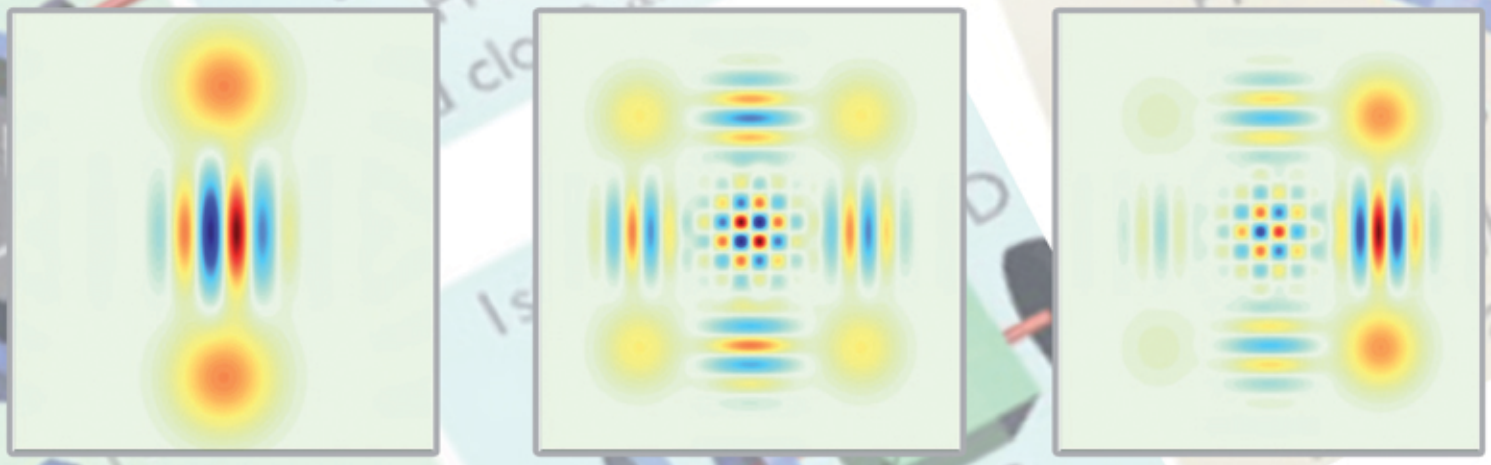
The Second Poznan Workshop on

Quantum Engineering, Quantum Information, and Semi-Quantum Biology QEIB 2012

16-18th October 2012

Faculty of Physics, Adam Mickiewicz University



Supported in part by the Polish National Science Centre under grant DEC-2011/03/B/ST2/01903 and the Physics Faculty of the Adam Mickiewicz University

Invited speakers:

- Konrad Banaszek (Warszawa)
- Karol Bartkiewicz (Olomouc)
- Antonín Černoch (Olomouc)
- Piotr Deuar (Warszawa)
- Paweł Horodecki (Gdańsk)
- Andrea Lehmann-Szweykowska (Poznań)
- Karel Lemr (Olomouc)
- Barbora Lemrová (Olomouc)
- Wiesław Leoński (Zielona Góra)
- Tadeusz Lulek (Poznań)
- Jan Milewski (Poznań)
- Jan Soubusta (Olomouc)
- Tomasz Sowiński (Warszawa)
- Ryszard Tanaś (Poznań)

Local Organizing Committee:

- Adam Miranowicz
- Ravindra Chhajlany
- Przemysław Grzybowski
- Bohdan Horst
- Anna Kowalewska-Kudłaszyk
- Małgorzata Paprzycka

This worshop is supported in part by the Polish National Centre for Science under grant No. DEC-2011/03/B/ST2/01903 and the Physics Faculty of Adam Mickiewicz University.

TUESDAY (2012-10-16)		
08:30-09:00	MORNING COFFEE	
Morning Session - chairman Ryszard Wojciechowski		
09:00-09:30	Ryszard Tanaś	Correlations in a two-atom system
09:30-10:00	Paweł Horodecki	Quantum privacy witness
10:00-10:30	Karel Lemr	Quantum information in the Joint Laboratory of Optics - last three years of photon pairs
10:30-11:00	Tadeusz Lulek	Galois qubits and Bethe Ansatz
11:00-11:30	COFFEE BREAK	
Noon Session - chairman Paweł Horodecki		
11:30-12:00	Piotr Deuar	Nonclassical atom pairs obtained from supersonic collisions of Bose-Einstein condensates
12:00-12:30	Jan Soubusta	Experimental implementations of linear-optical quantum devices
12:30-13:00	Antonín Černoch	Experimental implementations of quantum cloners
13:00-14:00	LUNCH	
Afternoon Session I - chairman Jan Soubusta		
14:00-14:30	Tomasz Sowiński	Dipolar molecules in optical lattices
14:30-14:50	Przemysław Grzybowski	Hubbard-I approach to the Mott transition
14:50-15:10	COFFEE BREAK	
Afternoon Session II - chairman Antonín Černoch		
15:10-15:30	Tomasz Polak	Dirac like physics in optical lattices
15:30-15:50	Jan Milewski	Anyonic harmonics and their Hodge structure deformation

WEDNESDAY (2012-10-17)		
08:30-09:00	MORNING COFFEE	
Morning Session - chairman Wiesław Leoński		
09:00-09:30	Barbora Lemrová	Solid phase synthesis of potentially biologically active compounds
09:30-10:00	Krzysztof Gibasiewicz	Influence of protein dynamics on intraprotein electron transfer in photosynthetic reaction centers
10:00-10:30	Jan Soubusta	Spatial and spectral properties of the pulsed second-harmonic generation in a PP-KTP waveguide
10:30-11:00	Andrea Lehmann-Szweykowska	Correlated cluster mean field theory in the hcp compressible Ising model
11:00-11:30	COFFEE BREAK	
Noon Session - chairman Tadeusz Lulek		
11:30-11:50	Marek Sawerwain	Perfect state transfers in finite Hilbert space (for qubits and qudits)
11:50-12:10	Karol Nowacki	Statistical testing of random number generators
12:10-12:30	Grzegorz Chimczak	Improving fidelity in atomic-state teleportation via non-maximally-entangled states
12:30-12:50	Joanna Pietraszewicz	Anharmonicity vs. higher orbital states in optical lattices
13:00-14:00	LUNCH	
Afternoon Session - chairman Tomasz Sowiński		
14:00-14:20	Piotr Tomczak	Entanglement in Quantum Spin Systems: RVB Approach
14:20-14:40	Marcin Karczewski	An algorithm for characterizing SLOCC classes of multiparticle entanglement
14:40-15:00	COFFEE BREAK	
15:00-15:20	Piotr Trocha	Spin and charge thermoelectric effects in a double quantum dot system
15:20-15:40	Michał Berent	Broadband Faraday isolator
15:40-16:00	Jan Tuziemski	Novel property of private states and its application

THURSDAY (2012-10-18)		
08:30-09:00	MORNING COFFEE	
Morning Session - chairman Karel Lemr		
09:00-09:30	Wiesław Leoński	Quantum state engineering - nonlinear quantum scissors
09:30-09:50	Anna Kowalewska-Kudłaszyk	Kerr couplers as nonlinear quantum scissors - entanglement creation and decay
09:50-10:10	Monika Bartkowiak	Amplification of Kerr nonlinearity and its application for deterministic entangling gates at the single-photon level
10:10-10:30	Karol Bartkiewicz	Experimental quantum cloning for hacking quantum-key distribution protocols
10:30-11:30	COFFEE BREAK and POSTER SESSION	
Noon Session - chairman Ryszard Tanaś		
11:30-12:00	Konrad Banaszek	Entanglement-based effects in two-photon propagation
12:00-12:30	Karel Lemr	Optimal linear-optical tunable controlled phase gate and related research
12:30-13:00	Antonín Černoch	Single photon detection in Olomouc
13:00-14:00	LUNCH and COFFEE and END OF PROGRAM	

ABSTRACTS

INVITED TALKS

1. **Konrad Banaszek**: Entanglement-based effects in two-photon propagation

   Radiation generated in spontaneous parametric down-conversion exhibits a number of interesting features. One of them is the phenomenon of non-local dispersion cancellation, in which strong temporal correlations between photon pairs are preserved despite propagation through dispersive media with group velocity dispersion coefficients of equal strength and opposite signs. An intriguing question is whether such features can be reproduced with classical radiation. In the case of non-local dispersion cancellation, an analogous effect can be shown to occur also for Gaussian mixtures of coherent states, but at the cost of introducing a uniform background of coincidence counts with a comparable magnitude. We present here a simple variance-based criterion identifying a feature of non-local dispersion cancellation that critically depends on the presence of entanglement in the propagating light. Analogous analysis can be applied also to directional correlations in free-space propagation.

2. **Karol Bartkiewicz**: Experimental quantum cloning for hacking quantum-key distribution protocols

   We describe a proof-of-principle experiment which shows that quantum cloning can be used for hacking quantum key distribution protocols. We analyze the conditions under which the cloning attack is successful and obtain the corresponding error rates.

3. **Antonín Černoch**: Experimental implementations of quantum cloners

   Review of several experimental implementations of qubit cloners implemented in the Joint Laboratory of Optics in Olomouc is presented. Quality of various implementations is discussed based on obtained clones fidelity.

4. **Antonín Černoch**: Single photon detection in Olomouc

   The talk presents several devices capable of detection of ultra-weak light signals. The main technological aspects and limitations of these devices are discussed with emphasis on possible usage in quantum optical experiments.

5. **Piotr Deuar**: Nonclassical atom pairs obtained from supersonic collisions of Bose-Einstein condensates

   Correlated atom pairs are scattered from colliding Bose-Einstein condensates by a process akin to parametric down conversion. I will describe an experiment and its numerical simulation that have shown number-difference squeezing and a violation of the Cauchy-Schwartz inequality. The long term goal is to test Bell inequalities with spatially separated massive particles.

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6. **Paweł Horodecki**: Quantum privacy witness

   Quantum private states are the states that represent perfectly secure bits of secret key. It is known that among quantum private states that are ones that are not maximally entangled. In those cases secret key extraction goes beyond entanglement distillation scheme. The construction of simple observable called quantum privacy witness which allows to correctly detect and qualitatively estimate privacy will be presented. In some cases the observable is experimentally very friendly still providing useful lower bound for secret key entanglement measure K beyond entanglement distillation regime.

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7. **Andrea Lehmann-Szweykowska**, Ryszard Wojciechowski, Michał Kurzyński: Correlated cluster mean field theory in the hcp compressible Ising model

   We derive an hcp compressible Ising Hamiltonian with a spin-phonon interaction and compute the influence of spin correlations on the empirically observed Brillouin shift. The spin correlations are found by an Oguchi-like method which is newly tailored variation of the Bethe-Peierls-Weiss (BPW) approximation. In the direct space, we consider a cluster consisting of a central spin and its 12 nearest neighbours. Each of the 12 nn pairs, consisting of the central spin and, in turn, all the neighbours , is treated exactly (Oguchi method) while the influence of the remaining spins is replaced by an effective field. In the present approach, the latter is not calculated self-consistently, but substituted by that found in the conventional MFA. In the reciprocal lattice, after the Fourier transformation, we finally arrive at the spin correlation which is temperature and wave-vector dependant. The result remains valid both in the ordered and disordered phases. In the ordered phase, the molecular-field approximation is extended to the static soliton theory.

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8. **Karel Lemr**: Quantum information in the Joint Laboratory of Optics - last three years of photon pairs

   This talk reviews recent experimental activities in the quantum information processing with linear-optics. The most important results over the past three years are presented.

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9. **Karel Lemr**: Optimal linear-optical tunable controlled phase gate and related research

   Controlled phase gate is one of the fundamental building blocks of quantum information devices. This talk presents our experimental implementation of such device and related research.

10. **Barbora Lemrová**: Solid phase synthesis of potentially biologically active compounds

    The talk presents the technique of the so-called solid phase synthesis of organic molecules. Its application on synthesis of compounds with potential biological activity is discussed with emphasis on current research at the Department of Organic Chemistry of Palacký University in Olomouc.

11. **Wiesław Leoński**: Quantum states engineering - nonlinear quantum scissors

    Several models involving nonlinear quantum Kerr-like oscillators are presented. Such models referred to as nonlinear quantum scissors can lead to finite-dimensional states generation, including maximally entangled ones.

12. **Tadeusz Lulek**: Galois qubits and Bethe Ansatz

    Implementation of an arithmetic qubit on the basis of exact Bethe Ansatz eigenstates of a Heisenberg magnetic ring is proposed. It bases on the Galois number field of an appropriate finite extension of rationals.

13. **Jan Milewski**: Anyonic harmonics and their Hodge structure deformation

    The space of anyonic harmonic function on a plane admits a deformed Hodge structure. The deformation of the Hodge structure is connected with the fractional statistics. The parameters of the structure are quantum numbers of the system.

14. **Jan Soubusta**: Experimental implementations of linear-optical quantum devices

    This review talk presents several linear-optical quantum devices suitable for discrete variables quantum information processing. The devices make use of single and bi-photon interference in both bulk and fibre optical setups.

15. **Jan Soubusta**: Spatial and spectral properties of the pulsed second-harmonic generation in a PP-KTP waveguide

    Spatial and spectral properties of the pulsed second harmonic generation in a periodically-poled KTP waveguide are analyzed. Experimental results are interpreted using a model based on finite elements method.

16. **Tomasz Sowiński**: Dipolar molecules in optical lattices

We study the extended Bose-Hubbard model describing an ultracold gas of dipolar molecules in an optical lattice, taking into account all on-site and nearest-neighbor interactions, including occupation-dependent tunneling and pair tunneling terms. We show that these terms can destroy insulating phases and lead to novel quantum phases.

17. **Ryszard Tanaś**: Correlations in a two-atom system

Evolution of the two-atom system driven by the resonant laser field is considered. It is shown that the two-photon entangled states can be generated in such a system. The role of the dipole-dipole interaction in generating of quantum correlations is discussed. The condition for obtaining steady-state entanglement is given and the time evolution of the quantum correlations is presented.

REGULAR TALKS

18. **Monika Bartkowiak**: Amplification of Kerr nonlinearity and its application for deterministic entangling gates at the single-photon level

An alternative approach to implement quantum entangling gates to the well-known linear-optical one is using nonlinear materials for deterministic nonlinear photon interactions. However only small conditional phase shift induced by a few photons in the Kerr nonlinearity was successfully measured. We show how to improve the phase-shift obtained for two single-photon states in the cross-Kerr interaction.

19. **Michał Berent**, Andon A. Rangelov and Nikolay V. Vitanov: Broadband Faraday isolator

Drawing on an analogy with the powerful technique of composite pulses in quantum optics and polarization optics we present a broadband optical diode (optical isolator) made of a sequence of ordinary 45° Faraday rotators sandwiched with quarter-wave plates rotated at the specific angles with respect to their fast polarization axes.

20. **Grzegorz Chimczak**: Improving fidelity in atomic-state teleportation via non-maximally-entangled states

The talk shows that non-maximally entangled states can be better for atomic state teleportation performed via cavity decay. The destructive influence of cavity decay on the fidelity can be minimized by using in the teleportation the non-maximally entangled states instead of the maximally entangled state.

21. **Krzysztof Gibasiewicz**: Influence of protein dynamics on intraprotein electron transfer in photosynthetic reaction centers

Photosynthetic reaction centers are pigment-protein complexes containing a chain of electron transfer carriers. A linear electron transfer between these carriers occurs on a wide time-scale spanning from picoseconds to microseconds depending on particular step of the transfer. In the talk, results of experimental studies of one particular step of this electron transfer will be shown. Multiphasic kinetics of this reaction is interpreted in terms of a model in which protein dynamically modulates the rate of the electron transfer with characteristic lifetimes of 1 and 10 ns.

22. **Przemysław Grzybowski**: Hubbard-I approach to the Mott transition

We analyse the Hubbard model with correlated hopping, at the double occupancy conservation symmetry point, using Hubbard-I approach which describes fractionalised electrons quasiparticles. We obtain description of Mott transitions and the surrounding extremely correlated quantum liquids. The calculations may be relevant for future experiments on optical lattices.

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23. **Marcin Karczewski**: An algorithm for characterizing SLOCC classes of multiparticle entanglement

A primer on how geometric invariant theory and momentum map geometry could be used to effectively find all stochastic local operations and classical communication (SLOCC) classes of pure states.

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24. **Anna Kowalewska-Kudłaszyk**: Kerr couplers as nonlinear quantum scissors - entanglement creation and decay

Various types of decay for entanglement obtained within nonlinear quantum scissors systems are discussed. Conditions for observing entanglement death or its revival are presented.

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25. **Karol Nowacki**: Statistical testing of random number generators

Review of statistical randomness tests and their software implementations used to verify quality of random number generators.

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26. **Joanna Pietraszewicz**: Anharmonicity vs. higher orbital states in the optical lattices

It is known that dipolar interactions in the presence of a resonant magnetic field can transfer atoms to higher excited states with non zero angular momentum (Einstein-de Haase effect). We investigate how this effect is modified by the lattice potential. In particular we explain in details the role of anharmonicity and anisotropy of a single lattice site.

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27. **Tomasz Polak**: Dirac like physics in optical lattices

This talk presents an elegant concept of the effective mass theory applied to the neutral bosons confined in two-dimensional square lattice under synthetic magnetic field. Analytically calculated band structure allows to predict the existence of the massless particles with neutrino like dispersion relation located in the particular points of the momentum space. It will be shown that the Dirac cones contain massless particles whose positions and velocities can be tuned by the external magnetic field giving rise to the exotic properties. The presence of the Hofstadter spectrum in the strongly interacting system of bosons reveals some unexpected behavior of the local effective mass dependence.

28. **Marek Sawerwain**: Perfect state transfers in finite Hilbert space (for qubits and qudits)

The talk presents the perfect state transfer (PST) protocols performed in 1D qubit or qudit chains. Dynamics of transfer is determined by the XY-like Hamiltonian which will be described by special unitary group operators SU(d).

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29. **Piotr Tomczak**: Entanglement in Quantum Spin Systems: RVB Approach

Recently proposed estimators for entanglement entropy in quantum spin systems in resonating valence bond (RVB) basis are reviewed. Some of them may be effectively calculated by using Monte Carlo techniques. Additionally properties of entanglement spectrum of small systems are presented in position and momentum space and their relation to topologically ordered states is discussed. An attempt to calculate such a spectrum of small spin systems in RVB basis is reported. A possibility of finding the topological order in quantum spin systems using RVB basis is discussed.

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30. **Piotr Trocha**: Spin and charge thermoelectric effects in a double quantum dot system

Thermoelectric effects in a double quantum dot system coupled to external magnetic/nonmagneticleads are investigated theoretically. The basic thermoelectric transport characteristics, like thermopower, electronic contribution to heat conductance, and the corresponding figure of merit, have been calculated in terms of the linear response theory and Green function formalism in the Hartree-Fock approximation for Coulomb interactions. An enhancement of the thermal efficiency (figure of merit ZT) due to Coulomb blockade has been found. The magnitude of ZT is further considerably enhanced by quantum interference effects. The influence of spin-dependent transport on the thermoelectric effects (especially on Seebeck and spin Seebeck effects) is also analyzed.

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31. **Jan Tuziemski**: Novel property of private states and its application

Quantum bipartite states with the direct accessible, ideal cryptographic key are known as private states. In this talk we will present a novel property, namely the invariance of distillable key under rotations around private axis in Devetak-Winter protocol, for general private states. Its application to the problem of searching optimal measurement basis for a given private state will be demonstrated. We will also provide results concerning error estimation of the proposed procedure.

POSTERS

1. Karol Bartkiewicz, Karel Lemr, Antonín Černoch, Jan Soubusta, Adam Miranowicz: Experimental tunable qubit cloner

2. Karol Bartkiewicz, Adam Miranowicz: Optimal cloning of axially symmetric qubit distributions on the Bloch sphere

3. Monika Bartkowiak, A. Miranowicz, X. Wang, Y.X. Liu, W. Leoński, and F. Nori: General occurrence of sudden vanishing of nonclassicality witnesses

4. Monika Bartkowiak, Adam Miranowicz: Linear-optical implementations of entangling quantum gates using conventional detectors

5. Ł. Czekaj, R. W. Chhajlany, P. Horodecki: Directed percolation effects in quantum communication

6. T. Bui Dinh, V. Cao Long, Wiesław Leoński and K. Dinh Xuan: Solitary waves in an elastic rod

7. Thuan Bui Dinh, Van Cao Long, Wiesław Leoński: Propagation in an autoionization medium with double Fano structure

8. Bohdan Horst, Satoshi Ishizaka, Andrzej Koper, and Adam Miranowicz: Comparative study of measures of quantum correlations in two-qubit systems

9. J.K. Kalaga, W.Leoński, A. Kowalewska-Kudłaszyk, V. Cao Long: Wehrl entropy as quantum chaos witness - kicked Kerr-like oscillator model

10. Karel Lemr and Jaromír Fiurásek: Conditional preparation of arbitrary superpositions of atomic Dicke states

11. Małgorzata Paprzycka, Adam Miranowicz: Phase-space description of quantum-to-classical transition of Schrödinger cats and kittens coupled to engineered environments

12. Małgorzata Paprzycka, Adam Miranowicz: Conditions for observation of nonclassical behavior of nanoscale mechanical membranes via phonon blockade

13. Jan Peřina Jr., Antonín Luks, Wiesław Leoński, Vlasta Peřinová: Photoelectron spectra and entanglement in an auto-ionization system interacting with a neighboring atom

14. Jan Peřina Jr., Ondrej Haderka, Martin Hamar, V. Michálek: Photon-number statistics of twin beams: self-consistent measurement, reconstruction, and properties

15. Khoa Doan Quoc, Van Cao Long and Wiesław Leoński: EIT for lambda-like systems with double Fano continuum and broad-band coupling laser

16. The RCPTM Team: Regional Centre of Advanced Technologies and Materials

17. G. Szawioła, D. Stefańska, A. Musiał, K. Murawski, A. Buczek: Experimental model of ion trap atomic force sensor

18. Nguyen Thanh Vinh, Bui Dinh Thuan, Cao Long Van, W. Leoński: Cellular automata in Matlab environment