaluate analytically both efficiencies assuming negligible second order terms in the transverse component of the wavevectors. Finally, we propose an experimental test to distinguish between the two. We also point out that understanding collection efficiency is a particularly crucial issue when it comes to PDC-based metrological applications, which are very sensitive to collection efficiency[19].

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Disentanglement possibility of EPR pairs in double-slit schemes

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The basic concepts of superposition and quantum entanglement have been considered as key ingredients in most of the foundations of quantum mechanics issues as well as quantum communication and computation schemes. Entanglement of EPRB pairs (two spin-entangled particles) [1] was applied to introduce Bell's inequality and some novel quantum communication scheme such as dense coding and teleportation [2]. It was shown that use of original EPR pair (two position and momentum-entangled particles) [3] can be resulted in obtaining more efficient dense coding and teleportation schemes [4, 5]. Here, we have studied the entanglement property of quantum systems including two EPR particles distributed according to a Gaussian wave function as a more realistic representation than the plane wave function. It is shown that, by considering superposition of the plane wave functions for describing the two-particle system, the probabilistic interpretation of the wave function and momentum eigenfunction relation show the same results for the entanglement property. However, using the Gaussian distribution for the two particles, the results of the probabilistic interpretation and the momentum eigenfunction relation can give inconsistent results at the individual level of the pairs. In fact, the momentum eigenfunction relation justifies the entanglement of the two particles, while the probabilistic interpretation shows a none zero probability for observing the two particles in a disentangled form. Instead, this inconsistency does not appear in a deterministic quantum theory of motion such as Bohmian quantum mechanics. Incidentally, the standard and Bohmian quantum mechanics predict the same results for an ensemble of the particles so that quantum equilibrium hypothesis is satisfied. In this regard, we have used such two-particle quantum system in double-slit schemes to propose that the standard and Bohmian quantum mechanics can show different predictions at the individual level of pairs. Recently, one of these schemes, presented in [6], has been put to experiment by Brida *et al.* [7] using two undistinguishable photons produced by type I parametric down-conversion method. However, some of the issues about the proposed scheme and its realization are still open to discussion [8, 9, 10].

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Test of Local Realism with Entangled Kaon Pairs

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It is well known that all the Bell–type tests designed to distinguish between Quantum Mechanics and Local Realism and performed so far (with photon and ion pairs) have been subject to loopholes; they could not test and disprove the full class of Local Realistic Theories since supplementary assumptions not implicit in Local Realism had to be introduced to analyse the data.

Motivated mainly by the desire to reach the conditions for closing the loopholes which affect the photon and ion experiments, recent studies [1] considered the use of the neutral kaon system. Adapting an argument by Hardy [2], in this talk we propose to discuss the use of entangled pairs of neutral kaons to prove Bell's theorem without employing Bell's inequalities [3]. The proof is then translated into a testable Eberhard's inequality. Being a genuine Bell's inequality, i.e., derived without introducing supplementary assumptions, it requires an analysis of the inefficiencies and nonidealities involved in kaon state preparation and measurement [4]. The conditions under which this inequality could conclusively refute any Local Realistic Theory is thus discussed [5].

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POSTERS

EPR inequalities - beyond the classical limit

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We derive a set of EPR inequalities in space-time variables which allow distinguishing quantum two-particle entanglement from classical correlation of two particles. In a recent two-photon 'ghost' interference and imaging experiment, the EPR inequalities have been directly demonstrated. Besides shading light on some fundamental issues of quantum theory, this experiment also emphasizes the unique advantage offered by quantum entanglement in nonlocal imaging and other practical applications. We show experimentally that entanglement can overcome the limitations imposed by the uncertainty principle, allowing high resolution measurements.

Realisation of a pulsed source of heralded photons with strong spectral selection for EIT at single photon level

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We will describe the realisation of a heralded photon source in pulsed regime with strong spectral selection to be used for performing an experiment of Electromagnetic Induced Transparency at single photon. level. Preliminar results will be presented.
The source has been obtained by pumping a BBO crystal with a laser beam at 355 nm (triplicate of a Neodimium Yag one) with pulses of 5 ns and energy per pulse up to 200 mJ. Thank to the strong energy per pulse one can then perform a strong spectral selection keeping a sufficiently high probability of having a photon for each pulse. The spectral selection is performed on two correlated directions by means of two monochromators.
In particular, with the purpose of realising an experiment of EIT at single photon level, we select 780 nm (corresponding to a specific transition of rubidium atoms) and its conjugate (which is used as a trigger for certifying the production of the pair). After the spectral selection the heralded photon at 780 nm is addressed to a Rb atoms cell. In the same cell it is sent a diode laser beam locked to the Rb line. A theoretical study show that EIT at single photon level should be observed in this configuration [1].
The observation of this phenomenon, would represent a step toward the realisation of a phase gate at single photon level based on Kerr interaction between photons in the atomic medium.

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Quantum dense key distribution and secure communication without cryptography

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Quantum dense coding (QDC) and quantum key distribution (QKD) are two direct applications of fundamental quantum mechanics, both involving two parties, Alice and Bob, exchanging some classical information.

By QKD Alice and Bob exchange secret random keys to implement a secure encryption-decryption algorithm (one-time pad) without meeting, and the security of the distributed keys is based on the laws of quantum physics [1].

Theoretically proposed in [2], QDC basically doubles the capacity of transmission of a classical channel by local operations on one particle of the EPR pair shared by the two parties. QDC has received only partial experimental verification [3] using polarization entangled states of photons because of the inefficiently implemented Bell's state analysis [4] and a lack of security in the transmitted information.

Recently, Bostroem and Felbinger [5] gave birth to the original idea of a protocol encoding secure information by local operations on an EPR pair, though rather proposing a *deterministic* and *secure* transmission than implementing a truly *dense* coding scheme.

Here we present a protocol for the quantum dense key distribution (QDKD) including the advantages of QKD and QDC in generating shared secret keys and enhancing transmission capacity [6]; this protocol can be modified and used also for *deterministic* and *secure* transmission as the one in [5]. The protocol has been proved to be secure against individual eavesdropping attack by using a non-local measurement. We proved also that QDKD reaches the maximum of the efficiency of QKD protocols.

We performed a experimental implementation establishing the conditions for a secure QDKD. The experiment in fact proved the feasibility of QDKD by showing high-visibility interferometric profiles as well as low-noise anticorrelation check.

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Orthogonality of Qutrits

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Annotation: Orthogonality of two-photon polarization states belonging to a single frequency and spatial mode is demonstrated experimentally, in a generalization of the well-known anti-correlation 'dip' experiment.

Entanglement-enhanced communication over a quantum channel with correlated noise

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We present an experiment demonstrating entanglement-enhanced classical capacity of a quantum channel with correlated noise. The channel is modelled by a fiber optic link exhibiting random birefringence that fluctuates on a time scale much longer than the temporal separation between consecutive uses of the channel. In this setting, introducing entanglement between two photons travelling down the fiber allows one to encode reliably one bit of information into their joint polarization degree of freedom. When no quantum correlations between two separate uses of the channel are allowed, this capacity is reduced by a factor of more than three.

Contextual realization of the universal quantum cloning machine and of the universal-NOT gate by quantum-injected optical parametric amplification

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A simultaneous, contextual experimental demonstration of the two processes of *cloning* an input qubit and of *flipping* it into the orthogonal one is reported. The adopted experimental apparatus, a quantum-injected optical parametric amplifier is transformed simultaneously into a universal optimal quantum cloning machine and into a universal-NOT quantum-information gate. The two processes, indeed *forbidden* in their *exact* form for fundamental quantum limitations, were found to be *universal* and *optimal*, i.e., the measured *fidelity* of both processes $F<1$ was find close to the limit values evaluated by quantum theory.

Squeezing properties of an isolated mesoscopic Josephson junction

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Josephson junctions are nowadays regarded one of the leading candidates for the actual implementation of a quantum computer.
In the present paper a theoretical analysis of the ideal case of an isolated mesoscopic junction in the superconductive (or phase) regime is described. In this regime the Hamiltonian of the junction proves to be

$$H_J = -4\,E_C \frac{d^2}{d\varphi^2} + E_J(1-\cos\varphi)\,, \tag{1}$$

where φ is the phase difference of the Ginzburg-Landau wave function between the two superconducting electrodes of the junction and E_J, E_C are energy parameters, with $E_J \gg E_C$ in the superconductive regime.
The investigation is carried out in terms of the dimensionless Hamiltonian $\mathcal{H} = \frac{1}{w^2}\frac{H_J}{E_J}$, where $w = (8\frac{E_C}{E_J})^{\frac{1}{4}}$. It is shown that $\mathcal{H}$ can be diagonalized once one realizes that the eigenvalue equation of $\mathcal{H}$ is the well-known Mathieu equation, which is usually written as

$$\frac{d^2 y}{dv^2} + (A - 2\,Q\cos(2v))\,y = 0\,. \tag{2}$$

From the analysis of the eigenvalues of Eq. (2) the perturbative expansions for both $\mathcal{H}$ and its spectrum of eigenvalues are obtained in terms of H_o and $(n+\frac{1}{2})$, respectively, being H_o the dimensionless Hamiltonian of the harmonic oscillator and $(n+\frac{1}{2})$ its eigenvalue corresponding to the Fock state $|n\rangle$. Explicit calculations are presented in the anharmonic oscillator approximation.
In this approximation the squeezing properties inherent in the nonlinearity of the junction are investigated. In particular, the variances of the dimensionless x and p operators are calculated in closed form. Such operators are part of the set of generators $\{\,\mathbb{I}, x, p, \mathcal{H}\}$ of the dynamical quantum algebra of the junction.