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15th Central European Workshop on Quantum Optics

CEWQO 2008

Book of Abstracts

Belgrade, 30 May – 03 June, 2008
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Editors
Mirjana Božić and Dušan Arsenović

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at the
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Phone: +381 11 3713 127 – Fax: +381 11 3162 190
Email: cewqo08@phy.bg.ac.yu
Web: http://cewqo08.phy.bg.ac.yu

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PREFACE

15th Central European Workshop on Quantum Optics (CEWQO 08) is a continuation of a successful series of yearly meetings bringing together scientists from Europe, in particular from Central Europe and from other parts of the world, as well. Previous meetings have offered excellent opportunities for the exchange of knowledge and ideas between leading scientists and young researchers in quantum optics, foundations of quantum mechanics, quantum informatics and related areas.

Previous meeting took place in Palermo (2007), Vienna (2006), Ankara (2005), Trieste (2004), Rostock (2003), Szeged (2002), Prague (2001), Balatonfüred (2000), Olomouc (1999), Prague (1997), Budmerice (1995 и 1996), Budapest (1994), Bratislava (1993).

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Conference topics

1. Fundamental aspects of quantum optics and quantum mechanics
2. Single photons and photon pairs
3. Cavity and circuit QED
4. Atoms in intense fields
5. Neutron, atom and molecular quantum optics
6. Quantum gases and fluids
7. Coherence, entanglement and decoherence
8. Optical properties of condensed matter and nanostructures
9. Open quantum systems and chaos
10. Quantum information processing

Mirjana Božić
Chairperson of CEWQO 08

Belgrade, May 2008

PARTICIPANTS

ADAM Peter, *Budapest, Hungary*, adam@szfki.hu
ANDREEV Vladimir, *Moscow, Russia*, andrvlad@yandex.ru
ANDREEVA Nina, *Moscow, Russia*, andrnin@mail.ru
ARSENOVIĆ Dušan, *Belgrade, Serbia*, arsenovic@phy.bg.ac.yu
AVETISSIAN Hamlet, *Yerevan, Armenia*, avetissian@ysu.am
BARENJI Mostafa Sahrai, *Tabriz, Iran*, sahrai@tabrizu.ac.ir
BAUCH Szymon, *Warsaw, Poland*, bauch@ifpan.edu.pl
BAUDON Jacques, *Paris, France*, baudon@galilee.univ-paris13.fr
BECKER Uwe, *Berlin, Germany*, becker_u@fhi-berlin.mpg.de
BELLINI Marco, *Florence, Italy*, bellini@inoa.it
BENEDICT Mihály, *Szeged, Hungary*, benedict@physx.u-szeged.hu
BERKDEMIR Cüneyt, *Kayseri, Turkey*, berkdemir@erciyes.edu.tr
BOUGOUFFA Smail, *Madina, Saudi Arabia*, sbougouffa@hotmail.com
BOŽIĆ Mirjana, *Belgrade, Serbia*, bozic@phy.bg.ac.yu
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BURIĆ Nikola, *Belgrade, Serbia*, nikola.buric@phy.bg.ac.yu
CHIRKIN Anatoly, *Moscow, Russia*, aschirkin@pisem.net
CIOBANU Nellu, *Chisinau, Moldova*, cnellu@gmail.com
CROSSE Alex, *London, United Kingdom*, jac00@imperial.ac.uk
ĆUK Senka, *Belgrade, Serbia*, cuk.senka@gmail.com
CVEJANOVIĆ Slobodan, *Rijeka, Croatia*, Cvejanov@medri.hr
CZIRJAK Attila, *Szeged, Hungary*, czirjak@physx.u-szeged.hu
D'ANGELO Milena, *Bari, Italy*, dangelo@fisica.uniba.it
D'ARRIGO Antonio, *Catania, Italy*, darrigo@femto.dmfci.unict.it
DAKIĆ Borivoje, *Vienna, Austria*, borivoje.dakic@univie.ac.at
DAVIDOVIĆ Milena, *Belgrade, Serbia*, milena@grf.bg.ac.yu
DELIĆ Nenad, *Novi Sad, Serbia*, bora@im.ns.ac.yu
DELIĆ Uroš, *Belgrade, Serbia*, delic.uros@gmail.com
DERMEZ Rasim, *Afyonkarahisar, Turkey*, dermez@aku.edu.tr
DIMITROVA Todorka, *Plovdiv, Bulgaria*, tldimitrova@abv.bg
DODONOV Victor, *Brasilia, Brazil*, vdodonov@fis.unb.br
DOMOTOR Piroska, *Szeged, Hungary*, Domotor.Piroska@stud.u-szeged.hu
DUCLOY Martial, *Paris, France*, martial.ducloy@univ-paris13.fr
DUGIĆ Miroljub, *Kragujevac, Serbia*, dugic@kg.ac.yu
DZIUBAK Tomasz, *Torun, Poland*, tomek@fizyka.umk.pl
FERRARO Elena, *Palermo, Italy*, ferraro@fisica.unipa.it
GABRIS Aurél, *Budapest, Hungary*, gabrisa@szfki.hu
GAINUTDINOV Renat, *Kazan, Russia*, Renat.Gainutdinov@ksu.ru
GAJIĆ Radoš, *Belgrade, Serbia,* rados.gajic@phy.bg.ac.yu
GAWLIK Wojciech, *Krakow, Poland*, gawlik@uj.edu.pl
GLADUSH Maxim, *Troits, Russia*, mglad@triniti.ru
GLIGORIĆ Goran, *Belgrade, Serbia*, goran79@vin.bg.ac.yu
GLUSHKOV Alexander, *Odesa, Ukraine*, glushkov@paco.net
GORELIK Vladimir, *Moscow, Russia*, gorelik@sci.lebedev.ru
GROZESCU Anamaria, *Timisoara, Romania*, grozescu_anamaria@yahoo.com

GRUJIĆ Zoran, *Belgrade, Serbia*, gruja@phy.bg.ac.yu
HASLINGER Philipp, *Vienna, Austria*, philipp.haslinger@univie.ac.at
HENNRICH Markus, *Innsbruck, Austria*, markus.hennrich@uibk.ac.at
HEREC Jiri, *Olomouc, Czech Republic*, herec@optics.upol.cz
ILIĆ Dušan, *Novi Sad, Serbia*, idilic@EUnet.yu
ILIĆ Jelena, *Belgrade, Serbia*, jilic@mas.bg.ac.yu
ISAR Aurelian, *Bucharest, Romania*, isar@theory.nipne.ro
ISIĆ Goran, *Leeds, United Kingdom*, elgi@leeds.ac.uk
ISKHAKOV Timur, *Moscow, Russia*, tiskha@gmail.com
IVKOVIĆ Milivoje, *Belgrade, Serbia*, ivke@phy.bg.ac.yu
JAMSHIDI-GHALEH Kazem*, Tabriz, Iran*, k-jamshidi@azaruniv.edu
JEKNIĆ-DUGIĆ Jasmina, *Kragujevac, Serbia*, jjeknic@pmf.ni.ac.yu
JELENKOVIĆ Branislav, *Belgrade, Serbia*, branaj@phy.bg.ac.yu
JIVULESCU Anastasia, *Palermo, Italy*, jivulescu@fisica.unipa.it
JOVANIĆ Branislav, *Belgrade, Serbia*, brana@phy.bg.ac.yu
KHANBEKYAN Mikayel, *Jena, Germany*, mkh@tpi.uni-jena.de
KHETSELIUS Olga, *Odessa, Ukraine*, okhetsel@paco.net
KHVESHCHENKO Dmitry, *Chapel Hill, USA*, khvesh@physics.unc.edu
KISS Tamas, *Budapest, Hungary*, tkiss@szfki.hu
KLIMOV Vasily, *Moscow, Russia*, vklim@sci.lebedev.ru
KONJEVIĆ Nikola, *Belgrade, Serbia*, nikruz@ff.bg.ac.yu
KOROLI Vlad, *Kishinev, Moldova*, vl.koroli@gmail.com
KOROLKOVA Natalia, *St. Andrews, United Kingdom*, nvk@st-andrews.ac.uk
KRMPOT Aleksandar, *Belgrade, Serbia*, krmpot@phy.bg.ac.yu
KUPCZYNSKI Marian, *Ottawa, Canada*, mkupczyn@uottawa.ca
KYOSEVA Elica, *Sofia, Bulgaria*, kyoseva@phys.uni-sofia.bg
LASKOWSKI Wieslaw, *Gdansk, Poland*, wieslaw.laskowski@univ.gda.pl
LASTRA Freddy, *Santiago, Chile*, flastra@uc.cl
LAWNICZAK Michal, *Warsaw, Poland*, lawni@ifpan.edu.pl
LAZAROU Constantinos, *Brighton, United Kingdom*, cl90@sussex.ac.uk
LEMR Karel, Olomouc, Czech Republic, lemr@orgchem.upol.cz
LEON Juan, *Madrid, Spain*, leon@imaff.cfmac.csic.es
LINDEN Björn Lyttkens, *Lund, Sweden*, f03bl@student.lth.se
MACOVEI Mihai, *Heidelberg, Germany*, mihai.macovei@mpi-hd.mpg.de
MAN’KO Margarita, *Moscow, Russia*, mmanko@sci.lebedev.ru
MAN’KO Olga, *Moscow, Russia*, omanko@sci.lebedev.ru
MAN’KO Vladimir, *Moscow, Russia*, manko@sci.lebedev.ru
MARIAN Paulina, *Bucharest-Magurele, Romania*, pemarian@gmail.com
MARIAN Tudor A., *Bucharest-Magurele, Romania*, tudor.aurel.marian@gmail.com
MARINKOVIĆ Bratislav, *Belgrade, Serbia*, bratislav.marinkovic@phy.bg.ac.yu
MARKO Márton, *Budapest, Hungary*, marko@szfki.hu
MASTELLONE Andrea, *Catania, Italy*, andrea@femto.dmfci.unict.it
MENDAŠ Istok, *Belgrade, Serbia*, mendas@phy.bg.ac.yu
MESSINA Antonino, *Palermo, Italy*, messina@fisica.unipa.it
MIGLIORE Rosanna, *Palermo, Italy*, rosanna@fisica.unipa.it
MIHAILESCU Ion, *Bucharest-Magurele, Romania*, ion.mihailescu@inflpr.ro
MIHALCEA Bogdan-Vasile, *Bucharest-Magurele, Romania*, bmihal@infim.ro
MIJAILOVIĆ Marina, *Belgrade, Serbia*, lekic@phy.bg.ac.yu
MINAGAR Golnaz, *Zanjan, Iran*, gol_mi@yahoo.com
MIRANOWICZ Adam, *Poznan, Poland*, miran@amu.edu.pl

MISHRA Devendra Kumar, *Kaushambi, India*, kndmishra@rediffmail.com
MISTA Ladislav, *Olomouc, Czech Republic*, mista@optics.upol.cz
MIZRAHI Salomon S., *Sao Carlos, Brazil*, salomon@df.ufscar.br
MOI Luigi, *Siena, Italy*, moi@unisi.it
MORANDI Giuseppe, *Bologna, Italy*, morandi@bo.infn.it
MOREV Dmitry, *Moscow, Russia*, dmitry.morev@gmail.com
MOREVA Ekaterina, *Moscow, Russia*, ekaterina.moreva@gmail.com
MOSZYNSKI Robert, *Warsaw, Poland*, robert.moszynski@tiger.chem.uw.edu.pl
MURIĆ Branka, *Belgrade, Serbia*, muric@phy.bg.ac.yu
NAPOLI Anna, *Palermo, Italy*, napoli@fisica.unipa.it
NEMETH Istvan, *Szombathely, Hungary*, inemeth@hunter.cuny.edu
NEMILENTSAU Andrei, *Minsk, Belarus*, andrei.nemilentsau@gmail.com
NIKOLIĆ Stanko, *Belgrade, Serbia*, stankon@phy.bg.ac.yu
OBLAK Daniel, *Copenhagen, Denmark*, oblak@nbi.dk
OGANESYAN Koryun, *Yerevan, Armenia*, koganesyan@yahoo.com
OKULOV Alexey, *Moscow, Russia*, okulov@kapella.gpi.ru
OOI Raimond, *Seoul, Republik of Korea*, bokooi73@yahoo.com,raybokooi@korea.ac.kr
ÖZSOY Sedat, *Kayseri, Turkey*, ozsoys@erciyes.edu.tr
PALADINO Elisabetta, *Catania, Italy*, epaladino@dmfci.unict.it
PANTELIĆ Dejan, *Belgrade, Serbia*, pantelic@phy.bg.ac.yu
PASCAZIO Saverio, *Bari, Italy*, saverio.pascazio@ba.infn.it
PATEREK Tomasz, *Vienna, Austria*, tomasz.paterek@univie.ac.at
PAUNKOVIĆ Nikola, *Lisbon, Portugal*, nikola.paunkovic@qubit.org
PERINA Jan, *Olomouc, Czech Republic*, perinaj@prfnw.upol.cz
PERINOVA Vlasta, *Olomouc, Czech Republic*, perinova@prfnw.upol.cz
POPOV Andrey, *Barnaul, Russia*, popov.barnaul@mail.ru
POPOV Dušan, *Timisoara, Romania*, dusan_popov@yahoo.co.uk
PORTALS Carmen, *Madrid, Spain*, cportals@gmail.com
PREDOJEVIĆ Ana, *Barcelona, Spain*, ana.predojevic@icfo.es
RADONJIĆ Milan, *Belgrade, Serbia*, milanr@phy.bg.ac.yu
RADOVANOVIĆ Jelena, *Belgrade, Serbia*, radovanovic@etf.bg.ac.yu
RADOVIĆ Marko, *Belgrade, Serbia*, marrad@phy.bg.ac.yu
RADULAŠKI Marina, *Belgrade, Serbia*, radulaski@gmail.com
RAUCH Helmut, *Vienna, Austria*, rauch@ati.ac.at
ROKNIZADEH Rasoul, *Isfahan, Iran*, roknbi@sci.ui.ac.ir, rokni@sci.ui.ac.ir
SABIN Carlos, *Madrid, Spain*, csl@imaff.cfmac.csic.es
SAJFERT Vjekoslav, *Indjija, Serbia*, sajfertv@ptt.yu
SALOMON Christophe, *Paris, France*, salomon@lkb.ens.fr
SAMBALE Agnes, *Jena, Germany*, agnes.sambale@uni-jena.de
SANZ Angel S., *Madrid, Spain*, asanz@imaff.cfmac.csic.es
SAVIĆ Ilija, *Belgrade, Serbia,* isavic@phy.bg.ac.yu
SAVIĆ-ŠEVIĆ Svetlana , *Belgrade, Serbia*, savic@phy.bg.ac.yu
ŠĆEPANOVIĆ Maja, *Belgrade, Serbia*, maja@phy.bg.ac.yu
SKENDEROVIĆ Hrvoje, *Zagreb, Croatia*, hrvoje@ifs.hr
SOLOMON Allan, *Watford, United Kingdom*, a.i.solomon@open.ac.uk
STEF Marius, *Timisoara, Romania*, stef@quantum.physics.uvt.ro
STOBINSKA Magdalena, *Erlangen, Germany*, fizia@nor.pl
SVOZILIK Jiří, *Olomouc, Czech Republic*, svozilijir@volny.cz
TADIĆ Milan, *Belgrade, Serbia*, tadic@etf.bg.ac.yu
TANAS Ryszard, *Poznan, Poland*, tanas@kielich.amu.edu.pl

TOMAS Marin-Slobodan, *Zagreb, Croatia*, tomas@thphys.irb.hr
TRUPPE Stefan, *Vienna, Austria*, stefan.truppe@univie.ac.at
VASIĆ Borislav, *Belgrade, Serbia*, bvasic@phy.bg.ac.yu
VASILE Mihaela Ionela, *Timisoara, Romania*, mihaela.vasile@icmct.uvt.ro
VASILJEVIĆ Darko, *Belgrade, Serbia*, darko@phy.bg.ac.yu
VILLAS-BOAS Celso, *Sao Carlos, Brazil*, celsovb@df.ufscar.br
VOGEL Werner, *Rostock, Germany*, werner.vogel@uni-rostock.de
VUČIĆ Svetlana, *Belgrade, Serbia*, vucic@phy.bg.ac.yu
VULETIĆ Vladan, *Cambridge, USA*, vuletic@mit.edu
VUŠKOVIĆ Leposava, *Norfolk, USA*, vuskovic@odu.edu
VVEDENSKII Nikolay, *Nizhny Novgorod, Russia*, vved@appl.sci-nnov.ru
WALTHER Philip, *Cambridge, USA*, pwalther@fas.harvard.edu
WEIS Antoine, *Fribourg, Switzerland*, antoine.weis@unifr.ch
ZARKOV Boban, *Belgrade, Serbia*, zarkov@phy.bg.ac.yu
ZIMAN Mario, *Bratislava, Slovakia*, ziman@savba.sk
ZIPPER Elzbieta, *Katowice, Poland*, elzbieta.zipper@us.edu.pl

ABSTRACTS

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Adam Peter **(10)** **Poster**

Quantum operations in probabilistic representation

A. Karpati, P. Adam, and J. Janszky
Research Institute for Solid State Physics and Optics,
Hungarian Academy of Sciences, Budapest, Hungary
adam@szfki.hu

Quantum states can be represented by a suficiently large set of probability values encoded in the diagonal elements of a density operator in a fixed basis. That way even entangled states can be mapped to non-entangled density operators, in a mathematically invertible way. Generally, reconstructing a quantum state by physical operations from such a representation is not possible. However, the quantum mechanical operations can be performed with a good approximation on the density operators, with not too high cost in the means of additional qubits needed for a given precision.

Andreev Vladimir **(1)** **Talk**

Bell inequalities and correlation of spin projection function

V.A. Andreev
P.N. Lebedev Physical Institute, Moscow, Russia
andrvlad@yandex.ru

The Bell and Bell-Clauser-Horne-Shimony-Holt inequalities for two-particle spin states are considered. It is known that these inequalities are violated by experimental verification. The assumption that the functions describing spin projections of separate particles are independent random variables is used at proofs of these inequalities. It is shown this assumption is the reason of violation of the inequalities. This assumption is correct only for factorizable and separable states. But in the case of entangled states the random functions are dependent and their correlation coefficient is not equal to zero. New inequalities containing the correlation coefficient are constructed. The problems of hidden variables and nonlocality in quantum mechanics are discussed.

Arsenović Dušan **(5)** **Poster**

Wave function of an atom hit by a photon in a three-grating interferometer

Dušan Arsenović[1], *Mirjana Božić*[1], *Ángel S. Sanz*[2] *and Milena Davidović*[3]
[1]Institute of Physics, Belgrade, Serbia
[2]Instituto de Física Fundamental, Madrid, Spain
[3]Faculty of Civil Engineering, Belgrade, Serbia,
arsenovic@phy.bg.ac.yu

In an experiment performed by Chapman *et al*. [1], single photons were scattered off atoms which passed through the first grating of a three-grating Mach-Zehnder interferometer [2] with the purpose to study the influence of the photon scattering processes on the atom interference. More specifically, the dependence of the atom transmission through the third grating on the distance d between the place of scattering event and the first grating was investigated. For each value of d, the transmission was measured as a function of the lateral shift of the third grating. The dependence of the relative fringe contrast on the ration d/λ, where λ is the photon wavelength, shows loss of contrast and several revivals. Authors conclude from this experiment that the loss of coherence cannot be attributed to smearing of the interference pattern caused by momentum transferred in the scattering process.

In this Communication, we present an analysis of the results and interpretation provided by Chapman *et al*. [1] based on the evaluation of the wave function of an atom in a three-grating interferometer. Two cases are discussed: a) the atom moves freely in between the gratings and b) the atom is hit by a photon in between the first and second grating. The transverse part of the wave function behind the first grating is expressed as a superposition of eigenfunctions of the transverse momentum, where the probability amplitude of the transverse momentum depends on the grating parameters [3,4]. This form is very convenient in order to incorporate the change of the transverse momentum of the atom caused by the scattered photon [5].

The wave function that reaches the second grating has two narrow maxima, each one covering several slits. The wave function behind the second grating is then determined from the previous one and the change of the distribution of transverse momentum induced by the second grating. The wave function incident to the third grating has a structure which is sensible to the grating structure. Consequently, the transmission of atoms through the third grating will strongly depend on its lateral shift, displaying characteristic interference oscillations.

In the limit of an infinite grating the above described wave function reduces to the wave function of Chapman *et al*. [1]. We study the relevance of this approximation to explain the contrast loss and revivals observed. To complete our study, it would be useful to compare directly our theoretical transmission curves (with and without photon scattering) with those obtained experimentally. Although the latter have been evidently used to evaluate and to plot the contrast as a function of d/λ [1,2], they have not been published, to our knowledge.

References

[1] M.S. Chapman *et al*., *Phys. Rev. Lett*. **75**, 3783 (1995).
[2] J. Schmiedmayer et al., in *Atom Interferometry*, ed. by P.R. Berman (Academic Press, New York, 1997) p.1.
[3] M. Božić, D. Arsenović and L. Vušković, *Z. fur Naturforschung* A **56**, 173 (2001).
[4] D. Arsenović, M. Božić and L. Vušković, *J. Opt. B: Quantum Semiclass. Opt*. **4**, S358 (2002).
[5] L. Mandel and E. Wolf, *Optical Coherence and Quantum Optics* (Cambridge University Press, Cambridge, 1995).

Avetissian Hamlet (4) **Poster**

Population Transfer by Multiphoton SCRAP in Atomic/Molecular Systems

H. K. Avetissian, B. R. Avchyan, and G. F. Mkrtchian
Department of Quantum Electronics, Yerevan State University,
1 A. Manukian, 0025 Yerevan, Armenia
avetissian@ysu.am

In the present work we consider the multiphoton population transfer process in laser fields that resembles the well known Stark-chirped rapid adiabatic passage (SCRAP). In considering scheme an atomic/molecular system has a mean dipole moment in the excited states which ensures eficient multiphoton resonant transitions between the ground and excited states [1].

As in usual SCRAP scheme, we investigate interaction of quantum system with the two laser fields of different frequencies. We assume a pump laser pulse tuned slightly away from the n-photon resonance and low frequency (far-off-resonance) second laser pulse that sweeps the states through the resonance by inducing a dynamic Stark shift. The time evolution of such systems is found analytically using resonant approximation. The numerical simulations show that by appropriate delay between the applied laser pulses it is possible to produce population transfer among the quantum states that are coupled by direct multiphoton resonance. The obtained results are applied to hydrogen atom at which due to the random degeneration upon orbital moment atom may have a mean dipole moment in the excited states.

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References

[1] H. K. Avetissian, G. F. Mkrtchian, Phys. Rev. A, 66, 033403 (2002); H. K. Avetissian, G. F. Mkrtchian, M. G. Poghosyan, Phys. Rev. A, 73, 063413 (2006); H. K. Avetissian, B. R. Avchyan, G. F. Mkrtchian, Phys. Rev. A, 74, 063413 (2006).

Bauch Szymon (9) **Poster**

Investigation of graphs with different time reversal symmetries

Michał Ławniczak[1], Oleh Hul[1], Szymon Bauch[1], Petr Šeba[2], and Leszek Sirko[1]
[1]Institute of Physics, Polish Academy of Science, Warsaw, Poland
[2]Institute of Physics, Academy of Sciences of the Czech Republic
bauch@ifpan.edu.pl

Quantum graphs are excellent paradigms of quantum chaos [1], and are widely investigated theoretically and numerically. Experimentally, quantum graphs are simulated by microwave graphs (networks) consisting of joints and microwave cables [2].

It is a great challenge to find proper criteria, which allow to determine whether a quantum system is chaotic or not, and to what ensemble with respect to a symmetry class it belongs. An enhancement factor [3] and autocorrelation functions of level velocities [4] are candidates for such criteria.

We present the results of experimental investigations of the enhancement factor of hexagon microwave networks which simulate hexagon quantum graphs. Each microwave network consists of fifteen bonds, which lengths are chosen to be incommensurable in order to form an irregular network. To determine the enhancement factor we measured the scattering matrix S. For the time reversal symmetry (TRS) case - Gaussian Orthogonal Ensemble (GOE), the measurements were performed as a function of absorption using a vector network analyzer (Agilent Technologies E8346B). Moreover, we present numerical calculations which were performed to investigate autocorrelation functions of level velocities of pentagon irregular, quantum graphs with and without TRS - Gaussian Unitary Ensemble (GUE). The total length of the graphs was kept constant whereas the length of two bonds out of the ten ones was changed. The experimental and numerical results are compared with the theoretical predictions based on random matrix theory (RMT).

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References

[1] T. Kottos, U. Smilansky, Phys. Rev. Lett. **79**, 4794 (1999)
[2] O. Hul, S. Bauch, P. Pakoński, N. Savytskyy, K. Życzkowski, L. Sirko, Phys. Rev. E **69**, 056205 (2004)
[3] D. V. Savin, Y. V. Fyodorov, H.-J. Sommers, Acta Phys. Pol. **109**, 53 (2006)
[4] A. Szafer and B.L. Altshuler, Phys. Rev. Lett. **70**, 587 (1993)

Baudon Jacques **(5)** **Invited talk**

Coherent atom optics with rare gas metastable atoms

M. Hamamda[1], J. Grucker[1], J. Baudon[1], F. Perales[1], G. Dutier[1], M. Ducloy[1], V. Bocvarski[2]
[1]Laboratoire de Physique des Lasers (CNRS-UMR 7538), Université Paris 13, 93430-Villetaneuse, France
[2]Institute of Physics-Belgrade, 11080-Zemun, Serbia
baudon@galilee.univ-paris13.fr

Owing to the resonant metastability exchange process, metastable atom beams having a velocity distribution as narrow as, and a coherence width as large as that of a good-quality ground state atom nozzle beam can be produced. This has allowed us to study atomic diffraction of metastable atoms by transmission nano-slit gratings [1] and micro-stripe reflection gratings [2], as well as surface-induced inelastic transitions (so-called van der Waals - Zeeman (vdW-Z) transitions) among Zeeman sublevels [3].

Metastable argon atoms in such a beam can be slowed down to a velocity of a few m/s by use of a Zeeman slower combining an appropriate magnetic field profile and a laser beam locked in frequency on the $^3P_2$-$^3D_3$ closed transition at 811.5 nm. This slowing process increases not solely the de Broglie wavelength but also the transverse coherence width and the vdW-Z transition probability. When such a beam impinges a pair of two opposite surfaces, such as the two edges of a slit or of an ensemble of periodic slits, two narrow atomic wave packets (width of 2-3 nm) are generated in the inelastic channel. Because of their narrowness, these packets strongly spread by diffraction as they freely propagate. Moreover, in the case of an exo-energetic transition, they are deflected towards each other. At some distance of the slit, within the overlap of the wave packets, interference fringes of the Young-slit type are expected to appear. This makes the device an atomic counterpart of the well known Fresnel biprism interferometer. Once eliminated the (dominant) wave packet remaining in the elastic-channel, *e.g.* by means of a convenient laser beam, the resulting diffraction pattern is actually a *Schlieren* photograph of the vdW-Z transition amplitude. Detailed information about this complex amplitude, at a scale of a few nanometers, can be derived from this interference pattern [4]. When a slit of an adjustable width is used, the device is equivalent to two Young slits separated by an adjustable distance. It allows, *via* the contrast of the fringes, to directly measure the transverse coherence length of an atomic beam.

Starting with an "exchanged" narrow beam of metastable atoms of helium (He* 2^3S_1) at thermal velocity (1750 m/s), initially polarized in Zeeman state M=0, one is able to modulate transverse intensity and phase profiles by use of a Stern-Gerlach atom interferometer. A specially designed phase object allows us to obtain, in the transverse plane, an extremely narrow profile (diameter of a few tens of nm). Because of the special shape of the resulting profile, the free-propagating outgoing beam has the amazing property – which is very important for further applications – to be almost devoid of spreading by diffraction, over distances of several cm [5]. This atomic beam is then quite similar to the so-called Bessel beams, well known in light optics.

References

[1] J.-C. Karam *et al*., J.Phys.B: At.Mol.Opt.Phys, **38**, 2691 (2005)
[2] J. Grucker *et al*., Eur.Phys.J D, **41**,467 (2007)
[3] J.-C. Karam *et al*., Europhys. Lett., **74**, 36 (2006)
[4] J. Grucker *et al*., DOI 10.1140/epjd/e2008-00051-1
[5] F. Perales *et al*., Europhys. Lett., **78**, 60003 (2007)

Becker Uwe **Invited talk**

Electron entanglement through tunneling-induced coherence between two emitter sites

Uwe Becker
Fritz-Haber-Institut der MPG, Berlin, Germany
becker_u@fhi-berlin.mpg.de

Coherence of quantum objects is the domain of quantum optics, whereby this subject has been extended from photon to atom optics during the last decade. Electrons, however, have not been considered by this development. Only very recently, people succeeded to produce coherent superpositions of electrons in the time domain. Parallel to this development, the coherent superposition of electrons due to the mirror symmetry of their emitter sites has been more closely investigated. These studies have been performed on the photoelectron emission from homonuclear diatomic molecules. The spatial coherence of this emission is generated by the tunneling effect. The studies show surprising analogies to quantum optics, but also to the entanglement of continuous variables like position and momentum. It will be shown, that the behavior of the different variables of quantum states is analogous, although their underlying variables are completely different. This will be the first proof of entanglement in real and momentum space.

Bellini Marco **(1)** **Invited talk**

Generation and tomographic analysis of quantum states of light

Marco Bellini, Alessandro Zavatta, Valentina Parigi

Istituto Nazionale di Ottica Applicata - CNR, L.go E. Fermi, 6, I-50125, Florence, Italy
LENS and Department of Physics, University of Florence, Italy
bellini@inoa.it

We present the generation of novel quantum light states by the experimental implementation of single-photon creation and annihilation operators. By applying such basic quantum operators to some paradigmatic light states, we generate new ones whose nonclassical character can be thoroughly investigated. More importantly, by the analysis of the resulting states of light, we are able to provide the first direct verification of some of the fundamental rules of quantum mechanics [1].

Conditional parametric amplification in a nonlinear crystal is used for single-photon excitation of the light states [2-4]. On the other hand, conditional attenuation by a high-transmissivity beam-splitter is employed for photon annihilation. If the parametric gain of the crystal and the reflectivity of the subtracting beam-splitter are low enough, the two above operations are a very good approximation of the ideal processes of photon creation and annihilation. We finally use ultrafast pulsed homodyne detection and quantum tomography to completely investigate the character of the resulting states.

By applying inverse sequences of annihilation and creation operators on thermal light states we show that the resulting states are completely different, and thus demonstrate the non-commutativity of such operators, at the heart of the quantum behavior of light [5]. Furthermore, the application of the annihilation operator to different quantum light states is shown to produce peculiar effects on the photon number distributions and mean photon numbers depending on the statistics of the original states.

Besides the fundamental importance of these results, the experimental implementation of such basic quantum operations and of their sequences has strong implications for future quantum applications, being the first step towards a full-scale engineering of a quantum light state.

References

[1] See the group homepage: http://www.inoa.it/home/QOG
[2] A. Zavatta, S. Viciani, and M. Bellini, *Science* **306**, 660 (2004).
[3] A. Zavatta, S. Viciani, and M. Bellini, *Phys. Rev. A* **72**, 023820 (2005).
[4] A. Zavatta, V. Parigi, and M. Bellini, *Phys. Rev. A* **75**, 052106 (2007).
[5] A. Zavatta, V. Parigi, M. S. Kim, and M. Bellini, *Science* **317**, 1890 (2007).

Berkdemir Cüneyt **(1)** **Talk**

The temperature-dependent analysis of the quantum limited noise figure for two-level optical fiber amplifiers

Cüneyt Berkdemir and Sedat Özsoy
Department of Physics, Erciyes University, 38039, Kayseri, Turkey
berkdemir@erciyes.edu.tr

The analysis of noise figure in optical fiber amplifiers is a sufficiently complex procedure that can be characterized by a thorough quantum optical regime. The ratio of the input signal-to-noise ratio (SNR_{in}) to the output signal-to-noise ratio (SNR_{out}) which called the noise figure (NF) is defined as [1];

$$NF = \left(\frac{SNR_{in}}{SNR_{out}} \right) \approx 2n_{sp} \frac{(G-1)}{G} + \frac{1}{G},$$

where G is the total gain of optical fiber amplifier and n_{sp} is the spontaneous emission factor. In the two-level amplification system, the n_{sp} is expressed as [2],

$$n_{sp} = \frac{N_2}{N_2 - S(\lambda)N_1} = \left\{1 - S(\lambda_s)/S(\lambda_p) - S(\lambda_s)P_p^{th}/P_p\right\}^{-1},$$

where N_1 and N_2 denote the carrier populations of the lower and upper states, respectively, $S(\lambda)$ is the ratio of the absorption and emission cross-sections at the signal and pump wavelengths, P_p is the pump power and P_p^{th} is the pump threshold power. For optical fiber amplifiers with large gain (G > 10 dB), the minimum NF is about 3 dB, as $n_{sp} \geq 1.0$. It has long been known that the noise figure of a high-gain optical fiber amplifier cannot be smaller than 3 dB [3]. The value of 3 dB is known as the quantum limited noise figure. This limit means that the SNR_{out} always degrades to less than half of the SNR_{in} before amplification. Thus, the 3-dB quantum limited noise figure of the optical amplifier has been still a matter of optical amplification.

In this study, to investigate the variation of quantum limited noise figure with temperature of two-level optical fiber amplifiers, we select a silica-based erbium-doped fiber amplifier (EDFA). For pumping configurations of EDFAs, there are two types of pump wavelength applications; 980 nm and 1480 nm. The latter characterizes a two-level amplification system. Our aim is to re-analyse the quantum limited noise figure for a two-level silica-based EDFA by using a simple temperature-dependent rate equation model. According to the model, the population distributions of the upper state ($^4I_{13/2}$) of amplifier are relocated obeying the occupancy rule of Boltzmann's law. The energy difference between the sub-levels of the $^4I_{13/2}$ state is assumed to be 200 cm^{-1} for simplicity. Moreover, the changes in cross-sections with temperature are also taken into account. It is seen that in the conventional wavelength band, the noise figure for typical gain values of about 30 dB can be very close to the quantum limit, and fluctuates around this limit for the temperature range from -30 ^oC to 50 ^oC.

References

[1] S. B. Alexander, Optical Communication Receiver Design, (SPIE, Washington DC, 1997).

[2] E. Desurvire and J. R. Simpson, J. Lightwave Technology, **7 (5)**, 835 (1989).
[3] C. M. Caves, Phys. Rev. D 26, 1817 (1982).

Bougouffa Smail **(1)** **Poster**

The Dynamics of Jaynes-Cummings Model in Nanostructures

Smail Bougouffa and Saud Al Awfi
Department of Physics, Faculty of Science, Taibah University, P.O.Box 30002,
Madina, Saudi Arabia
sbougouffa@hotmail.com

The Jaynes-Cummings model (JCM) is the prototype model in quantum optics. It exhibits interesting nontrivial quantum features, despite its conceptual simplicity. The remarkable fact that these have been observed experimentally in cavity quantum electrodynamics experiments [1]. We emphasize the JCM because we can often describe in detail the essential outline f the interaction of atom with single mode quantized field. However, this model is realistic only in cavity region, since in free space all modes may be contributed to the quantized field. It therefore seems appropriate to seek for an enlargement of the range of investigations in order to include more general types of problems, which are frequently met in practice. We consider in this work a particular cavity, namely a two infinite planar parallel perfectly conducting plates separated by a distance L in vacuum [2].

The motivation for such a structure reside essentially in the fact that this structure exhibits a the possibilities of enhanced and inhibited decay rates. The cavity modes will be fundamentally quantized, to allow the position-dependent spontaneous emission rate to be evaluated. The purpose of this work is to investigate the dynamics of JCM in uch a structure. We first quantize the single mode field. Then we explore the variations of JCM dynamics with the nanostructure parameters, and we call special attention to the quantum interference enhancement in terms of the distance between the plates. The principal interest in such an investigation arises from the theoretical difficulty in resolving the system of coupled differential equations, which is related to the JCM. This difficulty can be overcome using a new separation approach of coupled differential equations [3].

Using this new technique, the JCM can be solved exactly for both two and three level atoms, and various physical quantities are investigated.

References

[1] B. M. Shore and P. L. Knight, *J. Mod. Opt***.,** **7**, 1195(1993).
[2] Al-Awfi S. and Babiker M., *Phys Rev.* ***A*** **58**, 2274 (1998).
[3] Smail Bougouffa, Saud Al Awfi, *J. Mod. Opt.*, **55**,No. 3, 473(2008).

Božić Mirjana **(2)** **Poster**

Photon behavior in the Mach-Zehnder interferometer with removable output beam splitter

Mirjana Božić[1], *Leposava Vušković*[2] *and Milena Davidović*[3]
[1]Institute of Physics, Belgrade, Serbia
[2]Department of Physics, Old Dominion University, Norfolk, USA
[3]Faculty of Civil Engineering, Belgrade, Serbia
bozic@phy.bg.ac.yu

Photon behavior at a beam splitting interface can be described using a diffraction grating as a model [1,2]. This approach allows quantitative interpretation of photon dynamics in many systems that employ this kind of interface, which then can be regarded as a transformer of an incident photon field to a field that has narrow maxima at the points along and in close vicinity of two particular lines, and negligible values at all other points. Employing a Mach Zehnder interferometer with removable output beam splitter, Jacques et al. [3] reported the experiment with linearly polarized single photons in the two-path interferometer. The choice between open and closed configurations was realized with the electro-optical modulator which could be switched between two different configurations within 40 ns. Closing or opening was relativistically separated from the entry of the photon into the interferometer. The authors interpreted the results by referring to the Wheeler's delayed-choice gedanken experiment [4].

Our interpretation of the experiment [3] is in the following way. Photon acquires randomly the new momentum at the first beam splitter (modeled by a grating). This momentum directs the photon to one of two paths along which it continues to move. Two mirrors placed along these two paths change the direction of each path by 90^0. Note that a single photon, moving along one of the paths has the information about the existence of the other path, as a neutron in the neutron interferometer [5]. This information exists due to the wholeness of the photon field along and in between the two paths [1,6,7]. Photon field behind the output beam splitter, when it is on, is very different from the field when it is off. We determine the form of the field in these two cases, using the same incident field. Our explanation of the experimental result [3] follows from these two forms of the field at the exit from the interferometer. When the output beam splitter is on, it detects the structure of the incident photon field and modifies this structure in the appropriate way. The probability that a photon chooses one or the other direction is changed accordingly. When the beam splitter is off, the incident photon field, and photon as well, propagate freely.

Our explanation differs essentially from the explanation of Jacques et al., based on the reasoning introduced by Wheeler [4] who proposed and named delayed-choice experiment. They conclude using Wheeler's words: "we have a strange inversion of the normal order of time," since the behavior of the photon at the first beam splitter depends on the choice of the observable that is measured behind the output beam splitter, even when that choice is made at a position and a time such that it is separated from the entrance of the photon into the interferometer by a space-like interval.

References

[1] M. Bozic, http://www.fisica.unipa.it/~cewqo2007/Archive/presentation/Bozic.pdf
[2] E. Goulielmakis et al., *Appl. Phys. B* **74,** 197 (2002).
[3] V. Jacques et al., Science, **315**, 966 (2007).

[4] J. A. Wheeler, in *Mathematical Foundations of Quantum Mechanics*, ed. by A. R. Marlow, (Academic Press, New York, 1978) p.9.
[5] H. Rauch and S.A. Werner, *Neutron Interferometry: Lessons in Experimental Quantum Mechanics* (Clarendon Press, Oxford, 2000) p. 350-365.
[6] D. Arsenović, M. Božić and L. Vušković, *J. Opt. B: Quantum Semiclass. Opt*. **4,** S358 (2002).
[7] M. Davidović, A.Sanz, D.Arsenović, M.Božić and S.Miret Artés, CEWQO 2008, *Book of abstracts.*

Brukner Časlav **(1)** **Invited talk**

The quantum to classical transition and the complexity of Schrödinger-cat states

Časlav Brukner[1,2] *and Johannes Kofler*[1,2]
[1]Faculty of Physics, University of Vienna, Boltzmanngasse 5, 1090 Vienna, Austria
[2]Institute of Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences,Boltzmanngasse 3, 1090 Vienna, Austria
caslav.brukner@univie.ac.at

The descriptions of the quantum realm and the macroscopic classical world differ significantly not only in their mathematical formulations but also in their foundational concepts. When and how physical systems stop to behave quantumly and begin to behave classically is still heavily debated in the physics community. We have developed a novel approach to understand this transition, which neither needs to refer to the environment of a system (decoherence) nor to change the quantum laws itself (collapse models) but puts the stress on the limits of observability of quantum phenomena due to our measurement apparatuses.

We have demonstrated that under realistic conditions in every-day life, where we are only able to perform coarse-grained measurements, macroscopic realism and the classical Newtonian laws emerge out of the full quantum laws: the system's time evolution governed by the Schrödinger equation and the state projection induced by measurements [1]. We find the sufficient condition for these classical evolutions. Then we demonstrate that nevertheless there exist ”non-classical” Hamiltonians which are in conflict with macroscopic realism even under the coarse-grained measurements. Such Hamiltonians normally build up Schrödinger-cat state superpositions. We argue that these Hamiltonians are unlikely to be realized in nature because of their high computational complexity [2].

References

[1] J. Kofler and Č. Brukner, Phys. Rev. Lett. Phys. Rev. Lett. **99**, 180403 (2007). See also Nature News (22 Nov. 2007): P. Ball, Schrödinger's kittens enter the classical world
[2] J. Kofler and Č. Brukner, http://arxiv.org/abs/0706.0668

Buhmann Stefan Yoshi **(5)** **Talk**

Thermodynamics of atoms in nontrivial environments

Stefan Yoshi Buhmann, Stefan Scheel
Quantum Optics and Laser Science, Blackett Laboratory, Imperial College London, Prince Consort Road, London SW7 2BW, United Kingdom
s.buhmann@imperial.ac.uk

Macroscopic quantum electrodynamics in linear, causal media describes the structure of the quantum-electromagnetic field in the presence of dispersing and absorbing bodies, which can substantially differ from the free-space case. The principles of this field quantization and the coupling of the field to atoms are reviewed [1]. Special emphasis is placed on thermal fields, whose spectrum obeys the uctuation{dissipation theorem.
The dynamics of an atom coupled to a thermal field is solved and found to be governed by environment-dependent heating and cooling rates. Examples are given for the ground-state heating rates of polar molecules near a surface. Next, the time-dependent Casimir-Polder force [2] between an atom and a body at finite temperature is studied, where two cases need to be distinguished: For an initial non-equilibrium preparation of a ground-state atom in a finite temperature environment, resonant force components due to thermal-photon absorption are present. After the atom has reached thermal equilibrium with its environment, these components vanish and the force is given by a Matsubara sum.

References
[1] S. Y. Buhmann and D.-G. Welsch, Prog. Quantum Electron. 31, 51 (2006).
[2] S. Y. Buhmann, L. Kn□oll, D.-G. Welsch, Ho Trung Dung, Phys. Rev. A 70, 052117 (2004).

Chirkin Anatoly **(7)** **Talk**

Forming four-partite entangled states in nondegenerate parametric amplification at low frequency pumping

Anatoly S. Chirkin, and Mikhail Yu. Saigin
Faculty of Physics, M.V. Lomonosov Moscow State University, Moscow, Russia
aschirkin@rambler.ru

We study quantum properties of a process of nondegenerate parametric amplification at low-frequency pumping which can be implemented in coupled nonlinear optical interactions in an aperiodical nonlinear photonic crystal. Such crystal may be created by the method of the superposition of the modulation of the second-order susceptibility. It allows us to implement simultaneously several quasi-phase matched nonlinear processes. We consider the process of the parametric amplification of two waves with frequencies ω_1 and ω_2 in the field of the intense pumping wave with frequency ω_p so that $\omega_p = \omega_1 + \omega_2$. In the field of the same pumping wave the following three-frequency interactions occur: $\omega_p + \omega_1 = \omega_3$, $\omega_p + \omega_2 = \omega_4$. As a result the intensities of waves with frequencies higher than the pumping wave frequency can monotonically increase with the interaction length as in the case of the traditional process of parametric amplification at high-frequency pumping [1]. The possibility to realize the process under consideration, performed on the example of aperiodical nonlinear photonic crystal of lithium niobate, is shown.

The photon statistics and photon correlations between different frequencies are studied. We calculated the second, third and fourth Glauber correlation functions and established that correlations have essentially nonclassical character under small interaction lengths. To analyze the entanglement property of the generated four-frequency field, we applied the separability criterion based on the partial scaling transform of the covariance matrix for continuous variables [2]. Analysis includes examination of behavior of the principal minors of the matrix depending on scaling parameters. It is found that the four-frequency field is in the entangled state. A scheme for teleportation of unknown two-frequency entangled state using the four-frequency entangled state is also proposed.

References

[1] A.S. Chirkin, I.V. Shutov, JETP. Lett. 86, 693 (2007); Pis'ma v ZhETF 86, 803 (2007).
[2] O.V. Man'ko, V.I. Man'ko, G. Marmo, A. Shaji, E.C.G. Sudarshan and F. Zaccaria, Phys.Lett. A 339, 194 (2005).

Ciobanu Nellu **(1)** **Poster**

Partial restoration of a cascade three-level atom interacting with an off-resonant single mode cavity field

Ciobanu Nellu
Institute of Applied Physics, Academy of Sciences, Chisinau, Moldova
nellu_ciobanu@yahoo.com

Actually, in quantum physics a considerable attention has been devoted to the resonance interaction between one atom and the quantized field. This type of interaction was frequently used in classical physics for transmission or manipulation in time of information and remains attractive in quantum description of such effects. The quantum collapse and revival realization of two radiators is an interested problem due to the possibilities of restoration of initially separated states of atom and electromagnetic field after interaction. There are a lot of works in the literature devoted to the restoration of initial states in the process of interaction. One of this is the quantum trapping effect described in paper [1] in which the reversibility of a three-level system is realized as a consequence of the stationary solution of Schrodinger equation and optical reversible phenomenon [2, 3], where during the interaction time, two quantum subsystems pass through a collapse and restore their initial states. In this paper we analytically analyze the possibility of states restoration of two quantum oscillators in interaction which are off resonance each other. Taking into account that in according with uncertainty principle the energy and time of these subsystems in interaction must be larger than Planck constant, the time separability between such subsystems is more realistic in the case when the energy fluctuations of the system have large values.

The off resonance effect and its influence on the reversibility between two quantum subsystems (single mod cavity field and a three-level in cascade configuration) in interaction is studied. It is found the partial reversible condition for which these quantum subsystems can restore their diagonal moments, while the non diagonals remain correlated after the interaction process.

References
[1] G.S. Agarwal, Phys. Rev. Lett., 71, 1351 (1993)
[2] J.J. Slosser and P. Meystre, Phys. Rev. A 41 (1990) 3867
[3] N.A. Enaki, N. Ciobanu, Journal of Modern Optics, 272097 (TMOP-2007-0010.R1), (In press); N.A. Enaki, V.I. Ciornea, D.L. Lin, Optics Commun. 226, (2003) 285.

Crosse Alex (1) **Poster**

Quantum Electrodynamics in Absorbing Non-linear Media

J.A.Crosse, S.Scheel
Quantum Optics and Laser Science, Blackett Laboratory, Imperial College London,
Prince Consort Road, London, SW7 2BW, UK.
jac00@imperial.ac.uk

The effects of lossless dielectric media, described by a real susceptibility, on an applied electric field have been studied at length both classically and in the framework of quantum optics. However, it can be shown that any causal response function, such as the susceptibility, is necessarily complex, with the real and imaginary parts related by the Kramer-Kronig relations. Hence absorption, which is associated with the imaginary part of the susceptibility, is an unavoidable effect in causal dielectrics. The inclusion of absorption into a quantum description of matter assisted electromagnetic fields provides a rich area for new phenomena. A quantum field theory approach to linear optics in absorbing media has been known for sometime and involves expanding the electric field in terms of the classical Green's tensor and fundamental bosonic fields [1]. This approach has proved successful in describing many linear optical processes. More recently attempts have been made to extend this approach to non-linear media [2,3]. Here were present current work relating to further developments in the calculation of effective Hamiltonians for two-photon non-linear processes in absorbing media.

References
[1] Knoll L, Scheel S and Welsch D-G Coherence and Statistics of Photons and Atoms ed. J Perina (New York, Wiley, 2001) p.1
[2] Scheel S and Welsch D-G Phys. Rev. Lett. 96 (2006) 073601
[3] Scheel S and Welsch D-G J. Phys. B: At. Mol. Opt. Phys. 39 (2006) S711-S724

Czirjak Attila (4) **Talk**

Modeling attosecond streaking experiments on solid surfaces

Attila Czirják[1], Vladislav S. Yakovlev[2], Mihály G. Benedict[1] and Ferenc Krausz[2]
[1]Department of Theoretical Physics, University of Szeged, Szeged, Hungary
[2]Max Planck Institute of Quantum Optics, Garching, Germany
czirjak@physx.u-szeged.hu

Attosecond streaking experiments [1], which provide a tool to measure attosecond pulses [2], have recently been carried out on a solid surface [3], which demonstrate the feasibility of this experimental method in condensed matter. The interpretation of the photoelectron spectra needs new models for the dynamics of the photoelectrons, which take into account several important effects from the many phenomena around a solid surface. We report on some steps in this direction, using analytical and numerical methods.

References

[1] R. Kienberger, et al., *Atomic transient recorder*, Nature **427**, (2004) 817
[2] J. Itatani, et al., *Attosecond Streak Camera*, Phys. Rev. Lett. **88** (2002) 173903
[3] A. Cavalieri et al., *Attosecond spectroscopy in condensed matter*, Nature **449**, (2007) 1029

D'Angelo Milena **(7)** **Talk**

Toward real NOON-state sources

Milena D'Angelo[1], *Augusto Garuccio*[1,2], *Vincenzo Tamma*[1,3]
[1]Università degli Studi di Bari – Dip. Interateneo di Fisica, Bari, Italy
[2]INFN – Sez. di Bari, Bari, Italy
[3]UMBC - Physics Dept., Baltimore (MD), USA
dangelo@fisica.uniba.it

NOON states are the main ingredient of many quantum information and quantum imaging protocols (see, e.g., [1-4]).

The conditional generation of NOON states strongly relies on photon-counters, aiming to detect either vacuum [5] or single photons [6].

We study both the reliability and the signal-to-noise ratio of real NOON-state sources by quantifying the effect detection losses have on the desired NOON state. Furthermore, we compare the resources required to implement both protocols. Our results come out to be in favour of NOON-state sources based on non-detection. Finally, we propose and analyze a modified scheme to improve the performances of NOON-state sources based on single-photon detection.

References

[1] A. N. Boto, P. Kok, D. S. Abrams, S. L. Braunstein, C. P. Williams, and J. P. Dowling, Phys. Rev. Lett. 85, (2000) 2733; M. D'Angelo, M.V. Chekhova, and Y.H. Shih, Phys. Rev. Lett. 87, (2001) 013602
[2] K. J. Resch, K. L. Pregnell, R. Prevedel, A. Gilchrist, G. J. Pryde, J. L. O'Brien, and A. G. White, Phys. Rev. Lett. 98, (2007) 223601
[3] Knill, Laflamme, Millburn, Nature 409, (2001) 46
[4] N. Gisin, R. Thew, Nature Phot. 1, (2007) 165
[5] J. Fiurasek, Phys. Rev. A 65, (2002) 053818
[6] P. Kok, H. Lee, and J.P. Dowling, Phys. Rev. A 65, (2002) 052104

D'Arrigo Antonio (10) Talk

Dephasing channels with memory

A. D'Arrigo[1], *G. Benenti*[2,3] *and G. Falci*[1]
[1]MATIS CNR-INFM, Catania & Dipartimento di Metodologie Fisiche e Chimiche per l'Ingegneria, Università degli Studi di Catania, Viale Andrea Doria 6, 95125 Catania, Italy
[2]CNISM, CNR-INFM & Center for Nonlinear and Complex Systems, Università degli Studi dell'Insubria, Via Valleggio 11, 22100 Como, Italy and Istituto Nazionale di Fisica Nucleare, Sezione di Milano, via Celoria 16, 20133 Milano, Italy
[3]Istituto Nazionale di Fisica Nucleare, Sezione di Milano, via Celoria 16, 20133 Milano, Italy
antonio.darrigo@dmfci.unict.it

Quantum communication channels use quantum systems to transfer quantum information. In fact, we may want to transfer an unknown quantum state between different units of a quantum system, for instance of a quantum computer, or to distribute entanglement between communicating parties. The fundamental question is what is the maximum rate of quantum information that can be faithfully transmitted. Quantum *capacity*, defined as the maximum number of qubits that can be reliably transmitted per channel use, provide the answer to this question. Quantum channels with memory are the natural theoretical framework for the study of any noisy quantum communication system where correlation times are longer than time between consecutive uses. This scenario applies to optical fibers which may show a birefringence fluctuating with characteristic time longer than the separation between successive light pulses or to solid state implementations of quantum hardware, where memory effects due to low-frequency impurity noise produce substantial dephasing. We focus on dephasing channels, which are relevant for systems in which relaxation is much slower than dephasing. Then we study a dephasing channel with memory, modeled by a Markov chain or a multimode environment of oscillators. We analyze the channel aptitude to reliably transmit quantum information. We find that the coherent information transmitted down the channel is maximized by separable input states: for the first model a maximally mixed input state achieves the maximum, while in the second model is convenient to exploit the presence of a decoherence-protected subspace generated by memory effects. We explicitly compute the quantum channel capacity for the first model, while numerical simulations suggest a lower bound for the latter: in both cases memory effects enhance the coherent information [1].

This issue is relevant also for the performance of Quantum Error-Correcting Codes (QECCs). Since quantum capacity is the maximum rate of reliable quantum information transmission, it puts an upper bound to the asymptotic rate achievable by any QECC. On the other hand, realistic QECCs necessarily work on a finite number of channel uses. We show that in case of small dephasing, even if the quantum capacity is weakly affected by memory, small amount of memory is sufficient to have a significantly detrimental impact on few qubits quantum error correcting schemes designed for uncorrelated errors. We also discuss an alternative scheme that takes advantage of memory effects to protect quantum information [2].

References

[1] A. D'Arrigo, G. Benenti and G. Falci, "Quantum capacity of dephasing channels with memory", New J. Phys. 9, 310 (2007).
[2] A. D'Arrigo, E. De Leo, G. Benenti, and G. Falci, "Memory effects in a Markov chain dephasing channel", to be published on IJQI (2008).

Dakić Borivoje **(1)** **Poster**

Theories of systems with limited information resources

Tomasz Paterek[1], *Borivoje Dakić*[2] *and Časlav Brukner*[3]
[1]Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Boltzmanngasse 3, A-1090 Vienna, Austria
[2]Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Boltzmanngasse 3, A-1090 Vienna, Austria
[3]Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Boltzmanngasse 3, A-1090 Vienna, Austria
borivoje.dakic@univie.ac.at

Are theories different than quantum mechanics conceivable which share with it some of the basic features, or any change in its structure necessarily leads to inconsistencies? We introduce a full hierarchy of theories that describe (two-level) systems with fundamentally limited information resources. The limit gives rise to the generic feature of the theories: the existence of a set of mutually complementary measurements. A complete knowledge of the future outcome in one of the measurements is at the expense of complete uncertainty in others. The theories are ordered according to the number of mutually complementary measurements and their computational abilities. The classification includes classical physics with no complementary observables and quantum physics with three of them for a qubit.

References

[1] C. Brans and R.H. Dicke, Phys. Rev. 124, 925 (1961).
[2] A. Zeilinger, Found. Phys. 29, 631 (1999). Č. Brukner and A. Zeilinger, in Time, Quantum, Information, ed. by L. Castell and O. Ischebeck (Springer 2003).
[3] R.W. Spekkens, Phys. Rev. A 75, 032110 (2007).
[4] J.S. Bell, Physics 1, 195 (1964).
[5] S. Kochen and E.P. Specker, J. Math. Mech. 17, 59 (1967).
[6] W. K. Wootters, Found. Phys. 16, 391 (1986); W. K. Wootters in Complexity, entropy and the physics of information, ed. by W. H. Zurek (Addison-Wesley, 1990); R. D. Sorkin, Mod. Phys. Lett. A 9, 3119 (1994); L. Hardy, quant-ph/0101012v4; See also K. Życzkowski, http:/pirsa.org/07020004.
[7] Č. Brukner and A. Zeilinger, Phys. Rev. Lett. 83, 3354 (1999).
[8] D. Deutsch, Proc. Roy. Soc. Lond. A 400 553, 97 (1985).

Davidović Milena **(1)** **Talk**

Electromagnetic energy flow lines and/or the paths of photons

Milena Davidović[1], *Ángel S. Sanz*[2], *Dušan Arsenović*[3], *Mirjana Božić*[3] *and Salvador Miret Artés*[2]
[1]Faculty of Civil Engineering, Belgrade, Serbia,
[2]Instituto de Física Fundamental, Madrid, Spain
[3]Institute of Physics, Belgrade, Serbia
milena@grf.bg.ac.yu

The possibility to perform quantum interference experiments with low-intensity beams of one per one photon [1-3] or a material particle [4,5] have intensified the theoretical search of the topology of photon paths [6,7] and particle trajectories [8-11], respectively, that describe the process behind the interference grating. The aim of all the proposed approaches is to simulate the appearance of the interference pattern by accumulation of single particle events.

In Bohmian mechanics one may simulate this process for material particles. Bohmian trajectories follow the lines of the quantum mechanical probability current density, and therefore reproduce exactly the quantum mechanical particle space distribution in the far and near fields [8,9]. Alternatively, the emergence of the interference pattern in the far field has also been simulated by sets of rectilinear trajectories characterized by the momentum distribution associated with the particle wave function [10]. In the far field, the distribution of momentum components along Bohmian trajectories is consistent with this distribution [11].

In this communication, we show how to determine electromagnetic (EM) energy flow lines behind an interference grating, where the components of the magnetic and electric vector fields satisfy Maxwell's equations. These fields are expressed in terms of a function which explicitly takes into account the boundary conditions imposed by the grating [10,11]. Then, the energy flow lines are determined after numerically solving the path equation that arises from the Pointing energy flow vector. Here we will show flow lines behind gratings with different number of slits. These sets of lines supplement those presented by Prosser [6] for both a semi-infinite plane and gratings with one and two slits. The EM energy flow lines show that the energy redistribution behind a multiple slit grating corresponds with a Talbot pattern in the near field and with a Fraunhofer interference pattern in the far field.

It is tempting to conclude from the results obtained that the motion of an eventual photon wave packet thus represents an energy flow along a group of flow lines. This conclusion is supported also by the fact that the path equation for the EM energy flow lines has the same form as the equation for the quantum flow associated with material particles. This explains why there is a complete similarity in interference phenomena with photons and material particles. Experimentally, the final interference patterns as well as the processes of their emergence are analogous [1-5].

References

[1] S. Parker, *Am. J. Phys*. **39,** 420 (1971); **40,** 1003 (1972).
[2] T.L. Dimitrova and A. Weis, *Am. J. Phys.* **76,** 137-142 (2008).
[3] http://ophelia.princeton.edu/~page/single_photon.html
[4] A. Tonomura, J. Endo, T. Matsuda and T. Kawasaki and H. Ezawa, *Am. J. Phys*. **57**, 117 (1989).
[5] F. Shimuzu, K. Shimuzu, and H. Takuma, *Phys. Rev. A* **46,** R17 (1992).
[6] R. D. Prosser, *Int. J. Theor. Phys*. **15**, 169 (1976); **15**, 181 (1976).
[7] P.Ghose, A.S.Majumdar, S. Guha and J.Sau, *Phys. Lett*. A **290**, 205 (2001).

[8] A. S. Sanz, F. Borondo and S. Miret-Artés, *J. Phys.: Condens. Matter* **14**, 6109 (2002).
[9] A. S. Sanz and S. Miret-Artés, *J. Chem. Phys*. **126**, 234106 (2007).
[10] M. Božić and D. Arsenović, *Acta Phys. Hung. B* **26/1-2,** 219 (2006).
[11] M. Davidović, D. Arsenović, M. Božić, A. S. Sanz and S. Miret-Artés, *Eur. Phys. J. Special Topics* **xx**, xx (2008); arXiv:0803.2606.

Delić Nenad **(2)** **Poster**

Brain Photons

Bratislav Tošić[1], Nenad Delić[2], Ljiljana Mašković[3],
Dušan Ilić[4], Jovan P. Šetrajčić[5], Stevo Jaćimovski[6]
[1]Vojvodina Academy of Sciences and Arts, Novi Sad, Serbia
[2]Primary School "Svetozar Marković-Toza", Novi Sad, Serbia
[3]Police Academy, Belgrade, Serbia
[4]Faculty of Technical Sciences, Novi Sad, Serbia
[5]Faculty of Sciences, Novi Sad, Vojvodina – Serbia
[6]Faculty of Electrical Engineering, Belgrade, Serbia
idilic@EUnet.yu

Brain photons will be analyzed using linearized photon Hamiltonian.

It is known [1–3] that a photon Hamiltonian is on the form:

$$\hat{H} = \pm c\sqrt{\hat{p}_x^2 + \hat{p}_y^2 + \hat{p}_z^2} \tag{1}$$

After linearization of quadratic impulse operators, linearized photon Hamiltonian is obtained in the form of the product of components of photon impulse and corresponding spin components:

$$\hat{H} = \frac{2c}{\hbar}(\hat{p}_x\hat{S}_x + \hat{p}_y\hat{S}_y + \hat{p}_z\hat{S}_z) \tag{2}$$

Based on (2), it can be concluded that photon behavior is equally determined by its translation characteristics (impulse components) and its rotation characteristics expressed by way of spin operators [4]. After substitution of a single photon Hamiltonian becomes:

$$\begin{aligned} H = {} & \hbar c k_z (A + A^+) + \\ & + \hbar c(k_x - ik_y)A^+P + \hbar c(k_x + ik_y)P^+A + \hbar c(k_x - ik_y)AP + \\ & + \hbar c(k_x + ik_y)A^+P^+ + \hbar c P^+P(A + A^+) \end{aligned} \tag{3}$$

During further analysis, we shall use the approximate second quantization method (ASQ method) of Bogoljubov and Tyablikov [2,5]:

$$H = Ma^+b^+ + M^*b^+a + Mab + M^*a^+b^+ \tag{4}$$

Brain photon features are equally determined by means of their translation characteristics (photon impulse) and rotation characteristics (photon spin). The analysis has been made with double coherent Hamiltonian of a single photon.

In such found Hamiltonian, it can be concluded that brain photons are hybrid excitations of vacuum photons and spin excitations. The main characteristics of the obtained hybrids are dependence of energy on the direction of movement and damping (life times of hybrid excitations are final). The system of brain photons has rather a high internal energy because their real parts of dispersion law are rather low.

References
[1] Davydov A.S., Quantum Mechanics, Pergamon Press, Oxford, 1976.
[2] Bogoljubov N.N., **Izbranii trudi po statisticeskoi fizike**, MGU, Moskwa, 1979. (in Russian)
[3] Tošić B.S., **Statistical Physics**, Faculty of Sciences, Novi Sad, 1978 (in Serbian).
[4] Yuen H.P., *Two-photon coherent states of the radiation field*, Phys.Rev.A, V13, (1976)
[5] Abricosov A., Gorkov L.P., and Dzyaloshinski I.E., **Quantum Field Theoretical Methods in Statistical Mechanics**, Pergamon, New York, 1965.

Dermez Rasim **(10)** **Poster**

Higher dimensional entangled qudits in a trapped three-level ion

Rasim Dermez[1] *and Soner Ozen*[1]
[1]Department of Physics, Afyon Kocatepe Universitesi, Afyonkarahisar, 03200, Turkey
dermez@aku.edu.tr

Quantum entangled states in a system of trapped three-level ion interacting with two laser beams in Λ (Lambda) configuration is investigated. We have characterized many different initial conditions for their potential to generate quantum entanglement. It is found that entangled qudits, specifially qutrits and quadrits, can be constructed. Analytical results, describing the quantum entangled state explicity, are presented. The amount of quantum entanglement is quantified directly by calculating the generalized concurrence for arbitrary qudits. It is shown that higher dimensional entanglement can be established in a single step, with a tunable dimensionality and duration via the Lamb-Dicke parameter.

Dimitrova Todorka **(1)** **Talk**

Quantum erasing with single photons: a lecture demonstration experiment

Todorka L. Dimitrova(1) *and Antoine Weis*(2)
(1): University of Plovdiv "Paissi Hilendarski", Tzar Assen Str.24, BG-4000 Plovdiv
(2): University of Fribourg, Physics Department, Ch. du Musée 3, CH-1700 Fribourg
e-mail(1): tldimitrova@abv.bg
e-mail(2): antoine.weis@unifr.ch

Quantum mechanics is the most puzzling chapter of modern physics since it introduces concepts whose understanding is difficult for a classically trained mind. The principle of complementary is a prominent example. Students often accept it as a rule without the deep conviction that it describes real physical phenomena. Here we address the question of how information generated in the past can affect our interpretation of data in the present. So-called two-path-which-way interference experiments with photons are well suited for a discussion of this topic. The answer to the question "which path has the photon taken?" is not trivial [1]. Any attempt to put an individual label on the photon in each path leads to destruction of the interference pattern. Interference can arise only if we assume that the photon can take both paths simultaneously and that the paths are indistinguishable. Putting labels on the paths destroys the interference, which can, however, be restored by erasing the labels prior to the

detection of the photon, a phenomenon called quantum erasing. One can thus realize a situation in which the paths of the photon trough the apparatus were distinguishable by a specific label and that prior distinguishability can be erased by acting on the photon long after it has left the apparatus. In this sense a present action may influence a past event.

We present a lecture demonstration of quantum erasing based on a Mach-Zehnder interferometer (MZI). The MZI is composed by a beamsplitter separating light from a green laser pointer, two mirrors reflecting the two beams and a recombining beamsplitter. Compared to a double slit experiment the spatial separation of the interfering beams in the MZI has some methodological advantages and facilitates the manipulation of the light in the two paths. The experiment allows demonstrations both with strong laser light and on a photon-by-photon basis using appropriate attenuating filters before the MZI [2].

The which-way information is labelled by orthogonal (horizontal/vertical) linear polarizers inserted in the two paths. This path labelling destroys the interference as is well seen with strong light projected on a screen. A third (linear) polarizer placed after the exit of the MZI serves as quantum eraser. By rotating the erasing polarizer from 0º (horizontal) to 45º interference fringes with a smoothly increasing contrast appear. Conversely, the contrast decreases by rotating the eraser from 45º to 90º (vertical). The interference disappears for the horizontal/vertical orientations of the polarizer, since in that case the which-way information could be retrieved.

Besides their projection on a screen the interference fringes can be shown by modulating the path length difference in the MZI using a piezo-mounted mirror and an oscilloscope display of the light intensity detected by a photodiode (PD) or a photomultiplier (PM). The dependence of the degree of erasing on the polarizer orientation is visualized by the contrast of the interference fringes, seen as smooth traces with strong light and PD detection, or density of pulses with very weak light and PM detection. A smooth transition from the quantum to the classical case can be shown in real-time by varying the incident light intensity and averaging the PM signal.

This versatile apparatus allows demonstrations of the wave-particle nature of light and of specific implications such as quantum erasing.

References

[1] V. Scarani and A. Suarez, "introducing quantum mechanics: One particle interference", Am. J. Phys. **66** (8), August (1998).

[2] T. L. Dimitrova and A. Weis, "The wave-particle duality of light: a demonstration experiment", Am. J. Phys. **76** (2), February (2008)

Dodonov Victor **(3)** **Talk**

Dynamical Casimir effect and resonance frequency shifts in cavities with thin photo-excited semiconductor layers

Victor V. Dodonov[1] *and Alexandre V. Dodonov*[2]

[1]Instituto de Fisica, Universidade de Brasilia, Brasilia, DF, Brazil

[2]Departamento de Fisica, Universidade Federal de Sao Carlos, Sao Carlos, SP, Brazil

vdodonov@fis.unb.br

This is a report on a progress in studies of the so-called Dynamical Casimir Effect (generation of photons from vacuum in cavities with moving boundaries), in connection with an experiment which is under preparation in the University of Padua [1]. The main idea of this experiment is to simulate periodical displacements of the cavity wall by periodical strong changes of conductivity of a thin semiconductor slab illuminated by picosecond laser pulses. The theoretical grounds were discussed in [2,3] and presented at the CEWQO-06 in Vienna.

The emphasis in this talk is made on the calculation of the shift of resonance frequency of an electromagnetic cavity due to strong variations of dielectric properties in a thin layer near an ideally conducting wall. The magnitudes of real and imaginary parts of this shift are crucial for a feasibility of the experiment. We derive simple analytical formulas for the frequency shifts in different configurations and compare them with exact analytical solutions (which can be obtained for simple geometrical shapes), numerical calculations and experimental data. We also analyze the dependence of the photon generation rate on different parameters, such as the mobility of carriers, absorption coefficient of laser radiation, energy and shape of laser pulses, thickness of the slab and geometry of the cavity. Our evaluations show that under realistic experimental conditions, several thousands of quanta of EM field ("Casimir photons") could be produced from the initial vacuum state in a so-called reentrant cavity with the resonance frequency about 2.5 GHz.

References

[1] C. Braggio, G. Bressi, G. Carugno, C. Del Noce, G. Galeazzi, A. Lombardi, A. Palmieri, G. Ruoso, D. Zanello, Europhys. Lett. 70, 754 (2005).
[2] V.V. Dodonov, A.V. Dodonov, J. Phys. A 39, 6271 (2006).
[3] V.V. Dodonov, A.V. Dodonov, J. Phys. B 39, S749 (2006).

Domotor Piroska **(7)** **Talk**

On global entanglement of N-qubit pure states

Piroska Domotor, Mihaly G. Benedict
Department of Theoretical Physics, University of Szeged, Hungary
Domotor.Piroska@stud.u-szeged.hu
benedict@physx.u-szeged.hu

A proof will be given [1] that in the symmetric subspace of an N qubit system the only nonentangled states are the coherent ones. All states in the orthogonal complement of the symmetric subspace are globally entangled.

References

[1] P. Domotor, M.G. Benedict, Phys. Lett. A, (2008) in press
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Ducloy Martial **Invited talk**

Nanoscale Quantum Optics: nanocavity QED, atomic spectroscopy, etc.

T. Passerat de Silans, I. Maurin, M.-P. Gorza, D. Bloch, J.R. Rios Leite[1], V. Klimov[2], M. Ducloy
Laboratoire de Physique des Lasers (CNRS-UMR 7538), Université Paris 13, 93430-Villetaneuse, France
[1]L Universidade Federal de Pernambuco, Recife, Brasil 50670901
[2]P. N. Lebedev Physical Institute, RAS, Moscow119991, Russia
martial.ducloy@univ-paris13.fr

With the fast development of nanoscience and nanotechnologies, increasing attention has been devoted to the confinement of light near material nanostructures, as well as the confinement of atomic systems in nanometric spaces. The confinement of atoms inside a nano-sized space strongly alters the internal properties of the atomic system and its response to external excitation, *e.g.* light irradiation. In addition to surface-induced energy level shifts and spontaneous emission enhancement/inhibition, there is atomic symmetry break due to the anisotropy of the surface near-field, inducing energy level mixing, population transfer, forbidden transitions and selective surface-enhancement of forbidden lines [1]. These studies have potential applications in various research and technology fields like scanning near-field optical microscopy or cavity QED.

In this talk, we will review the recent work performed by our group in this area. This includes the present state of laser spectroscopy of gas nanocells and the monitoring of the surface van der Waals interaction in the nanometric range [2], the physics of excited atoms in interaction with dielectric (or metallic) surfaces or nanostructures (surface shifts and broadening, symmetry breaking, influence of surface waves, temperature effects [3]…), the influence of the sub-wavelength curvature of light fields near nanobodies on allowed/forbidden atomic transitions [4], with the potential applications to new types of light detectors. Connection with the physics of the so-called “spiral beams” (Laguerre-Gauss light beams) and their interactions with atomic systems, when these beams are strongly focused, will be discussed [5].

References

[1] *e.g.,* D. Bloch, M. Ducloy, Adv. At. Molec. Opt. Phys. (Academic Press, San Diego, 2005), **50**, 91
[2] M. Fichet *et al*., Europhys. Lett., **77**, 54001 (2007)
[3] M.-P. Gorza, M. Ducloy, Eur. Phys. J. **D**, **40**, 343 (2006) ; T. Passerat de Silans *et al.*, Ann. Physique (France) **32**, in press (2007)
[4] V. Klimov, M. Ducloy, Phys. Rev. A, **69**, 013812 (2004); **72,** 043809 (2005)
[5] V. Klimov, D. Bloch, M. Ducloy, J.R. Rios Leite, submitted (2008); ArXiv: 0802.0560v1

Ferraro Elena **(9)** **Talk**

Entanglement collapses and revivals in a spin star system

E. Ferraro, A. Napoli, A. Messina
Dipartimento di Scienze Fisiche ed Astronomiche,
Università di Palermo, via Archirafi 36, 90123 Palermo, Italy
ferraro@fisica.unipa.it

We study the exact dynamics of a spin star system composed by two uncoupled central spins ½ interacting with N identical spins ½ surrounding them [1,2]. Starting from appropriate initial conditions for the central system as well as for its environment, we find that the time evolution of the entanglement established between the two uncoupled spins is dominated by collapses and revivals phenomena. The spin star system we use is of interest in many physical situations such as quantum dots [3], cavity QED [4], two-dimensional electron gases [5] and optical lattices [6].

References

[1] H.-P. Breuer, D. Burgarth, F. Petruccione, Phys. Rev. B **70**, 045323 (2004)
[2] F. Palumbo, A. Napoli, A. Messina, Open Sys. and Information Dyn. **13**: 309-314 (2006)
[3] A. Imamoglu, D. D. Awschalom, G. Burkard, D. P. DiVincenzo, D. Loss, M. Sherwin, and A. Small, Phys. Rev. Lett. **83**, 4204 (1999).
[4] S.-B. Zheng and G.-C. Guo, Phys. Rev. Lett. **85**, 2392 (2000).
[5] V. Privman, I. D. Vagner, and G. Kventsel, Phys. Lett. A **239**, 141 (1998).
[6] A. Sørensen and K. Mølmer, Phys. Rev. Lett. **83**, 2274 (1999).

Gabris Aurel **(10)** **Talk**

Optimized quantum random walk search algorithms

Vaclav Potoček[1], Aurel Gabris[2], Tamas Kiss[2], and Igor Jex[1]
[1]Department of Physics, FJFI ČVUT, Brehova 7, 115
19 Praha 1 - Stare Mesto, Czech Republic
[2]Research Institute for Solid State Physics and Optics, H-1525
Budapest, P. O. Box 49, Hungary
gabrisa@szfki.hu

The quantum random walk search algorithm by Shenvi, Kempe and Whaley (SKW algo- rithm) yields a measurement probability of the marked element close to 1/2 [1]. Therefore, although the scaling of the search time is $O(\sqrt{N})$ which is the same as that of the Grover search, many repetitions of the algorithm might be necessary to find the marked element. This feature of the SKW algorithm can be prohibitive when the cost of preparing the initial state is high. In the talk we propose several alternative modifications to the original algorithm, allowing for the recovery of the marked element with almost certain probability in one or two repetitions.
All modifications are based on the complementarity behaviour of the two orthogonal subspaces spanned by the even and odd parity elements, and all conserve the original $O(\sqrt{N})$ scaling.

References
[1] N. Shenvi, J. Kempe, and K. Brigitta Whaley, Phys. Rev. A 67, 052307 (2003).

Gainutdinov Renat (1) **Talk**

Interaction of an Atom Subject to an Intense Laser Field with Its Own Radiation Field and Nonlocality of Electromagnetic Interaction

Renat Kh. Gainutdinov, Aigul A. Mutygullina
Kazan State University, Kazan, Russia
Renat.Gainutdinov@ksu.ru

In this talk we will discuss the interaction of an atom subject to an intense driving laser field with its own radiation field. Taking advantage of ideas from quantum optics and quantum electrodynamics and using the formalism of the generalized quantum dynamics [1], we will analyze the Lamb shift and the natural broadening of energy levels of laser-dressed states. It will be shown that, in contrast to bare atoms, in laser-dressed atoms the energy levels of states with the same values of the total angular momentum, its projection, and parity may overlap. We will present an equation which determines the natural broadening of spectral line profiles corresponding to transition from overlapping laser-dressed sates. The analysis of the interaction of an atom in such states with its own radiation field gives rise to the surprising finding that in describing the overlapping laser-dressed states QED faces the problem of unrenormalizable ultraviolet divergences. This may be an explicit manifestation of nonlocality of the electromagnetic interaction which in other cases is hidden in the regularization and renormalization procedures. This conclusion is confirmed by the fact that, as has been shown in Ref. [2], effects of nonlocality in time of interaction governing the dynamics of an atom can be very significant. Finally, we will discuss an experimental scheme to measure spectral observables in which the nonlocality of electromagnetic interaction may manifest itself.

References
[1] R.Kh.Gainutdinov, J. Phys. A **32**, 5657 (1999).
[2] R.Kh. Gainutdinov, A.A. Mutygullina and W. Scheid, Phys. Lett. A **306**, 1 (2002).

Gawlik Wojciech **(1)** **Invited talk**

Experiments on the Dynamics of Bose-Einstein Condensate in Finite Temperatures

Wojciech Gawlik[1] *and Michal Zawada*[2]
National Laboratory for Atomic, Molecular and Optical Physics,
ul. Grudziądzka 5, 87-100 Toruń, Poland
1) M. Smoluchowski Physical Institute, Jagiellonian University,
ul. Reymonta 4, 30-059 Kraków, Poland
2)Institute of Physics, Nicolaus Copernicus University, ul. Grudziądzka 5, 87-100 Toruń, Poland
gawlik@uj.edu.pl

The talk present results of experiments on BEC of ^{87}Rb atoms in a magnetic trap conducted in the Polish National Laboratory for Atomic, Molecular and Optical Physics [1]. We will briefly describe the experimental setup, diagnostics methods and main properties of the investigated atomic samples. Particular attention will be devoted to the hydrodynamic properties and dynamics of an ultra-cold atomic gas near the critical temperature. By applying a controlled perturbation we study the aspect ratio of an expending atomic cloud which reflects its hydrodynamic properties. On the other hand, by varying the temperature of the sample we are able to analyze dynamics of the collective atomic evolution as a function of the ratio between number of atoms in the thermal and condensed fractions. Such experiments allow studying of interaction between coherent and incoherent cold matter.

References

[1] F. Bylicki et al., Acta Physica Polonica A **113**, 691 (2008).

Gladush Maxim **(8)** **Poster**

Spectral properties of systems exhibiting intrinsic optical bistability

Maxim G. Gladush, Vladimir K. Roerich, Alexey A. Panteleev
State research center of Russian Federation,
Troitsk Institute for Innovation and Fusion Research,
TRINITI, Troitsk, Moscow region, Russia 142190
mglad@trinity.ru

Alternative hypothetic mechanisms to give rise to intrinsic optical bistability are studied theoretically as the field-controlled switching between different spectral patterns of the probe beam absorption and fluorescent light. The spectra are calculated both analytically and numerically for the entire hysteresis loop of atomic excitation. The specroscopic analysis is likely to provide graphic distinction between alternative models describing similar hysteresis behaviours. The master equation and equations to find the spectral properties of the non-linear optical response are derived from the Bogolubov-Born-Green-Kirkwood-Yvon hierarchy for reduced single particle density matrices of two-level atoms and quantized field modes and their correlation operators. The hierarchy is treated in the limit of the polarization approximation to make a correct account for radiative relaxation of an atom in the surrounding medium.

Gligorić Goran **(6)** **Talk**

Localized modes in the cigar-shaped Bose-Einstein condensates in a very deep optical lattice

Goran Gligorić[1], *Aleksandra Maluckov*[2], *Luca Salasnich*[3], *Boris Malomed*[4] *and Ljupčo Hažievski*[1]
[1]Vinča Institute of Nuclear Sciences, P.O. Box 522,11001 Belgrade, Serbia
[2]Faculty of Sciences and Mathematics, University of Niš, P.O. Box 224, 18001 Niš, Serbia
[3]CNR-INFM and CNISM, Unita di Padova, Via Marzolo 8, 35131 Padova, Italy, and Dipartimento di Fisica "Galileo Galilei", Universita di Padova, Via Marzolo 8, 35131 Padova, Italy
[4]Department of Physical Electronics, School of Electrical Engineering, Faculty of Engineering, Tel Aviv University, Tel Aviv 69978, Israel
goran79@vin.bg.ac.yu

Bose-Einstein condensates (BEC) featuring weak attractive interactions between atoms, i.e., a negative scattering length, support robust solitons in nearly one-dimensional (1D) prolate, alias "cigar-shaped", magnetic and/or optical traps. In the mean-field approximation, effective 1D equations for the condensate trapped in the prolate trap were derived, by means of various approximations, from the underlying 3D Gross-Pitaevskii equation. Only the 1D model based on the Schrodinger equation with the nonpolynomial on-site nonlinearity [1,2] admits a possibility of collapse, which corresponds to the possibility of the collapse in the self-attractive BEC confined in tight traps.

We derived a 1D model for a cigar-shaped BEC in the limit of a deep optical lattice, in the form of discrete nonlinear Schr□odinger equation with nonpolynomial nonlinearity (DNPSE). Our main interest was the generation and dynamics of localized modes in this model. Two families of unstaggered discrete solitons, stable and unstable, which include, respectively, broad and narrow solitons, and exactly comply with the Vakhitov-Kolokolov stability criterion are found. It is shown that the unstable on-site solitons either decay or transform themselves into robust breathers while the inter-site unstaggered solitons are unstable to collapse. However, the last may be stabilized by the application of a suficiently strong kick, which turns them into stable moving localized mode. The motion of localized modes was studied applying the concept of the Peierls-Nabarro (PN) barrier which was interpreted in the context of the free-energy and mapping analysis [3]. We showed that moving localized modes can be created by the application of a "kick" to a stable on-site soliton and corresponding unstable inter-site soliton with the same power and close free energy. In addition, we confirmed that the DNPSE model with self-repulsive intrinsic nonpolynomial nonlinearity can support the creation of the staggered solitons, which are counterparts of gap solitons in the continuum medium. We showed that the on-site staggered solitons are stable while the inter-site solitons are characterized by the appearance of small instability region. The main conclusion concerning the staggered solitons is their immobility.

References

[1] L. Salasnich, A. Parola, and L. Reatto, Phys. Rev. A 66, 043603 (2002).
[2] L. Salasnich, A. Cetoli, B. A. Malomed, and F. Toigo, Phys. Rev. A 75, 033622 (2007).
[3] A. Maluckov, L. Hadziveski, and B. A. Malomed, Phys. Rev. E 77, 036604 (2008).

Glushkov Alexander (4) **Talk**

QED theory of radiation emission and absorption lines for plasma atoms, ions and nuclei in a strong laser field. Nuclear quantum optics

Alexander V. Glushkov[1,2]
[1]Institute of Spectroscopy of Russian Academy of Sciences,
Troitsk, Moscow reg., Russia
[2]Odessa University,Odessa, South-East, Ukraine
glushkov@paco.net

A consistent QED approach [1,2] is applied to studying the interaction of the atoms and ions of plasma with an intense electromagnetic (laser) field. Method bases on description of atom in a field by the k- photon emission and absorption lines. The lines are described by the QED moments of different orders, which can be calculated with the use of the Gell-Mann and Low S-matrix adiabatic formalism (T=0). In relativistic version the Gell-Mann and Low formulae expresses an imaginary part of the energy shift Im E{a} through the QED scattering matrix, including interaction of atom with electromagnetic field and field of the photon vacuum. We present QED S-matrix energy formalism (T not equal 0) for calculation of the spectral lines shape in dense plasma. For any atomic level we calculate Im E{a}(w) as function of the laser pulse central frequency w (resonant curve). We calculate the moments for resonance, connected with concrete atomic a-p transition (a,p-discrete levels; k photons is absorbed). To calculate the moments we need to get the expansion of E{a} into the perturbation theory series. Numerical modelling carried out for H, Cs, Ar atoms and H-, Ne- and Ar-like plasma. QED approach to description of radiation atomic lines for atoms and ions in plasma is generalized on a case of the confined atomic systems, including a case of the Debye approximation.

We present the uniform energy approach, formally based on the QED perturbation theory [2,3] for the calculation of electron collision strengths and rate coefficients in a plasma of multicharged ions. The aim is to study, in a uniform manner, elementary processes responsible for emission-line formation in a plasmas. The electron collision excitation cross-sections and rate coefficients for some plasma Ne-like multicharged ions are calculated. To test the results of calculations we compare them with other authors' calculations and with available experimental data. The inclusion of Na-like states, accounting for diffusion-like processes, can increase the population inversion for the "lasing candidates" by at least a factor of two for a wide range of plasma conditions. Besides, we are calculating the functions, which describe the population distribution within each Rydberg series dependent on the Rydberg electron energy. These functions bear diagnostic information. Detailed calculations will be done for the homogeneous steady-state Maxwellian plasma. Modeling nuclear ensembles in a super strong laser field provides opening the field of nuclear quantum optics and is carried out in our work too. The Stark effect for nuclei is described within the operator perturbation theory [1].

References

[1] A.V.Glushkov, JETP Lett. **55**, 97 (1992); A.V.Glushkov, L.N. Ivanov, Phys. Lett. A**. 170**, 33 (1992); J.Phys.B **26,** L376-386 (1993); Preprint of Institute for spectroscopy of Russian Academy of Sciences, ISAN, N AS-1-3, Troitsk, (1992).

[2]. A.V.Glushkov et al, A.V.Glushkov, E.P. Ivanova, J.Quant. Spectr. Rad. Tr. (US) **36**,127 (1986); A.Glushkov et al, J.Phys.CS**. 11**, 188 (2005); **35**, 425 (2005); A.Glushkov etal, Nucl.Phys.A. **734**, e21 (2004).

[3]. A.V.Glushkov, S.V. Malinovskaya, In: New Projects and New Lines of research in Nuclear Phys. Eds. Fazio G. And Hanappe F., World Sci.. Singapore, 2003, 146, 242; A.V Glushkov, Low Energy Antiproton Physics. AIP Serie. **796**, 206 (2005); Glushkov A.V., Malinovskaya S.V., Dubrovskaya Yu.V., Vitavetskaya L.A., Recent Advances in Theory of Phys. and Chem. Systems **15,** 301 (2006); A.V.Glushkov et al, Int.J.Quant.Chem.**104**, 512, 562 (2005); Int. J.Quant. Chem. **99**, 889, 936 (2004); Recent Advances in Theory of Phys. and Chem. Systems (Springer). **15**, 285 (2006); Europ.Phys.Journ. in print (2008).

Gorelik Vladimir (1) Talk

Massive photons properties in 3D-photonic crystals, filled by dielectrics or metals

Vladimir S. Gorelik
P.N.Lebedev Physical Institute of Russian Academy of Sciences, Moscow, Russia
gorelik@sci.lebedev.ru

Optical properties of globular photonic crystals – artificial opals, consisting from monosized silica globules, have been investigated. Sizes of globules depended on conditions of 3D-photonic crystals growth and were 200-400 nm. Pores occupied 26 percent of total volume of photonic crystal. Such pores were filled by some liquids (ethanol, water, glycerin, acetone, nitrobenzene), solid dielectrics (stilbene, sulfur, ZrO_2), ferroelectrics (sodium nitrite), magnetics (ferrite), carbon (graphite) and metals (Ag, Au and Hg). Some samples were annealed at high temperature (up to 1200 C). As a result of high temperature annealing or some dielectrics filling the samples became almost transparent for visible region. Transmission and reflectance spectra of prepared samples of 3D-photonic crystals in visible region have been investigated. Halogen lamp has been used as a source of light in these cases. Transmission and reflectance spectra have been obtained with the help of fiber optic technique and have been recorded by minispectrometer. Experimental results on the secondary emission (photoluminescence) spectra properties of globular photonic crystals, filled by different dielectrics and metals, have been obtained. Parameters of dispersion laws were calculated from the secondary emission, transmission and reflectance spectra, revealing the forbidden zone in visible region. An approximation of one-dimensional photonic crystal dispersion law has been used. Such approximation described the dispersion law for [111] direction of three dimensional photonic crystal. As a result of such approximation three allowed and two forbidden photonic bands dispersion laws have been studied. The second allowed band corresponded to electromagnetic waves, with opposite directions of phase and group velocities. It is known, that in this case negative refraction index takes place. The analytical description of photonic bands dispersion law for small wave vector value and for the edges of the allowed zone has been proposed. The influence of dielectrics or metal presence inside porous of photonic crystals has been established. The dependencies of group velocity and effective photonic mass from wave vector and the frequency value of electromagnetic waves have been calculated. In this approximation photons become massive quasiparticles, propagating inside photonic crystal with velocity essentially less velocity of light in vacuum. Effective mass of photons, propagating inside photonic crystal, may be positive, negative or close to zero. For the second photonic band, corresponding to visible or ultraviolet region in our photonic crystals, the refraction index becomes negative; besides, for this band the effective mass of photons is negative at small impulse value and positive with impulse increase. At some impulse value photon velocity (group velocity of electromagnetic wave) becomes very small. Properties of photons, corresponding to electromagnetic waves

with negative refraction index have been discussed. With using of these properties new types of optical devices may be worked out: visible super lens, super spectrograph, super microscope and super focusator. We have analyzed the conditions for bound photonic states [1] realizing inside 3D-photonic crystals. In this case very slow massive photons are excited with using of light, frequency of which is close to the edges of the second or third allowed photonic zones. Tensor-type bound two-photonic states have scalar component. Such component is inactive for one photonic emission or absorption processes. Elementary excitations, corresponding to this type of electromagnetic waves, were named darktons [1]. Main property of darktons is the absence of their interaction with charge particles. Accordingly dielectrics and metals should be transparent for this type of particles. Experiments for darkton emission realizing with the help of photonic crystals have been proposed. This work was supported by Russian Foundation for Basic Research. Project Numbers: 07-02-00106, 07-02-12027 and 08-02-00114.

References

1.V.S. Gorelik. Bound and dark photonic states in globular photonic crystals. Acta Phys. Hung. B 26/1-2 (2006) 37-46.

Grozescu Anamaria **(8)** **Poster**

Advantage of hydrothermal synthesis cobalt ferritic nanostructures vs. coprecipitation

Paulina Vlazan[1], Marinela Miclau[1], Marilena Bradiceanu[1], Anamaria Grozescu[1], Paula Sfarloaga[1], Stefan Novaconi[1], Ioan Grozescu[1]

[1]National Research & Development Institute for Electrochemistry and Condensed Matter, Timisoara, Romania.

grozescu_anamaria@yahoo.com

Cobalt ferrite ($Co_xFe_{3-x}O_4$) is a cubic ferrite with an inverse and spinelic nanostructure, its particles being very special ones due their magnetically interesting properties. Cobalt ferrite nanopowders were produced using two methods: hydrothermal and chemical coprecipitation.

Nanocrystalline powders of cobalt ferrite with different morphology and particle size of a few nm, were prepared by hydrothermal method. Particle size, morphology and properties of the cobalt ferritic nanostructures were investigated by X-ray diffraction (XRD) and scanning electron microscopy (SEM). The results are compared with cobalt ferritic nanopowders obtained in chemical coprecipitation. It was found that hydrothermal processing results in formation of low dimensional dispersion of cobalt ferrite nanoparticles, a higher degree of crystallinity and much pronounced magnetic properties. In hydrothermal method, although the synthesis temperature is low, up to 200°C, it is possible to obtain clean nanoparticles of $Co_xFe_{3-x}O_4$ with high degree of crystallinity, desirable form and size. The most important attribute consists in reduction of particle agglomeration attended to narrow size distribution. For exemple, by chemical coprecipitation method , although is an economical synthesis way for ultrafine $Co_xFe_{3-x}O_4$ of different compositions (x = 0.25, 0.4, 0.5, 0.8) and sizes (6-10nm) at low synthesis temperature 50-95ºC, the powder is not very well crystallized, as results from small diffraction peaks in diffraction pattern.

The main advantage of hydrothermal synthesis method consists in dimensional control of particle form and dimensions according to desired magnetic properties.

Outstanding that particle's size represents the substance performance critical factor in monodisperse nanoparticles magnetic activity.

References
[1] V. L. Calero Díaz del Castillo, Synthesis and characterization of cobalt-substituted ferrite nanoparticles using reverse micelles, Master of sciences in Chemical Engineering, University of Puerto Rico Mayagüez Campus, Puerto Rico (2005).
[2] L. Xinyong, C. Kutalb, Synthesis and characterization of superparamagnetic $Co_xFe_{3-x}O_4$ nanoparticles, Journal of Alloys and Compounds, **349** (2003) 264–268.

Grujić Zoran **(5)** **Poster**

Numerical Simulation of Raman-Ramsey Effects Induced by Thermal Motion of Rubidium Atoms

Zoran Grujić, Dušan Arsenović, Milan Radonjić and Branislav Jelenković
Institute of Physics, Belgrade, Serbia
zoran.grujic@phy.bg.ac.yu

We use optical Bloch equations in order to calculate spontaneous emission and Zeeman coherences of the probe laser beam in coaxial pump-probe configuration [1] in rubidium vapor. The ^{87}Rb D1 line $F_g = 2 \rightarrow F_e = 1$ transition is open so solving time-dependent equations was necessary. Also due to the nature of room temperature Rb vapor we performed averaging over different atomic velocities according to Maxwell-Boltzmann distribution and over different directions of atoms propagation through pump and probe laser beams. Time dependent diagonal and non diagonal density matrix elements for atom are presented and discussed.

References
[1] Z.D. Grujić, M.M. Mijailović, B.M. Panić, M. Minić, A.G. Kovačević, M. Obradović, B.M. Jelenković and S. Cartaleva, Acta Physica Polonica A, No 5, 112, 799 (2007).

Haslinger Philipp **(5)** **Poster**

A new source for quantum optics with applications in molecule metrology with biomolecules

Philipp Haslinger , Markus Marksteiner, Hendrik Ulbricht, Michele Sclafani and Markus Arndt
Faculty of Physics, University of Vienna, Boltzmanngasse 5, A – 1090 Wien, Austria
philipp.haslinger@univie.ac.at

All successful experiments on macromolecule interferometry so far used thermal effusive beam sources [2]. In order to apply quantum interference to molecules of biological interest it is necessary to implement a soft volatilization method as well as an improved velocity selection of the molecular beam.
A pulsed laser desorption source now allows us to generate intense beams biomolecules [1]. We were recently able to extend our scheme to large neutral amino acid clusters, such as for

instance $CaTrp_{30}$, with masses exceeding 6000 amu: the addition of alkaline Earth salts in the desorption process leads to the inclusion of at least one metal atom per complex and is important for the catalysis and stabilization of the cluster formation process.

The pulsed desorption allows us to achieve a velocity resolution of below 1%, which is required and sufficient for interesting applications in molecule metrology in the gas phase. We present new ideas how to combine the laser desorption source with Talbot-Lau interferometry (TLI) for various measurements on neutral molecules: This includes the proposal to employ TLI as a mass spectrometer for neutral molecules as well as the combination with Stark deflectometry to determine electric susceptibilities of large molecules in the gas phase.

References

[1] M. Marksteiner, G. Kiesewetter, L. Hackermüller, H. Ulbricht and M. Arndt, *Cold Beams of Biomolecules for Quantum Optics,* Acta Phys. Hung. A **26** 87–94 (2006).

[2] B. Brezger, L.Hackermüller, Stefan Uttenthaler, Julia Petschinka, Markus Arndt, Anton Zeilinger, *Matter-Wave Interferometer for Large Molecules,* Phys. Rev. Lett. **88**, 100404 (2002).

Hennrich Markus **(10)** **Invited talk**

Universal ion trap quantum computation on logical qubits

M. Hennrich[1], *K. Kim*[1], *T. Monz*[1], *A. S. Villar*[1,2], *P. Schindler*[1], *M. Chwalla*[1], *M. Riebe*[1], *and R. Blatt*[1,2]

[1] Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, A-6020 Innsbruck, Austria

[2] Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, A-6020 Innsbruck, Austria

markus.hennrich@uibk.ac.at

Quantum computation is limited by decoherence from technical noise and coupling of the qubits to the environment. However, certain states were shown to be protected from decoherence due to their symmetry. These states form a decoherence-free subspace (DFS) of the Hilbert space. Using logical qubits from this subspace as a robust computational space could help to realize large scale quantum computing [1]. In this talk we show the first realization of a universal set of gate operations in such logical basis with ion strings. We use trapped ^{40}Ca ions and store quantum information in the ion's electronic states $S_{1/2}$ and $D_{5/2}$. A DFS is formed by the two states $|SD\rangle$ and $|DS\rangle$ which are used as logical qubits $|0_L\rangle$ and $|1_L\rangle$. In the logical basis, single-qubit rotations are realized using a Mølmer-Sørensen gate between the two ions of the logical qubit. For two-qubit operations between logical qubits a σ_z-type geometric phase gate is applied to neighbouring ions of two adjacent logical qubits [2]. We obtain fidelities of around 94% for a single qubit $\pi/2$-rotation and around 75% for a CNOT gate between two logical qubits.

References

[1] D. Kielpinski et al., Nature 417, 709 (2002).

[2] L. Aolita et al., Phys. Rev. A 75, 052337 (2007).

Herec Jiri **(10)** **Poster**

Asymmetric cloning of complementary quadratures between atomic memories

Jiri Herec and Radim Filip
Department of Optics, Palack´y University, 17. listopadu 50, 77200 Olomouc, Czech Republic
herec@optics.upol.cz

We extend continuous-variable cloning of quantum information into the atomic memories. The proposed method allows us to achieve optimal asymmetric cloning of information carried by the complementary quadratures. It requires only a single passage of light through the memories without any non-classical pre-processing of the initial atomic state. The asymmetric scheme enables us to control amount information contained in particular clones. Further, the cloning between quantum memories utilizing of squeezed light is proposed. Under the same conditions, the optimal cloning can be approached if a sufficiently high squeezing of light is used.

Ilić Dušan **(8)** **Poster**

Adapting and Application of the Green's Functions Method onto Research of the Molecular Ultrathin Film Optical Properties

Jovan P. Šetrajčić[1], *Dušan Ilić*[2], *Branko Markoski*[2], *Ana J. Šetrajčić*[3], *Siniša M. Vučenović*[4], *Dragoljub Lj. Mirjanić*[4], *Blanka Škipina*[5], *Svetlana Pelemiš*[6]
[1]Faculty of Sciences, Novi Sad, Vojvodina – Serbia
[2]Faculty of Technical Sciences, Novi Sad, Vojvodina – Serbia
[3]Faculty of Medicine – Pharmacy, Novi Sad, Vojvodina – Serbia
[4]Faculty of Medicine, Banja Luka, Republic of Srpska – Bosnia and Herzegovina
[5]Faculty of Technology, Banja Luka, Republic of Srpska – Bosnia and Herzegovina
[6]Faculty of Technology, Zvornik, Republic of Srpska – Bosnia and Herzegovina
idilic@EUnet.yu

The basic question to be solved concerning theoretical research of the spatially strongly bounded structures is inability of applying the standard mathematical tools: differential equations and Fourier analysis. In this paper is shown how the Green's functions method [1] also can be efficiently applied on the crystalline samples so constrained that the quantum size effects [2] play significant role upon them. For the purpose of exemplification of this method appliance we shall consider molecular crystal of the simple cubic structure: spatially unbounded (bulk) and strongly bounded alongside one direction (ultrathin film).

Starting point in our theoretical analysis will be the standard exciton Hamiltonian [3]:

$$H = H_0 + \sum_{\vec{n}} \Delta_{\vec{n}} P^+_{\vec{n}} P_{\vec{n}} + \sum_{\vec{n},\vec{m}} X_{\vec{n}\vec{m}} P^+_{\vec{n}} P_{\vec{m}} + \sum_{\vec{n},\vec{m}} Y_{\vec{n}\vec{m}} P^+_{\vec{n}} P_{\vec{n}} P^+_{\vec{m}} P_{\vec{m}} \qquad (1)$$

along with definition expression of the commutator paulion Green's function with equation of motion:

$$\Gamma_{\vec{n}\vec{m}}(t) = \left\langle\left\langle P_{\vec{n}}(t) \middle| P^+_{\vec{m}}(0) \right\rangle\right\rangle = \Theta(t) \left\langle \left[P_{\vec{n}}(t), P^+_{\vec{m}}(0) \right] \right\rangle \qquad (2)$$

$$i\hbar \frac{d}{dt}\Gamma_{\vec{n}\vec{m}}(t) = i\hbar\delta(t)\Big\langle \big[P_{\vec{n}}(t), P^{+}_{\vec{m}}(0)\big] \Big\rangle + \Theta(t)\Big\langle \big[P_{\vec{n}}(t), H\big]\; P^{+}_{\vec{m}}(0) - P^{+}_{\vec{m}}(0)\big[P_{\vec{n}}(t), H\big] \Big\rangle .$$

In this paper is thereafter represented in detail the defining procedure of Green's functions, calculated from the system of diference equations

$$G_{n_z-1,m_z} + \rho G_{n_z,m_z} + G_{n_z+1,m_z} = K\,\delta_{n_z,m_z}\,; \quad \rho = \frac{\hbar\omega - \Delta}{|X|} + 2\left(\cos ak_x + \cos ak_y\right) \qquad (3)$$

and by means of these equations the dispersion law and exciton states distribution is obtained and the relative permittivity for ultrathin films [4] is defined. These results are calculated numerically and tabular and graphically presented.

In addition to the basic task to adapt the Green's functions method to quantum systems, it is shown in this paper that the energy spectra of excitons in thin films are predominantly discrete inside the bulk boundaries. Different from bulk structures, where the continual absorption zone appears in the definite frequency band of externally radiation, the resonant peaks with film structures exist only on some resonant frequencies. As the observed film is thicker, the differences between its properties and the corresponding bulk structure become drastically smaller. All this indicates the existence, and represents the result of the quantum size effect.

References

[1] G.Rickayzen: Green's Functions and Condensed Matter, *Academic Press*, London 1980.
[2] M.C.Tringides, M.Jatochawski and E.Bauer: Quantum Size Effects in Metallic Nanostructures, *Physics Today*, pp.50-54 (April 2007).
[3] V.M.Agranovich and V.L.Ginzburg: Crystaloptic with Space Dispersion and Theory of Excitons, *Nauka*, Moskwa 1979. (in Russian)
[4] I.E.Dzyaloshinski, L.P.Pitaevski, *ZhETF* 36, 1797 (1959).

Ilić Jelena **(8)** **Poster**

Sellmeier parameters analysis in optical pulse shaping

Jelena Ilić[1], *Milesa Srećković*[2] *and Veljko Zarubica*[3]
[1]Faculty of Mechanical Engineering, University of Belgrade, Belgrade, Serbia
[2]Faculty of Electrical Engineering, University of Belgrade, Belgrade, Serbia
[3] Department of Measures and Precious Metals, Belgrade, Serbia
jilic@mas.bg.ac.yu

Materials suitable for light pulse propagation control are investigated in this paper. Many of recent papers reported the results of optical properties measurement in broad wavelength ranges for newly developed materials as well as thin films of more or less known materials [1] [2]. After the refractive indices are measured for set of wavelengths they are fitted usually by four-parameter Sellmeier equation, on the basis of which the phase matching curves for second-harmonic generation are calculated. In this paper further analyses of Sellmeier equation for various materials of interest in nonlinear optics are performed.

First, group velocity dispersions are calculated and wavelength regions of specific types of pulse propagation are distincted: regions of constant pulse width around the zero group velocity dispersion, regions of pulse compression possibilities with negative group velocity dispersion and regions of pulse broadening which though usually unwanted can be used for introducing a good quality chirp suitable fore effective pulse compression [3]. Temperature dependences of refractive indices also reported are taken into account [4] [5].

On the other hand, generalized Sellmeier equation which consists of several oscillator terms involve in its parameters more direct information about material such as electronic transitions or resonance wavelengths and average oscillator strengths i.e. oscillators volume concentrations and transition probabilities [6]. Therefore, four parameter Sellmeier equations are transformed by fitting into one-term (or one-oscillator) in order to get more useful information about a material. The necessity of second term introduction indicated by bad fitting are detected for some materials. The conditions for the second term parameters required for negative group velocity dispersion (as it is appropriate in pulse compression) are determined. Finally, correlation of the parameters of Sellmeier equation and some non-optical material properties, including mechanical and thermal, are considered.

The materials chosen for the analyses are rare earth oxides, borates, chalcopyrite crystals some laser host materials and some crystals such as langasite, langanite and langataite [7].

References

[1] N. Umemura, K. Miyata and K. Kato, 30, 532 (2007).
[2] C. Martinet, A. Pillonnet, J. Lancok and C. Garapon, J. Luminescence 126, 807 (2007).
[3] G. Hays, E. Gaul, M. Martinez and Todd Ditmire, Appl. Opt. 46, 4813 (2007).
[4] U. Schlarb, K. Betzler, Phys.Rev. B 50, 751 (1994).
[5] L. F. Jiang, W. Z. Shen, H. Ogawa, Q. X. Guo, J. Appl. Phys. 94, 5704 (2004).
[6] X. Wan, H. Chan, C. Choy, X. Zhao, H. Luo, J. Appl. Opt. 96, 1387 (2004).
[7] J. Stade, L. Bohaty, M. Hengst, R. B. Heimann, Cryst. Res. Technol. 37, 1113 (2002).

Isar Aurelian **(7)** **Talk**

Entanglement in open quantum dynamics

Aurelian Isar
Department of Theoretical Physics, Institute of Physics and Nuclear Engineering
Bucharest-Magurele, Romania
isar@theory.nipne.ro

In the framework of the theory of open systems based on completely positive quantum dynamical semigroups, we analyze the possibility of generating the quantum entanglement in a bipartite system during its interaction with an environment. We solve the master equation for two independent harmonic oscillators interacting with the environment and give a description of the induced continuous-variable entanglement in terms of the covariance matrix of the considered subsystem for an arbitrary Gaussian input state. Using Peres-Simon necessary and sufficient criterion for separability of two-mode Gaussian states, we show that for certain classes of environments the initial state evolves asymptotically to an entangled equilibrium bipartite state, while for other values of the coefficients describing the environment, the asymptotic state is separable. We calculate also the logarithmic negativity characterizing the degree of entanglement of the asymptotic state.

References

[1] A. Isar, J. Russ. Laser Res. 28, 439 (2007).
[2] A. Isar, Int. J. Q. Inf. 6, (2008) (in press).

Iskhakov Timur **(1)** **Poster**

Two-mode squeezing in Parametric Down Conversion

M.V.Chekhova, T.Sh.Iskhakov, E.D. Lopaeva.

Department of Physics, Moscow State University, Leninskie Gory,
Moscow, 119991 Russia
tiskha@gmail.com

Generation of novel nonclassical states of light attracts great interest in quantum optics and quantum information. One of the typical sources of nonclassical radiation is Parametric Down-Conversion (PDC). There are two extreme regimes of this process: two-photon light in the case of low parametric gain, and squeezed light in the case of high gain. In this last case, light does not only contain photon pairs, but all even-photon numbers. Signal and idle beams have perfectly correlated intensity fluctuations and are usually called twin beams.

In our work we trace the transition between these two regimes. Our simplest experimental scheme was based on collinear type-II PDC in a BBO crystal pumped by the 3rd harmonic of a Nd:YAG laser with pulse duration 5 ns and repetition rate 10 kHz. Signal and idler modes were registered by two APDs operating in the Geiger mode and two different values were measured: normalized second-order Glauber's correlation function, $g^{(2)}$ and the variance of the photocount-number difference, ΔN_-. One can show that while the normalized Glauber's correlation function decreases with the parametric gain, the photocount-number difference remains constant and is below than the shot-noise limit (equal in this case to the sum of the averaged photocount numbers in the signal and idler modes). Because the degree of squeezing is only determined by the losses in the channels it can be used for the absolute measurement of the detectors' quantum efficiency [1]. In our case, the quantum efficiency was confirmed independently using the Klyshko absolute calibration method. This possibility of absolute measuring quantum efficiency from the variance of photocount-number difference is important for the calibration of analog detectors.

In a more general scheme, one can use two type-I crystals pumped by the same beam [2] and oriented with their optic axes at +45° and -45° to the polarization of the pump. In this geometry, the state of light in the low-gain regime is given by the superposition

$$|\Psi\rangle = \frac{1}{\sqrt{2}}(\sigma|2,0\rangle + \sqrt{1-\sigma^2}e^{i\varphi}|0,2\rangle),$$

where $|n,m\rangle$ denotes a state with n photons in the +45° polarization mode and m photons in the
-45° polarization mode, and φ, σ are the relative phase and amplitude, controlled by polarization elements in the pump beam. By varying φ, σ one can obtain, in the low-gain regime, a nearly complete set of biphoton qutrits [3]. In the high-gain regime, the state manifests the most general form of squeezing. In particular, this scheme enables one to observe squeezing in any of the two Stokes parameters S_1, S_3.

References

[1] Giorgio Brida *et al*., *J. Opt. Soc. Am. B* **23,** 2185 (2006).
[2] P.G. Kwiat *et al*., Phys. Rev. Lett. **75**, 4337 (1995).
[3] Yu. Bogdanov *et al*., Phys. Rev. Lett. **93**, 230503 (2004).

Ivković Milivoje **(8)** **Poster**

Fabrication of the gold-polymer nanocomposites using pulsed laser deposition: dependence of the optical properties on the type of polymer substrates

M. Ivković[1], *D.K. Božanić*[2], *N. Bibić*[2], *J. Pionteck*[3], *R. Žikić*[1], *and V. Djoković*[2]
[1]Institute of Physics, Belgrade, Serbia
[2]Vinča Institute of Nuclear Sciences, Belgrade, Serbia
[3] Leibniz-Institut für Polymerforschung, Dresden, Germany
ivke@phy.bg.ac.yu

Nanocomposite materials comprised of gold nanoparticles and various polymer matrices (polystyrene, NH_2-terminated polystyrene, polymethylmethacrylate, NH_2 terminated polymethylmethacrylate, COOH terminated polymethylmethacrylate, and polymer blend of PS-NH_2 and PMMA-COOH), were prepared by pulsed laser deposition (PLD).

The obtained materials were light blue to purple in color indicating the formation of nano-sized gold strucures. Resulting nanocomposites were investigated by structural and optical methods. Transmission electron microscopy showed that the nanoparticles were well dispersed in polymer matrices with the average size of 10 nm, while the electron diffraction pattern of the nanocomposite confirmed the presence of cubic Fm3m crystal phase of gold. UV-VIS absorption spectroscopy revealed a presence of characteristic surface plasmon band of nanostructured gold that changed its position and shape with the change of matrix employed.

Using Maxwell-Garnett effective medium theory for the absorption of light of the composite materials, it was shown that these changes originate from the differences in spatial distributions of gold nanoparticles inside the matrices proving that functional groups in terminated polymers act as centers of nucleation and modify the growth of the deposited gold in direction parallel to the substrate.

Jamshidi Ghaleh Kazem **(8)** **Poster**

Optical properties modification in borosilicate glass using femtosecond laser pulses

Kazem Jamshidi-Ghaleh
Department of Physics, Azarbaijan University of Tarbiat Moallem, Tabriz, Iran
k-jamshidi@azaruniv.edu

The interaction of ultra-short powerful infrared laser pulses (femtosecond and in some cases even picosecond laser pulses) with transparent optical glasses, has attracted much attentions theoretically and experimentally [1-2].

In this paper, interaction of focused 200 femtosecond infrared laser pulses at 1 kHz repetition rate with bulk borosilicate glass is investigated. Effect of incident pulse energy and laser shout number on laser-induced optical properties modification, length and area size, are investigated. The interplay between self-focusing and filamentation of the laser pulses on laser-induced optical properties modification beginning position inside glass sample is analyzed for different incident pulse energies.

The laser pulse energy accumulation model [3] is applied to explain the evaluation of modification sizes with incident pulse energy and shout number. The moving focus model for self-focusing of laser beam [4] is also applied to explain the experimental result of the laser-induced modifications length. The experimental results and theoretical models in both cases, modification position and area size, are in good agreement.

References

[1] Y. Li, W. Watanabe, K. Yamada, T. Shinagawa, K. Itoh, J. Nishii and Y. Jiang, Appl. Phys. Lett. 80, 1508 (2002).
[2] L. Sudrie, A. Couairon, M. Franco, B. Lamouroux, B. Prade, S. Tzortzakis and A. Mysyrowicz, Phys. Rev. Lett. 89, 186601 (2002)
[3] Y. Jee, M.F. Becker, and R.M. Walser, J. Opt. Soc. Am. B 5, 648 (1988).
[4] Y.R. Shen, "Principles of Nonlinear Optics" (Wiley New York, 2002) Chap 3

Jeknić Dugić Jasmina **(7)** **Poster**

Protein folding: the optically-induced electronic transitions model

Jasmina Jeknić-Dugić
Department of Physics, Faculty of Science, Niš, Serbia
jjeknic@ni.ac.yu

Mechanism of the macromolecules conformation changes (transitions) is an open issue of significant importance for the foundations of bio- physics and chemistry, as well as for certain fields of modern technology (e.g. nanotechnology) [1, 2, 3, 4, 5, 6]. Here, we employ the recently developed decoherence-based model [7, 8, 9] as an extension of the standard quantum chemistry model [10] of molecule. Particularly, we introduce and analyze a model of the conformation changes that follow from the optically-induced transitions in the molecule electron-system. Our conclusion is that this model describes the comparatively slow changes of conformation, in qualitative agreement with some experimental results [6].

References

[1] C. Levinthal, J. Chim. Phys. **65**, 44 (1968)
[2] K. Dill, Protein Science **8**, 1166 (1999)
[3] S. Kachalo, H-M Lu, J. Liang, arXiv: q-bio.BM/0601018 v1
[4] G. Haran, J. Phys.: Condens. Matter **15**, R1292 (2003)
[5] R.A.L. Jones, „Soft Machines: Nanotechnology and Life“, Oxford University Press, Oxford, UK&NI, 2004
[6] A. Lendlein, H. Jiang, O. Junger and R. Langer, Nature **434**, 879 (2005)
[7] D. Raković, M. Dugić, M. Plavšić, Mat. Sci. Forum **453-454**, 521 (2004)
[8] M. Dugić, D. Raković, M. Plavšić, *Chapter 9* in „Finely Dispersed Particles: Micro-, Nano- and Atto-Engineering“, A. Spasić and J-P Hsu, *Eds*., Taylor and Francis CRC Press, Boca Raton, USA (2005)
[9] J. Jeknić, M. Dugić, D. Raković, *Mat. Sci. Forum* **555,** 405-411 (2007),
[10] L.A. Gribov, S.P. Mushtakova, „Quantum Chemistry“, Gardariki, Moscow, Russia (1999, *in Russian*)

Jivulescu Anastasia **(9)** **Talk**

Exact dynamics of a disordered spin star system

M. A. Jivulescu[1,2], *E. Ferraro*[1], *A. Napoli*[1], *A. Messina*[1]
[1]MIUR, CNISM and Dipartimento di Scienze Fisiche ed Astronomiche, Università di Palermo,
via Archirafi 36, 90123 Palermo, Italy,
[2]Department of Mathematics, "Politehnica" University of Timisoara,,
P-ta Victoriei Nr. 2, 300006 Timisoara, Romania
jivulescu@fisica.unipa.it

The dynamics of a single localized electron spin in solid structure, such as electrons bound to phosphorus donors in silicon, NV centers in diamond or semiconductor quantum dots has attracted in the last years the attention of many physicists both from a theoretical and experimental point of view. These systems are often modelled by disordered spin star systems when a single spin interacts with different coupling constants with N uncoupled identical spins[1-2]. In this talk I present the exact dynamics of such a system based on the resolution of the time-dependent Schrodinger equation starting from arbitrary initial spin configuration[3-5]. Some applications corresponding to specific initial conditions are discussed.

References

[1] H.P. Breuer, D. Burgarth, F. Petruccione, Phys. Rev. B **70**, 045323, (2004)
[2] E. Ferraro, A. Napoli, M. A. Jivulescu, A. Messina, EPJ Special Topics (2008) (in press)
[3] R.A. Horn, C. Johnson, Topics in Matrix Analysis, Cambridge University Press, 1991
[4] L.M. Woods, T.L. Reinecke, A.K. Rajagopal, Phys. Rev. B **77**, 073313 (2008)
[5] A.K. Rajagopal, quant-ph/0602092 (2006)

Jovanić Branislav **(8)** **Poster**

High pressure optical studies of α–$ZnAl_2S_4$:Cr^{3+}

Branislav R Jovanić[1], *Isabelle Broussell*[2], *Bratimir Panić*[1], *Božidar Radenković*[3]
[1]Institute of Physics, Center of Experimental Physics, Lab.Multidisc.Res., Belgrade Univ., P.O.Box 68, 11080 Zemun, Serbia,
[2]Department of Physics, University of Ottawa, Ottawa, ON KIN 6N5, Canada
[3]Faculty of Organization Science, Jove Ilića 154, 11000 Belgrade, Serbia
brana@phy.bg.ac.yu

The effect of hydrostatic pressure at room temperature on the emission spectra and fluorescence lifetime τ_{R1} of the R1 line in tiospinel (α-$ZnAl_2S_4$) crystal has been studied. Research was carried out in the interval between 0 and 70 kbar. On the basis of the position of the R1 line ($^2E \rightarrow {}^4A_2$ transition) in the emission spectrum, we have concluded that pressure induces red-shift $\Delta\lambda_{R1}$. The significant change in τ_{R1} with the change of pressure has also been noticed. The change of $\Delta\lambda_{R1}$ and τ_{R1} induced by pressure was explained by a simple model. A good correlation between theoretical and experimental values of $\Delta\lambda_{R1}$ and τ_{R1} within the pressure interval in question has been achieved.

Reference
[1] I.Broussell, E.Fortin, L.Lulyuk, S.Popov. Solid.Stat.Commun. 99 (1996) 921-925.
[2] B.R. Jovanić, B. Viana, M. Dramićanin, B.M. Panić, B. Radenković. Optical Materials 30 (2008) 1070–1073

Khanbekyan Mikayel **(3)** **Talk**

Spontaneous emission of a single atom in a high-Q cavity: Pulse shape and eficiency of one-photon Fock state preparation

Mikayel Khanbekyan[1], *Dirk-Gunnar Welsch*[1], *Christian Di Fidio*[2] *and Werner Vogel*[2]
[1]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universitat Jena, Jena, Germany
[2]Arbeitsgruppe Quantenoptik, Institut fur Physik, Universitat Rostock, Rostock, Germany
mkh@tpi.uni-jena.de

It is well known that cavity QED offers powerful possibilities for generation and processing of nonclassical states of light. In particular, strong interaction of the electromagnetic field with the radiating object achieved in high-*Q* cavities provides high eficiency of single-photon Fock state generation on demand. Quantum control over single-photon emission is of prime importance in quantum information science. In this contribution we study the quantum state of the radiation emitted by a single atom in a high-*Q* cavity including the regime where the emitted photon belongs to a wave packet that simultaneously covers the areas inside and outside the cavity.

Within the framework of exact QED in dispersing and absorbing media [1], we study the resonant interaction of an atom in a high-Q cavity with the cavity-assisted electromagnetic field. Considering a one-dimensional cavity bounded by a perfectly reecting and a fractionally transparent mirrors and using source-quantity representation of the electromagnetic field we treat the field as an entity without regarding the fields inside and outside the cavity as representing independent degrees of freedom. Applying the rotating-wave approximation to the atom-field interaction, we examine the mode structure of the outgoing field for both continuing and shortterm atom-field interaction. In the regime of strong atom-field coupling we find the Wigner function of the quantum state of the excited outgoing mode as well as the spatio-temporal shape of the corresponding wave packet.

In the case of continuing atom-field interaction the effciency of the excited outgoing mode to carry a one-photon Fock state is time-dependent and follows the Rabi oscillations of the atom-field coupling. This reects the fact, that the corresponding wave packet covers the regions both inside and outside the cavity a therefore can be reabsorbed by the atom. The part of the excited outgoing mode that is entirely localized outside the cavity determines the probability of registering the emitted photon by a photodetector placed outside the cavity|a quantity which monotonously increases with time.

In the case of short-term atom-field interaction, where the atom leaves the cavity at some time, the eficiency of the excited outgoing mode being prepared in a one-photon Fock state is constant for later times. In particular, if the atom leaves the cavity when it is the first time in the ground state, then the field can be regarded as a single-peak pulse, the trailing edge of which covers the areas inside and outside the cavity. Moreover, when the interaction time is sufficiently short, the pulse can be approximated by its trailing edge, the part of which that entirely located outside the cavity matches the field determined by the relevant mode appearing in the formalism of the input-output relations [2].

References
[1] L. Knoll, S. Scheel, and D.-G. Welsch, QED in dispersing and absorbing dielectric media, in Coherence and Statistics of Photons and Atoms, ed. by J. Perina (Wiley, New York, 2001), p.1.
[2] M. Khanbekyan, L. Kn□oll, D.-G. Welsch, A. A. Semenov and W. Vogel, Phys. Rev. A 72, 053813 (2005).

Khetselius Olga **(1)** **Talk**

Laser separation and detecting the isotopes and nuclear reaction products and relativistic calculating the hyperfine structure parameters for heavy-elements

Olga Yu. Khetselius[1]
[1]Odessa University,Odessa, Ukraine
okhetsel@paco.net

Relativistic calculation of the spectra hyperfine structure parameters for heavy elements is carried out. Calculation scheme is based on gauge-invariant QED perturbation theory with using the optimized one-quasiparticle representation at first in the theory of the hyperfine structure for relativistic atomic systems [1,2]. Within the new method it is carried out calculating the energies and constants of the hyperfine structure for valent states of cesium ^{133}Cs, Cs–like ion Ba, isotopes of ^{201}Hg, ^{223}Ra, ^{252}Cf are defined. The contribution due to inter electron correlations to the hyperfine structure constants is about 120-1200 MHz for different states, contribution due to the finite size of a nucleus and radiative contribution is till 2 dozens MHz. Otained data for hyperfine structute parameters are used in further in laser photoionization detecting the isotopes in a beam and the buffer gas for systematic studying the short-lived isotopes and nuclear isomers.

We propose a new approach to construction of the optimal schemes of the laser photoionization method for further applying to problem of the nuclear reactions products detecting. It's studied the reaction of spontaneous ^{252}Cf isotope fission on non-symmetric fragments, one of that is the cesium nucleus. The corresponding experiment on detecting the reactions products is as follows [1]. The heavy fragment of the Cf nucleus fission created in the ionized track 10^6 electrons which are collected on the collector during 2 mks. The collector is charged negatively 40mks later after nuclear decay and 10mks before the laser pulse action. The photo electrons, arised due to the selective two-stepped photoionization are drafted into the proportional counter for their detecting. Usually a resonant excitation of Cs is realized by the dye laser pulse, the spectrum of which includes the wavelengths of two transitions $6^2S_{1/2}$-$7^2P_{3/2}$ (4555A) and $6^2S_{1/2}$-$7^2P_{1/2}$ (4593A). This pulse also realizes non-resonant photoionization of the Cs excited atoms. The disadvantages of the standard scheme are connected with non-optimality of laser photoionization one, effects of impact lines broadening due to the using the buffer gas, the isotopic shift and hyperfine structure masking etc. We proposed new laser photoionization scheme, which is based on a selective resonance excitation of the Cs atoms by laser radiation into states near ionization boundary and further autoionization decay of excited states under action of external electric field [2]. The corresponding optimal parameters of laser and electric fields, atomic transitions, states, decay parameters etc are presented.

References
[1] A.V.Glushkov, JETP Lett. **55**, 97 (1992); A.V.Glushkov, L.N. Ivanov, Phys. Lett. A**. 170**, 33 Preprint of Institute for spectroscopy of Russian Academy of Sciences, ISAN, N AS-1-3, Troitsk, (1992) ; E.P. Ivanova, L.N.Ivanov, A.V.Glushkov , A.Kramida, Phys.Scripta, **32**, 512 (1985).
[2]. A.V.Glushkov, O.Yu.Khetselius etal, Nucl.Phys.A. **734**, e21 (2004); J.Phys.CS**. 35**, 420 (2005); Recent Advances in Theory of Phys. and Chem. Systems (Springer). **15**, 285 (2006);
[3] A.V.Glushkov, S.V.Malinovskaya, O.Yu.Khetselius, Europ.Phys.Journ. in print (2008) ; A.V.Glushkov, O.Yu.Khetselius, Recent Advances in Theory of Phys. and Chem. Systems **18,** 301 (2008);

Khveshchenko Dmitry (7) Talk

Many-body effects in multi-qubit arrays

D.V.Khveshchenko
University of North Carolina
Department of Physics and Astronomy
Chapel Hill, NC 27599, USA
khvesh@physics.unc.edu

We present a novel, condensed matter theory-based, approach to the problem of understanding of the nature and means of controling coherence and transfer of quantum entanglement in interacting multi-qubit arrays, also in the presence of dissipative environments and/or static disorder in the distribution of the qubits' parameters.

Specifically, we study the dynamics of entanglement and decoherence of propagating spin-1/2 excitations in generic (non-integrable and/or disordered) spin chains. Our findings have important implications for the recently proposed “all-spin” implementations of quantum information processing where such excitations can be utilized in the capacity of flying qubits.

Kiss Tamas (10) Invited talk

Recurrence Properties and Polya Number of Quantum Walks

T. Kiss[1], M. Stefanak[1], and I. Jex[1]
[1]Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, Budapest, Hungary
[2] Department of Physics, FJFI ČVUT, Prague, Czech Republic
tkiss@szfki.hu

The Polya number characterizes the recurrence of a random walk. We apply the generalization of this concept to quantum walks [1]. The Polya number of a quantum walk depends in general on the choice of the coin operator and the initial coin state, in contrast to classical random walks where the lattice dimension uniquely determines it. We analyze several examples to depict the variety of possible recurrence properties.

First, we show that for the class of quantum walks driven by independent coins for all spatial dimensions the Polya numbers are independent of the initial conditions and the actual coin operators, thus resembling the property of the classical walks. We provide an analytical estimation of the Polya numbers for this class of quantum walks. Second, we examine the 2-D Grover walk, which exhibits localisation and thus is recurrent, except for a particular initial state for which the walk is transient. We generalize the Grover walk to show that one can construct in arbitrary dimensions a quantum walk which is recurrent. This is in great contrast with the classical walks which are recurrent only for the dimensions d = 1, 2. Finally, we analyze the recurrence of the 2-D Fourier walk. This quantum walk is recurrent except for a two-dimensional subspace of the initial state. We provide an analytical formula of the Polya number in its dependence on the initial state.

References

[1] M. Stefanak, I. Jex and T. Kiss, Phys. Rev. Lett. **100**, 020501 (2008).

Klimov Vasily **(1)** **Talk**

Detection of Spiral photons in Quantum Optics

V.V. Klimov[1], *D. Bloch, M. Ducloy*[2], *J.R. Rios Leite*[3]
[1]P.N. Lebedev Physical Institute, Russian Academy of Sciences, 53
Leninsky Prospekt, Moscow 119991, Russia
[2]Laboratoire de Physique des Lasers, UMR 7538 du CNRS et de l'Universite Paris 13,
99 Avenue J-B. Clement F 93430 Villetaneuse, France.
[3]Departamento de Fisica Universidade Federal de Pernambuco, 50670-901 Recife, PE, Brazil
e-mail:vklim@sci.lebedev.ru

We show that a new type of photon detector, sensitive to the gradients of electromagnetic fields, should be a useful tool to characterize the quantum properties of spatially-dependent optical fields. As a simple detector of such a kind, we propose using magnetic dipole or electric quadrupole transitions in atoms or molecules and apply it to the detection of spiral photons in Laguerre-Gauss (LG) beams. We show that LG beams are not true hollow beams, due to the presence of magnetic fields and gradients of electric fields on beam axis. This approach paves the way to an analysis at the quantum level of the spatial structure and angular momentum properties of singular light beams. More complicated detectors made of chiral nanoparticles are also discussed.

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References

[1] V. Klimov, D.Bloch, M. Ducloy, and J.R. Rios Leite, Detecting of photons in optical fields of complicated spatial structure, http://arxiv.org/ftp/arxiv/papers/0805/0805.1697.pdf

Koroli Vlad **(1)** **Talk**

Two-photon Jaynes-Cummings model of a pair of indistinguishable two-level atoms interacting with squeezed vacuum

V. I. Koroli
Institute of Applied Physics, Academy of Sciences of Moldova
Academiei strasse 5, Kishinev MD-2028, Moldova
vl.koroli@gmail.com

The interaction between the pair of indistinguishable two-level atoms and the single-mode cavity field is investigated. This problem generalizes the two-photon Jaynes-Cummings model of a single two-level atom interacting with the squeezed vacuum [1]. The model of the pair of indistinguishable two-level atoms is equivalent to the problem of the equidistant three-level radiator with equal dipole moment matrix transition elements between the adjacent energy levels. In this situation the quantum states of the atomic pair can be represented in the three-level states representation by the following: in the ground state both two-level atoms in the pair are in the ground state, in the first excited state the first atom is in the ground state and the second one is excited and vice versa, in the second excited state both two-level atoms are excited.

In should be noted that in the present model the interaction Hamiltonian is similar with the Hamiltonian for the pair of cold atoms interacting with the quantized field via intensity-dependent coupling [2]. However, the realizations of the SU(1,1) symmetry group generators in these two models are substantially different. In contrast with the model with the intensity-dependent coupling the realization of the SU(1,1) symmetry group generators in the present model corresponds to the squeezed vacuum state with the Gaussian wave-function.

We suggest that at the initial moment the atomic pair is in the first excited state. In this situation the exact analytical solution for the atom-field state-vector is obtained with the help of the Schrodinger equation. By using this solution we examine the time-dependent behaviour of such important physical quantities as the mean photon number, their fluctuations and the atomic population inversion. It is found that for certain values of the initial average photon number takes place the Sub-Poissonian photon statistics, which has the tendency towards oscillations. Much attention is also devoted to the squeezing properties of the radiation field. The obtained results are compared with those for the single two-level atom model. It is found that in the equidistant three-level model the exact periodicity of the squeezing revivals is violated by the analogy with the single two-level atom one.

References

[1] C. C. Gerry, Phys. Rev. A **37**, 2683 (1988).
[2] V. I. Koroli, Int. J. Quant. Inf. **5**, 199 (2007).

Korolkova Natalia **(10)** **Invited talk**

Entanglement distribution: new concepts and the continuous variable toolbox

Natalia Korolkova[1], *Tomaš Tyc*[1,2], *Ladislav Mišta*[1,3], *David Menzies*[1], *Gary Sinclair*[1]
[1] University of St. Andrews, Scotland, UK
[2]Masaryk University, Brno, Czech Republic
[3] Palacky University, Olomouc, Czech Republic
nvk@st-andrews.ac.uk

We address different aspects of long-distance quantum communication using infinitely-dimensional, continuous-variable quantum systems. With examples of several schemes, we discuss the physics underlying entanglement distribution over large distances, tailoring of quantum systems for this purpose and address a quest for experimentally feasibility.

First, we discuss entanglement concentration scheme for infinite-dimensional quantum systems based on non-linear cross-Kerr coupling of the one part of two-mode squeezed vacuum and an ancillary coherent state. We then show how the whole family of such entanglement concentration protocols can be derived using the framework and concept of weak quantum measurement. Next, we modify this scheme for the quantum state engineering purposes. Both schemes can be implemented in the same experimental setting. We propose an experiment that employs the cross-Kerr effect to create highly non-classical non-Gaussian states of light via interaction of two coherent beams in an atomic medium exhibiting electromagnetically-induced transparency, subsequent measurement on one beam and feed-forward on the other. The resultant states are highly non-classical states of electromagnetic field and exhibit negativity of their Wigner function, sub-Poissonian photon statistics, and amplitude squeezing. Furthermore, the Wigner function has a distinctly pronounced ``crescent'' shape specific for the Kerr-type interactions, which so far was not demonstrated experimentally. We show that creating and detecting such states should be possible with the present technology using electromagnetically induced transparency in a four-level atomic system in N-configuration.

Finally, we address the question of quantum information distribution in general. As a development from the earlier work of Cubitt et al for qubits [1], we demonstrate the possibility to distribute entanglement without sending entanglement in infinite-dimensional systems. Remarkably, for mixed quantum states one can entangle two distant modes by sending a separable mode. This can be done using experimentally feasible Gaussian states and operations involving single-mode squeezed states, correlated displacements and beam splitters, dispensing with the CNOT gates of the qubit case. The distributed entanglement is distillable and therefore can be used for quantum communication.

The proposed schemes prepare the ground for better understanding and engineering of optical quantum networks, continuous-variable cryptography and other entanglement-based communication protocols using light modes and/or atomic ensembles.

References

[1] T. S. Cubitt *et al*, Phys. Rev. Lett. **91**, 037902 (2003)

Kupczynski Marian **(1)** **Talk**

Is the Quantum Theory Predictably Complete?

Marian Kupczynski
Department of Mathematics and Statistics, University of Ottawa, Canada
Département de l'Informatique, UQO, Gatineau , Canada
mkupczyn@uottawa.ca

Quantum theory (QT) provides statistical predictions for various physical phenomena. To verify these predictions a considerable amount of data has been accumulated in the "measurements" performed on the ensembles of identically prepared physical systems or in the repeated "measurements" on some trapped "individual physical systems". The outcomes of these measurements are in general some numerical time-series registered by some macroscopic instruments. The various empirical probability distributions extracted from these time-series were shown to be consistent with the probabilistic predictions of QT.

More than 70 years ago the claim was made that the QT provided the most complete description of the individual physical systems and when the measurement was performed on an "individual" physical system then the outcome of this measurement was obtained in intrinsically random way. This purely random behavior of "individual" physical systems in the moment of the measurement would made impossible the explanation of the existence of the long range correlations in the EPR type experiments without violation of locality. Spin polarization correlation experiments (SPCE), performed to test the validity of Bell inequalities, clearly demonstrated the existence of such long range correlations and confirmed that the beams hitting the far away detectors preserve somehow the memory of their common origin and therefore the individual detector counts cannot not be purely random.

It is now quite well understood that the contextual and local description of sub-phenomena in SPCE experiments may violate Bell inequalities and reproduce QT predictions.

Moreover the probabilities describe the random experiments and they are not the "attributes" of "individual" physical systems taking part in these experiments. Therefore the old claim that QT provides a complete description of "individual" physical systems seems to be unjustified.

In order to completely elucidate this issue we propose a different approach. We point out that in spite of a huge number of data the predictable completeness of QT has not been tested carefully enough. Namely the time- series of experimental data were analyzed in terms of empirical probability distributions which could average out any stochastic fine structure of these time-series not predicted by QT.

There exist simple statistical tests, which could be used to search for fine structure in these time- series and which could provide a decisive answer to the title question of this contribution. In particular we advocate nonparametric compatibility tests and tests of time-series based on the Box-Jenkins methodology.

References

[1] M.Kupczynski, Phys.Lett **A 116**, 417 (1986)
[2] M.Kupczynski,Riv.Nuovo Cimento **7,** 215(1977).
[3] M.Kupczynski, JRL **26**, 514 (2005);
[4] M,Kupczynski, in Albert Einstein Century Conference,J-M .Alimi and A.Füzfa eds.,AIP Conference Proceedings Volume **861**, pp. 516-523 (2006);

[5] M.Kupczynski , in QTRF-4 Proceedings, G. Adenier, A. Yu. Khrennikov, P. Lahti, V. Man'ko and T. Nieuwenhuizen, eds., AIP .Conference Proceedings, Volume **962**, pp.274-285 (2007)
http://arxiv.org/abs/0710.3510
[6] A.Khrennikov, in QTRF-4 Proceedings, G. Adenier, A. Yu. Khrennikov, P. Lahti, V. Man'ko and T. Nieuwenhuizen, eds., AIP .Conference Proceedings, Volume **962**, pp.121-129 (2007)
[7] Nina Golyandina, V. Nekrutkin and A.Zhigliavskii ,Time-Series Analysis,London,CRC Press,2001

Kyoseva Elica **(7)** **Poster**

Entangling distant quantum dots with classical interference

Jonathan Busch[1], Elica Kyoseva[12], Michael Trupke[3], and Almut Beige[1]
[1]School of Physics and Astronomy, University of Leeds, Leeds LS2 9JT, United Kingdom
[2]Department of Physics, University of Sofia, 1164 Sofia, Bulgaria
[3]Blackett Laboratory, Imperial College London, London SW7 2BZ, United Kingdom
kyoseva@phys.uni-sofia.bg

We show that it is possible to employ *reservoir engineering* to turn two distant and relatively bad cavities into one good cavity with a tunable decay rate. As a result, quantum computing schemes that otherwise require the shuttling of atoms in and out of an optical cavity can be applied to quantum dot systems. To illustrate this we transform a recent proposal by Metz *et al.* [1], and show that it is possible to entangle distant semiconductor quantum dots with electron-spin qubits via the observation of macroscopic fluorescence signals [2]. This neither requires the coherent control of qubit-qubit interactions nor the detection of single photons. Moreover, the scheme is relatively robust against spin-bath couplings, parameter fluctuations, and the spontaneous emission of photons.

References

[1] J. Metz, M. Trupke, and A. Beige, Phys. Rev. Lett. 97, 040503 (2006).
[2] R. Blatt and P. Zoller, Eur. J. Phys. 9, 250 (1988).

Laskowski Wieslaw **(1)** **Talk**

Experimentally friendly geometrical criteria for entanglement

Piotr Badziag[1,2], *Časlav Brukner*[4,5], *Wies law Laskowski*[2,3], *Tomasz Paterek*[4] *and Marek Žukowski*[2,3]
[1]Alba Nova Fysikum, University of Stockholm, S-106 91, Sweden
[2]Institute of Theoretical Physics and Astrophysics, University of Gdansk, ul. Wita Stwosza 57, PL-80-952 Gdansk, Poland
[3]National Centre for Quantum Information of Gdansk, ul. W. Andersa 27, PL-81-824 Sopot, Poland
[4]Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Boltzmanngasse 3, A-1090 Vienna, Austria
[5]Faculty of Physics, University of Vienna, Boltzmanngasse 5, A-1090 Vienna, Austria
wieslaw.laskowski@univ.gda.pl

Entanglement is one of the basic features of quantum physics and it is a resource for quantum information science [1]. Thus, detection of entanglement belongs to the mainstream of this field [2]. Today, the most widely used and experimentally feasible detectors of this resource are entanglement witnesses [3]. They are linked with positive but not completely positive maps [4], which are the most universal entanglement identifiers.

We shall present an alternative approach to entanglement detection. It is based on a very simple geometrical fact, used for example in [5] to derive a powerful series of Bell inequalities: if one has two vectors $\vec{s}$ and $\vec{e}$, and their scalar products satisfy $\vec{s}\cdot\vec{e} < \vec{e}\cdot\vec{e}$, then $\vec{s} \neq \vec{e}$. This can be utilized to find fruitful relations between separable and entangled states (for the first attempt see [6]). As a result we introduce a new family of entanglement identifiers. In their simplest form, the identifiers are defined in terms of the values of the correlation functions [7]. This makes them friendly to experiments, as only local measurements on individual subsystems are required. The generalized criterion is both necessary and suficient for entanglement, and the family of our entanglement identifiers is richer than the family of the witnesses.

References

[1] M. A. Nielsen and I. L. Chuang, Quantum Computation and Quantum Information (Cambridge University Press, Cambridge 2000).
[2] R. Horodecki, P. Horodecki, M. Horodecki, and K. Horodecki, e-print arXiv:quant-ph/0702225.
[3] M. Horodecki, P. Horodecki, and R. Horodecki, Phys. Lett. A 223, 1 (1996); for the PPT criterion see A. Peres, Phys. Rev. Lett. 77, 1413 (1996).
[4] A. Jamio lkowski, Rep. Math. Phys. 3, 275 (1972).
[5] M. Žukowski, Phys. Lett . A 177, 290 (1993).
[6] W. Laskowski, M. Žukowski, Phys. Rev. A 72, 062112 (2005).
[7] A set of different suficient criteria based on correlation functions can be found in e.g. H. Aschauer, J. Calsamiglia, M. Hein, H. J. Briegel, Quant. Inf. Comp. 4, 383 (2004).

Lastra Freddy **(7)** **Poster**

Entangled coherent states and entanglement sudden death

F. Lastra[2], *G. Romero*[1], *C. E. Lopez*[1], *N. Zagury*[3] *and J. C. Retamal*[1]
[1]Departamento de fisica, Universidad de Santiago de Chile, USACH casilla 307 correo 2 Santiago, Chile
[2]Facultad de Fisica, Pontificia Universidad Catolica de Chile, casilla 306 Santiago 22, Chile
[2]Instituto de Fisica, Universidade Federal do Rio de Janeiro, caixa Postal 68528, Rio de Janeiro, RJ 21941-972,Brazil
flastra@uc.cl

We study the evolution of a class of entangled coherent states of two quantized electromagnetic fields under dissipation. Under certain conditions the dynamics may be conveniently studied in a finite dimensional time dependent orthogonal basis. That is the case of superposing coherent states of real amplitudes on the line. In a more general case of complex amplitudes the dynamics can be studied in a higher dimensional time dependent orthogonal basis. Asymptotic decays as well as finite time disentanglement can be found depending on the initial condition and phase space distances among the components of each mode.

References

[1] M.A. Nielsen and I.L. Chuang, Quantum Computation and Quantum Information (CambridgUniv. Press.,Cambridge, 2000).
[2] T. Yu and J. H. Eberly, Phys. Rev. Lett. 93, 140404(2004); idem 97, 140403 (2006).
[3] M. Fran¸ca Santos, P. Milman, L. Davidovich, and N.Zagury, Phys. Rev.A. 73, 040305(R), 2006.
[4] K. Chen, S. Albeverio, S. Fei, Phys. Rev. Lett. 95,210501 (2005).
[5] F. Lastra, G. Romero, C. E. L´opez, M. Fran¸ca Santos,and J. C. Retamal, Phys. Rev.A 75, 062324 (2007).

Lawniczak Michal **(9)** **Poster**

Investigation of the reflection coefficient and the distributions of Wigner's reaction matrix for irregular graphs with absorption

Michał Ławniczak[1], *Oleh Hul*[1], *Szymon Bauch*[1], *Petr Šeba*[2], *and Leszek Sirko*[1]
[1]Institute of Physics, Polish Academy of Science, Warsaw, Poland
[2]Institute of Physics, Academy of Sciences of the Czech Republic
lawni@ifpan.edu.pl

We present results of experimental and numerical study of distributions of the reflection coefficient P(R) and of the imaginary part P(v) of Wigner’s reaction K matrix for irregular fully connected hexagon microwave and quantum graphs in the presence of strong absorption. The distributions P(R) and P(v) were obtained from the measurements and numerical calculations of the scattering matrix S. Experimentally, absorption was introduced

by attaching attenuators to the networks. In the numerical calculations absorption was included by introducing optical potentials. We show that the experimental and numerical results are in good agreement with the theoretical predictions [1].

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References

[1] D.V. Savin, Y.V. Fyodorov, and H.-J.Sommers, Phys. Rev. E **63**, 035202 (2005).

Lazarou Constantinos **(3)** **Talk**

Entanglement in the adiabatic limit of cavity QED with pairs of atoms

Constantinos Lazarou and Barry M. Garraway
Department of Physics and Astronomy, University of Sussex, Falmer, Brighton, BN 9QH, UK
cl90@sussex.ac.uk

We analyse the problem of a time dependent Tavis-Cummings Hamiltonian in the adiabatic limit. Instead of the usual constant coupling between a single mode cavity and a pair of atoms, we utilize the spatial profile of the interaction by using time dependent coupling functions. In considering the adiabatic limit, we were able to demonstrate an energy crossing in the vicinity of a local degeneracy. Furthermore, we show that conditional entanglement between the cavity and the atoms can be achieved or a maximally entangled state of the two atoms can be generated. Using the fidelity for particular entangled states, and the concurrence for bipartite and tripartite systems, we derive the properties of entanglement between all three systems. We also study the effect that cavity losses or atomic spontaneous emission have on the system.

Lemr Karel **(10)** **Talk**

Preparation of entangled states of two photons in several spatial modes

Karel Lemr, Jaromir Fiurasek
Department of Optics, Palacky University, 17. listopadu 50,
77200 Olomouc, Czech Republic
lemr@orgchem.upol.cz

We describe a protocol capable of preparing an arbitrary state of two photons in several spatial modes using pairs of photons generated by spontaneous parametric down-conversion, linear optical elements and single-photon detectors or post-selection. The protocol involves unitary and non-unitary transformations realizable by beam splitters and phase shifters. Non-unitary transformations are implemented by attenuation filters. The protocol contains several optimization capabilities with the goal of improving overall probability of its success. We also show how entangled two-photon states required for quantum computing with linear optics can be prepared using a very simple and feasible scheme.

References

[1] K. Lemr, J. Fiurasek, Phys. Rev. A 77, 023802 (2008).

Leon Juan **(1)** **Talk**

Atom-atom entanglement swapping generated by photon emission

Juan Leon[†] *and Carlos Sabin*[††]
Instituto de Fisica Fundamental, CSIC
Serrano 113-B, 28006 Madrid, Spain
[†]leon@imaff.cfmac.csic.es, [††]csl@imaff.cfmac.csic.es

May two lone parties, that remain causally disconnected from each other, become entangled? A treasure trove of related questions can be found in the literature subsequent to the two atom Fermi [1] problem. The entanglement between both parties has been analyzed in terms of algebraic [2] and standard [3] quantum field theory, and vacuum entanglement [4]. We studied this question [5] for the case of an isolated pair of two-level atoms *A* and *B*, separated by a distance *l*. Starting from an initial product state with zero photons, both parties are allowed to interact during a short time *t*. The resulting correlations and entanglement measures are obtained perturbatively, to order α_{em} and in the dipole approximation, for *l/t* smaller, equal, and larger than 1. We analyzed how the state of the electromagnetic field determines the properties of these correlations.

In this talk we focus on the case where the final state contains two photons. They could be emitted by the same atom, either *A* or *B*, or one by each atom. We analyze the emergence of entanglement swapping and source indistinguishability when the state of the final photons is measured. The analysis is made in terms of the inter-atomic separation *l* and the interaction time *t*, exploring the region $(l/ct)\cong 1$.

References

[1] E. Fermi, Rev. Mod. Phys. 4, 87 (1932).
[2] S. J. Summers and R. Werner, Commun. Math. Phys. 110, 247 (1987).
[3] J. D. Franson, quant-ph/0704.1468.
[4] J. Silman and B. Reznik, Phys. Rev. A71, 054301 (2005).
[5] J. León and C. Sabín, Generation of atom-atom correlations around the light cone, arXiv:0804.4641

Lyttkens Lindén Björn **(9)** **Poster**

Entanglement dynamics in systems of qubits with Markov environments

Bjorn Lyttkens Linden [1,2] *and Nikola Burić* [2]
[1]Division of Mathematical Physics, Lund University, Sweden.
[2]Institute of Physics, University of Belgrade,
PO BOX 68, 11000 Belgrade, Serbia
f03bl@student.lth.se

Entanglement dynamics in representative examples of Markov open quantum systems with qualitatively different dynamics is studied. Rings of qubits with thermal or dephasing local environment are used to study the qualitative properties of the entanglement dynamics in dependance of the inter-qubit interaction, type of the environment and the initial state. It is demonstrated that the effect of the local environment is manifested as exponential decrease of the entanglement superimposed on the entanglement dynamics in the isolated system.

Macovei Mihai **(4)** **Talk**

Phase dependent quantum dynamics induced by ultrashort laser pulses

Mihai Macovei, Xiao-Tao Xie, Martin Kiffner, and Christoph H. Keitel
Max-Planck Institute for Nuclear Physics, Saupfercheckweg 1,D-69117 Heidelberg, Germany
mihai.macovei@mpi-hd.mpg.de

It is shown that optical few-cycle pulses with adjustable carrier-envelope phase are an efficient tool to manipulate the quantum dynamics of few-level systems. In particular, we consider a two-level system and study the phase dependence of the population dynamics induced by an ultrashort laser pulse. It is found that quantum interference leads to a strong dependence of the upper state population on the carrier envelope phase if the system is initially prepared in a coherent superposition of its ground and excited state. We demonstrate that this effect can be employed to determine the absolute phase of a laser that prepares the initial state.

Man'ko Margarita **(10)** **Invited talk**

Probabilistic characteristics of classical and quantum waves

Margarita A. Man'ko
Lebedev Physical Institute, Moscow, Russia
mmanko@sci.lebedev.ru

Tomographic maps of solutions of classical and quantum dynamical equations onto probability-distribution functions are considered. The maps include symplectic tomography and Fresnel tomography of analytic signal realized by electromagnetic waves in waveguiding media structures like optical fibers or probability waves realized, for example, as matter

waves. The probabilistic characteristics of the wave's tomograms including entropies (Shannon entropy, Renyi entropy), highest momenta, especially, means, variances and covariances, as well as mutual information and mutual conditional information are discussed. The known and new inequalities like subadditivity and strong subadditivity relations for wave tomograms are studied. The discrete variable (qubits, qudits, qulbits) and the corresponding tomographic entropy inequalities are presented.

Man’ko Olga **(1)** **Talk**

Star-product quantization; symplectic and spin tomographies

Olga V. Man'ko
Lebedev Physical Institute, Moscow, Russia
omanko@sci.lebedev.ru

Tomographic representation is constructed for operators depending on continuous photon-quadrature components and operators depending on spin degrees of freedom. The relation between the tomographic schemes and star-product quantization procedure is discussed. The duality symmetry of star-product approach in the case of symplectic tomography is reviewed.

Man’ko Vladimir **(7)** **Invited talk**

Quantum correlations in the probability representation of quantum states

Vladimir I. Man'ko[1], *Giuseppe Marmo*[2], *E.C. George Sudarshan*[3]
[1]Lebedev Physical Institute, Moscow, Russia
[2]University “Federico II” Naples, Italy
[3]University of Texas, Austin, USA
manko@sci.lebedev.ru

Quantum states of multimode systems described by probability distributions (used instead of wave functions and density matrices) are analyzed in the context of correlations between different modes. Properties of the state joint probability distributions and their evolution in time corresponding to master equations for the system density operators are discussed. The fidelity is obtained in terms of nonlocal expressions like integrals or sums of the probability distributions. The examples of qubit correlations and photon quadrature correlations for the probability distributions of different states are given.

Marian Paulina **(1)** **Invited talk**

Quantum Chernoff bound as a measure of nonclassicality for Gaussian states

Mădălina Boca, Iulia Ghiu, Paulina Marian, and Tudor A. Marian
Centre for Advanced Quantum Physics, University of Bucharest, P.O.Box MG-11,
R-077125 Bucharest-Măgurele, Romania
pemarian@gmail.com

The present work parallels the previous papers [1] in studying the nonclassicality of one-mode Gaussian states using an important "distance" with recognized distinguishability virtues, the recently discovered quantum Chernoff bound [2]. The quantum Chernoff bound is defined as the asymptotic exponent of optimal error probability in symmetric quantum hypothesis testing: $\xi_{QCB} = \lim_{n\to\infty}\{-(\log P_{min})/n\}$. Here n is the number of copies of a quantum system prepared in the same quantum state, either the state ρ or another state σ. It was proved in [2] that the quantum Chernoff bound has the explicit expression $\xi_{QCB} = -\log Q(\rho,\sigma)$, where

$$Q(\rho,\sigma) = \min_{0\le s\le 1} \mathrm{Tr}\{\rho^s\sigma^{1-s}\}. \tag{1}$$

In view of its outstanding distinguishability properties, we introduce here a Chernoff-bound degree of nonclassicality and apply it to a single-mode Gaussian state ρ_G. Especially useful in experiments, the Gaussian states are defined by the exponential form of their density operators. We find it important to stress that our option to study the nonclassicality of Gaussian states has pragmatic reasons concerning the application of a distance-type degree of nonclassicality. Ideally, such a degree is defined as a distance between the given nonclassical state and the set of *all classical states*. Replacing this set by its subset C_0 of the classical one-mode Gaussian states, which is simply parametrized, we evaluate here a Gaussian degree of nonclassicality, just as in Ref. [1]:

$$\begin{aligned} D_0^{(C)}(\rho_G) &:= \min_{\rho_G^{'}\in C_0}[1 - Q(\rho_G,\rho_G^{'})] \\ &= 1 - \max_{\rho_G^{'}\in C_0} Q(\rho_G,\rho_G^{'}). \end{aligned} \tag{2}$$

We found that the calculation of the maximal quantum Chernoff bound in Eq.(2) can be performed only numerically even in the case of one-mode Gaussian states, for which an analytical treatment is at hand when employing the Bures distance. However, its numerical evaluation by saddle-point methods is straightforward and can be performed with great accuracy. The general properties of the quantum Chernoff bound and its relation to the Uhlmann fidelity are interestingly displayed by our approach. We thus give a first example of discriminating between a state and a set of states by use of the quantum Chernoff bound.

References

[1] Paulina Marian, T. A. Marian, and H. Scutaru, Phys. Rev. Lett. , 153001 (2002); Paulina Marian, T. A. Marian, and H. Scutaru, Phys. Rev. A , 022104 (2004).
[2] K.M.R. Audenaert, *et al.*, Phys. Rev. Lett. , 160501 (2007).

Marinković Bratislav **(5)** **Poster**

An experimental study of the excited electronic levels of N_2O molecule by electron energy loss spectroscopy and vacuum ultraviolet absorption

B. P. Marinković[1], *N. C. Jones*[2], *I. C. Walker*[3] *and N. J. Mason*[4]
[1]Institute of Physics, Belgrade, Serbia
[2]University of Aarhus, Aarhus, Denmark
[3]Heriot-Watt University, Edinburgh, United Kingdom
The Open University, Milton Keynes, United Kingdom
bratislav.marinkovic@phy.bg.ac.yu

The nitrous oxide molecule is important in many areas of science and technology including; its role in depletion of the ozone layer; its use as an electron scavenger in radiation chemistry, and its applications in medicine as an anesthetic. Nitrous oxide, as the main natural source of nitric oxides, is also a major greenhouse gas with substantial impact on global warming.

The vacuum ultraviolet absorption spectrum of nitrous oxide (N_2O) molecule has been recorded between 4.13 eV (300 nm) and 11.3 eV (110 nm) and absolute photoabsorption cross sections measured. The electronic excited states of the molecule have also been probed using High Resolution Electron Energy Loss Spectroscopy (HREELS), recorded under electric–dipole conditions. The HREELS data has confirmed the magnitude of the photoabsorption cross section values and extended the optical oscillator strength values up to 14 eV. Measurements at several scattering angles have allowed the angular behavior of differential cross section ratios for some features in the 5–7.1 eV region to be measured, which in turn have helped in the assignments of electronic states to each of the observed absorption bands.

We have alo measured absolute electron differential cross section (DCS) values for the excitation of the 2 $^1\Sigma^+$ and $^1\Pi$ states of N_2O [1] and such electron energy-loss data [2] have been used to derive the Apparent Differential Oscillator-strength (ADOS) distribution for N_2O. Our ADOS data may be compared with the electron impact energy loss spectrum of Jones [3], very good agreement has been found.

Optical spectra were obtained using the Seya monochromator on beam-line 3.1 at the Daresbury Laboratory synchrotron radiation source. The transmitted radiation was normalized to a constant ring current before data analysis using the Beer–Lambert expression. The spectra obtained were compared with the electronic spectra of Chan *et al* [4] who determined associated optical oscillator strengths using low resolution (e, e) spectroscopy and with the absolute photoabsorption cross sections by Shaw *et al* [5].

References

[1] B. Marinković, R. Panajotović, Z. D. Pešić, D. M. Filipović, Z.Felfli and A.Z.Msezane, J.Phys. B: At. Mol. Opt. Phys. **32**, 1949 (1999).
[2] B. Marinković, Cz. Szmytkowski, V. Pejčev, D. Filipović and L. Vušković, J.Phys. B: At.Mol.Phys. **19**, 2365 (1986).
[3] N. C. Jones, PhD Thesis, Univ. of London (2000).
[4] W.F.Chan, G. Cooper and C.E. Brion, Chem. Phys. 180, 77 (1994).
[5] D. A. Shaw, D. M. P. Holland, M. A. MacDonald, A. Hopkirk, M. A. Hayes and S. M. McSweeney, Chem. Phys. **163**, 387 (1992).

Markó Márton **(5)** **Talk**

Missing Kossel-lines and standing waves in neutron scattering

Marton Marko[1,2]*, Laszlo Cser*[1]*, Ivan Sharkov*[3]*, Gerhard Krexner*[4]*, Gyula Torok*[1]
[1]Research Institute for Solid State Physics and Optics
[2]Institute of Nuclear Techniques, Budapest University of Technology and Economics
[3]St.Petersburg State University, Institute of Physics, Chair of Optics and Spectroscopy,
[4]Faculty of Physics, University of Vienna
marko@szfki.hu

Kossel-lines [1] are diffraction patterns of a mono crystal sample created by spherical radiation from an atomic sized point source embedded in the crystal, while standing waves are diffraction patterns of a mono crystal sample caused by plane wave and atomic sized point detector put inside the sample. Kossel lines and standing waves (collectively called K-lines) can be calculated using the model of inside source and inside detector method of atomic resolution holography respectively. Although both type of holography is demonstrated for electron, X-ray and neutron radiation, nobody has observed neutron standing waves and neutron Kossel-lines either, except a single publication [2] where a very weak pattern of Kossel-lines was reported. In the present talk is shown that sharpness and the width of the K-lines are inversely proportional to the coherent length of the radiation used. Moreover, typical neutron scattering instruments use mosaic monochromator crystals, where the inverse of the coherent length of a neutron scattered on one crystalline of the mosaic monochromator is much smaller than the width of the resolution of the instrument in the k-space. As a consequence, the K-lines are much narrower than the apparative function, so the asymmetric part of the K-line will disappear, and the symmetric part will be decreased. At last, I is proposed a special measurement for detecting both type of K-lines.

References

[1] Kossel, W., Loeck, V. and Voges, H.,Z. Phys., 94, 139. (1935)
[2] B. Sur, R. B. Rogge, R. P. Hammond, V. N. P. Anghel, and J. Katsaras, PRL 88, 065505 (2002)

Mastellone Andrea **(7)** **Talk**

Protected subspaces against charge noise in coupled charge-phase qubits

A. Mastellone, A. D'Arrigo, E. Paladino and G. Falci
MATIS CNR-INFM, Catania, Italy, and Dipartimento di Metodologie Fisiche e Chimiche per l'Ingegneria (DMFCI), Universita di Catania, Viale Andrea Doria 6,
I-95125 Catania, Italy
andrea@femto.dmfci.unict.it

The realization of coupled qubit setups is a fundamental step towards implementation of universal quantum computing architectures [1]. Solid state nanodevices, despite being very promising from the point of view of scalability and integration, are strongly affected by noise from various sources. Especially in Josephson qubits, the charge impurities are the most detrimental against system dynamics [2]. They can be described as two-level fluctuators, characterized by a switching rate γ. Compared to the operating frequency of the system Ω, the set of slow fluctuators ($\gamma<<\Omega$) gives a 1/f power spectrum, whereas at high frequencies ($\gamma>\Omega$) the power spectrum is white, or ohmic [2,3]. The noise effects are minimized tuning the device to an optimal point where its sensivity to charge fluctuations is minimal.

In this work we perform a full analysis of the noise effects on the dynamics of two qubits in a fixed coupling scheme implementation [4] by means of both analytical and numerical methods. The fixed capacitive coupling of two charge-phase qubits at the optimal point is described by a purely transverse term, and two subspaces result fully decoupled. In this perspective, one can implement an i-SWAP gate by free evolution from a chosen state in only one subspace, which we term as SWAP one (the other is termed as Z subspace).

Firstly, stability conditions against charge fluctuations are identified. The SWAP subspace is well protected against charge noise, compared to the Z subspace and to a single qubit. In particular, the signal decay rate is minimized when the coupling is of the order of the variance of the fluctuations [5].

The time evolution is evaluated in the analytical case performing a two-stage elimination, separating the fast and slow noise components [6]. The reduced density matrix is determined in the Master Equation approach by considering the slow noise component as a classical field. The final density matrix is hence determined by a path integration over the slow noise variables. The numerical solution is obtained by performing an average time evolution of the solution of a stochastic Schrödinger equation over many noise realizations. The results in the time domain confirm the improved protection of the SWAP subspace with an additional exponential decay due to the fast noise, which turns out to be of the same order in the white and ohmic noise cases, for comparable values of their power spectra.

References

[1] M.A. Nielsen and I.L. Chuang, Quantum Computation, Cambridge (Cambridge, 2005).
[2] G. Ithier, E. Collin, P. Joyez, P.J. Meeson, D. Vion, D. Esteve, F. Chiarello, A. Shnirman, Y. Makhlin, J. Schriefl, and G. Schön, Phys. Rev. B 72, 134519 (2005).
[3] O. Astafiev, Yu. A. Pashkin, T. Yamamoto, Y. Nakamura, and J. S. Tsai, Phys. Rev. B 69, 180507(R) (2004).
[4] D. Vion, private communication.
[5] A. Mastellone, A. D'Arrigo, E. Paladino and G. Falci, to be published in European Physical Journal Special Topics; A. Mastellone, A. D'Arrigo, E. Paladino and G. Falci, in preparation.
[6] G. Falci, A. D'Arrigo, A. Mastellone, and E. Paladino, Phys. Rev. Lett 94, 167002 (2005).

Mendaš Istok **(1)** **Poster**

Album of 44 types of three-parameter density matrices for a four-state system

I. Mendaš
Institute of Physics, Belgrade, Serbia
E-mail: mendas@phy.bg.ac.yu
PACS numbers: 03.65.-w, 03.67.-a, 02.70.Uu
mendas@phy.bg.ac.yu

In full analogy with the case of a three-state system [1], the nontrivial geometry of the 15-dimensional parametric space of density matrices for a four-state quantum system is documented and illustrated with the help of three-dimensional cross sections, determined by extensive calculations based on the Monte Carlo sampling method, for all 44 types of three-parameter density matrices recently established in [2]. This provides insight into the intricate and complex structure of the space of density matrices for a four-state system [3-5].

References

[1] I. Mendaš, J. Phys. A: Math. Gen. 39 11313 (2006).
[2] I. Mendaš, submitted to J. Phys. A: Math. Gen. (2008).
[3] R. Bertlmann and P. Krammer, Preprint arXiv quant-ph/0706.1743 (2007).
[4] L. Jakobczyk and M. Siennicki, Phys. Lett. A 286 383 (2001).
[5] G. Kimura and A. Kossakowski, Open Sys. Information Dyn. 12 207 (2005).

Migliore Rosanna **(9)** **Poster**

Spontaneous emission for two interacting qubits coupled to independent reservoirs

R. Migliore[1,2], *M. Scala*[2], *M.A. Jivulescu*[2], *A. Messina*[2]
[1]CNR-INFM, UdR CNISM di Palermo
[2]Dipartimento di Scienze Fisiche ed Astronomiche,
Università di Palermo, via Archirafi 36, 90123 Palermo, Italy
rosanna@fisica.unipa.it

We derive the master equation of a system of two coupled qubits by taking into account their interaction with two independent bosonic baths.
Important features of the dynamics are brought to light, such as the stationary state at general temperatures and the behaviour of the entanglement at zero temperature, presenting the phenomena of sudden death and sudden birth as well as the presence of stationary entanglement for long times.
The model presented is quite versatile and can be of interest in the study of Josephson junction architectures and of cavity-QED.

Mihailescu Ion M. **Poster**

Time dependent variational principle and coherent states orbits

Bogdan M. Mihalcea and Ion M. Mihăilescu
National Institute for Laser, Plasma and Radiation Physics (INFLPR), Bucharest-Măgurele, Romania
bmihal@infim.ro; ion.mihailescu@inflpr.ro

Quantum state engineering has drawn a considerable interest in the last two decades. This is a consequence of both testing quantum fundamental concepts such as non-locality, as well as implementing various applications, such as quantum information processing (QIP) or studies of quantum integrability and quantum chaos. This paper focuses on the study of quantum dynamics for systems with dynamical symmetry, such as ions confined in electromagnetic traps. The coherent states orbits are introduced as sub-manifolds of the quantum states space, with a Kähler structure induced by the transition probability. The

coherent states formalism, introduced in [1, 2] and developed in [3] is used and the time dependent variational principle [4].

The variational principle results from the definition of an action integral $S=\int_{t_1}^{t_2} L(\psi)\,dt$, where the real Lagrange function is defined as

$$L(\psi)=\frac{1}{\langle\psi\,|\,\psi\rangle}\left[\langle\psi\,|\,H\,|\,\psi\rangle-\Im m\left\langle\frac{\partial\psi}{\partial t}\,|\,\psi\right\rangle\right], \qquad (1)$$

where $\hbar H$ is the quantum Hamiltonian of the system. In (1), ψ is a vector in the Hilbert space H for any moment of time t, which belongs to the domain of the self-adjoint quasienergy operator $K(t)=H-i\partial/\partial t$. By minimizing the action, $\delta S=0$, it can be shown that the Schrödinger equation is rigurously obtained from the variational principle. The natural symplectic structure induced by the transition probability between states for unitary transformations, enable approaching quantum mechanics issues through the formalism of the classical mechanics on symplectic manifolds, in particular Kähler manifolds. The variational principle was applied to a manifold $\mathcal{M}$ of test vectors, parametrized by the points of a finite $2n$ dimensional phase space M, with a Kähler manifold structure. The matrix of the symplectic structure $\Omega=\left(\frac{\partial^2}{\partial z_j\partial z_k^*}\ln\langle\psi(z^*)\,|\,\psi(z)\rangle\right)_{1\le j,k\le n}$ can be introduced, using a system of local complex coordinates. The Poisson paranthesis for the $f,g\in C^\infty(M)$ functions, smooth on M, can be defined as:

$$\{f.g\}=i\sum_{j,k=1}^{n}\left(\lambda_{jk}\frac{\partial f}{\partial z_j}\frac{\partial g}{\partial z_k^*}-\lambda_{kj}^*\frac{\partial g}{\partial z_j}\frac{\partial f}{\partial z_k^*}\right),\lambda=-i\left(\Omega^*\right)^{-1} \qquad (2)$$

The expression of the action integral modifies, while the equations of motion can be expressed as:

$$\frac{dz_j}{dt}=\{z,H_{cl}\},\ \frac{dz_j^*}{dt}=\{z^*,H_{cl}\},\ H_{cl}(z,z^*)=\frac{\langle\psi(z^*)|\,H\,|\,\psi(z)\rangle}{\langle\psi(z^*)|\,\psi left(z)} \qquad 3)$$

The group of the linear canonical transformations of a dynamical system system with n degrees of freedom, is the symplectic group $Sp(2n,R)$. In case of dynamical symmetry groups, the Schrödinger equation solutions associated to linear Hamiltonians are given by coherent vectors multiplied by geometrical phase factors. The associated classical Hamiltonians result from the expected values of the quantum Hamiltonians on coherent symplectic states. Thus spectral information is coded into the phase portrait. The formalism used allows to explicitly construct bases and systems of symplectic coherent states for the study of trapped ion systems.

References

[1] V. N. Gheorghe, F. Vedel, Phys. Rev A45, 4828 (1992)
[2] V. N. Gheorghe, G. Werth, Eur. Phys. J. D10, 197 (2000)
[3] F. G. Major, V. N. Gheorghe, G. Werth, *Charged Particle Traps*, Springer, Berlin (2005)
[4] M. Božić, R.J. Lombard, Z. Marić, Z. Phys. D18, 311 (1991)

Mihalcea Bogdan Vasile **(1)** **Poster**

Quantum parametric oscillator in an ion trap

Bogdan M. Mihalcea
National Institute for Laser, Plasma and Radiation Physics (INFLPR), Bucharest-Măgurele, Romania
bmihal@infim.ro

The last decades have shown an ever increasing interest towards studying and explaining harmonic oscillators with time-dependent frequencies or time dependent masses (or both simultaneously) [1]. These studies have applicability in fields such as quantum transport [2], quantum optics [3] and quantum information [4]. This paper presents a formalism for dealing with non-relativistic time-dependent quantum Hamiltonians. The starting point is the well-known Lewis and Riesenfeld idea [5] which involves the construction of an invariant operator $I(t)$ which defines both the dynamics of the physical system and the canonical formalism that has to be used in order to obtain a consistent theoretical framework.

We consider the Hamiltonian which characterizes the dynamics of an ion confined in a Paul trap, along a coordinate axis : $H = \frac{1}{2M} p^2 + \frac{1}{2M}\omega(t)^2 q^2$, where M is the ion mass and ω represents a time periodical function, of period T. A time dependent invariant I, is a differentiable application $t \to I(t)$ which associates to each moment of time t the self-adjoint operator $I(t)$, so that :

$$\frac{dI}{dt} = \frac{\partial I}{\partial t} + \frac{1}{i\hbar}[I, H] = 0. \tag{1}$$

We search the existence of a time dependent invariant such as :

$$I(t) = \frac{1}{2}\left[\alpha(t) q^2 + \beta(t) p^2 + \gamma(t)(pq + qp)\right], \tag{2}$$

unde α, β, γ are functions of class C^2. From eq. (1) it follows that: $\dot{\alpha} = \frac{2}{M}\omega^2\gamma, \dot{\beta} = -\frac{2}{M}\gamma, \dot{\gamma} = \frac{1}{M}\left(\beta\omega^2 - \alpha\right)$. We denote $\sigma = \sqrt{\beta}, \sigma \geq 0, \rho = c^{-1/4}\sigma$, where c is a positive constant. From (2) we infer :

$$I = \frac{1}{2}\left[\frac{1}{\rho^2} q^2 + \left(p\rho - M\dot{\rho}q\right)^2\right], M^2\ddot{\rho} + \omega^2\rho = \frac{1}{\rho^3} \tag{3}$$

The canonical annihilation and creation operators can be defined as:

$$a = \frac{1}{\sqrt{2\hbar}}\left[\frac{1}{\rho} q + i\left(\rho p - M\dot{\rho}q\right)\right], a^\dagger = \frac{1}{\sqrt{2\hbar}}\left[\frac{1}{\rho} q - i\left(\rho p - M\dot{\rho}q\right)\right]. \tag{4}$$

Then (4) can be expressed as $I = \frac{\hbar}{2}\left(a^\dagger a + \frac{1}{2}\right)$. We can introduce the vectors f_n with $n = 0, 1, \ldots$, defined as

$$f_n = \frac{1}{\sqrt{n!}}\left(a^\dagger\right)^n f_0, af_0 = 0, \langle f_0 \mid f_0 \rangle = 1. \tag{5}$$

The solution of the Schrödinger equation for an ion in a Paul trap, for the Hamiltonian H given above is :

$$\phi = \sum_{n=0}^{\infty} c_n \varphi_n, \varphi_n = \exp(i\alpha_n) f_n, \alpha_n(t) = \alpha_n(t_0) - \frac{1}{M}\left(n + \frac{1}{2}\right)\int_{t_0}^{t} \frac{1}{\rho^2} dt, \tag{6}$$

unde φ_n are the quasienergy vectors and $\alpha_n/(n+1/2)$ stands for the generalized canonical coordinate associated to the invariant I, considered as a generalized canonical impulse.

References

[1] C. M. A. Dantas, I. A. Pedrosa, B. Baseia, Brazilian J. Phys. 22, 33 (1992)
[2] C. S. Tang and C. S Chu, Phys. Rev. B60, 1830 (1999).
[3] C. Figueira de M. Faria, M. Dorr, W. Sandner, Phys. Rev. A55, 3961 (1996)
[4] M. A. Nielsen, I. L. Chuang, *Quantum Computation and Quantum Information*, Cambridge Univ. Press, Cambridge, England (2000)
[5] H. R. Lewis, Jr. and W. B. Riesenfeld, J. Math. Phys. 10, 1458 (1969).

Mijailović Marina **(5)** **Poster**

Narrowing of Hanle CPT resonances using ring shaped laser beam

Marina Mijailović, Zoran Grujić, Dušan Arsenović and Branislav Jelenković
Institute of Physics, Belgrade, Serbia
e-mail: lekic@phy.bg.ac.yu

We demonstrate experimentally and verified theoretically that by using the ring shaped laser beam we can censurably narrow CPT (Coherent Population Trapping) resonances in respect to resonances when we use Gaussian beam laser of the same diameter as the outer diameter of the ring. The CPT resonance is observed using laser light locked to F_g=2 –> F_e=1 transition of D1 line in ^{87}Rb. We detect the laser light behind the Rb vacuum cell placing the photo detector along the axis of the Rb cell, i.e., the axis of the of ring shaped laser beam. The outside diameter of the laser is the same as the cell diameter (1/2''). We present results using laser beam with different inner diameters. Our set-up thus allows for creation of atomic coherence while atom is in the ring of the laser beam, and subsequent probing of the coherence by the laser light which passes the cell along the cell's axis. The origin of the laser light traversing the sell near the cell axis and reaching the photo detector is multiple reflection of the ring shaped laser beam of the cell windows. This efficient narrowing of the CPT by a simple modification of the laser profile can be of interest for applications of CPT for magnetometers and atomic frequency standards.

Minagar Golnaz **(1)** **Talk**

Controlling the dispersion and the absorption in a single-channel four-level system

M. Sahrai[1], *M. Mahmoudi*[2], *and G. Minagar*[2]
[1] Research Institute for Applied Physics, University of Tabriz, Tabriz, Iran
[2] Department of Physics, Zanjan University, P.O.Box 45195-313, Zanjan, Iran
gol_mi@yahoo.com

We propose a four-level scheme for control the dispersion and the absorption by employing as ingle absorption (and spontaneous emission) channel. The upper state is coupled to two long lived nearly hyperfine doublet structure by two laser fields. This scheme provides a controllable way for the equivalent realization of a two-channel system and thus is

easier to implement. It is shown that the slope of dispersion can be changed with the intensity of driving fields, so the group velocity of probe field can be controlled as it passes through the medium. To show the attenuation of the weak probe field, the absorption properties of the medium are also discussed.

Miranowicz Adam **(10)** **Talk**

Entanglement manipulation via a pure state can cause a greater entanglement loss than that via a mixed state

Adam Miranowicz[1]*, Satoshi Ishizaka*[2] *and Bohdan Horst*[1]
[1]Faculty of Physics, Adam Mickiewicz University, 61-614 Poznan, Poland
[2]Nanoelectronics Research Labs., NEC Corporation 34, Miyukigaoka Tsukuba, Ibaraki 305-8501, Japan
miran@amu.edu.pl

In quantifying quantum entanglement of two-qubit mixed states the following measures are commonly applied: the relative entropy of entanglement (REE) - a measure of a "distance" of an entangled state from the set of disentangled states, the (logarithmic) negativity - a measure of entanglement cost under operations preserving the positivity of partial transpose (PPT), the concurrence - a measure of the entanglement of formation, and the entanglement of distillation (ED) - a measure of the entanglement as the fraction of Bell states that can be distilled using the optimal purification protocol.

It is well known that the upper bounds of the REE for a given concurrence and of the negativity for a given concurrence are reached by pure states. So, one could conjecture that pure states have also the highest REE for a given negativity.

By contrast, we demonstrate that there are mixed states for which the REE and the ED for a given negativity (≤ 0.5) are higher than those for pure states. The point is that the (logarithmic) negativity is equal to a PPT entanglement cost for an exact preparation, REE is equal to a PPT distillable entanglement for pure states, and ED is a lower bound of a PPT distillable entanglement. So, our findings provide an explicit example of the PPT operations that, even though the entanglement cost for an exact preparation is the same, ED of a mixed state can exceed that of pure states. In other words, the entanglement manipulation via a pure state can result in a larger entanglement loss than that via a mixed state.

Mishra Devendra Kumar **(1)** **Poster**

Quantum analysis of beam splitter having third-order nonlinearity

Hari Prakash[1, 2] *and* *Devendra Kumar Mishra*[3]
[1] Department of Physics, University of Allahabad, Allahabad (U.P)-211002, India
[2] M. N. Saha Centre of Space Studies, Institute of Interdisciplinary Studies,
University of Allahabad, Allahabad (U.P)-211002, India
[3] Department of Physics, V. S. Mehta College of Science,
Bharwari, Kaushambi (U.P)- 212201, India
kndmishra@rediffmail.com

A linear beam splitter mixes two input modes having annihilation operators $\hat{a}$ and $\hat{b}$ and generate two output modes having annihilation operators $\hat{c}$ and $\hat{d}$ which are linear in $\hat{a}$ and $\hat{b}$ and may be written as $\hat{c} = t\hat{a} + ir\hat{b}$ and $\hat{d} = t\hat{b} + ir\hat{a}$, where t and r are the real coefficients of transmission and reflection, respectively, with $r^2 + t^2 = 1$. We include third order nonlinearity and as a result we find input/output relations for such a nonlinear beam splitter. If two coherent beams are mixed through such a beam splitter having third order nonlinearity, squeezing and sub-Poissonian photon statistics is seen to be exhibited by output mixed beam.

Mista Ladislav **(1)** **Talk**

Localizable entanglement for continuous variables

Ladislav Mišta, and Jaromír Fiurášek
Department of Optics,Palacký University,Olomouc,Czech Republic
mista@optics.upol.cz

We investigate how much entanglement can be localized between a pair of modes of a multimode Gaussian state by local Gaussian measurements on remaining modes and classical communication. We show that for pure states and mixed bisymmetric states maximum entanglement is localized by homodyne detections, i.e. projections onto infinitely squeezed states. Further, we find a mixed Gaussian state for which maximum entanglement is localized by projection onto a finitely squeezed state. Finally, we show that non-Gaussian measurements outperform the Gaussian ones.

References

[1] J. Fiurášek and L. Mišta, Jr., Phys. Rev. A **75**, 060302(R) (2007).

Mizrahi Salomon S. **(1)** **Talk**

Information Theory and Quantum Mechanics

Salomon S. Mizrahi
Universidade Federal de São Carlos, São Carlos, SP, Brazil
salomon@df.ufscar.br

Quantum information (QI) theory has stimulated the creation of powerful and ingenious algorithms (without classical counterpart) as well as error correction methods, and has also inspired the realization of innovative state of the art experimental setups that produced novel and amazing results. The formal structure that supports QI theory is based on the well founded concepts and postulates of quantum mechanics. In the present contribution I am inverting the usual approach, beginning with the postulates of Boole algebra together with the realization of bits states (fundamental units of information) as basis vectors in a Hilbert space, I derive a map corresponding to the classical dynamical evolution of the bit states. Going one step further, I extend the bit state to a superposition of bit states, called a qubit (still an element of Hilbert space) and impose two conditions: (1) the map must be invertible, and (2) the qubit is necessarily carried by a massive particle. This procedure leads to the well known dynamical Schrödinger-Pauli equation (SPE) of quantum mechanics, where the bit concept is associated to a spin ½ – the particle internal degree of freedom. Within this approach, one may interpret the particle dynamics (which is classical) as being "enslaved" by the spin dynamics. In other words, the spin evolution precedes in status the particle space evolution and engraves on it its signature, being at the root of the quantum character of the standard Schrödinger equation, even when spin and spatial degrees of freedom are decoupled. Going further with the formalism, one finds that whereas the SPE equation evolves a single massive qubit, the Dirac equation is represented by a massive carrier that needs two bits.

Moi Luigi **(3)** **Invited talk**

Photoinduced effects on atoms and clusters embedded in polymer films and nanoporous silica

L. Moi[1], A. Burchianti[1], C. Marinelli[1], A. Bogi[1] and E. Mariotti[1]
[1]CNISM and Physics Department, University of Siena, I-53100 Siena, Italy
moi@unisi.it

The interaction of atoms with the walls of the confining cell plays an important role in many experiments. Optical pumping is a clear demonstration of it. No signal was in fact observed until the cell walls have been coated with special organic films that minimize the adsorption energy. Cell coating improves, for the same reason, CPT signals. When an atom hits a surface it can make an elastic bounce or can make chemical reaction and remain trapped forever. In between these two limit cases there is a large variety of conditions leading to new and unexpected effects that we have observed and studied during the last years. Important applications are in the improvement of trapping efficiency of radioactive atoms. Few years ago, A. Gozzini et al. [1] observed at room temperature a bright sodium fluorescence due to the sodium atoms desorbed by resonant yellow light from a siloxane film. Meucci et al. [2] reported a similar observation in a siloxane coated cell containing rubidium atoms. In this case the density increase was produced by weak noncoherent light. Since then a lot of experimental work has been done using a wide variety of organic coatings loaded with alkali metal atoms [3-6]. This effect, named LIAD (Light Induced Atomic Desorption), has been used for efficient loading of a standard Rb magneto-optical trap [7] and a photonic band gap fiber [8].

Atomic photodesorption is also observed from bare glass but, in this case, high laser intensities are required to get a reasonable number of atoms. We have increased the number of desorbed atoms by using nanoporous silica samples properly loaded with alkali atoms [9]. In this case, the sample surface illuminated by light is quite large and a huge number of atoms is detached from the silica walls. A small fraction of these desorbed atoms flows out of the sample, whereas the others, trapped in the matrix, change the alkali metal phase equilibrium inside the nanopores. Atomic photodesorption and confinement produce either formation or evaporation of nanoclusters [10]. These processes depend on light frequency and intensity making controllable by light the porous silica transparency. We have demonstrated that porous silica loaded with Rb can be used as a support to record a light pulse for a long time as well as to remember the order of light colors in an illumination sequence [11].

References

[1] A. Gozzini et al., Nuovo Cimento D **15**, 709 (1993)
[2] M. Meucci et al., Europhys. Lett. 25, 639 (1994)
[3] S.N. Atutov et al., Phys. Rev. A **60**, 4693 (1999)
[4] E.B. Alexandrov et al., Phys. Rev. A **66**, 042903 (2002)
[5] A. Cappello et al., J. Chem. Phys. **127**, 044706 (2007)
[6] S. Gozzini et al., Eur. Phys. J. D **47**, 1 (2008)
[7] S.N. Atutov et al., Phys. Rev. A **67**, 053401 (2003)
[8] S. Ghosh et al., Phys. Rev. Lett. **97**, 023603 (2006)
[9] A. Burchianti et al., Europhys. Lett. **67**, 983(2004)
[10] A. Burchianti et al., Phys. Rev. Lett. **97**, 157404 (2006)
[11] A. Burchianti et al., Opt. Exp. **16**, 1377 (2008)

Moreva Ekaterina **(10)** **Poster**

Optimal protocol for quantum state reconstruction

E.V. Moreva[1], *S.P.Kulik*[2], *I.Tikhonov*[2]
[1]Moscow Engineering Physics Institute (State University), Moscow, Russia
[2]M.V. Lomonosov Moscow State University , Moscow, Russia
ekaterina.moreva@gmail.com

In recent years, multi-dimensional quantum states (qudits) of an optical field have been the subject of theoretical and experimental investigations. Directions of these researches are defined by problems of quantum cryptography and calculations, quantum teleportation, check of Bell-type inequalities. In applications like these, it is necessary to implement the complete control over the state preparation, transfer and measurement.

Quality assurance of preparation and transformation requires a complete characterization of these states, which can be accomplished through a procedure known as quantum process tomography. Although tomographic procedure is used in many experiments as an “applied problem”, there are a lot of questions related with simple and optimal choice of protocols.

In this paper we address the experimental problem of implementing the optimal state reconstruction of ququarts by using the protocol of quantum tomography suggested earlier [1]. The method is based on an optimal choice of the measuring scheme's parameters that provides better quality of reconstruction at the fixed set of statistical data.

The experiment was aimed at reconstructing ququart states (optical state with dimension D=4) based on collinear frequency non-degenerate regime of biphoton field. At present, the only realistic way to register biphoton field is using the Brown-Twiss scheme. We supplied this scheme with two wave plates and polarization elements. To measure the quantum state one needs to perform a set of projective measurements on the state and then to apply some computation procedure to the data. The minimal number of projective measurements required for the reconstruction is given by the dimensionality of the Hilbert space. This procedure is mathematically expressed as the system of independent linear equations relating combinations of fourth order moments of the field and the number of detected events. The linear transformation of the state vector is described by a certain matrix depending on thicknesses and angles of the wave plates. The amount of singular numbers of this matrix specifies quantity of linearly independent equations.

In our work we introduce parameter R which is defined as the ratio of the minimal singular number to maximal. For optimal choice of the measuring scheme's parameters (for example wave plate thickness) this parameter should be maximal.

In our experiment, we have chosen two sets of wave plates with different thicknesses (optimal and nonoptimal) and made the reconstruction procedure at the fixed set of statistical data for each set. We have tested three states. Fidelity for all states in the first case (optimal) was above 99%, in the second case (nonoptimal) fidelity was much less 95%. A high accuracy of the reconstruction of the states indicates that the parameter proposed for optimal reconstructing the quantum state is adequate.

References

[1] Yu.Bogdanov, E.V.Moreva, G.Maslennikov, R.F.Galeev, S.S.Straupe, S.P.Kulik, Phys. Rev. A. **73**, 063810 (2006)

Moszynski Robert **(1)** **Talk**

Relativistic and QED treatment of long-range resonant interactions between like atoms

Wojciech Skomorowski, Tatiana Korona, and Robert Moszynski
Department of Chemistry, University of Warsaw, Poland
robert.moszynski@tiger.chem.uw.edu.pl

Theory of long-range relativistic interactions between identical atoms in their ground and excited states is formulated with a special emphasis on the spin-orbit interactions. It is shown that the relativistic resonant interaction between like atoms, one in the ground ^1S state and the other in an excited ^3L state, shows an $R^{-(2L+1)}$ behavior. Other contributions to the resonant relativistic potential are also considered and a complete treatment of the Casimir-Polder retardation effects within the long-wavelength quantum electrodynamics formalism is reported. Numerical results illustrating these theoretical developments are presented on the example of the calcium and strontium diatomic molecules. The accuracy of the results is proven by comparison of the computed and measured lifetimes for the electronically excited states of these atoms, and of the computed and measured transition frequencies in the high-resolution photoassociation spectra. The transition frequencies in the ultracold regime, from the rovibrational continuum of the ground electronic state to the long-range rovibrational levels of the excited electronic states corresponding to the $^1S+^3P$ dissociation, and bound by spin-orbit interactions, represent a very stringent test for the present theoretical developments.

Napoli Anna **(7)** **Invited talk**

A new measure of multipartite entanglement

A. Napoli, D. Teresi, A. Messina
Dipartimento di Scienze Fisiche ed Astronomiche dell'Università di Palermo
Via Archirafi 36, 90123 Palermo
napoli@fisica.unipa.it

Since the beginning of quantum mechanics, entanglement revealed to be a key concept for the understanding of the nature. Its link with the foundations of physics was immediately recognized, in particular in connection with the property of nonlocality of quantum theory. The last few years moreover have witnessed the possibility of generating entangled states in different physical systems promoting at the same time their role as applicative resources in emerging areas of physics such as teleportation, dense coding, quantum cryptography, computation and information.

In the last decade, in particular, the fundamental question to quantify entanglement has received a lot of attention. In this context different measures of entanglement have been proposed with respect, in particular, to bipartite system. On the contrary entanglement in multipartite systems remains an open and debated problem. In an axiomatic approach to quantify entanglement the monotonicity condition is certainly one of the inalienable property that a good measure must satisfy.

Consider a multipartite system composed by N not necessarily identical subsystems eachone living in a finite dimensional Hilbert space. In this talk I present a new measure of entanglement for such systems in pure states. The quantity I propose, called General Entanglement (GE), provides a measure of the entanglement present in the system independently on how it is distributed among the finitely many possible subsystems. Moreover the GE has a clear physical meaning and it is characterized by many appealing properties making it very attractive both from a conceptual and an experimental point of view. Finally I show that the GE reveals itself easily valuable and reduces to Meyer and Wallach's Global Entanglement when qubit systems are considered.

Nemeth Istvan **(3)** **Talk**

Quantum Theory of the Coherently Pumped Micromaser

Istvan Nemeth[1] *and Janos A. Bergou*[2]
[1]Department of Physics, University of West Hungary, Károlyi Gáspár tér 4., H-9700 Szombathely, Hungary
[2]Department of Physics, Hunter College, 695 Park Avenue, New York, New York 10021, USA
inemeth@hunter.cuny.edu

Detailed theoretical and experimental study of the atom-field interaction starting from first principles was made possible by the realization of the single-atom micromaser. The situation realized in a micromaser is very close to the ideal case of a single two-level atom interacting with a single quantized mode of a superconducting cavity. This system's ability to coherently transfer quantum states between atoms and photons made it relevant in the context of quantum computation as well. Although considerable work, both theoretical and experimental, has been devoted to this system, with a few exceptions, most cases involved only incoherent pumping. As a result, the density matrix describing the field remained always diagonal, preventing the appearance of coherences, which are central to quantum information processing.

We present here a comprehensive study of the coherently pumped micromaser: We introduce a model which includes coherent and non-coherent, as well as resonant and off-resonant, pumping. We provide an understanding of the large scale structure of the field density matrix of the coherently pumped micromaser formed under general conditions (the connections between the trapping states, the tangent and cotangent states and the steady state of the coherently pumped lossy micromaser formed in the non-decaying partition of the field density matrix). We introduce an analytic method we developed to obtain the steady state solution of the master equation governing the time evolution of the cavity field, and show the surprising results for the photon distribution and for the purity of the steady state of the coherently pumped micromaser we obtained using this method.

It is quite clear that the strong coherence present in this system also calls for an understanding of its features in terms of quantum phase. Therefore, we present a consistent quantum theory of the steady-state phase properties of the coherently pumped micromaser. This remarkable system allows us a detailed study of the connection between the classical phase and its closest quantum mechanical counterpart from first principles. We go beyond existing results in several ways. We apply recent advances in the treatment of the phase to represent the quantum phase observables as normalized positive operator measures and draw new conclusions regarding the phase of the coherently pumped micromaser. In particular, the effect of various detunings is incorporated, we show that the atom-cavity detuning governs branch selection in the injected coherence induced bifurcations of the phase density function, and we show first order phase transition-like discontinuities induced by atomic inversion. In the case of resonant pumping we provide an analytic theory of the phase locking of the resonantly pumped micromaser to the phase of the pumping atoms, and the interpretation of the phase shift of the non-resonantly pumped micromaser using the analogy with a simple classical model.

These features underline the significance of the study of the coherently pumped micromaser. The system exhibits a plethora of classical and quantum features and can serve as a theoretical paradigm for further investigations of the phase.

Nemilentsau Andrei **(8)** **Talk**

Photonic density of states in the vicinity of finite-length single-wall carbon nanotube

Andrei Nemilentsau, *Gregory Ya. Slepyan and Sergey A. Maksimenko*
Institute for Nuclear Problems, Belarus State University, Minsk, Belarus
andrei.nemilentsau@gmail.com

Electromagnetic density of states (DOS) is a fundamental physical quantity which defines such physical effects as the Casimir effect [1], the Purcell effect [2], the thermal radiation [3], etc. The DOS structure depends on the geometry and material properties of the system under the consideration. Nowadays, the most effective systems for DOS manipulation are microcavities, photonic crystals and systems supporting the surface waves propagation [2,3]. A very promising system in this case is a single-wall carbon nanotube (CNT) as it can support propagation of a strongly slowed down surface plasmons [4]. Moreover, the drastic enhancement (5-6 orders of magnitude) of the spontaneous decay rate of an atom placed in the vicinity of the infinite-length CNT in comparison with free-space atom predicted in [2] has revealed a strong influence of CNTs on DOS structure. But the model of infinite-length CNT does not allow studying the influence of CNT edges on the DOS distribution. In this report we present the model of a finite-length CNT and show that CNT edges drastically change the DOS structure in the CNT vicinity.

The photonic DOS $\rho(\mathbf{r},\omega)$ in nonmagnetic CNT is defined through the electric-field Green dyadic as follows [3]:
$\rho(\mathbf{r},\omega)=\omega/(\pi c^2)\,Im\{Tr[\underline{\mathbf{G}}(\mathbf{r}_1,\mathbf{r}_2,a)+(c/\omega)^2\nabla_{\mathbf{r}_1}\times\underline{\mathbf{G}}(\mathbf{r}_1,\mathbf{r}_2,\omega)\cdot\nabla_{\mathbf{r}_2}\times]\}$.
The Green dyadic is the solution of the equation
$(\nabla_{\mathbf{r}_1}\times\nabla_{\mathbf{r}_1}\times-(\omega/c)^2)\underline{\mathbf{G}}(\mathbf{r}_1,\mathbf{r}_2,\omega)=4\pi\underline{\mathbf{I}}\,\delta(\mathbf{r}_1-\mathbf{r}_2)$ imposed to the effective boundary conditions on the CNT surface [4], $\underline{\mathbf{I}}$ is the unit dyadic. Contrary to the infinite-length CNT case, considered in Ref. [2], these equations can not be solved analytically for the finite-length CNT. Thus, we have transformed the system of differential equations to integral Dyson equation for finite-length CNT Green tensor which then has been solved numerically by the method of the quadrature approximation for integral operators with the subsequent transition to the finite-order matrix equation [5].

To present our numerical results we have calculated the energy of thermal electromagnetic field at the equilibrium with CNT
$U(\mathbf{r},\omega)=\rho(\mathbf{r},\omega)\hbar\omega/(Exp(\hbar\omega/k_BT)-1)$, where T is the CNT temperature. In particular, we are interested in this quantity because its measurement could give us information about DOS structure in the CNT vicinity. Our analysis shows significant modification of the thermal radiation spectrum (and thus photonic DOS) as compared with the black-body thermal radiation. Particularly, resonances in the thermal radiation spectra of metallic CNTs are predicted in IR and terahertz ranges, dependently on the CNT length. These resonances are due to geometrical resonances of low-frequency surface plasmon-polaritons propagating in CNTs. As different from metallic CNTs, semiconductor ones do not reveal such resonances because of strong attenuation of surface waves in this case.
Thus our analysis shows that the edge effects in CNTs affect critically on DOS structure. The resonant behavior of DOS could lead to the nontrivial behavior of quantum vacuum related effects, in particular Casimir forces, in metallic CNTs.

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References
[1] M. Bordag, U. Mohideen, V. M. Mostepanenko, Phys. Rep. 353, 1, 2001.
[2] I.V. Bondarev, G.Ya. Slepyan, S.A. Maksimenko, Phys. Rev. Lett. 89, 115504, 2002.
[3] K. Joulain et al., Surf. Sci. Rep. 57, 59, 2005.
[4] G.Ya. Slepyan et al., Phys. Rev. B 60, 17136, 1999.
[5] A.M. Nemilentsau, G.Ya. Slepyan, S.A. Maksimenko, Phys. Rev. Lett. 99, 147403, 2007.

Oblak Daniel **(7)** **Talk**

Spin Squeezing on the Caesium Clock Transition

D. Oblak[1], P. Windpassinger[1], N. Kjergaard[1], U.B. Hoff[1], J. Appel[1], and E.S. Polzik[1]
[1]Danish Research Council Centre for Quantum Optics, Niels Bohr Institute, Copenhagen, Denmark
oblak@nbi.dk

Non-classical quantum states of either light or matter are central to quantum optics. In quantum information science these states lie at the heart of secret sharing communication protocols and computational algorithms that are projected to vastly outperform their classical counterparts. In spectroscopy non-classical quantum states harbour the potential to overcome the limits to the precision of measurements that is imposed by the quantum uncertainty. An important illustration of the limiting nature of classical quantum states is provided by the current frequency standard measurements, which are done on the microwave hyperfine transition between the two so called clock levels in the Caesium atom. In state-of-the-art experiments with microwave clocks it is the quantum uncertainty of the utilised coherent atomic states embodied by the atomic projection noise, which at present prevents any further improvements of the measurement precision. Using a (non-classical) squeezed atomic state that has a reduced uncertainty of the relevant quantum variable it is possible to overcome the standard quantum limitations to the precision of atomic clocks in a fashion that would apply equally well to current microwave clocks as to future clocks relying on optical transitions.

Non-classical quantum states do, however, require some effort to prepare and in the case of squeezed atomic states there are various options. In our experiment we explore the possibility of squeezing a quantum state by means of a quantum non-demolotion (QND) measurement of an appropriate quantum variable. Since the QND measurement yields information about the initial quantum state without disturbing it, the measurement result implicitly reduces the uncertainty of the quantum state in the measured variable, thus producing a squeezed state [1].

In our experimental realisation, the QND measurement is performed by an interferometric measurement on a sample of cold Caesium atoms trapped in an dipole-force trap [2]. As in microwave clocks we prepare the atoms in a superposition of the two magnetically insensitive Zeeman sub-levels of the two hyperfine ground states (clock-levels). This two-level system is conveniently described in the Bloch-vector formalism where the z-component corresponds to the population number difference while the x & y components relate to the coherences between the two levels. Two laser beams of infrared light, each near resonant with the transition between one of the ground states and some excited states, are used to probe the ground state populations. The dispersive interaction between light and atoms will cause the phase of either light beam to be shifted according to the population of the ground level that it is close to resonance with. This phase-shift is then measured in a white-light aligned and actively stabilised Mach-Zehnder interferometer, where the atomic sample is located in one arm of the interferometer [3]. Using the information that can be gained from the phase-shift of each probe beam we effectively measure the population number difference of the clock-levels corresponding to the z-projection of the Bloch-vector [1]. At the same time, the probe light is suficiently far detuned that the the initial atomic state is not destroyed by scattering events which lead to spontaneous emission [4].

We demonstrate that we can measure the quantum projection noise of the initially prepared coherent state and that we can estimate the outcome of a subsequent measurement with less uncertainty than that given by the quantum projection noise. Additionally, we gauge the degree of destruction of the initial atomic state by the measurement in order to verify that the final atomic state is indeed squeezed in the z-projection of the Bloch-sphere vector.

References

[1] Oblak et al. PRA 71, 043807 (2005),
[2] Petrov et. al. PRA 75, 033803 (2007),
[3] Windpassinger et al. PRL, 100, 103601 (2008), [4] Windpassinger et al. arXiv:0801.3242

Oganesyan Koryun **(4)** **Talk**

The Threshold Conditions for FELWI

A. B. Oganesyan[1], *M.L. Petrosyan*[1], *M.V. Fedorov*[2],
A.I. Artemiev[2], *D.I. Klochkov*[2], *Yu.V. Rostovtsev*[3]
[1] Yerevan Physics Institute, Yerevan, Armenia,
[2]General Physics Institute, Moscow, Russia , [3] Texas A&M University, Collage Station, USA
koganesyan@yahoo.com, bsk@mail.yerphi.am

The collective and single-electron amplification regimes of a non-collinear free electron laser (FEL) are studied within the framework of dispersion equations. In the limit of small-signal gain the growth rates of spatial amplification and the conditions for self-amplified excitations are found for the collective (Raman) and single-electron (Thompson) regimes. Taking into account the spatial scantiness of beams the estimations of amplification as a function of electron beam width is obtained. For FELWI application the threshold of the laser radiation power, for which the mechanism of transverse velocity selection of electrons in the drift region is possible, is obtained.

Okulov Alexey **(6)** **Talk**

Vortex-antivortex labyrinth wavefunction

A.Yu.Okulov
A.M.Prokhorov General Physics Institute of Russian Academy of Sciences
Vavilova str. 38, 119991, Moscow, Russia
okulov@kapella.gpi.ru

We analyze the pinning of quantized matter wave vortices by optical vortices in specially arranged optical dipole labyrinth traps [1]. Using previously obtained results for asymmetric elongated traps [2] and longitudinally modulated traps [3] we use the fact that $3D$ Gross-Pitaevsky equation[4]:

$$i\hbar\frac{\partial\Psi(\vec{r},t)}{\partial t}=-\frac{\hbar^2}{2m}\Delta\Psi(\vec{r},t)+V_{ext}(\vec{r})\Psi(\vec{r},t)+\frac{4\pi\hbar^2 a_s(\vec{B})}{m}\Psi(\vec{r},t)|\Psi(\vec{r},t)|^2, \quad (1)$$

where

$$V_{ext}(\vec{r}_\perp,z)=V_z+V_\perp=\frac{m\,\omega_z^2 z^2}{2}-Re[\alpha(\omega)]|E(\vec{r}_\perp)|^2+\frac{m\,\omega_\perp^2|(\vec{r}_\perp)|^2}{2} \quad (2)$$

and $\alpha(\omega)$ is atomic polarizability[5], admits the application of the standard method of separation of variables in pancake geometry[6].The equations for longitudinal and transversal parts of macroscopic wavefunction:

$$\Psi(\vec{r},t)=\Psi_{||}(z,t)\Psi_\perp(\vec{r}_\perp,t) \quad (3)$$

are solved separately[1]. The first equation for 1D harmonic oscillator is solved exactly. The transversal two dimensional GPE is solved numerically by means of split-step FFT transform method on 512x512 computational mesh[7]. The vortex-antivortex "antiferromagnet"-like optical lattice of rectangular symmetry is found to support vortex-antivortex "antiferromagnet-like" matter waves.

In contrast to rotating "bucket" trap [8] and rotating "busket" trap [9], where superfluid vortex lattices rotate as a rigid body, our solution [1] is static. The superfluid vortices in our "basket" trap[1] are pinned at the nodes (i.e. zeros of amplitude or phase singularities) of optical interference pattern. The argument of $arg(\Psi_\perp)$ versus transverse coordinates $\vec{r}_\perp$ shows clearly the loci of rectangularily spaced vortices with alternating circulations. The field of classical velocities obtained via Madelung transform is shown to form labyrinth pattern.

References

[1]A.Yu.Okulov, J.Mod.Opt. 55, N.2,p.241-257(2008).
[2]V.M.Perez-Garcia, H.Michinel and H.Herrero, Phys.Rev. A 57, 3837 (1998).
[3]R.Fidele, P.K.Shukla, S.De.Nicola, M.A.Manko, V.I.Manko, F.S.Cataliotti, JETP Lett. 80, 609 (2004).
[4]F. Dalfovo, S.Giorgini, S.Stringari, L.P.Pitaevskii, Rev.Mod.Phys. 71, 463 (1999).
[5] R.Grimm, M.Weidemuller and Yu.B.Ovchinnikov, Adv.At.Mol.Opt.Phys. 42, 95 (2000).
[6]L.C.Crasovan, V.Vekslerchik, V.M.Perez-Garcia, J.P.Torres, D.Mihalache, L.Torner., Phys.Rev. A 68 063609 (2003).
[7]A.Yu.Okulov, Opt.Comm. 99, p.350-354 (1993).
[8]J.R.Abo-Shaerr, C.Raman, J.M.Vogels and W.Ketterle, Phys.Rev.Lett. 88, 070409 (2002).
[9]S.Tung, V.Schweikhard, and E.A.Cornell, Phys.Rev.Lett. 97, 240402 (2006).

Ooi Raymond **(2)** **Talk**

Extended Photon Correlation in Superradiance with Negative Temperature

C. H. Raymond Ooi
Department of Physics, Korea University, Anam-dong, Seongbuk-gu, Seoul 136-713, Republic of Korea
bokooi73@yahoo.com;raybokooi@korea.ac.kr

We show how two-photon correlation of a two-level amplifier in small signal regime depends on the atomic populations and the propagation length. We predict that inverted population associated with negative temperature gives a very long correlation time even in the presence of decoherence. This finding would be a useful asset for quantum communication. The correlation vanishes for very dilute atomic gas. Analytical solutions for the field operators obtained by Fourier transform and Laplace transform (with initial condition) of the time variable appear very different but yield identical numerical results except for certain parameters. Physical explanation behind the deviation is given. The presence of thermal photons is found to reduce the correlation time.

Two-level laser amplifier was studied many years ago in the interest of pulse propagation. When the inversion is created by sweeping through a delta function pulse, it produces a gain-swept medium with superradiant emission with unrestricted gain [1]. The gain-swept concept is recently proposed for stand-off detection of impurities in the atmosphere [2]. Here, we take a new look on the system in the interest of two-photon correlation. As in previous works [3], [4] we use the Heisenberg-Langevin equations coupled to the Maxwell's equations for quantized macroscopic field, which incorporates quantum noise or vacuum fluctuations in a full quantum electrodynamical theory. We consider a medium with length L and radius w where the Fresnel number F ~1. Small signal regime gives a set of linearized equations that can be solved either by Fourier-Laplace transform or double-Laplace transform of the time-space variables. We obtain an analytical solution that generalizes the result of ref. [2] by including the quantum noise operator.

We study how the populations, optical density and thermal photons affect Glauber's two-photon correlation function. When the populations are mostly in the ground level $n_{ab} = \rho_{aa} - \rho_{bb} < 0$, the coherence time between photons reduces with amplifier length. On the other hand, the coherence time increases significantly with the length for inverted ($n_{ab} > 0$) case. This shows that a gain medium can sustain quantum correlation against decoherence, another magical effect of negative temperature [5]. This effect could be a key mechanism for producing correlated photon pairs with long time delay for quantum communication protocols.

It is remarkable that the results for inverted case obtained using the Fourier transform method coincide very well with that obtained using the Laplace transform. However, for non-inverted case and large optical density, the result by Laplace transform shows a peculiar dip in the correlation. This feature is due to the oscillatory behavior and not found in the solution by Fourier transform. This reflects the limitation of Fourier transform method for solving the time dependent problem, and the breakdown of linear approximation in neglecting excitation of the ground population by the macroscopic field.

References

[1] F. A. Hopf and Marlan O. Scully, Phys. Rev. 179, 399 (1969).
[2] V. Kocharovsky, S. Cameron, K. Lehmann, R. Lucht, R. Miles, Y. Rostovtsev, W. Warren, G. R. Welch, and M. O. Scully, Proc. Natl. Acad. Sci. U.S.A. 102, 7806 (2005).

[3] C. H. Raymond Ooi and Marlan O. Scully, Phys. Rev. A 76, 043822 (2007).
[4] C. H. Raymond Ooi, Qingqing Sun, M. Suhail Zubairy and Marlan O. Scully, Phys. Rev. A 75, 013820 (2007).
[5] N. F. Ramsey, Phys. Rev. 103, 20 (1956).

Özsoy Sedat **(1)** **Poster**

The effect of pair-induced quenching on the gain performance of erbium-doped fiber amplifiers (EDFAs)

Sedat Özsoy and Cüneyt Berkdemir
Department of Physics, Erciyes University, 38039 Kayseri, Turkey
ozsoys@erciyes.edu.tr

The efficiency of erbium-doped fiber amplifiers (EDFA's) depends strongly on erbium-ion concentrations [1-2]. For a low-erbium-doping concentration, the EDF length always exceeds several meters. This is not desired for all practical designs of amplifiers. At present, significantly shorter erbium-doped amplifiers, with erbium concentrations exceeding 10^{26} Er-ions/m^3, are needed for optical integration. In these amplifiers, it is necessary to incorporate high erbium doping concentrations to compensate for the long amplifier length, but the pair-induced quenching of active ions considerably reduces the amplification and lasing performance of these amplifiers [3]. Thus, the length and doping concentration of the amplifiers are optimized in order to obtain better gain performance [4-5]. For this optimization, both cooperative up-conversion and pair-induced quenching effects are taken into account.

We numerically investigate the effects of cooperative up-conversion and pair-induced quenching (PIQ) on the gain performance of EDFAs with high doping concentration. We use a two-level model to describe both the pairs and the ions themselves, assuming one ion per pair completely quenched. Using the numerical solution and analysis of the rate and power propagation equations, the optimal erbium doping concentrations are suggested to obtain higher gain per unit length in silica-based fiber amplifiers. The dependence of the calculated gain on the percentage of ion pair is compared for severel pump powers. Results are discussed to achieve a desired gain performance.

References

[1] P. M. Blixt, J. Nilsson, T. Carlnas, and B. Jaskorzynska, IEEE Photon. Technol. Lett. **3**, 996 (1991).
[2] P. Myslinki et al., IEEE Photon. Technol. Lett. **11**, 973 (1999).
[3] H. Musuda, A. Takada, and K. Aida, J. Lightwave Technol. **10 (12)**, 1789 (1992).
[4] E. Delevaque, T. Georges, and M. Monerie, IEEE Photon. Technol. Lett. **5 (1)**, 73 (1993).
[5] I. Nusinsky and A. A. Hardy, IEEE J. Quantum Electron. **39 (4),** 548 (2003).

Paladino Elisabetta **(7)** **Talk**

Characterization of coherent impurity effects in solid state qubits

E. Paladino[1], *M. Sassetti*[2], *G. Falci*[1] *and U. Weiss*[3]
[1]MATIS CNR-INFM, Catania &Dipartimento di Metodologie Fisiche e Chimiche, Università di Catania, Italy
[2]Dipartimento di Fisica, Università di Genova & LAMIA CNR-INFM,16146 Genova, Italy
[3]II. Institut fuer Theoretische Physik, Universitaet Stuttgart, D-70550 Stuttgart, Germany.
epaladino@dmfci.unict.it

Coherent nanodevices are inevitably exposed to fluctuations due to the solid-state environment. Well studied examples are charged impurities and stray flux tubes which are sources of telegraphic noise in a wide class of metallic devices. Large amplitude low-frequency (mostly 1/f) noise, ubiquitous in amorphous materials, is also routinely measured in single-electron-tunneling devices. Noise sources are sets of impurities located in the oxides and in the substrate, each producing a bistable stray polarization. Recent experiments on Josephson qubits indicated that charged impurities may also be responsible for noise exhibiting an ohmic power spectrum at GHz-frequencies. In addition, in superconducting qubits operating in the different implementations there has been experimental evidence of the presence of impurities *entangled* with the device, the first observations being reported in Ref. [1].

Solid-state noise also determines dephasing. This issue has attracted a great deal of interest in recent years since it has been recognized as a severe hindrance for the implementation of quantum hardware in the solid state. Slow noise explains the non-exponential suppression of coherent oscillations observed when repeated measurements are performed [2]. In addition fluctuations active *during time evolution* represent an unavoidable limitation even when a single-shot measurement scheme or dynamical decoupling protocols are available [3].

In this work we investigate qubit dephasing during time evolution due to coupling to a *coherent impurity* [4]. We introduce an effective impurity description in terms of a tunable spin-boson environment and solve the dynamics for the qubit coherences in the regime where qubit relaxation processes are absent. We show how the coherent and non-linear dynamics of the impurity is reflected in the qubit behavior. We identify regimes characterized by strong qubit-impurity back-action. Specifically, we discuss dependence on the impurity preparation and beating phenomena. Our analysis by changing temperature, impurity energy and qubit-impurity coupling strength, may provide valuable insights to realistic scenarios where a wide distribution of the parameters has to be considered. These non-Gaussian and quantum back-action effects may represent a ultimate limitation for solid state qubits even when single shot measurement schemes are available.

Finally, an alternative interpretation with the qubit acting as a measurement device for the impurity is proposed at the end of the presentation. Remarkably, the qubit acts as a detector despite the "dispersive", quantum non-demolition measurement regime for the qubit. Detection is feasible due to the qubit back-action on the damped impurity.

References

[1] R.W. Simmonds, K. M. Lang, D. A. Hite, S. Nam, D. P. Pappas, and John M. Martinis Phys. Rev. Lett. **93**, 077003 (2004); K.B. Cooper, M. Steffen, R. McDermott, R. W. Simmonds, Seongshik Oh, D. A. Hite1, D. P. Pappas, and John M. Martinis, Phys. Rev. Lett. **93**, 180401 (2004).

[2] G. Falci, A. D'Arrigo, A. Mastellone, E. Paladino, Phys. Rev. Lett. **94**, 167002 (2005).
[3] E. Paladino, L. Faoro, G. Falci, R. Fazio, Phys. Rev. Lett. **88**, 228304 (2002).
[4] E. Paladino, M. Sassetti, G. Falci and U. Weiss, Phys. Rev. B **77**, 041303R (2008).

Pascazio Saverio **(7)** **Invited talk**

Statistical mechanics of multipartite entanglement

Saverio Pascazio
Dipartimento di Fisica, Universita di Bari, Bari, Italy
and Istituto Nazionale di Fisica Nucleare, Sezione di Bari, Bari, Italy
saverio.pascazio@ba.infn.it

Entanglement is one of the most intriguing features of quantum mechanics. It is widely used in quantum communication and information processing and plays a key role in quantum computation. At the same time, entanglement is not fully understood. It is deeply rooted into the linearity of quantum theory and in the superposition principle and (for pure states) is essentially and intuitively related to the impossibility of factorizing the state of the total system in terms of states of its constituents.

The characterization and quantification of entanglement is an open and challenging problem. It is possible to give a good definition of bipartite entanglement [1] in terms of the von Neumann entropy and the entanglement of formation. The problem of defining multipartite entanglement is more diffcult and no unique definition exists [2].

I introduce the notion of maximally multipartite entangled states (MMES) [3] of n qubits as a generalization of the bipartite case. Their bipartite entanglement does not depend on the bipartition and is maximal for all possible bipartitions. Some examples of MMES for small n are investigated, both analytically and numerically. These states are the solutions of an optimization problem, that can be recast in terms of statistical mechanics [4].

References

[1] W. K. Wootters, Quantum Inf. Comput., 1, 27 (2001); L. Amico, R. Fazio, A. Osterloh and V. Vedral “Entanglement in Many-Body Systems”, arXiv:quant-ph/0703044 (Rev. Mod. Phys.,in print).
[2] V. Coman, J. Kundu and W. K. Wootters, Phys. Rev. A 61, 052306 (2000); A. Wong and N. Christensen, Phys. Rev. A 63, 044301 (2001); D. Bruss, J. Math. Phys. 43, 4237 (2002); D.A. Meyer and N.R. Wallach, J. Math. Phys. 43, 4273 (2002); V. I. Man'ko, G. Marmo, E. C. G. Sudarshan and F. Zaccaria, J. Phys. A: Math. Gen. 35, 7137 (2002).
[3] P. Facchi, G. Florio, G. Parisi and S. Pascazio, “Maximally multipartite entangled states” arXiv:0710.2868 [quant-ph].
[4] P. Facchi, G. Florio, U. Marzolino, G. Parisi and S. Pascazio, “Statistical mechanics of multipartite entanglement” arXiv:0803.4498 [quant-ph].

Paterek Tomasz **(1)** **Talk**

Mathematical undecidability and randomness in quantum experiments

Tomasz Paterek[1], *Markus Aspelmeyer*[1,2], *Časlav Brukner*[1,2], *Peter Klimek*[2,3], *Johannes Kofler*[2], *Robert Prevedel*[2] *and Anton Zeilinger*[1,2]
[1]IQOQI, Austrian Academy of Science, Vienna, Austria
[2]Faculty of Physics, University of Vienna, Austria
[3]Complex Systems Research Group, Medical University of Vienna, Austria
tomasz.paterek@univie.ac.at

The mathematics of the early twentieth century was concerned with the question whether a complete and consistent set of axioms for all of mathematics is conceivable [1]. In 1931 Godel showed that this is fundamentally impossible. In every consistent axiomatic system that is capable of expressing elementary arithmetic there are propositions which can neither be proved nor disproved within the system, i.e. they are undecidable. It was argued that mathematical undecidability arises whenever a proposition to be proved and the axioms contain together more information than the set of axioms itself [2]. We propose a new link between mathematical undecidability and quantum physics. We demonstrate that the states of elementary quantum systems are capable of encoding mathematical axioms. Quantum mechanics imposes an upper limit on how much information can be encoded in a quantum state [3,4], thus limiting the information content of the set of axioms. We show that quantum measurements are capable of revealing whether a given proposition is decidable or not within this set. This allows for an experimental test of mathematical undecidability by realizing the actual quantum states and operations required in the laboratory. We demonstrate experimentally both the encoding of axioms, using polarization states of photons, and that the decidability of propositions can be checked by performing suitable quantum measurements. We theoretically find and experimentally confirm that whenever a mathematical proposition is undecidable within the system of axioms encoded in the state, the measurement associated to the proposition gives random outcomes. Our results support the view that quantum randomness is irreducible and, in the line of statistical and algorithmic tests of quantum randomness [5], a manifestation of mathematical undecidability.

References

[1] D. Hilbert, Gesammelte Abhandlungen, Vol. 3, Springer Berlin (1935).
[2] G. J. Chaitin, Int. J. Theor. Phys. 21, 941 (1982).
[3] A. S. Holevo, Probl. Inf. Transm. 9, 177 (1973).
[4] A. Zeilinger, Found. Phys. 29, 631 (1999).
[5] K. Svozil, C. S. Calude, M. A. Stay, Int. J. Theor. Phys. 44, 1053 (2005).

Paunković Nikola **(10)** **Talk**

Macroscopic Distinguishability Between Quantum States Defining Different Phases of Matter

Nikola Paunković[1]
[1] *SQIG – Instituto de Telecomunicações, IST, Lisbon, P-1049-001 Lisbon, Portugal*
nikola.paunkovic@qubit.org

We introduce the fidelity approach to study both quantum and thermal phase transitions. Within the field of quantum information, the function widely used to quantify the distinguishability between two quantum states $\hat{\rho}_1$ and $\hat{\rho}_2$ is *fidelity*, given by the expression: $F(\hat{\rho}_1,\hat{\rho}_2) = \mathrm{Tr}\sqrt{\sqrt{\hat{\rho}_1}\hat{\rho}_2\sqrt{\hat{\rho}_1}}$, which in the case of pure states $\hat{\rho}_1 = |\psi_1\rangle\langle\psi_1|$ and $\hat{\rho}_2 = |\psi_2\rangle\langle\psi_2|$, reduces to $F(|\psi_1\rangle\langle\psi_1|,|\psi_2\rangle\langle\psi_2|) = |\langle\psi_1|\psi_2\rangle|$. In this study, we are interested in macroscopic features of matter that define its thermodynamical phase. As in the case of general quantum states, here as well, fidelity can be used as a function whose behavior can mark the regions of criticality in the system's parameter space (and therefore the phase transitions).The basic logic behind this idea is strikingly simple — two quantum states defining different macroscopic phases are expected to have enhanced distinguishability that would quantitatively exceed that taken between states from the same phase. Yet, it isprecisely the simplicity where one of the advantages of this approach lies: being rooted on a basic notion such as state distinguishability, the fidelity study provides a general approach to phase transitions.

In the case of quantum phase transitions, which occur at zero temperature and are driven by purely quantum fluctuations, we analyze the fidelity between two global ground states of the system, given for two close values of the parameter(s) (i.e. coupling constants, external fields, etc.). On the examples of the Dicke and the XY models we show that approaching the regions of criticality the fidelity between two neighboring ground states exhibits a dramatic drop [1].

We also study general thermal phase transitions [2]. On the examples of the Stoner-Hubbard itinerant electron model of magnetism and the BCS theory of superconductivity, we show that the sudden drop of the mixed state fidelity between two neighboring global thermal states marks the line of the phase transition. We conduct a detailed analysis of the general case of systems given by mutually commuting Hamiltonians, where the non-analyticity of the fidelity is directly related to the non-analyticity of therelevant response functions (susceptibility and heat capacity), for the case of symmetry-breaking transitions. Further, on the case of BCS theory of superconductivity, given by mutually non-commuting Hamiltonians, we analyze the structure of the system'seigenvectors in the vicinity of the line of the phase transition showing that their sudden change is quantified by the emergence of a generically non-trivial Uhlmann mixed state geometric phase, the mixed-state generalization of the Berry geometric phase.

Finally, we introduce a partial state fidelity approach to quantum phase transitions [3]. We consider a superconducting lattice with a magnetic impurity inserted at its centre, and look at the fidelity between partial (either one-site or two-site) quantum states. In the vicinity of the point of the quantum phase transition, we observe a sudden drop of the fidelity between two one-site partial states corresponding either to the impurity location or its close vicinity. This enables us to identify the on-site magnetization as the order parameter for the phase transition studied. In the case of two-site states, the fidelity reveals the transition point as long as one of the two electron sites is located at the impurity, while the other lies elsewhere in the lattice.

References

[1] P. Zanardi and N. Paunković, Phys. Rev. E 74, 031123 (2006).
[2] N. Paunković and V. R. Vieira, Phys. Rev. E 77, 011129 (2008).
[3] N. Paunković, P. D. Sacramento, P. Nogueira, V. R. Vieira and V. K. Dugaev, accepted for publication in PRA, arXiv:0708.3494v1 [quant-ph].

Perina Jan **(2)** **Talk**

Generation of entangled photon pairs from nonlinear layered structures

Jan Perina, Jr.[1], Marco Centini[2], Concita Sibilia[2], Mario Bertolotti[2], Michael Scalora[3]
[1]Joint Laboratory of Optics, Palacky University and Institute of Physics of AS CR, Olomouc, Czech Republic
[2]Dipartimento di Energietica, Universita La sapienza di Roma, Italy
[3]Charles M. Bowden Research Center, RD & EC, Alabama, USA
perinaj@prfnw.upol.cz

Vectorial quantum model of spontaneous parametric down-conversion in nonlinear layered media considering both cw and pulsed pump fields will be discussed [1]. Relation between transmissivity of a nonlinear structure and ability to generate eficiently entangled photon pairs will be elucidated using several structures made of GaN/AlN and operating in visible spectral range. Also transverse intensity profiles of the down-converted fields and correlation areas of the signal and idler beams will be mentioned. Generation of photon pairs at a boundary of two dielectrics and its contribution to photon-pair generation rate will be discussed. As special cases, emission of photon pairs from random 1D structures and emission of entan-gled photon pairs anti-symmetric in frequencies will be discussed [2]. Temporal anti-bunching and anti-coalescence on a beam splitter are typical properties of states anti-symmetric in frequencies.

References

[1] J. Perina Jr., M. Centini, C. Sibilia, M. Scalora, M. Bertolotti, Phys. Rev. A 73, 033823 (2006).
[2] J. Perina Jr., M. Centini, C. Sibilia, M. Bertolotti, and M. Scalora, Phys. Rev. A 75, 013805 (2007).

Perinova Vlasta (1) **Talk**

Propagation of radiation in the state with at most one photon in a dielectric

V. Perinova and A. Lukš
Laboratory of Quantum Optics, Faculty of Natural Sciences
Palacky University, Olomouc, Czech Republic
perinova@prfnw.upol.cz

We examine the problem of a source atom radiating into a dielectric. The change in propagation velocity occurs also in the case where the electromagneticfield is in the state with at most one photon. The atom is located at the centre of a dielectric sphere of a finite radius according to [Berman (2007)]. A microscopic approach is adopted. For the medium to be isotropic, four-level dielectric atoms in the configuration of inverted tripod are assumed [Berman and Milloni (2004)]. The possibility of a continuum approximation is investigated.

References

1. P. R. Berman, Phys. Rev. A 76, 042106 (2007).
2. P. R. Berman and P. W. Milloni, Phys. Rev. Lett. 92, 053601 (2004).

Popov Andrey (4) **Poster**

Beryllium Atoms in Intense Fields

Andrey Popov
Altai State Technical University, Barnaul, Russian Federation
Popov.Barnaul@mail.ru

Deep and full enough understanding of interaction of atoms and clusters (building elements of created materials) is required for purposeful creation of nanostructural materials in a mode of "self-assembly". The most complex evolution of atoms and clusters occurs in conditions of external fields by means of which it is possible to operate these processes. The most complete and deep understanding of processes, which happen while clusters passing from one metastable state to another, can be achieved only by using such *ab initio* theory which allows calculating a set of different properties of material in the framework of unified scheme. By using calculations based on an *ab initio* theory one can get a complete knowledge about the properties of a matter which even is not yet synthesized.

For the description of the excited states of atoms and clusters, we have made generalization of the idea offered in [1]. The given idea is based on refusal of boundary conditions of wave function on the polar variable which are connected with "orbital" excitations. On trying all the boundary conditions it is possible to select realizable excitation with the minimum of total energy of the given system and to track the change of its spectral characteristics caused by orbital transitions of electrons. The Hartree-Fock method was used as the basic one for numerical realization. Note that, this eigenvalue problem is essentially non-Hermitian, with complex values of energies. The problem was solved numerically in a basis of Gaussian functions.

It is shown that, during the excitation of a beryllium atom in the X-ray energy range, the following processes occur: 1) the splitting of the 2p states increases with increasing excitation energy; 2) the probability of decay of the excited state of an atom drops starting from an excitation energy 6.7 Ry (i.e., the excited state is observed to be stabilized); and 3) the 2s and 2p states are observed to mix at excitation energies of 10 and 14 Ry. In the optical range of excitation energies, a condensed excited state of beryllium with a lifetime on the order of 0.1 fs was revealed [2].

By the example of beryllium the basic opportunity of the method to predict existence of long-living excitations is shown. It is shown, that except for experimentally observable stable clusters with distances between atoms of the order of 4 Bohr radiuses, existence of long-living excitations in beryllium clusters with distances between atoms of the order of 11 Bohr radiuses is possible. Existence of condensed excited states in beryllium clusters with distances between atoms of the order of 11 Bohr radiuses can be explained by strong correlations of electrons in external fields.

References

[1] A.V. Popov, Optics and Spectroscopy **93**, 1 (2002).
[2] A.V. Popov, Plasma Physics Reports **31**, 253 (2005).

Popov Dušan **(1)** **Poster**

Pair-coherent states of the pseudoharmonic oscillator

Dušan POPOV [1], *Vjekoslav SAJFERT* [2]
[1] University "Politehnica" of Timisoara, Romania, e-mail: dusan_popov@yahoo.co.uk
[2] Technical Faculty "M. Pupin" Zrenjanin, University of Novi Sad, Serbia, e-mail: sajfertv@vektor.net

In the paper we have constructed and examined some properties (as well as non classical statistics, correlation effects, *Q*- and *P*- functions) of pair-coherent states (pair-CSs) for two non interacting subsystems (*a* and *b*) of pseudoharmonic oscillators (PHOs). The PHO is an intermediate anharmonic oscillator situated (on an anharmonicity scale) nearly to the harmonic oscillator (HO) than to other oscillators with stronger anharmonicity.

Moreover, the PHO obeys the SU(1,1) group symmetry which was extensively used to study many problems in quantum optics. For the PHO quantum systems it is possible to construct three kinds of CSs: Barut-Girardello (BG-CSs), Klauder-Perelomov (KP-CSs) and Gazeau-Klauder (GK-CSs) [1], [2], [3]. Based on the properties of the CSs for an individual system of PHOs, in the present paper we have examined the pair-BG-CSs for the PHO, defined as:

$$K_-^{(a)} K_-^{(b)} \,|\, z;k;q >= z \,|\, z;k;q > , \tag{1}$$

$$\left(K_3^{(b)} - K_3^{(a)}\right) |\, z;k;q >= q \,|\, z;k;q > , \tag{2}$$

where $K_{-,3}^{(a,b)}$ are the SU(1,1) group generators of the subsystems *a* and *b*, z is the complex variable which characterize the CSs, k is the Bargman index which labels the UIR and q is a constant representing the difference between the boson numbers in both modes.

Explicit development of the pair-BG-CSs in the Fock vector basis $|\, n, n+q;k >=|\, n;k > \otimes |\, n+q;k >$ is of the following manner:

$$|\, z;k;q >= \frac{1}{\sqrt{{}_0F_3\left(;2k, q+1, q+2k; |z|^2\right)}} \sum_{n=0}^{\infty} \frac{z^n}{\sqrt{\rho(n;k;q)}} \,|\, n, n+q;k > , \tag{3}$$

where ${}_0F_3\left(;2k, q+1, q+2k; |z|^2\right)$ is the hypergeometric function and

$$\rho(n;k;q) = \Gamma(n+1)\frac{\Gamma(2k+n)}{\Gamma(2k)}\frac{\Gamma(q+n+1)}{\Gamma(q+1)}\frac{\Gamma(q+2k+n)}{\Gamma(q+2k)} \tag{4}$$

are the structure constants of the pair-BG-CSs (here $\Gamma(x)$ are the Euler's Gamma functions).

We have examined the nonclassical properties of these pair-CSs, by calculating the corresponding Mandel parameter and also by using the density operator formalism: both for pure states (a pair-CSs projector) and for mixed (thermal) states. Generally, the CSs approach not only greatly simplifies the calculations of various expectation values for the examined quantum system, but also may be of potential use in developing the quantum information theory. The pair-CSs are important in quantum information processing (as a quantum transmission channel [4]) and also in the physics of nano systems (quantum dots, quantum wells, nano tubes and nano wires [5]). These kinds of systems have been extensively used, in the last decades, among others, also in solar photovoltaics.

References

[1] D. Popov, J. Phys. A: Math. Gen. **34**, 5283 (2001).
[2] D. Popov, D. M. Davidović, D. Arsenović and V. Sajfert, Acta Phys. Slovaca **56**, 445 (2006).
[3] D. Popov, V. Sajfert and I. Zaharie, Physica A doi: 10.1016/j.physa.2008.02.062 (2008).
[4] A. Gabris, G. S. Agarwal, arXiv:quant-ph/0607162 (2006).
[5] B. Tošić, V. Sajfert, D. Popov, J. Šetrajčić, D. Ćirić, *Primena diferencnog računa u analizi nanostruktura*, VANU, Novi Sad, 2005.

Predojević Ana **(7)** **Poster**

Narrowband Rb-Resonant Diode Laser-Based Squeezing Source for Quantum Memories

A. Predojevic[1], *Z. Zhai*[1], *E.S. Polzik*[1,2], *M. W. Mitchell*[1]
[1]ICFO, Mediterranean Technology Park, 08660 Castelldefels (Barcelona), Spain
[2]Quantop, Niels Bohr Institute, Copenhagen University, Denmark
ana.predojevic@icfo.es

We present a rubidium resonant source of squeezed light pumped by a diode laser and equipped with a computer controlled locking scheme. To produce squeezed light, we use the proven technique of downconversion in a subthreshold OPO [1].
Compared to Ti:Sapphire laser systems, diode lasers are easy to operate, versatile and much lower priced in acquisition and maintenance. However, the excess phase noise of the diode laser limits its coherence length, and for a long time it was believed that squeezed light could not be produced using diode lasers.

Our laser system consists of an external-cavity diode laser which is amplified by an optical tapered amplifier and then frequency doubled in an LBO doubling cavity. The complete system of diode laser, amplifier and doubling stage is commercially available. We stabilized this system to the F=2 $\rightarrow$ F\`=1 transition of ^{87}Rb by a standard FM locking technique. The lock of the laser to the atomic sample takes effect via the piezo-electric transducer of the laser external cavity and the speed of its response is limited by the response of the piezo. The lock of the doubling cavity to the laser is much faster consisting of both a slow response part acting on the cavity piezo and a fast response part acting on the current of the diode. The fast part of the lock affects the laser linewidth which can be set in the range 300-400 kHz.

The output of the laser system is mode-matched to a doubly-resonant OPO cavity in bow-tie configuration and 10mm long PPKTP as nonlinear material. Both the lock of the laser to the atomic resonance and the lock of the OPO are performed via a PID control programmed on a National Instruments FPGA card.

The power of the OPO pump is 45mW which leads to rather low gain of 3. Consequently the squeezing obtained was gain limited but it was at the level -2.5dB at 2MHz demodulation frequency which is consistent with the expected high escape efficiency and moderate losses after the cavity. These losses include the homodyne efficiency, losses on propagation and the detectors quantum efficiency and all together are 16%. This number is obtained by comparing the theoretical degree of squeezing at the gain of 3 and the experimental results we obtained.

The local oscillator excess phase noise results from two factors: the noise spectrum of the diode itself and the delay introduced in the squeezed beam by different cavities. These two sources of noise simultaneously increase the phase variance. We have performed a series of measurement where a controllable delay was introduced in the path of the local oscillator. During these measurements the linewidth of the laser was 400 kHz. These measurements show a clear influence of the delay introduced in the local oscillator path on the degree of squeezing.

With these measurements we have proven that it is possible to generate squeezing light in downconversion in the OPO when the pump laser is a diode laser. Furthermore we have shown the conditions in which this process is feasible having in mind the origin of the excess phase noise.

References

[1] G. Hétet, O. Glöckl, K.A. Pilypas, C.C. Harb, B.C. Buchler, H.-A. Bachor, P.K. Lam, “Squeezed Light for Bandwidth-Limited Atom Optics Experiments at the Rubidium D1 Line” *J. Phys. B: At. Mol. Opt. Phys.* **40**, 221 (2007)

Radonjić Milan **(5)** **Talk**

Line-shapes and widths of CPT resonances - laser beam profile and atomic polarization effects

Milan Radonjić, Dušan Arsenović and Branislav M. Jelenković
Institute of Physics, Belgrade, Serbia
milanr@phy.bg.ac.yu

This work is concerned with the line profiles, amplitudes and widths of the coherent population trapping (CPT) resonances due to low frequency Zeeman coherences, in the Hanle configuration, applied to Rb atoms in the vacuum cell. Detailed calculations of the transmission of laser tuned to either open or closed F_g=2 to F_e=1 transitions were done with different transverse intensity profiles of the excitation laser beam. Calculations will be reported as a function of the laser intensity. These analyses will extend previous calculations of effects of the laser beam profile [1] and of the laser intensity [2] on line widths of the CPT induced between hyperfine levels of the ground state of Rb.

References
[1] A. V. Taichenachev et all., Phys. Rev. A 69, 024501 (2004).
[2] C. Y. Ye, A. S. Zibrov, Phys. Rev. A 65, 023806 (2002).

Radovanović Jelena **(8)** **Poster**

Modeling of dwell time and group delay in dispersive and absorptive media

Igor Ilić[1], *Petra P. Beličev*[1], *Vitomir Milanović*[2] *and Jelena Radovanović*[2]
[1]Vinca Institute of Nuclear Sciences, Atomic Physics Laboratory, Belgrade, Serbia
[2]Faculty of Electrical Engineering, University of Belgrade, Serbia
igi.ilic@gmail.com

In this paper a more general expression that describes relationship between dwell time and group delay is derived. This expression is valid for all kind of materials, including negative index metamaterials (NIMs) [1]. An obstacle made of double negative NIMs (DN-NIMs) and surrounded by a double-positive waveguide, was used as a model [2]. In cases when the obstacle was made of left-handed materials and the surroundings was air, it has been shown that dwell time and absorption have similar dependences of incident wave frequency. On the other hand, group delay becomes negative in some cases. Numerical results show that increasing of the length of the obstacle leads to saturation of dwell time and absorption, which is in accordance with the phenomenon known as the Hartman effect [3]. Similar results are acquired for THz range of frequencies and for dispersive waveguide. In this case, it is shown that there is a certain range of frequencies where group velocity is positive, while phase velocity remains negative, i.e. peak of the output pulse appears before the peak of the input pulse. Finally, the use of a model which considers an obstacle made of a lossless, non-magnetic metamaterial, with background permittivity equal to 1 and a dispersive waveguide, leads to appearance of a new delay, called self-interference time [4].

References
[1] U. K. Chettiar, A. V. Kildishev, H.-K. Yuan, W. Cai, S. Xiao, V. P. Drachev, V. M. Shalaev, Opt. Lett. **32**, 1671-1673 (2007)
[2] R. Ruppin, Phys. Rev. A **299**, 309-312 (2002)
[3] T. E. Hartman, J. of Appl. Phys. **33**, 3427 (1962)
[4] H. G. Winful, Phys. Rev. B **68**, 016615 (2003)

Rauch Helmut **(1)** **Invited talk**

Basic Quantum Irreversibility in Neutron Interference Experiments

Helmut Rauch
Atominstitut der Oesterreichischen Universitaeten, A-1020 Wien, Austria
rauch@ati.ac.at

The quantum behavior of massive particles is well described by quantum mechanics usually treated as fully reversible. A more complete quantum approach has to include small terms which are often neglected in the formalism [1]. Such terms arise for instance from unavoidable reflection processes when a particle enters an interaction region or when the

plane wave assumption is made, which contradicts in many aspects the spirit of quantum mechanics. Situations existing in spin- and phase-echo experiments will be discussed, which show that a complete retrieval of a quantum state is impossible in principle. It will also be shown that in nearly all experiments there is much more information in the data sets as extracted, which makes several conclusions more mystic than necessary. These phenomena have been demonstrated in various post-selection experiments performed by means of neutron interferometry. The EPR-situation and the quantum ZENO-effect will be discussed in detail, because they show clearly that quantum phenomena have to be considered in phase space rather than in ordinary space only. Non-locality of quantum theory seems to be connected with the coupling in phase space. Recent experiments have demonstrated quantum contextuality as an entanglement effect in a single particle system [2].

References

[1] H. Rauch, "Towards More Quantum Complete Neutron Experiments" in: Quantum [Un]speakables. R. Bertlmann, A. Zeilinger, Eds. Springer Verlag, Berlin-Heidelberg-New York, 2002, ISBN: 3540427562, 351-373

[2] Y. Hasegawa, R. Loidl, G. Badurek, M. Baron, H. Rauch, "Quantum contextuality in a single-neutron optical experiment", Phys. Rev. Lett. 97 (2006) 230401-230404

Roknizadeh Rasoul **Poster**

Spatial confinement effects on quantum field theory using nonlinear coherent states approach

M.Bagheri Harouni, R. Roknizadeh[1], M. H. Naderi
Quantum Optics Group,Physics Department, University of Isfahan, Isfahan, Iran
[1]rokni@sci.ui.ac.ir, rasoul_roknizadeh@yahoo.com

We study some basic quantum confinement effects through investigation a deformed harmonic oscillator algebra. We show that spatial confinement effects on a quantum harmonic oscillator can be represented by a deformation function within the framework of nonlinear coherent states theory. Using the deformed algebra, we construct a quantum field theory in confined space. In particular, we find that the confinement influences on some physical properties of the electromagnetic field and it gives rise to nonlinear interaction. Furthermore, we propose a physical scheme to generate the nonlinear coherent states associated with the electromagnetic field in a confined region.

Salomon Christophe **Invited talk**

Precision Time Measurement and Fundamental Physics

Christophe Salomon
Laboratoire Kastler Brossel
Ecole Normale Supérieure
24 rue Lhomond, 75231 Paris, France
salomon@lkb.ens.fr

We will first describe the present status for the realization of the SI unit of time, the second. Microwave frequency standards operating with laser cooled cesium and rubidium atoms have advanced by two orders of magnitude in the last two decades. Cesium fountains currently operate at the fundamental quantum noise limit with 10^7 detected atoms and display a relativefrequency stability of 1.5 10^{-16} after 50 000 seconds of averaging time [1]. The SI second is realized with an accuracy of 3 10^{-16} implying an error of less than a second over 100 million years.

In a second part, we will describe tests of fundamental physical laws using ultra-stable clocks in space and on the ground. By comparing clocks of different nature new limits are obtained for the time variation of the fundamental constants of physics such as the fine structure constant alpha. The ability to compare microwave and optical clocks using the newly developed frequency comb technique opens a wide range of possibilities in clock comparisons.

By installing in space an ultra-stable cold atom clock (European ACES/PHARAO project for flight in 2013), improved tests of general relativity will be performed, such as a measurement of Einstein's gravitational red-shift at the one part per million level [2]. A new kind of relativistic geodesy based on the Einstein effect will provide information on the Earth geoïd. Finally prospects for laser cooled atomic clocks operating in the optical domain with frequency stability in the 10^{-18} range will be outlined.

References
[1] S. Bize et al, J. Phys. B: At. Mo. Opt. Phys., **38**, 449 (2005).
[2] C. Salomon, L. Cacciapuotti, and N. Dimarcq, Int. Journ. Mod. Phys. D **16**, 2511 (2007).

Sambale Agnes **(1)** **Talk**

Interaction of an atom with absorbing left-handed media

Agnes Sambale, Dirk-Gunnar Welsch, Ho Trung Dung, Stefan Yoshi Buhmann
Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universitat Jena, Max-Wien-Platz 1, D-07743 Jena, Germany
agnes.sambale@uni-jena.de

Left-handed materials have gained in importance during the last decade since their fabrication has become feasible (e.g. [1]) and novel effects due the negative index of refraction of such materials have been predicted [2,3]. Within the framework of macroscopic quantum electrodynamics, we discuss the resonant van der Waals potential experienced by an excited two-level atom near a planar magnetodielectric three-layer system which contains a slab of left-handed material. It is shown that care should be taken when assuming an absolutely nonabsorbing medium, which leads to unphysical results with divergent values for the potential away from the surface. Under appropriate conditions, the geometry is found to exhibit a repulsive barrier near the surface which can be employed to levitate particles or used as a trapping mechanism. This effect is governed by the magnetic properties of the system rather than resulting from the lefthandedness [4].

Further, the spontaneous decay rate of an excited atom in the same system is studied where drastic differences between the absolutely nonabsorbing case [3] and the case of a tiny but nonvanishing absorption are pointed out. We find that doubling or strong reduction of the spontaneous decay rate at particular atom-slab distances, which has been predicted for lefthanded media, can also occur for right-handed (meta-) materials [4].

References

[1] H. J. Lezec, J. A. Dionne, and H. A. Atwater, Sci. 316, 430 (2007).
[2] J. B. Pendry, Phys. Rev. Lett. 85, 3966 (2003).
[3] J. Kastel, and M. Fleischhauer, Laser Phys. 15, 135 (2005).
[4] A. Sambale, D.-G. Welsch, S. Y. Buhmann, Ho Trung Dung, van der Waals interaction and spontaneous decay of an excited atom in a planar meta-material structure, eprint quantph/ 0711.3369 (2007), to be published.

Sanz Angel S. **(1)** **Talk**

Bohmian mechanics: A trajectory picture of quantum mechanics

A. S. Sanz and S. Miret Artés
Instituto de Física Fundamental, Madrid, Spain
asanz@imaff.cfmac.csic.es

At least, up to date, quantum mechanics can be considered the most successful, fundamental theory that we have to explain the Physical World around us. Nevertheless, despite its success, it presents an important fundamental problem: independently of the version considered (Heisenberg, Schrödigner or Feynman), its descriptions are purely probabilistic-statistical. Quantum mechanics only provides probability distributions to describe systems, but no clue on its particular dynamics to go from the initial state to the final one, as happens in classical mechanics. This is not a problem, of course, if we only want to explain the data patterns obtained from an experiment; their distributions are well described by the corresponding quantum probability distributions. However, before observing such results, there is a process in which such patterns are constructed by collecting single events. Standard quantum mechanics cannot describe the dynamics displayed by these single events, but only their ensemble statistics.

In order to explain and describe single-event dynamics, as well as to later interpret the subsequent ensemble statistics, different trajectory-based approaches have been proposed in the literature. One of these approaches is Bohmian mechanics [1-3]. This theory is a direct and exact reformulation of standard or conventional quantum mechanics which arises after rearranging conveniently the time-dependent Schrödiger equation. Within this theory it is possible to follow the single-event dynamics at the same time that, collecting many of them (as in a real experiment), one can reproduce the distributions rendered by the standard quantum mechanics [4,5]. The interpretational power of Bohmian mechanics thus goes beyond standard quantum mechanics and also classical trajectory formalisms, since the dynamics displayed by (Bohmian) quantum trajectories is ruled by external classical potentials and also by a quantum potential. This makes the quantum motion to be very different from the classical one and so the interpretations based on quantum and classical grounds.

Here we will show the applicability and interest of Bohmian mechanics in different problems related to the optics of material particles, such as slit diffraction and interference [5,6], the Talbot effect [7] or waves in cavities [7,8]. This theory not only helps to understand different theoretical and practical (numerical) aspects involved in this field, but also to provide new insights into phenomena whose previous interpretations lied on classical and/or semiclassical analysis.

References

[1] D. Bohm, *Phys. Rev.* **85**, 166, 184 (1952).
[2] P. R. Holland, *The Quantum Theory of Motion* (Cambridge University Press, 1993).
[3] A. S. Sanz and S. Miret-Artés, *Trajectory Formulations of Quantum Mechanics* (to appear in the Springer series "Lecture Notes in Physics", 2009).
[4] A. S. Sanz, F. Borondo and S. Miret-Artés, *Phys. Rev. B* **61**, 7743 (2000).
[5] A. S. Sanz, F. Borondo and S. Miret-Artés, *J. Phys.: Condens. Matter* **14**, 6109 (2002).
[6] A. S. Sanz and S. Miret-Artés, in *Quantum Dynamics of Complex Molecular Systems*, edited by D. Micha and I. Burghardt, **83** (Springer, Berlin, 2006), p. 343.
[7] A. S. Sanz and S. Miret-Artés, *J. Chem. Phys.* **126**, 234106 (2007).
[8] A. S. Sanz, *J. Phys. A* **38**, 6037 (2005).

Savić Sević Svetlana **(8)** **Poster**

Experimental measurement of photonic bands gaps in holographic photonic crystals

Svetlana Savic Sevic , *Dejan Pantelic and Branislav Jelenkovic*
Institute of Physics, Belgrade, Serbia
savic@phy.bg.ac.yu

One and two dimensional photonic crystals are fabricated in a dichromate-sensitized pullulan by holography. One – dimensional photonic crystals are created as volume reflection holograms [1-2]. Two - dimensional photonic crystals are generated as surface relief structures by double-exposure holographic method [3]. A single-frequency, diode pumped Nd-YAG laser, at 532 nm, is used for exposure. Band gaps in the visible range are observed.

References

[1] Z. Ye, J. Zheng, D. Liu, S. Pei, Physics Letters A **299***,* 313 (2002).
[2] R. Ma, J. Xu, and W. Y. Tam, Applied Physics letters **89**, 081116, (2006).
[3] R. C. Gautheir, K. W. Mnaymneh, Optics & Laser Techology **36**, 625 (2004).

Šćepanović Maja **(8)** **Poster**

Raman spectroscopy of anatase TiO_2 nanopowders doped with various contents of La^{3+}

M. Šćepanović[1], V. Berec, S. Aškrabić[1], A. Golubović[1], Z. Dohčević-Mitrović[1], A. Kremenović[2], and Z. V. Popović[1]
[1]Center for Solid State Physics and New Materials, Institute of Physics, Belgrade, Serbia
[2]Faculty of Mining and Geology, Laboratory for Crystallography, University of Belgrade, Serbia
maja@phy.bg.ac.yu

Anatase TiO_2 nanopowders doped with 1, 2, 3 and 4 wt. % of La^{3+} are synthesized by sol-gel method. Dependence of structural and morphological characteristics of anatase nanopowders on La^{3+} content is investigated by Raman spectroscopy method. In order to estimate variation of nanocrystallite size with dopant content, shift and asymmetrical broadening of the most intensive E_g Raman mode of anatase are analyzed by phonon confinement model [1, 2]. Obtained results are compared with the results of XRD spectroscopy. Special attention is dedicated to the anharmonic behavior of all anatase Raman modes observed in high temperature Raman spectra [3] of nanopowders synthesized with different La^{3+} content.

The influence of dopant content and synthesis conditions on the additional Raman modes of extremely low intensity is also analyzed. These modes may be related to the presence of small content of brookite amorphous phase [4] in nanopowders.

References

[1] M. J. Šćepanović, M. U. Grujić-Brojčin, Z. D. Dohčević-Mitrović, and Z. V. Popović, Mater. Sci. Forum **518**, 101 (2006).
[2] M. J. Šćepanović, M. Grujić-Brojčin, Z. Dohčević-Mitrović, Z. V. Popović, Appl. Phys. A **86**, 365 (2007).
[3] Y. L. Du, Y. Deng, and M. S. Zhang, J. Phys. Chem. Solids **67**, 2405 (2006).
[4] Y. Djaoued, R. Bruning, D. Bersani, P. P. Lottici, and S. Badilescu, Mat. Lett. **58**, 2618 (2004).

Skenderovic Hrvoje **(7)** **Invited talk**

Four Wave Mixing with femtosecond pulses

Hrvoje Skenderović
Institute of Physics, Zagreb, Croatia
hrvoje@ifs.hr

Recent development of noncolinear optical parametric amplifiers (NOPA) equipped many laboratories with the widely tunable, spectrally broad ultrashort laser pulses with duration of 15 to 30 fs. Among other applications we find that this source has a very important role in a fs time-resolved four-wave mixing experiments (FWM). In the various FWM schemes in time domain, like coherent anti-Stokes Raman scattering (CARS), degenerate FWM (DFWM) and coherent Stokes Raman scattering (CSRS), the shape of the transients and the embedded information depend crucially on the bandwidth of the pulses.

In the first part of the talk we present fs CARS and DFWM measurements in hydrogen which can be used for temperature measurements. Time-resolved fs spectroscopy on vibrational Q-branch transition [1] and on pure rotational Raman transitions [2] shows the full potential of ultrashort pulse FWM.

The second part of the talk deals with sub-20 fs pulsed DFWM on high frequency vibrational levels in *all-trans-β carotene*. Wave-packet motion on the electronic ground and excited dark state was observed [3]. Moreover, we show that pump-DFWM in combination with spectral detection can be applied to the study of complex molecular systems, where optically dark electronic states are common.

In the third part of the talk the coherent control in an open loop is demonstrated with FWM in *all-trans-β carotene*. The difference between resonant and non-resonant case clearly shows enhancement of Raman modes in the resonant case [4].

References

[1] H. Skenderović, T. Buckup, W. Wohlleben, and M. Motzkus, J. Raman Spectrosc. **33**, 866 (2002).
[2] T. Hornung, H. Skenderović, K-L. Kompa, and M. Motzkus, J. Raman Spectrosc. **35**, 934 (2004).
[3] T. Hornung, H. Skenderović, and M. Motzkus, Chem. Phys. Lett. **402** 283 (2005).
[4] J. Hauer, H. Skenderović, K-L. Kompa, and M. Motzkus, Chem. Phys. Lett. **421** 523 (2006).

Solomon Allan **(1)** **Talk**

Quantum Entanglement and Braid Groups

Allan Solomon
Dept. Phys, & Astronomy, Open University Walton Hall MK7 6AA, UK
a.i.solomon@open.ac.uk

The objective of this talk is to show that the relation between Quantum Entanglement and Topological Entanglement is more than one of linguistic analogy. We first explore the problem of extending the Von Neumann entropy-type of entanglement measure to a tripartite system, showing how a naive extension fails. We relate this case to the theory of links, specifically the model of the Borromean rings, and on the basis of this analogy introduce the theory of Braid Groups. We then discuss the relation between standard representations of these groups (Burau representations) and unitary entanglement-producing operators in the quantum case

Stef Marius **(8)** **Poster**

Some dielectric and optical properties of PbF_2 and YbF_3-doped CaF_2 crystals

Marius Stef, Gabriel Buse, Andreea Pruna and Irina Nicoara
West University of Timisoara, Dept. of Physics Timisoara, Romania
stef@quantum.physics.uvt.ro

The alkaline-earth fluorides crystals doped with rare-earth (RE) ions are good laser materials. Trivalent RE ions in CaF_2 tend to form pairs of adjacent ions, for charge compensation, even at low dopant concentrations. The extra positive charge is usually compensated by interstitial F_i^- ions. The resultant dipolar complexes can reorient by "jumps" of one of the charges to other lattice sites. Information on impurity-defect aggregates can be obtained from spectroscopic and dielectric relaxation techniques, the last being sensitive to aggregates with a dipole moment which can reorientate through migration of the anions. In order to use the laser properties of the crystals it is necessary to study their defect properties. Temperature and frequency dependence of the complex dielectric constant give information about the relaxation processes and permits the determination of the activation energy and the reciprocal frequency factor of the relaxation time [1, 2].

The objective of the paper is to analyze the effect of Yb^{3+} and $Pb2^{+}$ ions on the optical and dielectric spectra of CaF_2 crystals, to determine the activation energy of various structural defects in doped crystals.

YbF_3, PbF_2 doped CaF_2 crystals and (YbF_3 + PbF_2) :CaF_2 crystals have been grown using the vertical Bridgman method [3]. Transparent crystals of about 10mm diameter over 6-7cm long were obtained in spectral pure graphite crucible in vacuum ($\approx 10^{-1}$ Pa). The pulling rate was 4mm/h. In order to obtain good-quality CaF_2 crystals, an addition of PbF_2 is necessary as a scavenger of oxygen impurities. If the crystal growth process is not correctly established the obtained crystals may contain some amount of undesired lead ions. This is the reason why in this work we study the influence of Pb^{2+} ions on the optical and dielectric spectra of YbF_3-doped CaF_2 crystals.

Room temperature optical absorption spectra were recorded by a Shimadzu 1650 PC. The dielectric measurements were performed using a RLC Meter ZM 2355, over the temperature range 150–300 K, at five audio-frequencies 1–100 kHz. The real part of the dielectric constant, ε_1, has been calculated from the measured capacitance. The ε_2 has been then calculated from $D = \varepsilon'' / \varepsilon'$. The activation energy and the reciprocal frequency factor have been calculated in order to characterize the observed relaxations. The influence of the Pb^{2+} ions on the optical and dielectric spectra of YbF_3:CaF_2 crystals were analyzed.

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References

[1] J. Fontanella, D.J. Treacy, J. Chem. Phys. **72**, 2235,(1980).
[2] C. Andeen, J. Fontanella et al., J. Phys. C.: Solid State Phys. **14**, 3557 (1981).
[3] D. Nicoara and I. Nicoara, Mater. Science and Eng. A **102**, L1 (1988).

Stobinska Magdalena (10) Talk

Perfect Photon-Atom Coupling in Free Space

Magdalena Stobinska[1], *Luis L. Sanchez-Soto*[2] *and Gerd Leuchs*[1]
[1]Institute fur Optik, Information und Photonik, Max-Planck Forschungsgruppe, Universitat Erlangen-Nurnberg, Gunter-Scharowsky-Str. 1, Bau 24, 91058, Germany
[2]Departamanto de Optica, Facultad de Fisica, Universidad Complutense, 28040 Madrid, Spain
fizia@nor.pl

The main goal of this work is the theoretical investigation of a perfect photon-atom coupling in a free space. So far only 10% of coupling in experiment has been achieved. We show that by strong focusing and tailoring polarization pattern of the beam this limit can be overcome. Our experiment is in progress. This research also addresses spontaneous emission in free space time reversibility for a single trapped ion. The time reversion of the unitary process (evolution), although possible in principle, has never been demonstrated explicitly for spontaneous emission.

Special attention will be paid to an issue of coupling between light and a single atom (ion) in order to determine the probability of the time-inversed spontaneously emitted photon to be re-absorbed.

Strong coupling between light and matter is also a milestone towards teleportation of a state of an atom to a light beam; a protocol which has also never been realized experimentally so far. It also addresses another hot topic in quantum information which is coupling between ying and stationary qubit allowing quantum state transfer between distant nodes. It can also find applications in quantum repeaters.

Svozilik Jiri (2) Poster

Periodically poled nonlinear crystals as a useful source of entangled photon pairs

Jiri Svozilik[1] *and Jan Perina jr.*[2]
[1, 2] Joint Laboratory of Optics of Palacky University and Institute of Physics of Academy of Sciences of the Czech Republic, 17. listopadu 50A, 772 00 Olomouc, Czech Republic
svozilik@optics.upol.cz

We describe properties of entangled photon pairs generated by spontaneous parametric down-conversion in periodically poled nonlinear crystals [1]. These materials can serve as a useful bright source of photon pairs which properties can be tailored on demand. Especially photon pairs with broad spectra and sharp temporal characteristics can be observed. Both uniform poling and chirped poling are considered. Spectral properties of the generated photons, photon fluxes, coincidence-count patterns in a Hong-Ou-Mandel interferometer [2], entropy of entanglement [3,4], as well as transverse profiles of intensities of the generated photons are investigated in detail and discussed. Mathematical model introduced in [5] is adopted in these calculations. We show that knowing spectra of both photons entropy of entanglement and Schmidt number can be directly determined. Also correlation area of two photons comprising a photon pair has been studied as it depends on parameters of periodical poling.

References
[1] D. S. Hum, M. M. Fejer, C.R.Physique, 8 (2007).
[2] C. K. Hong, Z. Y. Ou, L. Mandel, Phys. Rev. Lett., 59, 2044 (1987).
[3] C. K. Law, J. H. Eberly, Phys. Rev. Lett.,92 ,127903 (2004).
[4] C. K. Law, I. A. Walmsley, J. H. Eberly,Phys. Rev. Lett., 84, 5304(2000).
[5] J. Perina Jr., M. Centini, C. Sibilia, M. Bertolotti, M. Scalora, Phys. Rev. A, 73, 033823 (2006).

Tadić Milan **(8)** **Talk**

Excitons in stacks of semiconductor quantum rings

Milan Tadić[1] *and François M. Peeters*[2]
[1]Faculty of Electrical Engineering, University of Belgrade, Serbia
[2]Department of Physics, University of Antwerp, Groenenborgerlaan 171, B-2020 Antwerp, Belgium
tadic@etf.bg.ac.yu

Recently, it has been demonstrated that certain modifications of the Stranski-Krastanov growth sequence can change the morphology of lens-shaped InGaAs/GaAs quantum dots into quantum rings. Inhomogeneous strain is present in the structure, which as recently found, facilitates growth of rings in vertical stacks, similar to the case of smaller quantum dots. In the present study, we employ the effective mass model to compute the single-particle electron and hole states in stacks of these quantum rings, and compare the energy spectra with the case of unstrained GaAs/AlGaAs quantum rings. In order to compute the exciton states, we used an exact diagonalization approach, while the continuum mechanical model was employed to compute the strain distribution in the InGaAs/GaAs vertically coupled rings. We investigate variations of the exciton energy levels with the spacer thickness and transitions between the lowest exciton states of different angular momenta in a normal magnetic field. The variation of the oscillator strength for exciton recombination was also explored. The essential differences between the two analyzed stacks of nanorings with respect to the dependence on the spacer thickness were found. These differences were attributed to strain. On the other hand, qualitatively similar variations of the exciton states on the magnetic field were obtained in both cases. As a matter of fact, the exciton energy levels were found to exhibit a few angular momentum transitions when the magnetic field increases. These transitions indicate that the *excitonic Aharonov-Bohm* effect is existant in three-dimensional (3D) rings. However, no oscillations in the dependence of the oscillator strength for interband optical transitions were found. Therefore, we were not able to reproduce the *optical excitonic Aharonov-Bohm effect*, which was previously strictly proved to exist in concentric 1D rings.

Tanas Ryszard **Invited talk**

Dynamics of entanglement in a dissipative environment

Ryszard Tanaś[1] *and Zbigniew Ficek*[2]
[1] *Nonlinear Optics Division, Department of Physics, Adam Mickiewicz University, Poznań, Poland*
[2] *Department of Physics, The University of Queensland, Brisbane, Australia*
tanas@kielich.amu.edu.pl

Two two-level atoms, or two qubits, interacting with a common reservoir of vacuum modes of the electromagnetic field, behave collectively. The collective behaviour of the two qubits in such a dissipative environment exhibits some unusual features. Depending on the initial state of the system, entanglement can be created in the process of spontaneous emission [1]. It turn out that initially entangled state of the two-qubit system can disentangle in a finite time [2]. Yu and Eberly called this phenomenon the "sudden death" of entanglement. It has been shown recently that after sudden death of entanglement it is possible to observe the revival of entanglement [3].

We have recently discussed a process opposite to the sudden death of entanglement, the delayed sudden birth of entanglement [4]. It has been shown that in the dissipative process of spontaneous emission, initially unentangled qubits can be entangled after a finite time despite the fact that the coherence between the qubits exist for all time. The threshold time for creation of entanglement can be controlled by by the distance between the qubits and the direction of the initial excitation relative to the interatomic axis. The dynamics of entanglement of the two qubits is described by the Markovian master equation, and many aspects, including sudden death and birth of entanglement, will be discussed.

References

[1] Z. Ficek, R. Tanaś, J. Mod. Opt. 50, 2765 (2003); R. Tanaś, Z. Ficek, J. Opt. B 6, 590 (2004); L. Jakóbczyk, A. Jamróz, Phys. Lett. A 318, 318 (2003).
[2] T. Yu, J. Eberly, Phys. Rev. Lett. 93, 140404 (2004); L. Jakóbczyk, A. Jamróz, Phys. Lett. A 333, 35 (2004).
[3] Z. Ficek, R. Tanaś, Phys. Rev. A 74, 024304 (2006).
[4] Z. Ficek, R. Tanaś, arXiv:0802.4287v1 [quant-ph] (Phys. Rev. A, accepted for publication).

Tomaš Marin Slobodan **(1)** **Poster**

Surface enhanced van der Waals force

Marin-Slobodan Tomaš
Rudjer Bošković Institute, Zagreb, Croatia
tomas@thphys.irb.hr

Recently, we have demonstrated that the (generalized) Sherkunov formula for the interaction energy between an excited and a ground-state atom [1] implies a strong enhancement of the van der Waals (atom*-atom) force near an interface between two media under the circumstances of the resonant coupling of the excited atom to the surface polariton mode of the system [2]. In the present work, we further explore this effect by considering the atom*-atom interaction across an interface between two media. We demonstrate that the nonretarded interaction between the atoms is in this case the same as in an effective medium described by the average dielectric function of the media in contact except for the different local-field correction factor. The estimate performed for the vacuum-sapphire interface shows that the nonretarded van der Waals (atom*-atom) force can be at the surface polariton resonance enhanced by almost three orders of magnitude in comparison with its free-space value. Owing to the the local-field effects in the present configuration this enhancement factor is larger then previously estimated for atoms in front of the same medium [2] by (almost) an order of magnitude.

References

[1] Y. Sherkunov, Phys. Rev. A 75, 012705 (2007).
[2] M. S. Tomaš, J. Phys. A: Mathematical and Theoretical, to be published; http://arxiv.org/abs/0710.3503

Truppe Stefan (1) **Poster**

Scanning tunneling microscopy as a nanolithographic detection scheme for molecule interferometry

Stefan Truppe, Thomas Juffmann, Philipp Geyer, Andras Major, Hendrik Ulbricht and Markus Arndt
Faculty of Physics, University of Vienna, Boltzmanngasse 5, A 1090 Wien
stefan.truppe@univie.ac.at

We present a new way of detecting molecular quantum interferograms and for impressing nanolitographic structures on a silicon surface.

Our research is motivated by the challenge to detect high contrast quantum interferograms of high-mass molecules in a Talbot-Lau-interferometer [1,2] with high efficiency and thus to overcome the limitations of the established ionization detection methods. We here discuss progress made with a detecting screen, i.e. an adsorbing surface, which is then analyzed by a scanning tunneling microscope. The molecules are deposited and immobilized on a Si(111) 7x7 surface [3] which is then transferred to a UHV scanning tunneling microscope system, where we are able to actually "see" individual molecules. Such a scheme is easily scalable to larger particles – as the detection is even facilitated for larger objects. In principle this method will lend itself to future explorations of the molecular Wigner function [4]. Moreover, our interferometer may eventually be used for the fabrication of nanometer-scale molecular structures composed of individual molecules [5].

References

[1] S. Gerlich, L. Hackermüller, K. Hornberger, A. Stibor, H. Ulbricht, F. Goldfarb, T. Savas, M. Müri, M.Mayor and M. Arndt, Nature Physics **3,** 711 (2007).
[2] B. Brezger, L. Hackermüller, S. Uttenthaler, J. Petschinka, M. Arndt, A. Zeilinger, Phys. Rev. Lett. **88**, 100404 (2002).
[3] D. Chen and D. Sarid, *Surf. Sci.,* **1994***, 74*, 318
[4] M. Berry, I. Marzoli and W. Schleich, Physics World, 2001, 1-6
[5] Markus Arndt, Lucia Hackermüller, Anton Zeilinger Proc. 4th EC/NSF Workshop on Nanotechnology, Grenoble, France, June 12.-13. (2002)

Vasić Borislav **(8)** **Poster**

Optical design of 2D confined structures with metamaterial layers based on coordinate transformations

Borislav Vasić[1], Goran Isić[1,2], Radoš Gajić[1] and Kurt Hingerl[3]
[1]Institute of Physics, Belgrade, Serbia
[2]School of Electronic and Electrical Engineering, University of Leeds, Leeds, United Kingdom
[3]Christian Doppler Lab, Institute for Semiconductor and Solid State Physics, University of Linz, Linz, Austria
bvasic@phy.bg.ac.yu

Electromagnetic devices designed using coordinate transformations and based on metamaterials can be used in order to control propagation of electromagnetic waves even in an unexpected way. Some of the devices designed so far using this method are the electromagnetic cloak [1], the omni-directional electromagnetic field concentrator [2], metamaterial coatings for scatterer reshaping [3], and the electromagnetic field rotator [4].

The cloak, being both the firstly proposed and the most prominent among these devices, has been shown to be an idealization requiring unphysical parameters for the metamaterial of which it is comprised. We have discussed [5,6] that if realistic parameters are assumed, the cloak could only reduce the scattering cross section by an order of magnitude.

The above mentioned devices change the electromagnetic field only in a bounded region within the device and do not affect the field behaviour outside. Rahm et al. introduced a new class of coordinate transformations in order to transfer changed electromagnetic field from metamaterial devices to the outer space [7] thus significantly extending the scope and applicability of the coordinate transformation design.

In this paper we propose a novel approach to the coordinate transformation design by discussing 2D confined structures, i.e. structures in which the electromagnetic field is confined in a domain by perfectly conducting boundary conditions. The previous approach is naturally retained by placing the boundary conditions at infinity. For these confined structures, we show that it is possible to change the direction in which the field propagates, narrow down segments of the structure [8] and completely displace its parts without causing any reflection or phase change. This is achieved by the use of appropriate metamaterial layers while the perfectly conducting boundaries are shown to remain invariant under the transformation. Our ideas are confirmed by results of full wave finite element simulations.

References

[1] J. B. Pendry, D. Schurig, and D. R. Smith, Science **312**, 1780 (2006).
[2] M. Rahm, D. Schurig, D. A. Roberts, S. A. Cummer, D. R. Smith, and J. B. Pendry, Photon. Nanostruct.:Fundam. Applic. (2007), doi:10.1016/j.photonics.2007.07013.
[3] O. Ozgun and M. Kuzuoglu, Microwave Opt. Technol. Lett. **49**, 2386 (2007).
[4] H. Chen and C. T. Chan, Appl. Phys. Lett. **90**, 241105 (2007).
[5] G. Isić, R. Gajić, B. Novaković, Z. V. Popović, and K. Hingerl, Acta Phys. Pol. A **112**, (2007).
[6] G. Isić, R. Gajić, B. Novaković, Z. V. Popović, and K. Hingerl, Opt. Express **16**, 1413 (2008).
[7] M. Rahm, S. A. Cummer, D. Schurig, J. B. Pendry, and D. R. Smith, Phys. Rev. Lett. **100**, 063903 (2008).
[8] O. Ozgun and M. Kuzuoglu, IEEE Microw. Wirel. Compon. Lett. **17**, 754 (2007).

Vasile Mihaela **(8)** **Poster**

Luminescent properties of $ZnGa_2O_4$ spinel doped with Eu^{3+} and Er^{3+} ions

Mihaela Vasile[1], Paulina Vlazan[1], Paula Sfirloaga[1], Ioan Grozescu[1] and Emil Rusu[2]
[1]National Institute for Research and Development in
Electrochemistry and Condensed Matter Timisoara, Romania
[2]Institute of Applied Physics, Academy of Sciences of Moldova
mihaela.vasile@icmct.uvt.ro

Nanophosphor of $ZnGa_2O_4$: Eu^{3+} and Er^{3+} were synthesized by hydrothermal method. $ZnGa_2O_4$ is an intrinsic blue light emitter, with a wavelength peak of approximately 450 nm depending on the gallium ratio [1]. A green light emission can be obtained by doping $ZnGa_2O_4$ materials with Mn^{2+} [2] while efficient red light emission is achieved by doping with Cr^{3+} or Eu^{3+} [3] ions. The average size of the crystallites was about 20nm. The luminescent analysis of the materials shows that the rare earth ions are localized in the defect sites at the crystallite boundaries. The emission spectra of the europium doped samples are characterized by an intense emission in red region due to the $^5D_0$ - $^7F_{1,\,2}$ transitions of Eu^{3+} ions, whereas in the case of erbium doping the highest intensity corresponds to the green light emission due to the $^4I_{13/2}$ - $^4I_{15/2}$ transitions of the Er^{3+} ions.

The results of this work reveal the difficulties of the incorporation of rare earth ions in the octahedral sites of the spinelic oxide crystalline lattices. These difficulties are caused by the large radius of the RE ions, that prefer to be located in the sites with coordination number bigger than six. These powders were analyzed by X-ray diffraction (XDR) and characterized by scanning electron microscopy (SEM), energy dispersive spectroscopy (EDAX) and atomic force microscopy (AFM). Photoluminescence (PL) and photoluminescence excitation (PLE) measurements were obtained with a conventional lamp as an excitation source [4].

References

[1] I. J. Hsieh, K. T. Chu, C. F. Yu, and M. S. Feng, J. Appl. Phys. **76**, 3735 (1994)
[2] T. Minami, T. Maeno, Y. Kuroi, and S. Takada, Jpn. J. Appl. Phys. **34,** L684 (1995)
[3] N. M. Kalkhoran, W. D. Halverson, and G. D. Vakerlis, SID **96** Digest 474 (1996)
[4] J. S. Kim, A. K. Kwon, I. S. Kim, H. L. Park, G. C. Kim and S. do Han, J. Lumin., **122-123**, 851 (2007).

Vasiljević Darko **(8)** **Poster**

Influence of chemical processing on imaging properties of microlenses

Darko Vasiljeviuć[1], Branka Murić[1], Dejan Pantelić[1], Bratimir Panić[1]
[1]Institute of Physics, Belgrade, Serbia
e-mail:darko@phy.bg.ac.yu

Microlenses are produced by irradiation of tot'hema eosin sensitized gelatin (TESG) layer with laser light (2nd Nd:YAG harmonic, 532 nm). After production microlenses are chemically processed with various concentration of alum. All obtained microlenses are concave with parabolic profile. Following imaging properties of microlenses are calculated and analyzed: the RMS wave front aberration, the diffraction point spread function cross section and the spot diagram. All microlenses had very well, near diffraction limited, performance for moderate field of view.

References
[1] B. Murić, D. Pantelić, D. Vasiljević, B. Panić, "Microlens fabrication on tot'hema sensitized gelatin," *Opt. Mater*. vol. 30, pp.1217-1220, 2008.
[2] B. D. Murić, D. V. Pantelić , D. M. Vasiljević , B. M. Panić, "Properties of microlenses produced on a layer of tot'hema and eosin sensitized gelatin," *Appl. Opt.* vol. 46, pp. 8527-8532, 2007.
[3] D. Vasiljević, B. Murić, D. Pantelić, B. Panić, "Imaging properties of laser-produced parabolic profile microlenses,"*Acta Phys. Pol.* vol. 112, pp. 993-*999, 2007.*

Villas Boas Celso **(3)** **Talk**

Reservoir engineering for cavity field and atomic states and decoherence-free evolutions in cavity quantum electrodynamics

T. W. de Oliveira[1], F. O. Prado[1], E. I. Duzzioni[1,2], R. Guzmán[3], M. H. Y. Moussa[4], N. G. de Almeida[5], and C. J. Villas-Bôas[1]
[1]Departamento de Física, Universidade Federal de São Carlos, 13595-905, São Carlos, Brazil.
[2]Centro de Ciências Naturais e Humanas, Universidade Federal do ABC, Rua Santa Adélia, 166, Santo André, São Paulo, 09210-170, Brazil.
[3]Departamento de Ciencias Físicas, Universidad de La Frontera, Casilla Postal 54-D, Temuco, Chile.
[4]Instituto de Física de São Carlos, Universidade de São Paulo, Caixa Postal 369, 13560-970, São Carlos, São Paulo, Brazil.
[5]Núcleo de Pesquisas em Física, Universidade Católica de Goiás, 74.605-220, Goiânia (GO), Brazil
celsovb@df.ufscar.br

In the present work we analyze how to engineer an effective Anti-Jaynes-Cumming and a Jaynes-Cumming interaction between an atomic system and a single cavity mode and how to employ it in reservoir engineering processes. To build this effective Hamiltonian we have considered the interaction of an atomic system in a Λ configuration, driven by classical fields, and a single cavity mode. With this interaction we firstly show how to generate a decoherence-free displaced squeezed state for the cavity field. In our scheme an atomic beam works as a reservoir for the radiation field trapped inside the cavity, as employed in Ref. [1] for the generation of an Einstein-Podolsky-Rosen entangled radiation state [2] in high-Q resonators. In our scheme, all the atoms have to be prepared in the ground state and, as in reference [1], it does not require atomic detection nor precise interaction times between the atoms and the cavity mode. Considering the same interaction we are also able to generate an ideal squeezed reservoir for atomic systems [3]. For this purpose we have to assume, besides the engineered atom-field interaction, a strong decay of the cavity field, i.e., the cavity decay much bigger than the effective atom-field coupling. With this purpose some interesting effects in the dynamics of an atom in a squeezed reservoir can be tested. Also in the context of reservoir engineering, in the present work we extend current perspectives in engineering reservoirs by producing a time-dependent master equation leading to a nonstationary superposition equilibrium state that can be nonadiabatically controlled by the system-reservoir parameters. Working with an atom trapped inside a nonindeal cavity we first engineer effective Hamiltonians that couple the electronic states of the atom with the cavity mode. Subsequently, two classes of decoherence-free evolution of the superposition of the ground and decaying excited levels are achieved: those with time-dependent azimuthal or polar angle. As an application, we generalize the purpose of an earlier study [4], showing how to observe the geometric phases acquired by the protected nonstationary states even under a nonadiabatic evolution.

References

[1] R. R. Puri, C. K. Law, and J. H. Eberly, Phys. Rev. A **50**, 4212 (1994); S. Pielawa, G. Morigi, D. Vitali, and L. Davidovich, Phys. Rev. Lett. **98**, 240401 (2007); P. Li, Phys. Rev. A **77**, 015809 (2008).
[2] M. D. Reid, Phys. Rev. A **40**, 913 (1989); A. Einstein, B. Podolsky, and N. Rosen, Phys. Rev. **47**, 777 (1935).
[3] M. O. Scully and M. S. Zubairy, "Quantum Optics", Cambridge University Press, Cambridge, (1997); N. Lutkenhaus, J. I. Cirac, and P. Zoller, Phys. Rev. A **57**, 548 (1998).
[4] A. Carollo, G. M. Palma, A. Lozinski, M. França Santos, and V. Vedral, Phys. Rev. Lett. **96**, 150403 (2006); Z. Q. Yin , F. L. Li, and P. Peng, Phys. Rev A **76**, 062311 (2007); A. Carollo, M. França Santos, and V. Vedral, Phys. Rev. Lett. **96**, 020403 (2006).

Vogel Werner **(1)** **Invited talk**

Nonclassical P-functions and space-time dependent correlations

Werner Vogel
Institut für Physik, Universität Rostock, Rostock, Germany
werner.vogel@uni-rostock.de

In Quantum Optics the widely accepted definition of nonclassicality is based on the *P*-function of Glauber and Sudarshan. When it fails to be interpreted as a classical probability, the corresponding quantum state is said to be a nonclassical one. However, the *P*-function may not only become negative, it also can be highly singular. Because of this fact, in many cases the experimental determination of a nonclassical *P*-function is hardly possible.

Here we show that a nonclassical *P*-function can be reconstructed from the measured data of a single-photon-added thermal state (SPATS) [1]. We obtain the characteristic function of the *P*-function by balanced homodyne detection of an experimentally prepared SPATS. From the set of data we derive the *P*-function, which clearly attains negative values. This is the first direct proof of nonclassicality which is based on its original definition.

The first experimental demonstration of nonclassical radiation properties was obtained in the pioneering photon-antibunching experiment by Kimble, Dagenais and Mandel. In this case it was shown that the normal- and time-ordered second-order intensity correlation function shows a positive initial slope. The nonclassicality of such a behaviour was related to the violation of a Schwarz inequality, which is fulfilled for any radiation field that can be described by a classical stochastic process. Only recently it could be demonstrated how one can relate the photon antibunching to negativities attained by a *P*-functional, which generalises the *P*-function to include space-time dependent correlation properties. On this basis one may formulate a complete hierarchy of conditions for field correlation functions, which gives full insight in the nonclassical effects described by correlation properties in a manyfold of space-time points [2]. We obtian conditions in terms of correlation functions of arbitrarily high orders in the intensity and field-strength operators.

The detection of correlation functions of such a general type requires special methods of correlation measurements. For this purpose we have proposed a balanced homodyne correlation technique, which unifies the advantages of balanced homodyning with those of correlation measurements [3]. The set of data is recorded by correlation measurements, after superimposing the signal field with a strong local oscillator. A special combination of the observed intensity correlation functions eventually allows one to determine the needed correlation functions of high orders in the field-strength and intensity. In principle, in this way the nonclassical correlation properties of radiation fields can be fully characterised.

References

[1] T. Kiesel, W. Vogel, V. Parigi, A. Zavatta, and M. Bellini, arXiv:0804.1016 [quant-ph].
[2] W. Vogel, Phys. Rev. Lett. 100, 013605 (2008).
[3] E. Shchukin and W. Vogel, Phys. Rev. Lett. 96, 200403 (2006).

Vučić Svetlana **(4)** **Poster**

Resonance enhanced ionization of Argon in a strong laser field

Svetlana Vučić[1]*, and Robert Potvliege*[2]
[1]Institute of Physics, Pregrevica 118, 11080 Belgrade, Serbia
[2]Departement of Physics. Durham University, Durham DH1 3LE, UK
vucic@phy.bg.ac.yu

Atomic systems exposed to intense laser radiation emit continuum electrons whose energiesmay correspond to the absorption of many more photons than necessary for ionization. The energy spectrum of the ejected electrons (the above-threshold ionization spectrum, ATI) shows regularly spaced peaks, in intervals of the photon energy. The envelope of an ATI spectrum usually decreases in magnitude after the first few peaks, levels off in a plateau which may extend up to high orders, and then drops to noise level. The low energy electrons are ionized after multiphoton absorption without further interaction with the parent ion. The high-energy electrons gain most of their energy from rescattering by the ionic core under the inuence of the driving laser field, subsequent to which the rescattered electrons are further accelerated by the field. Both, the low- and high-energy part of the ATI spectrum may be strongly enhanced by series of multiphoton resonances between the ground state and excited states Stark-shifted by the field. In many cases a same resonant state is responsible for an enhancement of ATI in low orders, as well as in high orders. In our recent publications [1] the relevant resonant dressed states of argon are fully identified by comparing the existing high resolution ATI spectra for a laser of 800nm wavelength, to a newly compiled Floquet quasienergy map. The most intense enhancements in low- as well as in the high-orders of ATI spectrum below the intensity of $7x10^{13}$ W cm^{-2} originate from Stark shift induced resonances with overlapping dressed 4f and 5f states, from the intermediate part of atomic energy spectrum. The structures and shifts which the two resonances induce in various-order ATI peaks may be interpreted by the constructive interference between the recolliding wave packets.

We apply here the Floquet method with complex discrete Sturmian basis expansion to study the argon atom in a strong laser field. The method provides an accurate description of resonant multiphoton transitions between bound states, giving thereby the precise position and width of the resonant peaks in the spectrum. The densities of the probabilities concerning parts of the ground-state wavepacket where N-photon absorption processes occur are analysed, as well as the corresponding average values of radius r and its inverse powers $1/r$ and $1/r^2$, as well as of the kinetic energy operator. All of the quantities are averaged over one optical cycle. A partial waves analysis of these quantities is made, and their dependence in the total number N of photons absorbed by the atom and in the laser intensity is analysed. At high intensity, both the ground and excited resonant wave functions are perturbed in a wide region of N around the dominant resonant transition. The strong radiative coupling affects even the large N density of the probability distribution, leading the partial wave with the same angular momentum to be dominant as in the resonance. Further, the analogous distributions of partial waves of the mean values of kinematical operators concerning the ground and the resonant states, have almost the same shape for large N, meaning that both states produce similar high-order photoionization yield. Since all the excited states in argon at the intensities considered lie very far above and outside the potential barrier created by the combined action of the nuclear Coulomb attraction and the laser field, they should have similar properties as the analogous excited states of the hydrogen atom. Our calculations show that this is indeed the case. The analysis of the mean values of kinematical operators may be useful for making more complete diagnoses of the dressed states in ambiguous cases.

References

[1] R. M. Potvliege and Svetlana Vučić, Phys. Rev. A 74, 023412 (2006); Physica Scripta 74, C55-C60 (2006).

Vuletic Vladan **(2)** **Invited talk**

Single-photon bus between atomic spin-wave quantum memories

Haruka Tanji[1,2] *, Jonathan Simon*[1,2] *, Saikat Ghosh*[1] *, and Vladan Vuletić*[1]

[1] *Department of Physics, MIT-Harvard Center for Ultracold Atoms, and Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA*

[2] *Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA*

vuletic@mit.edu

Generation of non-classical correlations (entanglement) between atoms, photons, or combinations thereof is at the heart of quantum information science [1-4]. Of particular interest are material systems serving as quantum memories that can be interconnected optically [1-7]. An ensemble of atoms can store a quantum state in the form of a quantized collective spin excitation (magnon) that can be mapped onto a photon with high efficiency [6]. We report the phase coherent transfer of a single magnon from one atomic ensemble to another via an optical resonator serving as a quantum bus that in the ideal case is only virtually populated. Partial transfer deterministically creates an entangled state with one excitation jointly stored in the two ensembles. The entanglement is verified by mapping the magnons onto photons, whose correlations can be directly measured [7].

While it is easiest to represent a photonic quantum bit in the $|0\rangle = |\text{no photon}\rangle$, $|1\rangle = |\text{one photon}\rangle$ basis, this encoding is not symmetric to photon loss, and it is preferable to use a photon polarization basis. We also demonstrate the heralded storage of photon polarization states in an atomic ensemble of laser-cooled cesium atoms. A heralding photon of fixed polarization announces the polarization-preserving storage of a single photon of (potentially unknown) polarization. The stored photon can then be later read out of the memory on demand with fidelities near 90% for all polarization states. Since the photon can be restored with the same polarization and frequency characteristics very similar to the incoming photon, this system can be viewed as a quantum non-demolition experiment for a single photon.

References

[1] L.-M. Duan, M. D. Lukin, J. I. Cirac, and P. Zoller, Nature , 413 (2001).
[2] C.W. Chou *et al.*, Nature , 828 (2005).
[3] D.N. Matsukevich *et al.*, Phys. Rev. Lett. , 030405 (2006).
[4] B.B. Blinov, D. L. Moehring, L.-M. Duan, and C. Monroe, Nature , 153 (2004).
[5] M. D. Eisaman, A. Andre, F. Massou, M. Fleischhauer, A. S. Zibrov, and M. D. Lukin, Nature , 837 (2005).
[6] J. Simon, H. Tanji, J. K. Thompson, and V. Vuletic, Phys. Rev. Lett. , 183601 (2007).
[7] J. Simon, H. Tanji, S. Ghosh, and V. Vuletic, Nature Physics , 765 (2007).

Vuškovic Leposava **(3)** **Poster**

The high quality factor niobium cavities preparation by plasma treatment

M. Rašković, L. Vušković, and S. Popović
Old Dominion University, Department of Physics, Norfolk, Virginia, USA
vuskovic@physics.odu.edu

Cavity quantum electrodynamics (QED) is a powerful experimental tool for investigating the most fundamental aspects of coherence and decoherence in quantum mechanics [1]. Core of each cavity QED experimental set-up is an open cavity made of two superconducting niobium (Nb) mirrors facing each other [2]. Niobium is a superconducting transition element with low critical temperature $T_c = 9.1$ K and high critical magnetic field $B_c = 200$ mT. High critical magnetic field is necessary for achieving high quality factor cavities for particle accelerators and cavity QED, as well as Josephson junctions for the circuit QED [3]. For cavity QED application, the surface imperfection of Nb mirrors contribute to lowering achievable cavity quality factor and therefore decreasing field energy damping time of cavity [4]. For particle accelerator application, roughness and impurities in Nb cavity surface contribute to lowering achievable accelerating field inside of cavity. Therefore, particular attention must be devoted to the cavity surface preparation. Plasma based Nb surface treatment provides an excellent opportunity to eliminate surface imperfections and increase cavity quality factor in both application. Here we will present ongoing work on the disc shaped Nb samples surface's treatment using Cl_2 as reactive gas in microwave (mw) glow discharge system [5]. Influence of plasma parameters such as input power, pressure, and concentration of the reactive gas on etching rates and surface quality will be presented.

References

[1] H. Mabuchi and A. C. Doherty, Science **298**, 1372 (2002).
[2] S. Gleyzes, et al., Nature **446**, 297 (2007).
[3] D. I. Schuster, et al., Nature **445**, 515 (2007).
[4] S. Kuhr, et al., Preprint at http://arhiv.org/quant-ph/0612138v2 (2007).
[5] M. Rašković, et al., 13th International Workshop on RF Superconductivity, Beijing, China2007, Proceedings
http://www.pku.edu.cn/academic/srf2007/download/proceedings/TUP73.pdf (2007).

Vvedenskii Nikolay **(4)** **Talk**

Quantum and Semiclassical Calculations of Quasi-DC Current Excitation in Plasma Created by Few-Cycle Laser Pulse

A.A. Silaev and N.V. Vvedenskii
Institute of Applied Physics, Russian Academy of Sciences, Nizhny Novgorod, Russia
vved@appl.sci-nnov.ru

The phenomenon of quasi-DC current excitation in dense plasma created by femtosecond laser pulses is now actively investigated in connection with the problem of terahertz waves generation [1-8]. The different physical mechanisms of photoelectrons acceleration for realization of this phenomenon are known: (i) acceleration by nonlinear ponderomotive force of laser pulses with very high intensity ($\sim 10^{18} - 10^{19}\,\mathrm{W/cm^2}$) [1, 2]; (ii) by external static or microwave electric field in the presence of which one there is a photoionization [3, 4]; (iii) by the field of second harmonic of laser pulse (so-called four-wave difference mixing process in ionized air plasmas) [5, 6]; (iiii) directly by the electric field of ionizing few-cycle laser pulse imparting a large constant velocity component (depending on the field phase) to the newly born electrons [7, 8].

In this paper, we report on results of theoretical investigations of the last scheme (in which one the quasi-DC current is excited by few-cycle laser pulse) on the basis of simple model of hydrogen atoms ionization in the laser field of moderate optical intensity ($\sim 10^{14} - 10^{16}\,\mathrm{W/cm^2}$). We present the results of quantum mechanical calculations based on numerical solution of a time-dependent Schrödinger equation for a hydrogen atom in a linear polarized few-cycle laser field and the results of semiclassical calculations based on numerical solution of classical equation for free-electron current density in non-steady-state plasma with the equation for the time variation of the plasma density using given dependence of the strong-field ionization rate on the laser electric field. We have found the normalized density of the quasi-DC current (after passing of the laser pulse) as a function of the absolute (carrier-envelope) phase, pulse duration, and the electric field intensity. For pulses with 1–4 optical cycles duration we have found optimum values of the carrier-envelope phase and the electric field amplitude when normalized current density has maximum and the conversion efficiency takes quite high value. We have performed a comparison between results given by quantum mechanical and semiclassical models. The results obtained show the possibility of high-efficiency conversion of few-cycle laser pulses into terahertz radiation and may be used for solving an important problem of carrier-envelope phase control of few-cycle laser pulses.

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References

[1] H. Hamster *et al.*, Phys. Rev. E **49**, 671 (1994).
[2] W.P. Leemans *et al.*, Phys. Plasmas **11**, 2899 (2004).
[3] T. Löffler and H.G. Roskos, J. Appl. Phys. **91**, 2611 (2002).
[4] A.M. Bystrov, N.V. Vvedenskii, and V.B. Gildenburg, JETP Lett. **82**, 753 (2005).
[5] D.J. Cook and R.M. Hochstrasser, Opt. Lett. **25**, 1210 (2000).
[6] K.Y. Kim *et al.*, Opt. Express **15**, 4577 (2007).
[7] M. Kreß, T. Löffler, M.D. Thomson *et al.*, Nature Phys. **2**, 327 (2006).
[8] V.B. Gildenburg and N.V. Vvedenskii, Phys. Rev. Lett. **98**, 245002 (2007).

Walther Philip **(2)** **Invited talk**

Multi-photon entanglement and the possibility to generate single-photons using room-temperature ensembles of ^{87}Rb atoms

Philip Walther[1], *Mikhail D. Lukin*[1,2] *and Anton Zeilinger*[3,4]
[1] Physics Department, Harvard University, 17 Oxford Street, Cambridge, MA 02138, USA;
[2] Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA;
[3]Institute for Experimental Physics, University of Vienna, Boltzmanngasse 5, A-1090 Vienna;
[4]Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, Boltzmanngasse 3, A-1090 Vienna, Austria
pwalther@fas.harvard.edu

Photons are robust and efficient carriers of quantum information, while atoms are well-suited for long-lived storage of quantum states. Recent results of several experimental demonstrations using linear optics and spontaneous parametric down-conversion demonstrate the high feasibility of photonic qubits. Depending on which sort of entangled photon-state was created, different experiments concerning quantum metrology [1] and quantum computing [2], including the recent progress towards deterministic linear optics quantum computing by the implementation of active feed-forward in a one-way quantum computer [3], could be demonstrated.

However, for the realization of a quantum network or efficient generation of multi-photon states quantum repeaters, which utilize quantum memory to store and release single-photons, are required [4]. Recent experiments demonstrating the generation of narrow-bandwidth single photons using a room-temperature ensemble of ^{87}Rb atoms and electromagnetically induced transparency should emphasize the progress towards a quantum network [5,6].

References

[1] P. Walther, et al., Nature **429**, 158 (2004).
[2] P. Walther et al., Nature **434**, 169 (2005).
[3] R. Prevedel et al., Nature **445**, 65 (2007).
[4] L. M. Duan, M. D. Lukin, J. I. Cirac, and P. Zoller, Nature **414**, 413, (2001).
[5] M. D. Eisaman, et al., Nature **438**, 837 (2005).
[6] P. Walther et al. Proc. of SPIE Vol. **6664**, G (2007).

Weis Antoine **(5)** **Invited talk**

Multichannel atomic magnetometers

Antoine Weis[1], Natascia Castagna[1], Adrian Hofer[1], Paul Knowles[1], Georg Bison[2], Gianni DiDomenico[3], and Anatoly S. Pazgalev[4]
[1]Physics Department, University of Fribourg, Switzerland
[2]Biomagnetisches Zentrum, Universitätsklinikum Jena, Germany
[3]Institut de Microtechnique, Neuchâtel, Switzerland
[4]Ioffe Physical Technical Institute,St. Petersburg, Russia
antoine.weis@unifr.ch

Magnetometers combining both resonant optical preparation and detection with magnetic resonance in alkali vapors have been known for more than half a century. While conventional magnetometers use filtered light from spectral discharge lamps, the advent of inexpensive tunable lasers has given a new impetus to optical magnetometry [1]. Since the operation of a magnetometer head requires less than 10 μW of laser radiation, a laser of moderate power can be used to drive a large number of sensor heads. This allows the realization of spatially distributed magnetometer arrays that can monitor the magnetic field and its higher order gradients over a large volume.

Our research team develops such arrays for two specific applications:

1. Monitoring the temporal and spatial magnetic field fluctuations in the five-fold mu-metal shield of a new experiment searching for an electric dipole moment of the neutron. Specific requirements here are vacuum and high voltage compatibility and the opto-coupling of the sensor heads to the processing electronics. The simultaneous operation of eight sensor has been proven and an extension to several dozen sensors is foreseen.

2. Measuring maps of the cardiomagnetic field of human adults. In the past we have shown that two sensors, operated in a first order gradiometer mode allow the recording of magneto-cardiographic field maps in two hours [2]. In order to reduce the recording time to a diagnostically affordable level of two minutes we plan a three-dimensional sensor array with up to 100 sensors that permit suppression of first and second order time-varying gradients.

The magnetometers are operated either in the self-oscillating mode or in the phase-stabilization mode [1]. In the past we have used both home-built analog electronics and commercial phase detectors, none of which can be easily upscaled to a multi-sensor system. We currently pursue a fully digital approach, based on FPGAs (field-programmable gate arrays), for the operation and read-out of the magnetometers. Besides the miniaturization of the electronics, the multi-sensor system poses other challenges, such as the design of appropriate algorithms for the magnetometer operation in second-order gradiometry mode, the design of compact sensor heads, the mass production of paraffin-coated Cs cells, and the optical multiplexing of the laser beam. Recently we have made good progress along all of those lines, among which we mention in particular the manufacture of 100 sensor cells with an intrinsic sensitivity below 20 $fT/Hz^{1/2}$.

At CEWQO I will present details of the present status of those developments.

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References

[1] S. Groeger, A. S. Pazgalev and A. Weis, Appl. Phys. **B80**, 645-654 (2005).
[2] G. Bison, R. Wynands, and A. Weis, Optics Express **11**, 904-909 (2003).

Ziman Mario **Invited talk**

Discrimination of quantum observables

Mario Ziman
Research Center for Quantum Information, Institute of Physics
84511 Bratislava, Slovakia
ziman@savba.sk

We shall introduce the framework for discrimination of quantum observables. In particular, we shall analyze the perfect and unambiguous discriminability of qubit observables.

Zipper Elzbieta **(7)** **Talk**

Entanglement of distant flux qubits by swapping

Elzbieta Zipper
Institute of Physics, University of Silesia
40-007 Katowice, Poland
elzbieta.zipper@us.edu.pl

The mechanism for entanglement of two flux qubits each interacting with a single mode electromagnetic field created in separate quantum cavities is discussed. This interaction leads to two independent entangled qubit-field states. The Bell State Measurement performed on the electromagnetic field modes projects the qubits onto an entangled state depending on the degree of entanglement of the composed subsystems. To quantify the entanglement we calculate negativity. We discuss the results for two initial states and take into account the influence of decoherence.

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