A B S T R A C T S

SEMICLASSICAL MODEL OF THE RESONANCE FLUORESCENCE OF A TWO LEVEL ATOM IN A ONE DIMENSIONAL PHOTONIC CRYSTAL.

A. Alejo-Molina, S. Sánchez-Sánchez y J. J. Sánchez-Mondragón

The possibility of studying the resonance Fluorescence of a Two Level Atom (TLA) in an Omniguide Fiber (a Bragg fiber produced by a circular Stack) is discussed using a semiclassical model of a TLA in the defect of a One Dimensional quarter wave Stack. We describe the spectral and temporal evolution of the TLA Resonance Fluorescence, pointing out the relative dimensions of the gap half-width, with the Rabi frequency and the detuning between the center gap and the atomic frequency.

QUANTUM OPTICAL REALIZATION OF AN ENTANGLEMENT WITNESS AND QUANTUM TOMOGRAPHIC INVESTIGATION OF WERNER AND MEMS ENTANGLED STATES

M. Barbieri, F. De Martini, P. Mataloni

By a novel ultra-bright parametric source of photon pairs[1], hyper-entangled in polarization and k-vectors, relevant physical processes are investigated in crucial and hitherto rather unexplored areas of quantum information (QI). Some of these QI processes will be analyzed theoretically and experimentally. In particular, a detailed quantum tomographys analysis of the Werner states and of the Maximally Entangled Mixed States (MEMS) will be presented[2]. Furthermore, the first realization of an *Entanglement Witness* to achieve a complete characterization of entanglement is presented[3]. The new source is found to represent the only resource to investigate quantum nonlocality in the ideal conditions implied by the premises established in 1935 by Einstein, Podolsky and Rosen. A loophole-free nonlocality experiment along this direction, now in preparation, is discussed.

[1] G.Giorgi *et al*., Laser Physics, 13, 350 (2003).
[2] M.Barbieri *et al.*, Phys. Rev. Lett. (in press).
[3] M. Barbieri *et al.,* Phys.Rev. Lett. 91, 227901 (2003).

RESONANCE FLUORESCENCE OF A TRAPPED THREE LEVEL ATOM

Marc Bienert, Wolfgang Merkel and Giovanna Morigi

We theoretically analyse the spectrum of resonance fluorescence of a single, harmonically trapped atom. The internal transitions are Λ-shaped and driven at two-photon resonance by a pair of cooling lasers, cooling the centre-of-mass motion. We use the spectral decomposition of the Liouville operator of the atomic master equation and apply second order perturbation theory in the Lamb-Dicke parameter. The properties of the spectrum of resonance fluorescence are discussed, we explain the physical origin of the spectral components and also show how one can recover the temperature and the cooling rate from the spectrum.

POLARIZATION DESCRIPTIONS OF QUANTIZED FIELDS

Gunnar Björk

The polarization state of a propagating electromagnetic field is a robust characteristic, which is relatively simple to manipulate without inducing more than marginal losses. For this reason, many recent experiments in quantum optics, such as Bell tests, quantum tomography, entanglement witnesses, quantum cryptography, and quantum dense coding, have been performed using polarization states. As long as single photon states are used in these applications, the classical description of polarization is valid and can be used. However, for states with higher excitation, the classical and quantum descriptions differ, leading, e.g., to states with "hidden polarization". Various attempts have been made to define the degree of polarization for quantized fields. In the talk some formalisms will be reviewed and compared.

DYNAMICAL THEORY OF VAN DER WAALS FORCES

S. Buhmann, D.-G. Welsch, L. Knoell and Ho Trung Dung

Based on macroscopic quantum electrodynamics, we present a dynamical theory of the van der Waals (vdW) interaction between a single atomic system in an arbitrary internal state and an arbitrary arrangement of dispersing and absorbing magnetodielectric bodies, including bodies containing the recently fabricated left-handed materials. It can be used to describe the vdW force in both strong and weak coupling regimes, for arbitrary states of the electromagnetic field, and (within the frame of macroscopic electrodynamics) for arbitrary distances. In particular, we show that atomic quantities such as the atomic polarizability become position-dependent and in consequence the vdW force is in general not conservative, even if the atomic system is in the ground state.

ENTANGLEMENT AND QUANTUM PHASE TRANSITIONS IN THE DICKE MODEL

Vladímir Bu ek , Miguel Orszag and Marián Roško

We show that using tools of quantum information theory one can identify in the ground state of the Dicke model a sequence of N quantum phase transitions. These phase transitions appear at specific values of the coupling constant κ_j that are functions of the number of atoms N. We prove that the ground state of the Dicke model exhibits bi-partite entanglement between arbitrary pair of atoms for an arbitrary value of the coupling constant $\kappa \geq \kappa_1 = 1/N^{1/2}$. The degree of the entanglement between the atoms (as measured by concurrence) is discontinuously changed at the points κ_j of phase transitions.

ENGINEERING NOVEL QUANTUM INFORMATION PROCESSING DEVICES.

Giacomo Mauro D'Ariano

A quantum computer may help in solving many problems, including the possibility of engineering new quantum processors and new measuring devices. However, it is often natural and convenient to process quantum information directly, such as in Quantum Optics, where the information could be encoded on the field quadratures, or on the photon number. The problem is then to find which are the building blocks to network in order to engineer new quantum processing devices. The starting point for this search are the three quantum convex structures: (S) states, (O) operations, and (P) POVM's (measurements). The ``maps" between the convex structures correspond to different kinds of quantum information processing, such as tomography and quantum calibration, programmable processors and measuring apparatuses, universal observables, pre-processing and post-processing of measurements. We will present some recent results on some of these novel devices, in particular quantum programmable measurements, universal observables, and quantum calibration, with some implementations in Quantum Optics, and concluding with a list of relevant open problems.

DECOHERENCE AND THE CLASSICAL LIMIT OF QUANTUM MECHANICS FOR CHAOTIC SYSTEMS.

L. Davidovich, R. L. de Matos Filho, and F. Toscano

We investigate how decoherence affects the short-time separation between quantum and classical dynamics for classically chaotic systems, within the framework of a specific model. For a wide range of parameters, the distance between the corresponding phase-space distributions depends on a single parameter χ that relates an effective Planck constant $\hbar_{eff}$, the Lyapunov coefficient, and the diffusion constant. This distance peaks at a time that depends logarithmically on $\hbar_{eff}$, in agreement with previous estimations of the separation time for Hamiltonian systems. However, for $\chi \lesssim 1$, the separation remains small, going down with $\hbar_{eff}$, so the concept of separation time loses its meaning.

SU(3) PHASE OPERATORS: SOME SOLUTIONS AND PROPERTIES

Hubert de Guise

The construction of SU(3) phase operators via polar decomposition of su(3) generators is not unique. Some SU(3) phase operators acting inside finite dimensional su(3) spaces will be presented, with emphasis on the connection between boundary conditions and commutativity properties of relative phases.

ENTANGLEMENT AND THE QUANTUM MEMORY FORCE

J.H. Eberly, K.W. Chan, C.K. Law and M.V. Fedorov

abstract: Generalization of the so-called Pauli exchange force to non-identical particles gives rise to the concept of a quantum memory force. This is manifest in the spatial coordination that is enforced between quantum-entangled systems, and has consequences for EPR experiments of various kinds [1-3].

[1] J.H. Eberly, K.W. Chan and C.K. Law, Phil. Trans. R. Soc. London A 361, 1519 (2003).
[2] M.V. Fedorov, et al., Phys. Rev. A 69, 052117 (2004) .
[3] C.K. Law and J.H. Eberly, Phys. Rev. Lett. 92, 127903 (2004).

DECOHERENCE CONTROL BY SPECTRAL REDISTRIBUTION OF THE NOISE

K. M. Fonseca Romero, S. Kohler and P. Hänggi

We characterize the decoherence process using the average rate of loss of purity. Using a quantum Wiener-Khinchin theorem we show that the use of high frequency driving fields bring about an spectral redistribution of noise (SRN), which can be exploited to stabilize coherence. Two particular instances of SNR are the dynamical decoupling and the recently proposed coherent destruction of tunneling. As examples we study the influence of an external periodic driving field on the coherence properties of (i) a qubit and (ii) a CNOT gate, subjected to a noise source of ohmic type. We show that there are parameter regimes (temperature, frequency and amplitude of the driving field) in which the characteristic time for coherence loss is longer for the driven system. Our analysis reveals the existence of two different physical phenomena, which are able to improve the coherence performance: one causes the freezing of the degrees of freedom responsible for the noise, and the other leads to the suppression of the relaxation processes.

CORRELATED IMAGING WITH QUANTUM ENTANGLED BEAMS AND CLASSICAL THERMAL BEAMS

A. Gatti, M. Bache, E. Brambilla and L.A. Lugiato

Spatial quantum entanglement is a fundamental property of parametric down-conversion, the first observation of this phenomenon in the macroscopic regime of large number of signal-idler photon pairs has been attained very recently in our Institute by Paolo Di Trapani with Ottavia Jedrkiewicz. The same phenomenon is the basis for the technique of entangled imaging or ghost imaging, which has attracted noteworthy attention in the recent years. We focus on the case in which the entangled beams 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. These results are fully confirmed by a very recent experiment performed by Fabio Ferri with Davide Magatti in our Institute.

DECOHERENCE, ALIAS FIDELITY DECAY OF THE ENVIRONMENT

T. Gorin, T. Prosen, T.H. Seligman and W. Strunz

For a wide class of practically important situations we show that the decay of off-diagonal matrix elements of the density matrix is proportional to fidelity decay in the environment induced by the coupling to the central system. This in turn allows to relate known results on fidelity decay to decoherence, and in particular dispells a common an erroneous prejudice, that chaos accelerates decoherence, while often the contrary may be true.

DIPOLE-DIPOLE INTERACTION IN QUANTUM LOGIC GATES AND QUANTUM REFLECTION

Angela M. Guzmán

The effective quantum dipole-dipole interaction includes spatially modulated radiation losses that are shown to affect fidelity of a phase quantum gate based on controlled adiabatic collisions between atoms confined in a bright optical lattice. With evanescent-wave atomic mirrors, the dipole-dipole interaction between the induced atomic dipole and its dipole image in the dielectric results in a dynamic London-van der Waals potential between the atoms and the wall and in radiative losses that reduce the reflectance of the mirror close to resonance. The quantality functions of the effective reflection potential are large, and quantum reflection may occur at non-zero atomic velocities.

PHOTON ANGULAR MOMENTUM AND GEOMETRIC GAUGE

Margaret Hawton and William E. Baylis

We show that nonparaxial photon beams and localized states necessarily have non-zero orbital angular momentum due to their transverse nature. As is now well known, this orbital angular momentum is associated with an optical vortex of the electric field. The problem is mathematically analogous to that of a magnetic monopole where the vector potential depends on the choice of gauge and determines the direction of a Dirac string singularity. By analogy, we use a family of photon position operators [Hawton and Baylis, Phys. Rev. A 64, 012101 (2001); arXiv: quant-ph/0408017] to define a geometric gauge which determines the angular momentum of the transverse basis.

CONTROLLING THE SPEED OF LIGHT USING WEAK MEASUREMENTS

Jandir M. Hickmann

The role of measurement in quantum mechanics has posed challenges for physicists for nearly a century. According to standard textbooks describing the theory of the microscopic world, the measurement of a physical property of a subatomic particle can only produce values within a finite range. The particle's intrinsic properties are then inferred as the extreme values of this range. Contrary to traditional quantum measurement theory, certain experiments can return results that are beyond the range of an observable's eigenvalues. Here, we demonstrate that these so-called "weak values" have a direct relationship with the response function of a system, and have a much wider range of applicability in both the classical and quantum domains than previously thought. Using this idea, we have built an optical system based on a birefringent photonic crystal with an infinite number of weak values. In this system, the propagation speed of a polarized light pulse displays both fast and slow light behavior with a sharp transition between the two >regimes. Because this system's response possesses vortex-antivortex, two-dimensional phase singularities, astonishingly, the photon's angular momentum emerges as an unbounded weak value. The system gives us total control over the speed of light and may lead to several important applications in optical signal processing, such as optical delay lines with polarization-tuned characteristics and dynamical optical clock multipliers. This new approach to quantum weak values should also open the door for many new precision measurements of very tiny quantities.

QUANTUM MECHANICAL PROPERTIES OF BESSEL MODES AND THEIR EFFECT ON ATOMIC SYSTEMS

R. Jáuregui and S. Hacyan

Bessel modes are studied within the general framework of quantum optics. The two modes of the electromagnetic field are quantized and the basic dynamical operators are identified. The operators that are usually associated to linear momentum, orbital angular momentum and spin are shown to not satisfy the algebra of the translation and rotation group. As a mean to measure the dynamical properties of the modes, the transition probability for the emission of a Bessel photon by an atomic system is calculated within first order perturbation theory. A closed expression yielding a systematic multipole scheme is obtained. The matrix elements between center of mass and internal states are evaluated for some specially relevant cases. This permits to analyze the feasibility of observing the rotational effects of twisted light on atoms.

MEASURING CHAOTIC SCATTERING WITH CANONICALLY DEFORMED WAVE PACKETS

C. Jung, T.H. Seligman, J.M. Torres,

We study the quantum and classical scattering of Hamiltonian systems whose chaotic saddle is described by ternary horseshoes. We are interested in parameters of the system for which a stable island exists and is large, but chaos around it is well developed. We use the self-pulsing effect of chaotic scattering (scattering echoes) for the chaotic inverse scattering problem. We study a system with a purely attractive potential where the outer fixed points of the Poincare map sits at infinity. In this case the measurement of scattering echoes becomes more difficult in the classical as in the quantum case. We propose a new kind of measuring experiment involving canonical transformations.

CLASSICAL EVOLUTION OF QUANTUM FLUCTUATION IN SPIN-LIKE SYSTEMS: SQUEEZING AND ENTANGLEMENT

A.B. Klimov

It is shown that the dynamics of quantum fluctuations of certain states for non linear spin-like Hamiltonians can be described in terms evolution along the classical trajectories on the sphere. Two non-linear effects: a) spin squeezing and b) spin entanglement are analyzed using the Wigner function approach in the quasiclassical limit.

OPTIMUM COUPLING OF LIGHT TO A SINGLE ATOM IN FREE SPACE

G. Leuchs and S. Quabis

The performance of experiments on quantum information with atoms and light depends on the efficiency of the light-atom coupling. The standard procedure is to locate the atom in a cavity to enhance the coupling. We address the question how efficiently a photon can couple to a single quantum system in resonance. An obvious choice for the field geometry to be focused to the atom is the time reversed version of the wave the atom would emit spontaneously. This is not a TEM 00 but a radially polarized mode which is a superposition of two TEM 01's. Radial polarization also leads to a smaller focal spot in free space (see R. Dorn, S. Quabis and G. Leuchs, Phys. Rev. Lett. **91**, 233901(2003)).

PHOTON CREATION IN RESONANT CAVITIES: MOVING MIRRORS VS TIME DEPENDENT CONDUCTIVITY

Fernando C. Lombardo and Francisco D. Mazzitelli

In an electromagnetic cavity, photons can be created from the vacuum state by changing the cavity´s properties with time. In this work we summarize recent results for resonant photon creation in two different situations: cavities with time dependent length, and cavities containing a thin film with a time dependent reflectivity. We conclude that the last setup offers several advantages for experimental detection: faster photo-production rates and milder fine tuning problems.

DETERMINISTICALLY POLARIZED SINGLE-PHOTON SOURCE

Svetlana G. Lukishova, Ansgar W. Schmid, Russell Knox, Patrick Freivald, Robert W. Boyd, Carlos R. Stroud, Jr

We provide a solution for a deterministically polarized single photon source based on fluorescence from single-dye molecules in liquid-crystal hosts. The results are presented on both antibunching correlation measurements and deterministically polarized fluorescence from the single-dye molecules in glassy oligomer liquid crystals.

FACTORIZATION OF NUMBERS USING CHIRPED PULSES

Wolfgang Merkel, H. Mack, E. Lutz, W.P. Schleich and B. Girard

In this work we present a physical system that combines wavepacket dynamics and number theory. It has been shown that Gauss-sums, which involve quadratic phase factors, may be utilized to obtain the prime factor components of a given number N. As physical system we choose a two-photon transition which is driven by a chirped laser pulse. In addition to a ground and an excited state the underlying lebvel scheme contains a harmonic manifold of intermediate states. Quantum interference of multiple excitation paths is the key mechanism of this factorization scheme. We show how quadratic phase factors enter and present a recipe to encode the number N and reveal its prime components.

THREE-WAVE MIXING OF MATTER WAVES

Pierre Meystre

Photoassociation and Feshbach resonances permit the realization of the matter-wave analog of three-wave mixing, leading in particular to the coherent production of ultracold molecular fields. After a general introduction I will concentrate on the specific example of a molecular analog of the micromaser, discussing in particular the coherent control of molecular field, and the interplay between collisions and quantum tunneling on the dynamics of coupled “molecular micromasers."

COHERENCE AND INTERFERENCE WITH NUCLEAR ELECTROMAGNETIC RADIATION

Jos Odeurs

Nuclear quantum optics investigates the resonant interaction of single gamma photons with an ensemble of nuclei incorporated in a solid-state lattice, leading to interference phenomena. Absorption can be seen as destructive interference between the incoming beam and the forward scattered beam. Two examples are given to show how this destructive interference can be changed into constructive interference, leading to inhibition of absorption of gamma rays by a resonant medium: "phase shift induced transparency" and "level mixing induced transparency', which is a version of "electromagnetically induced transparency". Nuclear emission holography using single gamma photons will be explained.

QUANTUM CLONING MACHINE AND CAVITY QED

Miguel Orszag

A Universal 1 → 2 cloner is proposed using Cavity QED.This is a deterministic proposal that takes far few steps than previous models, and makes use of dispersive C-NOT gates.

QUBITS IN PHASE SPACE

Juan Pablo Paz

A discrete version of the Wigner function was recently introduced by Wootters and co-workers for systems of n qubits. I will review the main ingredients of this approach and show how it can be applied to study quantum information problems. Mutually unbiased basis, stabilizer states and error correcting codes have a natural phase space representation using this approach.

FIDELITY REVIVAL IN THE KICKED ISING MODEL

Carlos Pineda

We present and study in detail the kicked Ising model. We obtain and characterize, with a very efficient method, its. We present two versions of the model, belonging to GOE and GUE ensembles. We study evolution of fidelity under a static perturbation and observe a revival for times near to Heisenberg time, in agreement with previous results obtained with random matrix methods.

ON THE STATISTICS OF COHERENT QUANTUM PHASE-LOCKED STATES

Michel Planat

Coherence in quantum optics is discussed in relation to phase-locking. The quantum phase-locking operator was found related to the cyclotomic field, having matrix elements equal to Ramanujan sums, leading to a strong variability of phase oscillations versus the dimension of the Hilbert space, mimicking Mangoldt function of prime number theory, but being possibly squeezed to a weak amplitude. In a more general frame [1] due to Bost and Connes, quantum statistical states at finite temperature are based on an algebra of shift and clock operators. The group of symmetry is still the cyclotomic field, the partition function is the Riemann zeta function and phase oscillations are cancelled at the temperature of the pole.

[1] M. Planat: Invitation to the "spooky" quantum phase-locking effect and its link to 1/f fluctuations, quant-ph/0310082.

WIGNER DISTRIBUTION FUNCTION ON SPHERES

George S. Pogosyan, Miguel Angel Alonso, and Kurt Bernardo Wolf

The form of the Wigner distribution function for Hamiltonian systems, is extended to spaces with positive constant curvature. An essential part of this construction is the use of the functions of Sherman and Volobuyev, which are an overcomplete set of plane-wave-like solutions of the Laplace-Beltrami equation for this space. Rotations that displace the poles transform these functions with a multiplier factor, and their momentum direction becomes formally complex; the covariance properties of the proposed Wigner function are understood in these terms. As an example for the 1-dimensional case, we consider the energy eigenstates of the oscillator on the circle. The standard theory of quantum oscillators is regained in the contraction limit to the space of zero curvature.

SQUEEZING AND REVIVALS IN A CAVITY-ION SYSTEM IN CONTACT WITH A RESERVOIR

R. Rangel, L. Carvalho and N. Zagury

We consider a system consisting of a single ion in a trap, localized inside a non-ideal optical cavity and subjected to the action of two external lasers. We obtain an analytical solution for the master equation and show that squeezing in the motion of the ion and in the cavity field is generated. We also show that complete revivals of the states of the motion of the ion and of the cavity field occur periodically.

PURE-STATE, SINGLE-PHOTON WAVE-PACKET GENERATION BY PARAMETRIC DOWN CONVERSION IN A DISTRIBUTED MICROCAVITY

M. G. Raymer, Jaewoo Noh, K. Banaszek and I.A. Walmsley

We propose an optical parametric down conversion (PDC) scheme that does not suffer a trade-off between the state-purity of single-photon wave-packets and the rate of packet production. This is accomplished by modifying the PDC process by using a microcavity to engineer the density of states of the optical field at the PDC frequencies. Spectral filtering of the field occurs prior to photon creation rather than afterward as in most other schemes. Greater than 99% pure-state packet production is predicted to be achievable. The degree of entanglement can be quantified by using a Schmidt-mode decomposition.

PAIRING GAP AND IN-GAP EXCITATIONS IN TRAPPED FERMIONIC SUPERFLUIDS

M. Rodríguez, J. Kinnunen and P. Törmä

We consider trapped atomic Fermi gases with Feshbach-resonance enhanced interactions in pseudogap and superfluid temperatures. We calculate the spectrum of RF(or laser)-excitations for transitions that transfer atoms out of the superfluid state. The spectrum displays the pairing gap and also the contribution of unpaired atoms, i.e. in-gap excitations.

The results[1] support the conclusion that a superfluid, where pairing is a many-body effect, was observed in recent experiments on RF spectroscopy of the pairing gap.

[1] J. Kinnunen, M. Rodríguez, and P. Törmä, Science 20 August 2004, 305, 1131-1133.

REVERSING DYNAMICS IN THE ION-LASER INTERACTIONS

B.M. Rodríguez-Lara, H. Moya-Cessa and A.B. Klimov

We show that it is possible to generate two revival series of electronic level oscillations in ions interacting with lasers as well as in atoms interacting with quantized fields. To produce the second series of revivals we pass from red to blue side band interactions in the ion-laser case and to Jaynes-Cummings (JC) to anti-JC interactions in the case of two-level atoms and the quantized field.

SCHEME TO MEASURE SQUEEZING AND PHASE PROPERTIES OF A HARMONIC OSCILLATOR

G.T. Rubín-Linares, J.M. Vargas-Martínez and H. Moya-Cessa

We propose a simple scheme to measure squeezing and phase properties of a harmonic oscillator. We treat in particular the case of a the field, but the scheme may be easily realized in ion traps. It is based on integral transforms of measured atomic properties as atoms exit a cavity. We show that by measuring atomic polarizations it is possible, after a given integration, to measure several properties of the field.

ASSESSING THE DEGREE OF POLARIZATION IN QUANTUM OPTICS

Luis L. Sanchez-Soto

The major emphasis of standard quantum optics is concerned with the uniquely quantum properties of the electromagnetic field, which are not present in a classical treatment. In the case of the polarization of a light beam, nonclassical correlations entail polarization correlations that cannot be fully described by the classical Stokes parameters. In this paper I will characterize the polarization of quantum fields in operational terms and show some intriguing effects that have been experimentally demonstrated. Finally, I will discuss possible definitions of the degree of polarization, which allow for a full classification of quantum states.

DISORDER ULTRACOLD BOSE-FERMI MIXTURES IN OPTICAL LATTICES.

A. Sanpera, V. Ahufinger, L. Sanchez-Palencia, A. Kentian, M. Lewenstein

A new possibility to design and control discreteness in non linear system has emerged with the loading of Bose-Einstein Condensates (BEC) into optical lattices created by two counter propagating laser beams whose intensity, geometry, polarization and phase can be manipulated. This unprecedent level of control makes condensates in optical lattices a unique candidate to explore a new range of fundamental phenomena that are extremely elusive in other areas of physics like e.g. condensate matter systems Here we present our recent studies on atomic cold mixtures of Fermi-Bose gases in inhomogeneous and random optical lattices in the limit of strong interactions. By controlling the interactions at local level, we demonstrated the possibility of achieving quantum spin glasses as well as other relevant quantum phases.

IMPROVING QUANTUM MICROSCOPY AND LITHOGRAPHY VIA QUANTUM ERASURE

Marlan O. Scully

In ordinary (classical) microscopy and lithography, the limit of resolution is governed by the wavelength of light used to illuminate the sample. However, by using correlated photon pairs this limit can be overcome. Such correlated photon pairs are usually generated by cascade emission. However, if we use instead the two photon produced in the Raman type quantum erasure, the resolution of two-photon quantum microscopy is further improved. To that end, we here present the two-photon quantum state generated by sequential Raman, quantum erasure, emissions and investigate its application to microscopy and lithography. The photon-photon correlation function for the quantum erasure pairs is of interest in itself and has features in common with photon antibunching.

DISSIPATIVE CONSTRAINTS ON LASER CONTROL

A. Solomon and S. Schirmer

Although dissipation may occasionally be exploited to induce changes in a system otherwise impossible under Hamiltonian evolution, more often it presents an unwelcome intrusion into the quantum control process. Generally, when we try to control a system, say by a laser, then not only do we obligatorily have dissipation but positivity imposes certain constraints on the dissipation. In this talk we describe these constraints for N-level systems which for $N>2$ are quite non-intuitive. We exemplify the relations obtained by discussing the effects in certain specific N-level atomic systems, such as lambda- and V-type systems.

QUANTIZATION VIA FRACTIONAL REVIVALS

C. R. Stroud, Jr.

The path integral representation of quantum mechanics tells us that the propagator is made up of the sum of the classical actions over every possible path from the initial state to the state at some later time. When one restricts oneself to periodic orbits this leads to the familiar quantization rules such as those for the stationary states of the hydrogen atom. For more general wave packet propagation problems the evolution is not strictly periodic, but instead proceeds through a complex series of decays, revivals, fractional revivals, super-revivals, etc. We will show that this evolution naturally leads to a quantization of orbits different from the conventional stationary states. In the case of Rydberg wave packets the integer Bohr orbits are replaced in general by fractional integer orbits, and the quantization itself may be time dependent. Calculation of the time of occurrence and the phase of the wave function at higher-order revivals has proven difficult for even simple potentials. We will present a new general calculus that allows one to work out the properties of these revivals for a broad class of problems of interest.

COHERENT SPECTROSCOPY OF COLD CESIUM ATOMS USING LIGHT CARRYING ORBITAL ANGULAR

J. W. R. Tabosa

In this talk we will discuss on the observation of coherent Bragg diffraction spectroscopy in cold cesium atoms using light modes carrying orbital angular momentum (OAM). First, we will report on the generation of coherent superposition of light beams carrying OAM, obtained by real time Bragg diffraction into an induced Zeeman coherence grating. In the second part of our presentation, we will describe the observation of spontaneous coherence grating transfer between different pairs of Zeeman sub-levels belonging to different hyperfine states of cold cesium atoms. Possible applications of the observed effects to multidimensional quantum information processing will be discussed.

DETECTING GENUINE MULTIPARTITE ENTANGLEMENT WITH TWO LOCAL MEASUREMENTS SETTINGS

G. Toth

A method is described for constructing entanglement witnesses with a simple local decomposition. These witnesses detect states with genuine multi-qubit entanglement around a GHZ state or a cluster state. The approach is based on the stabilizer formalism. Our method is important for experimental entanglement detection where only local (=single qubit) measurements are possible. Its advantage is that it requires much less experimental effort than other approaches for detecting multi-qubit entanglement. In practice, the experimental effort is determined by the number of measurement settings needed. For our approach only two measurement settings are used independent of the number of qubits. With other methods (e.g., Bell inequalities, local decomposition of the projector based-witness) the number of settings increases exponentially with the system size. For more details please see quant-ph/0405165.

TWO-DIMENSIONAL FINITE OSCILLATOR; SEPARATION OF DISCRETE VARIABLES

<u>Luis Edgar Vicent</u>, N. M. Atakishiyev, George S. Pogosyan, and Kurt Bernardo Wolf

The finite oscillator system in two dimensions is a group-theoretical model having *so(4)* as its underlying dynamical algebra. It is defined on a discrete and finite configuration space, whose points can be described in Cartesian or in polar coordinates. In these coordinates, wavefunctions representing this system satisfy a difference analog to the Schrödinger equation. It is shown in this work that in Cartesian coordinates, these wavefunctions are Wigner *d*-functions (and involve Kravchuk polynomials), while in radial polar coordinates they are *su(2)* Clebsch-Gordan functions (involving dual Hahn polynomials). Time evolution proceeds with the Fourier-Kravchuk and Hankel-Hahn summation transforms, respectively. We show how to import the group of rotations from the ordinary harmonic oscillator for functions on a square pixellated screen. Applications of the model are envisaged for finite signal analysis and image processing.

QUANTUM KEY DISTRIBUTION USING POLARIZED COHERENT STATES

Antonio Vidiella-Barranco

We propose a continuous variables method of quantum key distribution employing strongly polarized coherent states of light. Alice transmits a (relatively easy to generate) two-mode coherent state which is conveniently modulated in the polarization variables know as Stokes parameters. Their quantum counterpart, the Stokes operators S_i ($i=1,2,3$), constitute a set of non-commuting operators, being the precision of simultaneous measurements of a pair of them limited by an uncertainty-like relation. Bob randomly measures one of the Stokes parameters of the incoming beam, and after performing reconciliation and privacy amplification procedures, a secret common key can be generated.

MODULATING THE CRITICAL TEMPERATURE IN BOSE-EINSTEIN CONDENSATION

Carlos Villarreal and Laura Rosales

We study the influence of finite size on the problem of Bose-Einstein condensation (BEC) for a quantum gas with arbitrary dispersion relation, and confined within a small spatial region. With that purpose, we determine the exact mode density of the confined boson gas and use it to calculate the changes of the critical BEC temperature T_C with the geometry of the system and the specific boundary conditions. The usual expressions for BEC T_C are recovered in the large size limit. We discuss the possible implications of this effect in the context of Quantum Optics, and also in BCS superconductivity models.

NONCLASSICALITY OF QUANTUM STATES

W. Vogel

An overview is given on some new possibilities to characterize the nonclassical nature of quantum states of a harmonic oscillator. A recent proposal to demonstrate the nonclassicality in terms of observable characteristic functions [1] is further developed. This leads to new criteria formulated in terms of normally-ordered moments of two noncommuting operators. Appropriate measurement schemes for the required moments are introduced. It is outlined how our methods can be generalized to demonstrate entanglement of quantum states.

[1] Richter and Vogel, Phys. Rev. Lett. **89**, 283601 (2002).

NON-MARKOVIAN PARTICLE DYNAMICS IN CONTINUOUSLY CONTROLLED QUANTUM GASES

S. Wallentowitz and D. Ivanov

For a quantum gas, being subject to continuous feedback of a macroscopic observable, the single-particle dynamics is studied. Albeit feedback-induced particle correlations, it is shown that analytic solutions are obtained by formally extending the single-particle Hilbert space by an auxiliary degree of freedom. The particle's motion is then fed by colored noise, which effectively maps quantum-statistical correlations onto the single particle. Thus, the single particle in the continuously controlled gas follows a non-Markovian trajectory in phase-space.

GROUND STATE CORRELATIONS OF A TRAPPED QUASI, ONE DIMENSIONAL TRAPPED BOSONIC GAS

Reinhold Walser

The thermo-dynamic behavior of quantum gases responds sensitively to the dimensionality of a system. Consequently, one finds that the importance of fluctuations growths with the reduction of available phase-space. For example, this suppresses BEC in a strictly one-dimensional homogeneous gas (Mermin-Wagner-Hohenberg theorem). However, it has been demonstrated already in many contexts that trapped gases of finite number and spatial extension are qualitatively different. In the present contribution, we are going to study the equilibrium correlations of a quasi one-dimensional gas, as it is realized in a prolate configuration. In particular, we will investigate the spatial g1 and g2 correlation functions and find a suppression of density fluctuations or, in other words, atomic number squeezing.

ABERRATIONS OF PHASE SPACE

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The independent aberrations of phase space -polynomial canonical transformations- have a 1:1 correspondence with the states of the quantum harmonic oscillator. A Lorentz group of comatic aberrations is produced by relative motion between object and image. Although these results stem from Hamilton-Lie geometric optics, they suggest applications on the phase space of the quantum optical field, and on the (compact) phase spaces of finite systems. In particular, we follow the evolution of the finite Kerr medium with its Wigner function on the sphere.