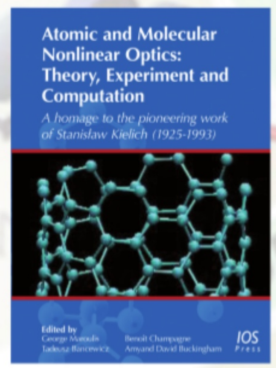
The Third Poznań Symposium on

Quantum Engineering, Information, and Nonlinear Optics (QEINO 2013)

15th (Tuesday) -17th (Thursday) October 2013

Physics Faculty, Adam Mickiewicz University, Poznań, Poland
Symposium venue: room 16 (in front of dean's office).

This Symposium is dedicated to the memory of Stanisław Kielich.



Invited speakers

Konrad Banaszek *(Warsaw)*
Georges Boudebs *(Angers)*
Dariusz Chruściński *(Toruń)*
Marek Czachor *(Gdańsk)*
Antonín Černoch *(Olomouc)*
Zbigniew Ficek *(Riyadh)*
Jean-Luc Godet *(Angers)*
Przemysław Głowacki *(Poznań)*
Keith Gubbins *(Raleigh)*
Qiongyi He *(Beijing)*
Tadeusz Hilczer *(Poznań)*
Paweł Horodecki *(Gdańsk)*
Ryszard Horodecki *(Gdańsk)*
Dobrosława Kasprowicz *(Poznań)*
Marek Kuś *(Warsaw)*
Karel Lemr *(Olomouc)*
Tadeusz Lulek *(Poznań)*
Igor Lyubchanskii *(Donetsk)*
Małgorzata Makowska-Janusik *(Częstochowa)*
George Maroulis *(Patras)*
Jan Martinek *(Poznań)*
Jan Mostowski *(Warsaw)*
Jan Perina Jr. *(Olomouc)*
Jan Soubusta *(Olomouc)*
Tomasz Sowiński *(Warsaw)*
Werner Vogel *(Rostock)*
Jerzy Warczewski *(Katowice)*
Alexandre Zagoskin *(Loughborough)*
Anna Zawadzka *(Toruń)*
Marek Żukowski *(Gdańsk)*
Karol Życzkowski *(Warsaw)*

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Tuesday, 15 Oct 2013

STANISŁAW KIELICH - A FEW WORDS ABOUT HIS LIFE

Tadeusz Bancewicz, Ryszard Tanaś

Nonlinear Optics Division, Physics Faculty, Adam Mickiewicz University, Poznań, Poland

9:00
NO1
1

The Symposium is dedicated to the memory of Prof. Stanisław Kielich. Stanisław Kielich is considered to be one of the founders and leading experts in nonlinear optics, with forty years of continuous research work in the subject. He authored more than three hundred scientific papers. He had more than twenty PhD students. Four of his students are professors now. He was a member of the Polish Accademy of Sciences. Among other distinctions he was awarded the Marian Smoluchowski Medal (1983) and the Cross of Merit (1976,1983).

THE EARLY DAYS OF PHYSICS OF DIELECTRICS IN POZNAŃ

Taddeusz Hilczer

Division of Dielectrics Physics, Physics Faculty, Adam Mickiewicz University, Poznań, Poland

9:30
NO1
2

Physics of dielectrics started in Poznań when professor Arkadiusz Piekara took chair in Experimental Physics at the Poznań University in 1952. At the beginning a lot of effort was taken to prepare the measuring basis, that is to construct the measuring condensers, Schering bridges, resonance circuits, heterodyne beat apparatus ($\Delta C/C \approx 10^{-6}$), to purifying liquid dielectrics and to synthesize ferroelectrics. Later, professor Piekara got Stanisław Kielich interested in theoretical approach to the physics of dielectrics and his Master of Science dissertation in 1955 can be considered as the beginning of the work of young Poznań staff in theory of dielectrics.

THE THEORY OF POLAR LIQUIDS AND THEIR MIXTURES: A HISTORICAL REVIEW

Keith Gubbins

Department of Chemical and Biomolecular Engineering, North Carolina State University, Raleigh, NC 27695-7905, U.S.A.

The primary goal of a theory of liquid mixtures is to determine, using statistical mechanics, how the structure and free energy varies with the composition, and with the chemical composition of its components. Such a theory provides the key to the determination of dielectric and spectral properties, phase transitions, critical points, solubilities, immiscible regions, metastable and unstable regions, etc.

Theories proposed in the first half of the 20th century were, for the most part, lattice theories, and many of these are described in the books by Guggenheim [1] and Prigogine [2]. These early theories pre-dated molecular simulations and the availability of electronic computers, so that they were tested by direct comparison with experimental data. Since such comparisons, in the case of the lattice theories, involved adjustment of various parameters to experimental data, these tests were of dubious value. Once molecular simulation data became available in the early 1960s these theories were shown to be in serious error, and can now be considered to be extinct.

Modern theory of polar liquids (the last 60 years) has followed a dual path. The first has been perturbation theory, in which the free energy and other properties of the solution of interest are related to those of a simpler solution having simple intermolecular forces, for example hard spheres or Lennard-Jones mixtures. 10:00
Perturbation theory has been particularly successful for thermodynamic properties. The theory of Wertheim NO1
[3], relates the free energy of a polar or associating fluid to that of a hard body (non-associating) fluid through a clever resummation of a cluster series for the free energy. It and its later extensions are finding widespread 3
practical application [4].

The second route to a theory of polar liquids has been integral equation theory, which yields the structure in the form of distribution functions [5]. Although less successful than the perturbation theories for thermodynamic properties, integral equation theories have been successful for other properties, in particular dielectric and spectral properties.

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[2] I. Prigogine, The Molecular Theory of Solutions, North-Holland Pub. Co., Amsterdam, 1957.
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QUANTIFYING THE PERFORMANCE OF QUANTUM CHEMISTRY METHODS

Georges Maroulis

Department of Chemistry, University of Patras, Greece

We present a general method for the quantification of the performance of quantum chemical methods over 10:45
an arbitrary collection of atomic/molecular properties. Our approach relies on the Minkowski metric , graph NO1
theoretic concepts and pattern recognition techniques. The method should be of interest as a rigorous 4
approach to the introduction of order and classification in spaces of theoretical descriptions. We show how it can be used to quantify the relative merit of ab initio and DFT methods.

OPPORTUNITIES FOR $Bi_2ZnOB_2O_6$ SINGLE CRYSTAL: SECOND AND THIRD ORDER NONLINEAR OPTICAL APPLICATIONS

D. Kasprowicz[1], K. Iliopoulos[2], A. Majchrowski[3], and B. Sahraoui[2]

1 Faculty of Technical Physics, Poznan University of Technology, Nieszawska 13 A, 60-965 Poznan, Poland
2 LUNAM Université, Université d'Angers, CNRS UMR 6200, Laboratoire MOLTECH-Anjou, 2 Bd Lavoisier, 49045 Angers Cedex, France
3 Institute of Applied Physics, Military University of Technology, Kaliskiego 2, 00 - 908 Warszawa, Poland

11:15
NO1
5

$Bi_2ZnOB_2O_6$ nonlinear optical single crystals were grown by means of the Kyropoulos method from stoichiometric melt. The SHG and THG response of the $Bi_2ZnOB_2O_6$ crystal was studied by the Maker fringes techniques. Moreover SHG microscopy studies were carried out providing two-dimensional SHG images as a function of the incident laser polarization. The crystals have been shown to have high SHG and THG efficiency, comparable with those of well-known crystals such as BBO, KDP, KTP, which makes them very attractive materials for NLO applications. The high nonlinear optical efficiency combined with the possibility to grow high quality crystals make $Bi_2ZnOB_2O_6$ an excellent candidate for photonic applications.

OPTICAL NONLINEAR CHARACTERIZATION USING IMAGING TECHNIQUE IN A 4f-Z-SCAN SYSTEM

Georges Boudebs

Laboratoire de photonique d'Angers (LPhiA), University d'Angers, France

13:30
NO2
1

We show that the direct measurement of the beam radius in Z-scan experiments using a CCD camera at the output of a 4f-imaging system allows a higher sensitivity and a better accuracy than other methods. One of the advantages is to be insensitive to pointing instability of the pulsed laser because no hard aperture is employed as in the usual Z-scan. In addition, the numerical calculations involved here and the measurement of the beam radius are simplified since we do not measure the transmittance through an aperture and it is not subject to mathematical artefacts related to a normalization process, especially when the diffracted light is very low.

Keywords: Nonlinear optics, Z-scan, diffraction, image processing, Fourier optics

NONLINEAR MAGNETO-OPTICAL ELLIPSOMETRY

Yu. S. Dadoenkova[1], **I. L. Lyubchanskii**[1,2], Y.P. Lee[3], and Th. Rasing[4]

1 Donetsk Physical and Technical Institute of the National Academy of Sciences of Ukraine, 83114, Donetsk, Ukraine
2 Department of Physics and Technology, Donetsk National University, 83001, Donetsk, Ukraine
3 Quantum Photonic Science Research Center (q-Psi) and Hanyang University, 133-791, Seoul, Republic of Korea
4 Radboud University Nijmegen, Institute for Molecules and Materials, 6525 AJ, Nijmegen, the Netherlands

14:00
NO2
2

The ellipsometric parameters for light reflection from a dielectric film with Kerr optical nonlinearity on a bigyrotropic magneto-electric film are theoretically investigated. The combined contributions of the cubic optical nonlinearity and the magneto-electric coupling allows to control the ellipsometric parameters and thus for example the Kerr rotation with the incoming light intensity, in particular at incidence angles close to the pseudo-Brewster angle.

SPIN GLASS STATE AND OTHER MAGNETIC STRUCTURES WITH THEIR SYMMETRIES IN TERMS OF THE FIBRE BUNDLE APPROACH

Jerzy Warczewski[1], Paweł Gusin[2] and Daniel Wojcieszyk[1]

1 University of Silesia, Institute of Physics, 40-007 Katowice, Poland

2 University of Wrocław, Institute of Theoretical Physics, 50-204 Wrocław, Poland

The fibre bundle approach [1] has been applied to the unified description of all the eight fundamental magnetic structures and their symmetry groups [2]. On this basis the explicit formulas describing both the variety of magnetic structures and their symmetry groups have been derived. In the particular case of the spin glass state (SGS) the global magnetic coupling constant has been interpreted as a section of the corresponding fibre bundle. The fibre of this bundle makes the space of the Gaussian distributions. Thus one can say that the randomness of the distribution of both the magnetization and the individual magnetic moments in the SGS is of the Gaussian-like character. An observation was made that another kind of the fibre bundle sections make the magnetization vectors **M** multiplied by a certain Gaussian factor defined in R^3, the last factor making the problem continuous and more physical [3, 4]. In one of the previous papers the authors have proved that an internal spontaneous magnetic field Hint is necessary for the SGS to be stable and just to exist [5]. For the angle between **M** and $\mathrm{H}_{\mathrm{int}}$ equal to ϕ one can say that at ϕ=const any rotation (precession) of **M** around the direction of Hint makes the operation of symmetry of the SGS. Thus the magnetic symmetry group of SGS turns out to be SO(2). The role of both the Hint and the external magnetic field $\mathrm{H}_{\mathrm{ext}}$ as well as of the average kinetic energy $\mathrm{E}_{\mathrm{kin}}$ of the separate magnetic atoms in the explanation of the experimental temperature dependencies of susceptibility is shown. Thus the fibre bundle approach equates the method of the symmetry analysis of magnetic structures with the method of the higher dimensional embeddings of the modulated structures. The symmetry groups appearing in the method of the symmetry analysis become the structural groups of the bundles. From the other side a higher dimensional space needed to the description of a modulated structure makes here the total space of the bundle. Thus these three methods, namely the symmetry analysis, the higher dimensional embeddings and the fibre bundles are equivalent. The analogous situation is with the description of the magnetic structures with the use of the spin groups, where an additional type of symmetry is introduced. Note that the Gaussian factor introduced above plays a double role: it makes the vector **M** to be a field and simultaneously makes the description of the magnetic structures more physical [6, 7]. It seems that the fibre bundle approach could serve also for the description of the symmetry groups of all the other aperiodic structures, like e.g. the modulated nonmagnetic structures, quasicrystals (nonmagnetic and magnetic) etc. It is worthwhile to mention here that these different magnetic structures under consideration have been found by the authors to be related with the values of the certain topological invariants [8].

14:30

NO2

3

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A SHORT HISTORICAL RECALL ABOUT THE STORY OF THE CONCEPT OF REFRACTIVE INDEX: FROM THE ANTIQUE TO THE 19TH CENTURY

Jean-Luc Godet

University of Angers, UFR Sciences Institute of Sciences and Molecular Technologies of Angers, France

15:00
NO2
4

The research of a refraction law played a major role in the development of the optics since the first attempts of Ptolemy until the more accomplished results of Ibn Sahl, Snel or Descartes. However, it is necessary to wait for the beginning of the XIXth century, much later than the theory of colours of Newton and thanks to the researches on the achromatic glasses, so that emerges the concept of refractive index and so that it begins to be understood well. We propose a historical reminder and an outline of the obstacles and epistemological advances which allowed to establish it.

MACROSCOPIC OPTICAL PROPERTIES OF COMPOSITE MATERIALS - COMPUTATIONAL APPROACH

Małgorzata Makowska-Janusik

Institute of Physics, Jan Długosz University, Częstochowa, Poland

16:00
NO3
1

One of the possibilities to obtain efficient and stable nonlinear optical (NLO) material is to dope an amorphous polymer with organic donor-acceptor molecules forming a composite. The appropriate material for the first NLO effect as persistent second harmonic generation (SHG) requires large number of polarizable molecules embedded in polymeric matrix preventing polar orientation. The polar orientation may be induced by external electric field at the temperatures where the matrix is sufficiently mobile to allow fast alignment of the dopants. The experimental explanation of the origin of their NLO response is very difficult because optical susceptibilities are measured in condensed matter where the molecular properties are affected by the host matrix. Molecular simulations can help to explain the nature of the guest-host interaction and separate the different contribution of the material to the optical output signal. A goal of many theoretical works is to find appropriate model describing optical properties of molecules incorporated into polymeric environment. In the presented work linear and nonlinear optical susceptibilities of guest-host polymer systems were calculated applying the hierarchic procedure . The wild variety of chromophores characterized by different size, shape and charge distribution incorporated into different polymer matrix were studied. First of all the structures of the investigated systems have been modeled by molecular dynamic simulations applying molecular mechanics CVFF force field method. The obtained structures are amorphous. Investigations of radial distribution function prove that location of chromophores in polymeric matrix is an intrinsic property of polymer. The motion of polymer chain allows a rotation of dopants under influence of an external electric field.

The electronic properties of the NLO chromophores were computed at the HF and DFT level using different exchange - correlation potentials. These properties were investigated for the isolated NLO molecules as well as for the ones in polymer environment. In the second case the first-order susceptibilities corresponding to SHG were calculated using discrete local field approach. The implemented method is very efficient to the molecules with high charge transfer effect and give the data approximately consistent with the experimental results. It was also proved that the optical response, especially NLO output signal of chromophores embedded into polymeric matrix, depends on their local environment.

NONLINEAR OPTICAL PROPERTIES OF ORGANOMETALLIC THIN FILMS

Anna Zawadzka

Institute of Physics, Nicolaus Copernicus University, Toruń, Poland

This work contains investigation results of the structural and nonlinear optical properties of organometallic thin films and nanostructures. The films and nanostructures were successfully grown by Physical Vapor Deposition technique in high vacuum on transparent (quartz, glass) and semiconductor (n-type silica) substrates kept at room temperature during the deposition process. Selected films were annealed after fabrication in ambient atmosphere for 24 hours at the temperature in the range from 50°C to 250°C. Spectral properties were examined using transmission, photoluminescence, Second and Third Harmonic Generation's techniques. The experimental spectra were allowed to determine optical constant of the films. Structural properties were investigated by AFM measurements. The organometallic films and nanostructures exhibit high structural quality regardless of the annealing process, but the stability of the film can be improved by using an appropriate temperature during the annealing process. We find that the optical properties were strictly connected with the morphology and the annealing process can significantly change the structural properties of the films and lead to the formation of various nanostructures.

16:30
NO3
2

NONLINEAR MAGNETOOPTICS, SYMMETRY BREAKINGS AND ASCENTS, AND THE MAGNETIC TRANSLATION GROUPS

Tadeusz Lulek

Mathematical Physics Division, Physics Faculty, Adam Mickiewicz University, Poznań, Poland

This commemoration intertwines between various physical ideas (as presented in the title), shared within the scientific works of Professors: Stanisław Kielich, Louis Michel, Jan Mozrzymas, Joshua Zak, Marian Surma, and others. It goes from experimental studies on Cotton-Mouton effect (heavy electromagnesses in the basements of Collegium Chemicum), through symmetry considerations in phase transitions (nematics, smectics, etc., mainly breaking of symmetry, but, somehow exceptionally, also ascent), to the magnetic translation group as a mathematical tool for the Bohm-Aharonov effect (everybody knows Landau levels of a free two-dim electron gas, and the magnetic translation group serves as an equivalent for the case of itinerant electrons, with its irreducible representations labeling the levels, and the basis functions describing degenerate cyclotronic orbits). Nowadays, these ideas can be converted to "reality" within nanotechnology, e. g. magnetic quantum dots.

17:00
NO3
3

Wednesday, 16 Oct 2013

OBJECTIVITY FROM FIRST PRINCIPLES - NEW ROLE OF BROADCASTING STRUCTURE

Ryszard Horodecki

Instytut Fizyki Teoretycznej i Astrofizyki, Uniwersytet Gdański, 80-952 Gdańsk oraz Krajowe Centrum Informatyki Kwantowej w Gdańsku, 81-824 Sopot, Poland

9:00
QI1
1

Incessant run of successes of quantum mechanics suggests that quantum formalism plays decisive role in the description of physical phenomena. It leads inevitably to the problem: How does Nature create a "footbridge" from fragile quanta to the objective world of everyday experience? The subject of the talk will provide an answer to this fundamental issue. We will show how a crucial for quantum mechanics notion of non-disturbance due to Bohr and a natural definition of objectivity lead to a canonical spectrum broadcasting structure of a quantum system-environment state, reflecting objective information records about the system stored in the environment.

GENERALIZED HARDY CORRELATIONS AND QUANTUM COMMUNICATION PROBLEMS

Ramij Rahaman, Marcin Wieśniak, and **Marek Żukowski**

Institute of Theoretical Physics and Astrophysics, University of Gdańsk and National Quantum Information Centre in Sopot, Poland

9:30
QI1
2

We present multi-partite Hardy-type test against local realism. For n qubit systems, we prove the uniqueness and purity of the Hardy state (that is the one that satisfies Hardy conditions), and its genuine n-partite entanglement. We show an that Hardy correlations allow one to find solutions to some quantum communication problems. As an example we present a secure quantum scheme for the original *Byzantine Generals* problem. Our protocol is based on Hardy's paradox, which uses a set of conditions impossible for classical systems, but satisfied by a unique quantum two-particle state, and on entanglement swapping methods.

NON-MARKOVIAN QUANTUM DYNAMICS

Dariusz Chruściński

Institute of Physics, Nicolaus Copernicus University, Toruń, Poland

10:00
QI1
3

We discuss recent concepts of non-Markovianity of quantum evolution. The discussion is illustrated by simple examples (pure decoherence, amplitude damping and random unitary dynamics).

UNIVERSAL SCHEME FOR VIOLATION OF LOCAL REALISM FROM QUANTUM ADVANTAGE IN ONE-WAY COMMUNICATION COMPLEXITY

L. Czekaj[1], **A. Grudka**[2], M. Horodecki[1], P. Horodecki[3], and M. Markiewicz[1]

1 Faculty of Mathematics, Physics and Informatics, Gdańsk University, 80-952 Gdańsk, Poland
2 Faculty of Physics, Adam Mickiewicz University, Umultowska 85, 61-614 Poznań, Poland
3 Faculty of Applied Physics and Mathematics, Gdańsk University of Technology, 80-952 Gdańsk, Poland

10:30
QI1
4

We consider relations between communication complexity problems and detecting correlations (violating local realism) with no local hidden variable model. We show first universal equivalence between characteristics of protocols used in that type of problems and non-signaling correlations. We construct non linear bipartite Bell type inequalities and strong nonlocality test with binary observables by providing general method of Bell inequalities construction and showing that existence of gap between quantum and classical complexity leads to violation of these inequalities. We obtain, first to our knowledge, explicit Bell inequality with binary observables and exponential violation.

UNIFIED REPRESENTATION OF NONCLASSICALITY AND ENTANGLEMENT

Werner Vogel and Jan Sperling

Arbeitsgruppe Quantenoptik, Institut für Physik, Universität Rostock, D-18051 Rostock, Germany

11:30
QI2
1

In Quantum Optics the widely used definition of nonclassicality is based on the Glauber-Sudarshan P function [1]. If the P function has the properties of a classical probability density, the state is a classical mixture of coherent states. In any other case, the quantum state clearly shows quantum interference effects. In general, the P function is strongly singular and, hence, not applicable in experiments. A universal regularization resolves this problem [2], as it was demonstrated in experiments. In view of its structure [3], entanglement can also be visualized by quasiprobabilities. This requires an optimization based on the solution of the separability eigenvalue problem [4]. Its extension to the multipartite case yields multipartite entanglement witness for complex quantum states [5]. To characterize general quantum correlations, the concept of the P function was extended to a functional [6]. Its regularized version visualizes quantum correlations, even when the state is not entangled and has zero quantum discord [7].

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ENGINEERING SU(3) MODELS: TRAPPED IONS, QUANTUM CHAOS, CLASSICAL LIMIT(S)

Marek Kuś

Center for Theoretical Physics, Polish Academy of Sciences, Warsaw, Poland

12:00
QI2
2

One of the current trends in quantum physics is the quest for controllable quantum many-body systems which can be used as quantum simulators. In particular, there is a growing interest in simulating spin and quantum magnetism. In recent years, the focus is moving from SU(2) spins towards SU(N)-symmetric models. The SU(3) systems, having their origin in nuclear physics, were a fruitful playground for quantum chaos investigations, in particular due to they reach possible behavior in the classical limit. Now it seems to be possible to realize such models experimentally with trapped ions providing a large degree of control from the experimental point of view.

DEVICE INDEPENDENT ARBITRARY WEAK RANDOMNESS AMPLIFICATION WITH NOISE TOLERANCE

Paweł Horodecki

Faculty of Applied Physics and Mathematics, Technical University of Gdańsk and National Quantum Information Centre in Sopot, Poland

12:30
QI2
3

Recently the protocols of randomness amplification have been introduced secure against quantum and no-signaling adversaries. Here we present the first fully constructive proof of existence of the protocol that is secure against general no-signaling adversary and amplifies arbitrary small randomness (in standard terms of Santha-Vazirani source) in a fully device independent way. The protocol tolerates some amount of noise depending among others on the initial randomness that is to be amplified.

MEASURING THE DEGREE OF QUANTUM ENTANGLEMENT

Karol Życzkowski

Jagiellonian University, Krakow and Center for Theoretical Physics, Polish Academy of Sciences, Warsaw, Poland

13:00
QI2
4

Measures of quantum entanglement are reviewed and compared. We focus quantities characterizing entanglement which could be experimentally accessible. A quantity called 'collectibility' is proposed which can be determined in a coincidence experiment involving two copies of the state analyzed. Our approach, initially designed for the case of pure states, works also in the general case of mixed quantum states of a multi-partite system.

TIME CRYSTALS

Jan Mostowski

Institute of Physics, Polish Academy of Sciences, Warsaw, Poland

15:30
QE1
1

A system of two charged particles in a harmonic trap with additional magnetic field is considered. The problem is reduced to a single-particle one in relative coordinates. The ground- and lowest excited-state energies and wave functions are found. The ground state exhibits non-zero expectation value of the velocity (kinetic momentum) and the probability current density does not vanish as well. When the ground state becomes degenerate the expectation value of velocity becomes discontinuous. The effects associated with turning on of the magnetic field are studied by solving the appropriate time-dependent Schroedinger equation. No substantial differences between abrupt (discontinuous in time) and continuous switching on have been observed. Evolution of a wave packet which is initially Gaussian is also investigated. The wave packet loses its Gaussian nature and, after sufficiently large time, a system of diffractive maxima and minima is built.

UNIVERSALITY OF EXTENDED BOSE-HUBBARD MODELS WITH LOCAL THREE-BODY INTERACTIONS

Tomasz Sowiński

Institute of Physics of the Polish Academy of Sciences, Warsaw, Poland and Center for Theoretical Physics of the Polish Academy of Sciences, Warsaw, Poland

Experimental progress on trapping and manipulating ultra-cold atoms confined in optical lattices has opened new perspectives for controlling many-body states of different quantum systems. In the simplest case such systems are described in the context of the Bose-Hubbard (BH) model. In my talk I will consider the class of extended BH models with additional three-body on-site interactions. After short introduction I will divide the talk into two parts: (i) Standard BH with additional three-body term: I will show that the shape of insulating lobes may crucially depend on the three-body interactions and in the case of attractive three-body term may lead to vanishing of the second insulating lobe [1,2]. (ii) Attractive BH model with soft-core three-body repulsion: I will show that the critical behavior of the system undergoing a phase transition from pair-superfluid to superfluid at integer filling depends on the value of the three-body repulsion. In particular, a critical exponent and the central charge governing the quantum phase transitions are shown to have repulsion dependent features. In consequence, the model extends the list of known systems violating the universality hypothesis [3].

16:00
QE1
2

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GAUGE DEPENDENT TIME OF FLIGHT PATTERNS IN ABELIAN SYNTHETIC MAGNETIC FIELDS

Tomasz Polak

Solid State Theory Division, Physics Faculty, Adam Mickiewicz University, Poznań, Poland

I will show how to calculate the time-of-flight patterns of strongly interacting bosons confined in two-dimensional square lattice in the presence of an artificial magnetic field. I will discuss the cases with the artificial magnetic field being uniform, staggered or forming a checkerboard configuration. Effects of additional temporal modulation of the optical potential that results from application of Raman lasers driving particle transitions between lattice sites are also included. The presented time-of-flight patterns may serve as a verification of chosen gauge in experiments, but also provide important hints on unconventional, non-zero momentum condensates, or possibility of observing graphene-like physics resulting from occurrence of Dirac cones in artificial magnetic fields in systems of ultra-cold bosons in optical lattices. Also, I elucidate on differences between effects of magnetic field in solids and the artificial magnetic field in optical lattices, which can be controlled on much higher level leading to effects not possible in condensed matter physics.

16:30
QE1
3

COOPER PAIR SPLITTING AS A SOURCE OF ENTANGLED ELECTRONS

J. Martinek[1], D. Tomaszewski[1], M. Czechlewski[1], P. Rożek[1], R. Zitko[2], R. Lopez[3], M. Lee[4], W. Kłobus[5], A. Grudka[5], A. Baumgartner[6], and C. Schönenberger[6]

1 Institute of Molecular Physics, Polish Academy of Sciences, 60-179 Poznan, Poland
2 Jozef Stefan Institute, Jamova 39, SI-1000 Ljubljana, Slovenia
3 Departament de Física, Universitat de les Illes Balears, E-07122 Palma de Mallorca, Spain
4 Department of Physics, Kyung Hee University, Yongin 446-701, Korea
5 Faculty of Physics, Adam Mickiewicz University, Umultowska 85, 61-614 Poznań, Poland
6 Department of Physics, University of Basel, CH-4056 Basel, Switzerland

17:00
QE1
4

We study an entangled state of spatially separated electrons, in particular its spins, in a solid state electronic system. The ground state of conventional superconductors is a singlet state of electron Cooper pairs that can provide a natural source of entangled electrons. One of the proposals to obtain the nonlocal entanglement of electrons is to use the Cooper pairs split in the Double Quantum Dot (DQD) system using the Coulomb interaction between electrons [1]. We have analyzed an efficiency of the separation of Cooper pairs in systems, where the DQD is connected to the two superconducting leads, or to the superconducting and normal leads [2,3]. Addressing the idea of quantum communication with entangled electrons in a solid state, where ferromagnetic detectors allow for spin correlation detection, we provide, using quantum information theory, a lower bond on the spin polarization of detectors [4]. In ferromagnetic detectors the spin information is transformed into charge information, however, any real magnetic materials feature imperfect spin polarization due to presence of both spin component in density of states at the Fermi surface. We find that lower bond for the spin polarization is $p > 58\%$ for detection of entanglement using an optimal entanglement witness [4]. It provides the minimal spin polarization of ferromagnetic materials that can be useful in quantum communication.

[1] L. Hofstetter, S. Csonka, J. Nygard, and C. Schönenberger, Nature 461, 960 (2009).
[2] J. Eldridge, M. G. Pala, M. Governale, and J. König, Phys. Rev. B 82, 184507 (2010).
[3] R. Zitko, J. Lim, R. Lopez, J. Martinek, P. Simon, Phys. Rev. Lett. 108, 166605 (2012).
[4] W. Kłobus, A. Grudka, A. Baumgartner, D. Tomaszewski, C. Schönenberger, and J. Martinek, (in preparation).

Thursday, 17 Oct 2013

QUANTUM METAMATERIALS: CONCEPT AND APPLICATIONS

Alexandre Zagoskin
Loughborough University, Loughborough, UK

Quantum metamaterials are optical media comprised of artificial quantum scatterers (e.g., qubits), in such a way that (1) these unit blocks maintain quantum coherence for times exceeding the characteristic travel time of an electromagnetic wave through the system, and (2) their quantum state can be directly controlled. For example, a periodic arrangement of qubits in a register of an adiabatic quantum computer can be considered as a quantum metamaterial.

9:00
QE2
1

The simplest case of a quantum metamaterial is a one-dimensional set of superconducting qubits in a transmission line. It was shown in experiment that a single qubit in such a line demonstrates all the expected of a pointlike quantum scatterer, with a much stronger coupling to the field than can be achieved with natural atoms in 3D space. Other implementations of quantum metamaterials (like quantum dots placed inside photonic crystals, which would operate in the optical range) are also being considered.

In my talk I will discuss some of the unusual properties of a quantum metamaterial, which stem from its being an extended quantum object, and their possible applications.

THE KONDO EFFECT IN QUANTUM DOTS

Ireneusz Weymann
Mesoscopic Physics Division, Physics Faculty, Adam Mickiewicz University, Poznań, Poland

Quantum dots are promising candidates for future quantum computing devices. They are also considered as ideal model systems to study fundamental correlations and interactions between single charges and spins. We will here present the basic transport properties of quantum dots coupled to external leads, with a special focus on the strong coupling regime where the electronic correlations can give rise to the Kondo effect. The case of the spin S=1/2 Kondo effect will be analyzed for quantum dots with both nonmagnetic and ferromagnetic leads. Moreover, we will also discuss the SU(4) Kondo effect, which can occur in double quantum dots when the system possesses both spin and orbital degeneracy.

9:30
QE2
2

SPECTROSCOPIC INVESTIGATIONS OF THE ATOMIC STRUCTURE IN SUPPORT OF QUANTUM ENGINEERING AND METROLOGY

P. Głowacki[1], A. Krzykowski[1], A. Jarosz[1], O. A. Herrera-Sancho[2], M. V. Okhapkin[2], E. Peik[2]

1 Laboratory of Quantum Engineering and Metrology, Poznań University of Technology, Poland
2 Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

10:00
QE2
3

The contribution is focused on spectroscopic investigations of electronic levels, in particular metastable ones, in free atoms and ions.
A system consisting of a metastable atomic state and the ground state is very favorable for optical atomic frequency standards, since the levels are connected via a forbidden transition with possible application as a "clock" transition. The same system of levels may serve as a basis for construction of a quantum bit.
Within the work some recent achievements in high precision spectroscopy of metastable levels in chromium atoms, obtained with ABMR-LIRF (laser - microwave double resonance on an atomic beam) method [1, 2], are presented. A brief review of experimental investigations of thorium ion structure aimed at construction of an extremely precise optical nuclear frequency standard [3], performed in cooperation in PTB, is also given.

[1] A. Jarosz, D. Stefańska, M. Elantkowska, J. Ruczkowski, A. Buczek, B. Furmann, P. Głowacki, A. Krzykowski, Ł. Piątkowski, E. Stachowska, J. Dembczyński, High precision investigations of the hyperfine structure of metastable levels in chromium atom, J. Phys. B: At. Mol. Opt. Phys. 40: 2785-2797 (2007).
[2] A. Krzykowski, P. Głowacki, A. Jarosz Precise measurements of the hyperfine structure of the levels belonging to the terms $3d^5 4s^5G$ and ^5P in Cr(I), Acta Phys. Pol. A, 122, 78-81 (2012).
[3] O. A. Herrera-Sancho, M. V. Okhapkin, K. Zimmermann, Chr. Tamm, E. Peik, A. V. Taichenachev, V. I. Yudin, P. Głowacki, Two-photon laser excitation of trapped $^2 32Th^+$ ions via the 402-nm resonance line Phys. Rev. A 85, 033402 (2012).

REVIEW AND PROSPECTS OF MAGNONIC CRYSTALS

Maciej Krawczyk

Nanomaterials Physics Division, Physics Faculty, Adam Mickiewicz University, Poznań, Poland

10:30
QE2
4

Magnonic crystals are the magnetic equivalent of photonic crystals, with spin waves as the counterpart of electromagnetic waves, playing the role of information carriers. We will present short overview of research performed on magnonic crystals offering tailored band structures for spin waves. The promising directions of magnonic crystals research and its applications will be briefly discussed.

ROLE OF THE FIRST-ORDER COHERENCE IN ENTANGLEMENT BETWEEN GAUSSIAN MODES

Zbigniew Ficek[1], Li-hui Sun[2] and Gao-xiang Li[3]

1 The National Centre for Mathematics and Physics, KACST, Riyadh, Saudi Arabia 2 College of Physical Science and Technology, Yangtze University, Jingzhou, P. R. China 3 Department of Physics, Huazhong Normal University, Wuhan, P. R. China

11:30
QE3
1

The coherence and entangled properties of coupled Gaussian modes of optical systems are discussed. The systems considered are (1) an atomic ensemble located inside a ring cavity, and (2) an optical lattice trapped inside a cavity with a movable mirror. We examine separately the cases of two-mode and three-mode interactions, which are distinguished by a suitable tuning of the mode frequencies. We find that the occurrence of entanglement in the system is highly sensitive to the presence of the first-order coherence between the modes. In particular, the creation of the first-order coherence between modes is achieved at the expense of entanglement between them.

EINSTEIN-PODOLSKY-ROSEN PARADOX AND QUANTUM STEERING IN PULSED OPTOMECHANIC

Q. Y. He[1,2], M. D. Reid[2], and P. D. Drummond[2]

1 State Key Laboratory of Mesoscopic Physics, School of Physics, Peking University, Beijing, China
2 Centre for Quantum Atom Optics, Swinburne University of Technology, Melbourne, Australia

We describe how to generate an Einstein-Podolsky-Rosen (EPR) paradox between a mesoscopic mechanical oscillator and an optical pulse. We find two types of paradox, defined by whether it is the oscillator or the pulse that shows the effect Schroedinger called steering. Only the oscillator paradox addresses the question of mesoscopic local reality for a massive system. In that case, EPRs elements of reality are defined for the oscillator, and it is these elements of reality that are falsified (if quantum mechanics is complete). For this sort of paradox, we show that a thermal barrier exists, meaning that a threshold level of pulse-oscillator interaction is required for a given thermal occupation n_0 of the oscillator. We find there is no equivalent thermal barrier for the entanglement of the pulse with the oscillator, nor for the EPR paradox that addresses the local reality of the optical system. Our work highlights the asymmetrical effect of thermal noise on quantum nonlocality.

12:00
QE3
2

WHICH-WAY EXPERIMENT WITH AN INTERNAL DEGREE OF FREEDOM

Konrad Banaszek

Institute of Theoretical Physics, Department of Quantum Optics and Atomic Physics, Faculty of Physics, University of Warsaw, Poland

We present an inequality relating visibility and which-way information for a particle equipped with an internal degree of freedom travelling through a Mach-Zehnder interferometer. The inequality paints an unexpectedly intricate picture of wave-particle duality in the general case. Strikingly, in some instances which-way information becomes erased by introducing classical uncertainty in the internal degree of freedom. Furthermore, even imperfect interference visibility measured for a suitable set of inputs can be sufficient to infer absence of which-way information.

12:30
QE3
3

ARE EPR CORRELATIONS SENSITIVE TO THE FORM OF FIELD QUANTIZATION?

Marek Czachor

Faculty of Applied Physics and Mathematics, Technical University of Gdańsk and National Quantum Information Centre in Sopot, Poland

As is widely known, the standard "one oscillator per one mode" quantization of free fields leads to the correct physical prediction $\langle AB\rangle = \cos(a-b)$ for entanglement of linear polarizations, and violates the Bell inequality. This seems to suggest that the tensor product structure associated with the "oscillator per mode" quantization is indeed THE tensor structure associated with quantum fields. However, I will show that $\langle AB\rangle = \cos(a-b)$ is typical also of fields quantized in a different way, where there is no relation at all between the number of modes and the number of oscillators.

13:00
QE3
4

SUB-POISSONIAN-LIGHT GENERATION BY POSTSELECTION FROM TWIN BEAMS

Jan Peřina, Jr.[1], Ondřej Haderka[2], Vaclav Michalek[2]

1 RCPTM, Joint Laboratory of Optics of Palacky University and Institute of Physics of AS CR, Palacky University, 17. listopadu 12, 77146 Olomouc, Czech Republic

2 Institute of Physics of Academy of Sciences of the Czech Republic, Joint Laboratory of Optics of Palacky University and Institute of Physics of Academy of Sciences of the Czech Republic, 17. listopadu 12, 772 07 Olomouc, Czech Republic

14:30
QE4
1

States with sub-Poissonian photon-number statistics obtained by post-selection from twin beams are characterized. States with Fano factors around 0.7 and mean photon numbers around 12 are experimentally reached. Their quasi-ditributions of integrated intensity attaining negative values are determined. An intensified CCD camera with quantum detection efficiency exceeding 20% is utilized both for post-selection and characterization. Experimental results are compared with theory that provides optimum conditions for the experiment.

RECENT RESULTS OF THE EXPERIMENTAL-OPTICS GROUP IN OLOMOUC

J. Soubusta

Institute of Physics of Academy of Science of the Czech Republic, Joint Laboratory of Optics of PU and IP AS CR, Olomouc, Czech Republic

15:00
QE4
2

We summarize ten years of experiments dealing with quantum cloning and implementations of linear-optical quantum devices. We tried several concepts and several platforms for optimal cloning of photon qubits. We developed several linear-optical quantum information processing devices and we used them for cloning.

LINEAR-OPTICAL QUBIT AMPLIFIER

Antonín Černoch

Institute of Physics of Academy of Science of the Czech Republic, Joint Laboratory of Optics of PU and IP AS CR, Olomouc, Czech Republic

15:30
QE4
3

We propose a linear-optical scheme for heralded qubit amplification. The device is able to change the ratio between probabilities of detecting vacuum or a photonic qubit in the signal transmitted via some lossy channel by using a pair of entangled ancillae. The probability of successful amplification does not asymptotically drop to zero for infinite gain and it can be optimized if (i) some a priory knowledge of input state is known or (ii) some noise in the output signal is tolerated.

LINEAR OPTICAL QUANTUM ROUTERS

Karel Lemr

Joint Laboratory of Optics of Palacký University and Institute of Physics of Academy of Sciences of the Czech Republic, Faculty of Science, Palacký University, Olomouc, Czech Republic

This talk summarizes our recent results in the field of quantum routing. First, we define a fully functional quantum router with emphasis on the features such router has to provide. Then we review some of the previously published schemes showing the lack for genuine linear-optical quantum router for individual photons. Subsequently we present our two proposals for linear-optical quantum routers [1,2] and discuss their advantages and disadvantages. Finally we address the experimental implementation that is currently under construction in our laboratory.

16:00
QE4
4

[1] K. Lemr, A. Černoch, Linear-optical programmable quantum router, Opt. Comm. 300, 282-285 (2013).
[2] K. Lemr, K. Bartkiewicz, A. Černoch, and J. Soubusta, Resource-efficient linear-optical quantum router, Phys. Rev. A 87, 062333 (2013).

Wednesday, 16 Oct 2013

Poster Session

1. K. Bocian and W. Rudziński: Andreev reflection in spin-polarized transport through an interacting quantum dot in a hybrid tunneling junction.
2. M. Bula, K. Bartkiewicz, A. Černoch, J. Soubusta, E. M. Scott, T. Jennewein, and K. Lemr: Tunable gate for quantum amplification and nondemolition presence detection.
3. B. Bylicka, D. Chruściński, and S. Maniscalco: Non-Markovianity as a resource for quantum technologies.
4. A. Černoch, K. Bartkiewicz, K. Lemr, and J. Soubusta: Quantum routing with linear optics.
5. D. Chruściński and F. Wudarski: Non-Markovian random unitary qubit dynamics.
6. W. Głaz, T. Bancewicz, J.-L. Godet, G. Maroulis, and A. Haskopoulos: Evolution of collisional nonlinear spectral properties of light scattered in H_2-Rg mixtures. From Rg=He to Xe.
7. P. Horodecki, J. Tuziemski, P. Mazurek, and R. Horodecki: Can communication power of separable correlations exceed that of entanglement resource?
8. B. Horst, K. Bartkiewicz, and A. Miranowicz: Relative entropy of entanglement for fixed nonlocality: two-qubit mixed states superior to pure states.
9. J. K. Kalaga, W. Leoński, and V. Cao Long: Mean number of photons as witness of quantum chaotic dynamics of nonlinear Kerr-like oscillator.
10. W. Kłobus, A. Grudka, M. Horodecki, P. Horodecki, R. Horodecki, and Ł. Pankowski: Mutual uncertainty.
11. J. W. Kłos, M. Krawczyk, D. Kumar, B. Rana, and A. Barman: The influence of structural changes on the spin waves spectra of periodic antidot wire.
12. K. Lemr, K. Bartkiewicz, A. Černoch, M. Dušek, and J. Soubusta: Applications of linear-optical controlled-phase gate with tunable phase shift.
13. M. Mruczkiewicz, M. Krawczyk, G. Gubbiotti, S. Tacchi, Yu. A. Filimonov, and S. A. Nikitov: Nonreciprocal dispersion of spin waves in magnonic crystals.
14. T.D. Nguyen, W. Leoński, A. Kowalewska-Kudłaszyk, J. Peřina Jr., and V. Cao Long: Kerr-like coupler excited by a series of ultra-short external pulses as a source of entangled states.
15. Nguyen Thanh Vinh, Bui Dinh Thuan, Cao Long Van, and Wiesław Leoński: Dynamics of a set of two-level subsystems in two-dimensional cavity simulated with cellular automata formalism.
16. K. Nowicka: Nonlinear electro-optical spectroscopy of liquid crystals.
17. M. Paprzycka, A. Miranowicz, Y.X. Liu, J. Bajer, and F. Nori: Two-photon blockade in a driven cavity with a qubit.
18. P. Rożek, M. Czechlewski, D. Tomaszewski, and J. Martinek: Entanglement detection of split Cooper pairs by direct current measurements using double quantum dots and ferromagnetic detectors.
19. M. Smaczyński: Model quantum neuron: Construction based on nonunitary dynamics.
20. J. Soubusta, R. Machulka, J. Svozilík, J. Peřina Jr., and O. Haderka: Second harmonic generation in periodically poled KTP.
21. D. Tomaszewski, R. Zitko, R. Lopez, M. Lee, and J. Martinek: Cooper pair splitting efficiency in double quantum dot in cotunneling regime.
22. D. Tomaszewski, A.-D. Crisan, S. Datta, J. J. Viennot, M. R. Delbecq, C. Feuillet-Palma, A. Thiaville, A. Cottet, T.Kontos, and J. Martinek: Quantum spin torque in quantum dot coupled to ferromagnetic leads.
23. D. Tomaszewski, P. Makk, A. Halbritter, Z. Balogh, S. Csonka, M. Wawrzyniak, M. Frei, L. Venkataraman, and J. Martinek: Correlation analysis of atomic and single-molecule junction conductance.

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