XII Symposium
of the Institute of Experimental Physics

Faculty of Physics, University of Warsaw
November 28, 2016

Web page of the Symposium:

http://ifd.fuw.edu.pl/wydarzenia/sympozjum-ifd/sympozjum-ifd-2016

Indico page of the Symposium with all oral contributions:

http://indico.fuw.edu.pl/event/ifd2016/

The Organising Committee of the Symposium:

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dr hab. Andrzej Wysmolek, prof. UW, prof. dr hab. Aleksander Filip Żarnecki (chair).

Preface

Symposia of the Institute of Experimental Physics are organised every two years since December 1994. The main purpose is to inform members of the Faculty of Physics, as well as students associated with the Faculty, about the present scientific activities of the experimental research groups. The 12th Symposium took place on Monday, November 28th 2016, in the main lecture room of the Faculty of Physic building at Pasteura 5 street in Warsaw. Various aspects of spin were the leading subject of the Symposium this year, from proton spin structure, spin of the atomic nuclei and quantum dots, to spin related research in biophysics, medical physics and astronomy. Selected results from other research areas covered in the Institute were also presented. The Symposium included four invited lectures, including the presentation of the winner of the Professor Stefan Pienkowski Award 2016, 15 oral contributions, poster session and the final of Professor Jan Gaj Physics Demonstration Competition. There were 174 participants registered to the Symposium including many researchers and students from other faculties of the University of Warsaw, institutes of the Polish Academy of Sciences and other institutions collaborating with the Institute of Experimental Physics. This book collects abstracts of all accepted oral and poster contributions presented at the Symposium.

Laureates

Professor Jan Gaj Physics Demonstration Competition:

1st prise
Aleksander Bogucki and Łukasz Zinkiewicz for *Ekran dotykowy* and *Konwekcja*

2nd prise
Piotr Orłowski for *Magnetohydrodynamika*

3rd prise
Jan Stefan Bihałowicz for *Przesłanianie pola magnetycznego*

Poster competition:

1st prise
Rekonstrukcja torów cząstek naładowanych w detektorze mini-eTPC
Jan Stefan Bihałowicz

2nd prise
WSe_2 based light-emitting tunneling van der Waals heterostructures in magnetic fields
Johannes Binder

3rd prise
β-decay fast-timing study of ^{138}Xe
Monika Piersa

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See the abstract for the full author list.

Invited contributions

Mobilome of extremophilic bacteria and its role in adaptation to extreme environments

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Horizontal gene transfer plays an important role in shaping bacterial genomes. The key players in this process are mobile genetic elements (MGEs), which may be considered as the driving force of the bacterial evolution. Therefore, identification and analysis of novel MGEs in the light of an overall characterization of their hosts provides insight into biology, ecology and adaptation of bacteria, especially those inhabiting various extreme environments.

Mobile genetic elements are components of almost all prokaryotic genomes and constitute the mobilome. They are diverse in the meaning of their structure and functioning. MGEs include: (i) plasmids, (ii) bacteriophages, (iii) transposable elements and (iv) genetic cassettes of integrons. In the presented study, MGEs identified in extremophilic bacteria (psychrotolerants, metalotolerants and bacteria utilizing toxic organic compounds) were analyzed.

In the course of performed analyses over 300 bacterial strains, 200 plasmids and several other MGEs were isolated, identified and characterized. Amongst identified MGEs there were several “unusual” ones, including: (i) miniature plasmids (of the sizes not exceeding 800 bp) of Arctic *Variovorax* spp., (ii) unique helper-satellite bacterial viruses systems, in which one virus is a parasite of another one and (iii) chromids, i.e. indispensable extrachromosomal elements sharing characteristics of both plasmids and chromosomes, which are responsible for utilization of toxic, one-carbon (C1) compounds.

The complex analyses of MGEs of extremophilic bacteria allow detecting of various phenotypic modules (e.g. UV resistance genes, osmo- and cryoprotection modules, heavy metal and antibiotic resistance genes and modules responsible for utilization of toxic compounds), which proofs an important role of MGEs in biology, ecology and adaptation of bacteria to extreme environmental conditions. The analyses were focused on the interactions between genetic modules, MGEs and host strains. It was shown that some plasmids-encoded genetic modules may ”do not fit” to some strains, which may result in surprising phenotypes, e.g. decreasing of the resistance to particular heavy metals after introducing the resistance module into the cell .

Moreover, in the course of carried analyses, the plasmids similarity networks were constructed. It brought direct evidences for horizontal gene transfer in polar regions, which, as it was shown, may occur even at the inter-genus level.

Black holes and their spin

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Black holes are routinely observed by astronomers in all bands of electromagnetic radiation, from radio waves, through X-rays, to hard gamma-rays. Several black holes that are the end product of stellar evolution are known in the Milky Way and neighboring galaxies, they were typically born in supernova explosions. In addition, each galaxy is thought to contain in its center a supermassive black hole, millions or billions time more massive then the Sun. Many of these are observed as extremely luminous sources of radiation, powered by efficient conversion of the rest mass of infalling matter into electromagnetic energy. In rapidly spinning black holes the efficiency of conversion may at times exceed 100 per cent, as the reservoir of rotational energy of the black hole is tapped in the radiation process. Astronomers have three accurate ways of measuring the spin of the observed black holes, none of them as yet reliable. The most reliable (to date) spin measurements in astrophysics have been achieved by the LIGO collaboration in the famous gravitational wave detection of merging black holes which was announced earlier this year.

Radioisotopes for medical use

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Radiopharmaceuticals are used extensively as diagnostic and therapeutic agents in nuclear medicine. These medicinal products contain a radionuclide in their molecule' structure. The molecule conveys the radionuclide to specific organs, tissues or cells whilst the radionuclide is selected for its radioactive properties. In the recent years the capacity for production of radionuclides and the range of these radionuclides are growing worldwide in order to meet the medical demand. The long list of medically useful radionuclides can be produced in the nuclear reactors and in cyclotrons. However, when designing the radiopharmaceutical, either for diagnostic use or for therapy, one not only needs to bear in mind the physical properties of the radionuclide such as the decay mode and the energy of emitted radiation but also the chemical properties of the element, in order to provide the stable bond between the radionuclide and the carrier molecule.

Current knowledge about the molecular processes taking place at the cellular and sub-cellular allows to identify the potential molecular targets and to select biologically active molecules, which can effectively deliver radionuclides to the target tissue, while sparing the normal tissues and organs. Extensive research programs are carried out to develop new radiopharmaceuticals, also Polish research teams contribute to that achievements. The examples are the new diagnostic agents based on the receptor targeting peptides used in SPECT or PET techniques or the novel applications of β^- or α-emitters for internal radiotherapy.

^{15}N relaxation – a tool to study internal protein dynamics

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Development of Nuclear Magnetic Resonance (NMR) techniques and applications has been awarded six times by the Nobel Prize: in Physics (1943, 1944, and 1952), Chemistry (1991, 2002), and Medicine (2003). Among the others NMR has been successfully used for determination of protein structure in solution (K. Wüthrich – 2002), being an reasonable alternative for crystallography. Moreover, contrary to X-ray approach, NMR techniques can deal with proteins carrying flexible regions, or even with those, which are partially disordered. Proteins of the latter type, so called intrinsically disordered proteins (IDPs), were shown to be involved in the essential processes of the living cell. Free IDPs in a solution are highly flexible, thus sampling a large conformational space, with some of the conformers, called a transient structures, resembling properly folded protein.

We have been studying a virtual folding of domain 4 of an *E. coli* RNA polymerase subunit [1], which is involved in the recognition of promoter regions in DNA structure initiating DNA to RNA translation. Application of Lipari-Szabo model-free formalism to the ^{15}N relaxation data, together with standard NMR approach (Nuclear Overhauser Effect) demonstrated that the studied protein is intrinsically unfolded, however occasionally adopts the structure required for DNA recognition [2],[3].

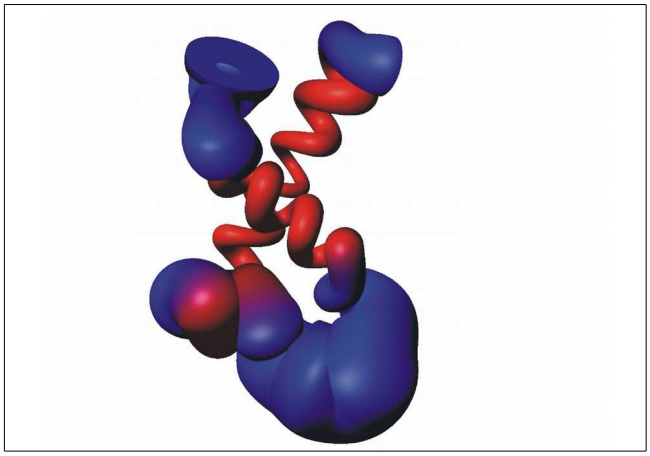

Figure 1: Model of inte owing protein backbone represents the local RMSD. Helical structures are in red, while loops are denoted in blue.

[1] J. Poznanski, K. Bolewska, I. Zhukov, K.L. Wierzchowski, Biochemistry, 42 (2003) 13438 13448.
[2] P. Kaczka, A. Polkowska Nowakowska, K. Bolewska, I. Zhukov, J. Poznanski, K.L. Wierzchowski, Proteins, 78 (2010) 754 768.
[3] P. Kaczka, M. Winiewska, I. Zhukov, B. Rempola, K. Bolewska, T. Lozinski, A. Ejchart, A. Poznanska, K.L. Wierzchowski, J. Poznanski, European Biophysics Journal, 43 (2014) 581 594.

Oral contributions

Einstein-Podolsky-Rosen Paradox in a Hybrid Bipartite System

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Nowadays, with the rapid development of spatially-resolving single-photon detectors, spatially-multimode entangled states start to play a key role in modern quantum science, including quantum communication, computation and imaging schemes.

Here we experimentally generate [1] a hybrid bipartite 12-dimensional entangled state of a single photon and collective atomic spin-wave excitation consisting of 10^{12} atoms. The state lives for an unprecedented time of 6 microseconds, which is two orders of magnitude improvement over hitherto performed experiments. One of the striking properties of the generated micro-macro entangled state is the perfect correlation of positions and anti-correlation of momenta in the photon-atom wavefunction, demonstrated here for the first time. We verify such a state exhibits an original version of the famous Einstein-Podolsky-Rosen (EPR) paradox [2], namely violation of the Heisenberg inequality $\Delta x \Delta p_x \geq \hbar/2$, with continuous position-momentum variables of two different physical entities.

Our experiment lies at nodal point of multiple paths undertaken in modern quantum information processing, such as the fundamental study of entanglement, research on the spatially-multimode structure of atom-photon states and finally atomic quantum memories with their broad applications. Prospectively, the manipulation of the stored atomic state conditionally on the measurement of the photonic state provides ways to perform novel tests of the quantum theory or generation of the hyperentanglement.

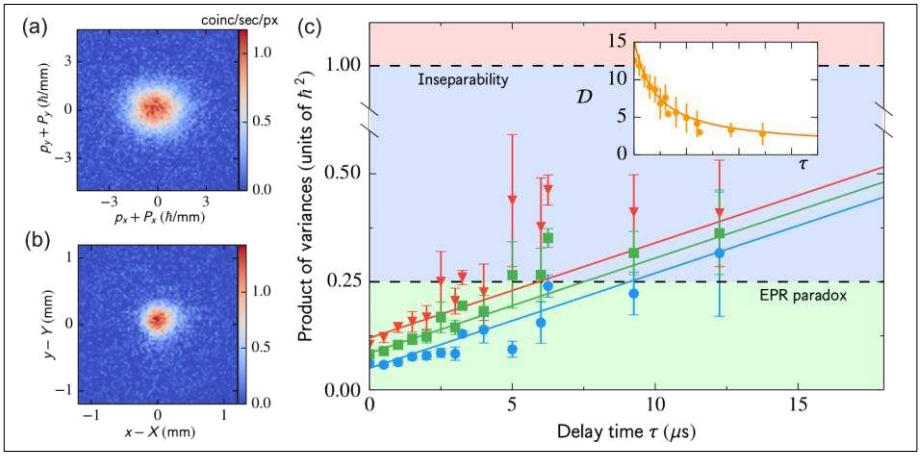

Figure 1: Demonstration of the EPR paradox. The width of narrow two-dimensional coincidence peaks at zero coordinates for sum of momenta (a) and difference of positions (b) allows us to estimate the degree of violation EPR criterion as well as the amount of entanglement present in the system. (c) The product of variances for a set of different delay times. Solid lines correspond to the expected decay of entanglement due to atomic diffusion for x-dimension (red triangles), y-dimension (blue circles) and average of coordinates (green squares). Inset shows the corresponding dimension of entanglement *D*.

[1] M. Dąbrowski, M. Parniak, and W. Wasilewski, arXiv: 1607.05865 (2016).
[2] A. Einstein, B. Podolsky, and N. Rosen, Phys. Rev. **47**, 777 (1935).

Non-equilibrium condensation of exciton-polaritons with giant Zeeman splitting in semiconductor microcavities.

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Despite the many interesting phenomena predicted theoretically [1] – like resonant Faraday rotation, Meissner effect or spin superfluidity – the experimental investigations of the magneto-optical properties of cavity polaritons were so far rather limited. In the extensively studied GaAs-based microcavities the Zeeman splitting of exciton-polariton is of the order of polariton linewidth. Semimagnetic semiconductors offer the opportunity to enhance magneto-optical effects via the exchange interaction between the *d*-shell electrons of a magnetic ion and the *s*-shell electrons and *p*-shell holes of the conduction band of the host material. This *s,p-d* exchange interaction leads to enhanced magneto-optical effects like giant Faraday rotation and giant Zeeman splitting [2, 3]. Our approach to semimagnetic cavity polaritons is based on redesigned structures where magnetic ions are inserted only in the quantum wells, while cavity and distributed Bragg reflectors are made of non-magnetic materials [4] (Fig. 1a). We show that the giant Zeeman effect of polaritons results only from the strong coupling of cavity photons with semimagnetic excitons confined in CdTe quantum wells containing manganese ions.

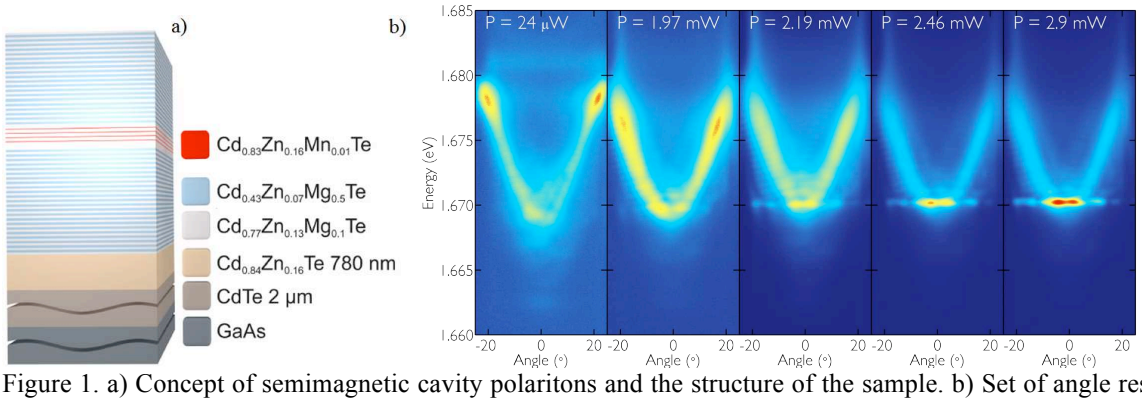

Figure 1. a) Concept of semimagnetic cavity polaritons and the structure of the sample. b) Set of angle resolved photoluminescence maps for increasing excitation power demonstrating non-equilibrium exciton-polariton condensation with increasing polariton density.

These results pave the way to the study of polariton spinor condensates with enhanced magnetic properties. Under strong excitation we observe a non-linear transition to a non-equilibrium polariton condensate (Fig. 1b). We demonstrate that the condensation threshold strongly depends on magnetic field. Moreover, the onset of the condensation can be changed by the external magnetic field – with increasing magnetic field the emission from the condensate can be switched on and off. Magnetic field introduces the imbalance between spin-up and spin-down polariton densities by tending to align the spins. Therefore, it is an important parameter that allows tuning the interactions between polaritons and influences critical conditions for polariton condensation. This is particularly revealed by the polarization properties of the condensate, which are also strongly affected by magnetic field. At zero magnetic field we observe linearly polarized condensate. As magnetic field increase the condensate becomes elliptically polarized and it's energy is close to the dominant σ^+ circular polarization. Our results open now a wide possibility to experimentally study the magnetic interactions in exciton-polariton non-equilibrium condensates.

[1] A. V. Kavokin in *Exciton Polaritons in Microcavities* edited by D. Sanvitto and V. Timofeev, Springer Series in Solid-State Sciences (2012) [2] J. A. Gaj, R. Planel, G. Fishman, *Solid State Commun.* **29**, 435 (1979). [3] R. Mirek et al., arXiv:1609.00405 (2016). [4] J.-G. Rousset et al., *Appl. Phys. Lett.* **107**, 201109 (2015).

Crystal and magnetic structure of layered perovskite $Sr_{3-x}Y_x(Fe,Ni)_2O_{7-\delta}$

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Complex transition metal oxides with layered intergrowth structures between perovskite and rock salt blocks like the Ruddlesden-Popper (RP) phases are considered as promising candidates for cathode materials in intermediate temperature solid oxide fuel cells (ITSOFC) because they can exhibit high mixed oxide-ion and electronic conductivities.[1] The ideal stoichiometry of RP phases is $A_{n+1}B_nO_{3n+1}$, where *A* is an alkaline-earth or rare-earth element, *B* is a transition metal element, and n = 1, 2 or 3. Their structures contain $n{\cdot}ABO_3$ perovskite blocks that alternate with single *A*O rock-salt blocks.[2] The ideal n=2 RP structure is illustrated in Fig. 1a. The oxygen atoms can occupy three different positions (O1, O2 and O3) forming in the ideal case octahedra around the *B* atom. The *B* position is occupied either by Fe or Ni atoms.

Here we would like to present studies of the crystal and magnetic structure of n=2 RP phase $Sr_{3-x}Y_xFe_{2.25}Ni_{0.75}O_{7-\delta}$ (SrYFeNiO) for several compositions with varying x from 0 to 0.75 and with different oxygen content. For this purpose we used X-ray (XRPD) and neutron (NPD) powder diffraction technique combined with the Extended X-ray Absorption Fine Structure (EXAFS) spectroscopy.

The crystal structure of SrYFeNiO can be described in tetragonal system with lattice parameters a = 3.8651(1) Å and c = 19.6583(1) Å for x = 0.75 and δ = 1.[3] XRPD and NPD data showed that the O1 and O3 positions are not fully occupied resulting in four possible coordination environments which depend on the Y and O content.

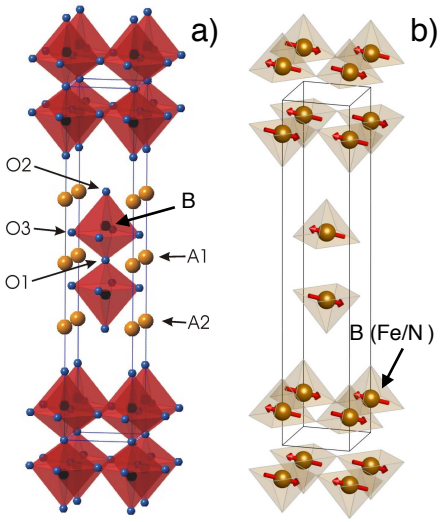

Figure 1: a) Crystal structure of n = 2 RP with the ideal stichiometry; b) G-type antifferromagnetic magnetic ordering of the sample $Sr_{2.25}Y_{0.75}(Fe,Ni)_2O_6$

The magnetic moments of the *B* atoms lead to the magnetic ordering below the critical temperatures, which depend on the Y content. For all samples with $\delta \geq 1$ the magnetic structure is found to be a G-type antiferromagnet within the perovskite layer as shown in Fig 1b. The oxygen rich samples ($\delta \approx 0.5$) do not show the magnetic ordering in the NPD patterns. However, the magnetizations curves for these compositions suggest the spin glass state below the critical temperature.

[1] Kharton, V. V.; Viskup, A. P.; Naumovich, E. N.; Marques, F. M. B., *J. Mater. Sci.* ***9***, 2623 (1999).
[2] Ruddlesden, S. N.; Popper, P. *Acta Crystallogr*. ***11***, 54 (1958).
[3] Samain , L., Amshoff, P., .Biendicho, J., Tietz, F., Mahmoud, A., Hermann, R. P., Istomin, S. Ya., Grins, J., Svensson, G., J. Solid State Chem. **227**, 45 (2015).

Analysis of interevent times by methods of statistical physics

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The problem of excessive losses is a central one (both from theoretical and practical points of view) in market activity. One of the significant questions in the analysis of losses in financial market time series, closely related to the economic concept of value at risk (VaR), is the description of distance between subsequent losses of a particular magnitude. We provide such a description under two complimentary approaches.

First, we propose an agent-based model of financial markets being a generalization of the Ising model from statistical mechanics [1]. A spin variable in our model represents an investor while its value – a short, neutral, or long position taken on the market. Investor's action (or decision) is, in turn, defined as a *change* of the spin value. A novelty herein is the identification of the actual state of a spin with investor's market *state* (the position taken on the market), not the *action* (buy or sell) as in the previous works. The model reproduces, inter alia, the statistics of interevent times [2].

Secondly, we present a model of superstatistics founded on continuous-time random walk (CTRW) and extreme value theory (EVT) and providing a closed analytic formula valid for excessive losses, profits, as well as for earthquake magnitudes [3]. Our description is an alternative to taking ad hoc Tsallis q-exponential functions [4].

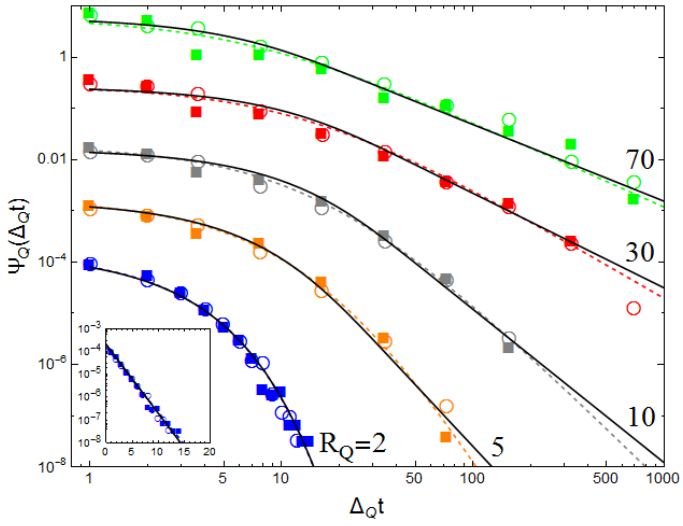

Figure 1: The superstatistics $\psi_Q(\Delta_Q t)$ vs. interevent time $\Delta_Q t$ in log-log scale from our spin model (full colored squares) for mean discrete interevent time R_Q = 2, 5, 10, 30, 70 and 10^3 rounds (estimated one trading day). The inset is the semi-log plot for R_Q = 2. The solid curves are our analytic predictions, while the dashed curves are q exponentials. Empty colored circles are empirical data taken from [4].

[1] M. Denys, T. Gubiec, R. Kutner, *Acta Phys. Pol. A* **123** (3) 513–517 (2013).
[2] M. Denys, T. Gubiec, R. Kutner, arXiv:1411.1689 (2014).
[3] M Denys, T Gubiec, R Kutner, M Jagielski, H E Stanley, *Phys Rev E* **94** (4), 042305 (2016).
[4] J. Ludescher, C. Tsallis, and A. Bunde, *Europhys. Lett.* **95** (6) 68002 (2011).

Microscopy and spectroscopy studies of graphene deposited on gallium nitride nanowires with different variations in height

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Studies of graphene on gallium nitride nanowires might be very interesting not only because of their possible applications for example in photovoltaic devices but also because of physical phenomena occurring on the interface between two low dimensional materials. During our studies of Raman spectra of graphene deposited on gallium nitride nanowires with equal height, large enhancement of Raman scattering was observed [1]. This effect was explained by Surface Enhanced Raman Scattering, where the major role plays an interaction between electrons in graphene and charges located on the top of the gallium nitride nanowires. In order to explain the role of variations in nanowires height to the observed enhancement, graphene transferred onto nanowires with different variations in height was studied. Scanning electron microscopy images show that graphene lies smoothly only on the nanowires with equal height (Fig. 1a). Higher variations in nanowires causes that number of nanowires in contact with graphene is decreasing (Fig 1b) and finally, for highest variations graphene lies only on the top of the highest nanowires (Fig 1c). Enhancement of Raman spectra intensity was observed only for sample with equal nanowires height (Fig 1d). In order to explain this, Kelvin Probe Atomic Force Microscopy (KPAFM) measurements were performed. This experimental technique allows to measure both: sample topography and potential. Periodic modulation of potential in graphene deposited on nanowires with equal height correlated with topography of the sample was observed, whereas variations of potential in graphene on nanowires with non-equal height were weaker. Detailed analysis of Raman bands parameters and results of KPAFM measurements showed that nanowire substrate strongly impact strain and carrier concentration in graphene. Substrates with different density of nanowires in contact with graphene noticeably modified local distribution of carrier concentration and suppressed its modulation. This consequently led to the reduction of spectra intensity.

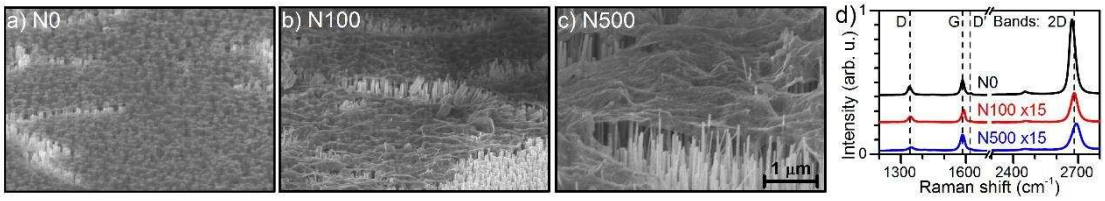

Figure 1: a) Scanning Electron Microscopy images of graphene on gallium nitride nanowires with different value of variations in height: a) 0 nm (N0), b) 100 nm (N100), c) 500 nm (N500), d) Raman spectra of samples collected under 532 nm laser excitation and with the same power excitation.

[1] J. Kierdaszuk, et al., Phys. Rev. B **92**, 195403 (2015).

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Magnetic Ground State of an Individual Fe^{2+} Ion in a Strained Semiconductor Quantum Dot

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Spin manipulation of individual magnetic ions embedded in quantum dots (QDs) has attracted a lot of scientific attention over the last years [1,2]. One of the strongest motivations for the research in this area is a possibility to obtain long spin coherence time of a single ion. From that perspective the nuclear-spin-free Fe^{2+} ion in a QD seems a promising system. However, it was not considered as a candidate for quantum information applications, since the Fe^{2+} ion in bulk zinc-blende or wurtzite semiconductors was found to inherently exhibit a single non-degenerate ground state.

Here we show that by using strong structural strain of a semiconductor QD it is possible to tailor the energy spectrum of the Fe^{2+} ion to exhibit doubly degenerate (i.e., magnetic) ground state [3]. This concept is evidenced experimentally by our photoluminescence (PL) studies of a novel QD system: self-assembled CdSe/ZnSe QDs doped with individual Fe^{2+} ions. A direct fingerprint of a nonzero spin of the Fe^{2+} ion ground state is a pronounced twofold splitting of the emission lines visible in a QD PL spectrum, which is observed for all excitonic complexes (Fig. 1). In each case, the splitting originates from the *s,p-d* exchange interaction between the ion and confined carriers, which leads to two different energies of the optical transitions depending on the Fe^{2+} ion spin projection $S_z = \pm 2$. An excellent agreement between our model and experimental results, including the magneto-PL results, unequivocally confirms the magnetic character of the Fe^{2+} ion in a CdSe/ZnSe QD. Such a novel system is thus a prominent candidate for quantum information processing, since both the CdSe lattice and Fe^{2+} ion can be free of any nuclear spin fluctuations.

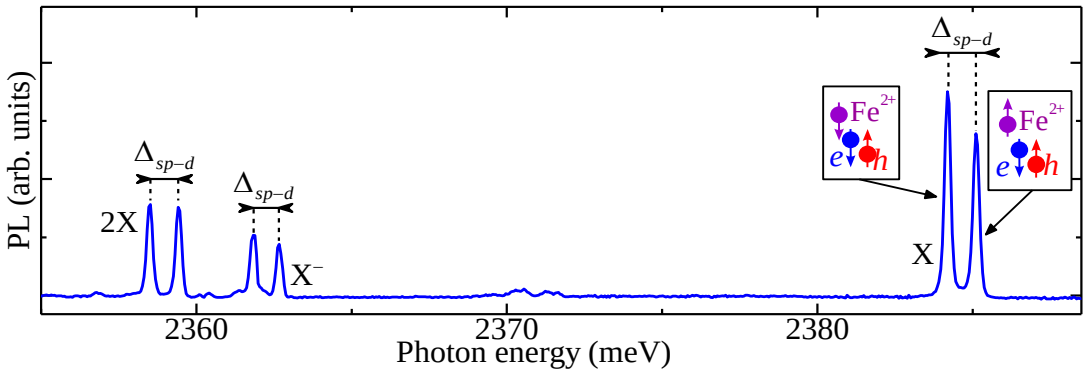

Figure 1: PL spectrum of a CdSe/ZnSe QD with a single Fe^{2+} ion (Δ_{sp-d} represents the *s,p-d* exchange splitting visible for all excitonic complexes).

[1] J. Kobak, T. Smoleński *et al.*, Nat. Commun. **5**, 3191 (2014).
[2] M. Goryca *et al.*, Phys. Rev. Lett. **113**, 227202 (2014).
[3] T. Smoleński *et al.*, Nat. Commun. **7**, 10484 (2016).

Direct measurement of the geometry defined by three coupled angular momenta vectors

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[6] *Instituto Nationale di Fisica Nucleare, Padova, Italy*
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For the first time the quantum features of a three coupled angular momenta vectors have been studied by a magnetic moment measurement in ^{128}Cs nucleus. It has been found in the previous works [1] that the total angular momentum of positive parity states in the ^{128}Cs isotope may be formed by three constituent angular momenta vectors. These three angular momentum vectors may span a three-dimensional space. In such a case, the positive parity excited states are linked to spontaneous time reversal symmetry breaking by the eigenstates of finite system [2] and may be of interest to quantum description of three coupled angular momenta vectors in other fields of physics.

The first direct measurement of the geometry of the three constituent spins will be presented. An interaction of the applied external magnetic field with the magnetic moment of the 7+ state in the 128Cs nucleus have been chosen as an experimental method. In the generalization of the additivity formula for magnetic moments [3] to 3-component system a term sensitive to mutual orientation of the three angular momenta vectors of the components appears. This feature has been used in the magnetic moment measurement performed with the Tandem accelerator of the ALTO facility at the Institut de Physique Nucleaire.

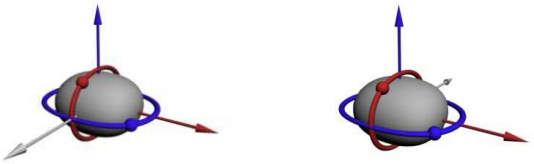

Figure 1: Time reversion changes the handedness of three coupled angular momenta vectors. The states with opposite handedness cannot be linked by other symmetry transformation (rotation, space inversion etc.).

[1] E. Grodner *et al*, Phys. Rev. Lett **97**, 172501 (2006)
[2] E. Grodner, Int. J. of Mod. Phys. **E20**, 380 (2010)
[3] P.J. Brussaard, *Shell-model and applications in nuclear spectroscopy*, North-Holland 1977

Spatiotemporal dynamics of DNA damage in cells exposed to mixed beams of ionizing radiation

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A particular problem of modern external beam radiotherapy like IMRT and proton therapy is associated with simultaneous exposure of patients to the therapeutic beam and scattered neutrons with a high relative biological effectiveness (RBE). The interesting question is whether the high and low LET radiations act in a synergistic or additive manner. If they act additively, then the risk of radiotherapy-induced cancer can be deduced from the results of exposures to the single agents. Otherwise, RBE values must be generated for the mixed exposure scenarios or corrected to account for the synergism.

The goal of this study is to analyse the kinetics of formation and repair of ionising radiation-induced DNA repair foci in cells exposed to α particles, X-rays and a mixed beam of both. We focus on studying if exposure to mixed beams leads to the formation of clustered damage which poses serious problems for the DNA repair machinery. Increased damage complexity following exposure to mixed beams will suggest a higher than expected risk of cancer induction by modern radiotherapy.

Human U2OS cells were transfected with plasmids coding for the DNA repair proteins 53BP1 that are tagged with the green fluorescence protein. Cells were exposed to mixed beams in a dedicated exposure facility installed at the Stockholm University. The facility is composed of an YXLON 200 X-rays source and a 50 MBq Am-241 alpha source kept inside a 37^{o}C cell incubator. Spatiotemporal dynamics of 53BP1 foci formation and repair was recorded by time-lapse photography and image analysis (Figure 1). Additionally, PARTRAC [1] MC codes were used to understand the processes underlying DNA damage and repair mechanisms.

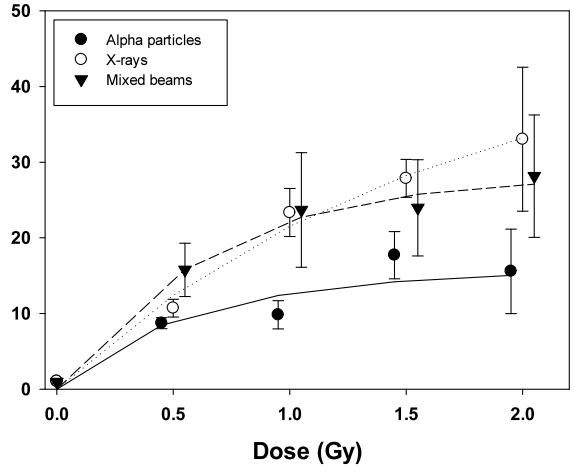

Figure 1: Dose response curves for 53BP1 foci induced in U2OS cells exposed to α particles, X-rays and a mixture of both (unpublished results).

[1] Friedland W. et al. 2011. Mutation Research 711: 28-40.

Sterile neutrinos - do they exist ?

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Sterile neutrinos would not interact with matter except through gravity. The first hints that there could be a new type of neutrino apart from the three known: electron, muon and taon neutrinos appeared in 1990s when the LSND experiment in Los Alamos announced evidence of anomalous appearance of electron neutrinos in the beam of muon neutrinos. This could be explained by the phenomenon of oscillations of one type of neutrinos into another only if the new, sterile neutrino existed. Over the last twenty years many experiments have tried to confirm of refute LSND result. One of them , MINOS experiment, sending neutrinos from Fermilab near Chicago to Soudan mine, have set some unique limits on parameters of models with sterile neutrinos. MINOS alone [1] cannot directly exclude or confirm LSND result, but together with results from reactor experiment Daya Bay in China have recently set the limits that exclude most of the scenarios involving sterile neutrinos that could explain LSND result [2]. Additionally, both experiments have still more data to be analyzed. Therefore, even more sensitive search for sterile neutrinos is anticipated soon.

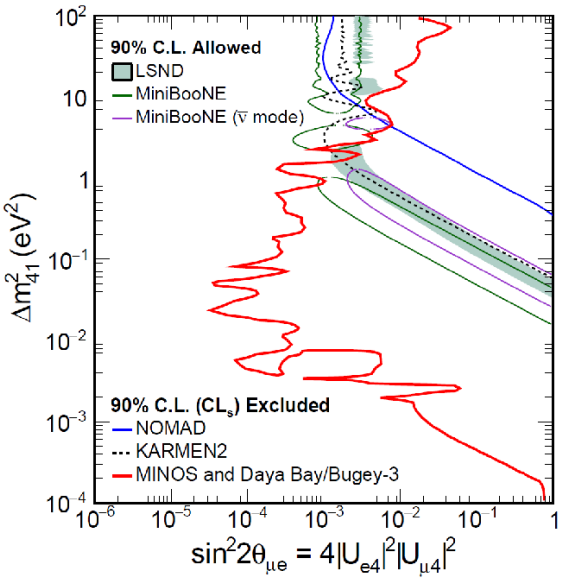

Figure 1: Combined 90% C.L. exclusion limit from MINOS,Daya Bay and Bugey-3 on parameters of model with sterile neutrino compared to limits from NOMAD and KARMEN2 and allowed regions by LSND and MiniBooNE. Regions to the right of red,blue and dotted curves are excluded.

[1] Search for Sterile Neutrinos Mixing with Muon Neutrinos in MINOS, MINOS Collaboration, Phys.Rev.Lett.117,151803, 2016.

[2] Limits on Active To Sterile Neutrino Oscillations from Disappearance Searches in the MINOS, Daya Bay, and Bugey-3 Experiment, MINOS Collaboration, Phys.Rev.Lett.117,15801,2016.

„Analytical ultracentrifugation: a versatile tool for hydrodynamic and thermodynamic studies of biomolecules”

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Analytical ultracentrifugation (AUC) is a versatile, rigorous and accurate biophysical technique for determining the mass, shape, size distribution, solvation, and composition of macromolecules and nanoparticles. It also provides a detailed view of their reversible single- or multi-component interactions over a wide range of affinities [1]. We applied the AUC method to solve several biologically important problems at the molecular level. We found that: (i) eukaryotic translation initiation is controlled by cooperativity effects within ternary complexes of eukaryotic initiation factor 4E (eIF4E), 4E-BP1 inhibitory protein, and the mRNA 5’cap. The affinity of the 4E-BP1 to eIF4E is significantly higher when eIF4E is bound to the cap. The 4E-BP1 binding stabilizes the active eIF4E conformation and, on the other hand, facilitates dissociation of eIF4E from the cap [2]; (ii) purine nucleoside phosphorylases (PNP) from mammalian and bacterial sources exist in solution as a stable homotrimer and homohexamer, respectively. Packing of the PNP monomers into a oligomeric structure is necessary for the stability and enzymatic activity of PNPs. The activity decline is accompanied by a decrease of the population of the PNP oligomers and an increase of the population of its aggregated forms [3-5]; (iii) ATPgammaS shifts the monomer-hexamer equilibrium of molecular chaperone ClpB from the pathogenic bacterium *Leptospira interrogans* towards its hexameric form. It provides further insight into the role of ClpB in mechanisms of the *Leptospira interrogans* virulence. Above issues will be discussed in detail during the presentation.

[1] P. Shuck, „Analytical ultracentrifugation as a tool for studying protein interactions”, *Biophys Rev* 5, 159–171 (2013)
[2] A. Modrak-Wojcik, M. Gorka, K. Niedzwiecka, K. Zdanowski, J. Zuberek, A. Niedzwiecka, R. Stolarski „Eukaryotic translation initiation is controlled by cooperativity effects within ternary complexes of 4E-BP1, eIF4E, and the mRNA 5’cap”, *FEBS Letters* 587, 3928–3934 (2013)
[3] A. Modrak-Wojcik, K. Stepniak, V. Akoev, M. Zolkiewski and A. Bzowska „Molecular architecture of E. coli purine nucleosidephosphorylase studied by analytical ultracentrifugation and CD spectroscopy”, *Protein Sci.* 15, 1794-1800 (2006)
[4] A. Modrak-Wojcik, K. Stepniak, B. Kierdaszuk and A. Bzowska „Is purine nucleoside phosphorylase an example of amorpheein?”, *J. Phys.: Condens. Matter* 19 (2007)
[5] B. Wielgus-Kutrowska, A. Modrak-Wojcik, A. Dyzma, K. Breer, M. Zolkiewski, A. Bzowska, „Purine nucleoside phosphorylase activity decline is linked to the decay of the trimeric form of the enzyme”, *Arch. Biochem. Biophys* 549, 40-48 (2014)

How emotions affect resting state brain activity – a functional magnetic resonance imaging study (preliminary results).

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Functional magnetic resonance imaging is a non-invasive method of studying brain activity through registration of a blood oxygenation level dependent signal during execution of cognitive tasks. Additionally, observation of resting state activity (when no task is present) provides a basis for inference regarding functional connectivity between specialized brain regions. The connectivity is interpreted in terms of networks formed by spatially remote regions showing correlated activity, such as Default Mode, Salience or Amygdala Networks.

The aim of the study was to investigate the influence of various emotions on brain activity, especially during resting state. While emotions are usually defined as having quick onset and brief duration, they arguably leave an effect which persists for some time after an emotion-inducing situation or stimulus are experienced.

In the fMRI experiment, participants watched a total of 30 emotion-inducing movie excerpts, belonging to joyful, erotic, fearful, sad and neutral categories. Each excerpt lasted 60 seconds and was followed by 90 seconds of eyes-closed resting.

Data was analysed both in general linear model (revealing regions differentially activated between conditions) and functional connectivity (focusing on signal correlations) frameworks. The results showed different activity patterns and changes of functional connectivity during resting depending on the emotion category with the strongest effects observed for positive emotions. Further analyses, which will focus on different networks, are planned.

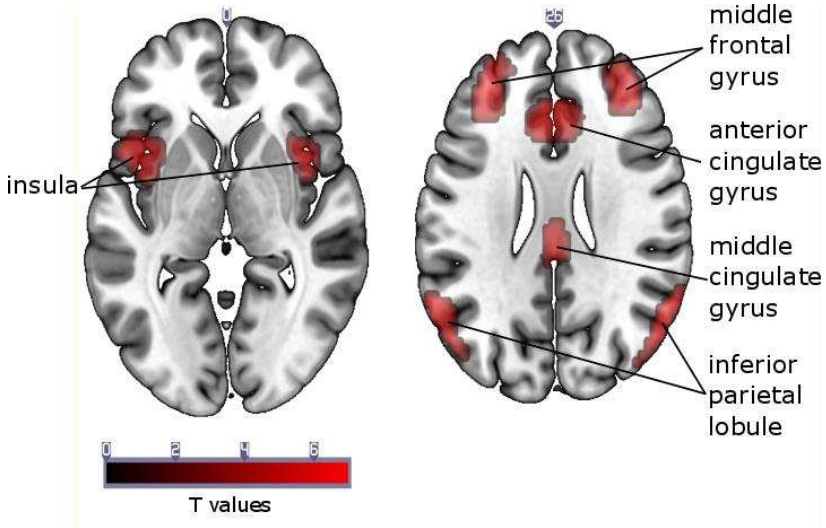

Figure 1: The highlighted regions were significantly ($p < 0.05$ FWE corrected) more active during resting than during movie watching, exhibiting a typical resting state pattern. Two axial slices shown.

Hyperpolarization of ^{3}He and ^{129}Xe for Medical Magnetic Resonance Imaging

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The two most common polarization techniques of noble gases with nuclear spin one-half (^{3}He and ^{129}Xe) will be presented: Spin Exchange Optical Pumping (SEOP) and Metastability Exchange Optical Pumping (MEOP). SEOP and MEOP use circularly polarized laser light to change distribution of the atomic magnetic moments in the optical pumping process [1]. In the SEOP method, alkali metal atoms (like rubidium) are first optically pumped, and then, due to collisions, exchange spins polarization with noble gas atoms. In the MEOP process, ^{3}He atoms are repositioned to metastable state, optically pumped, and then, due to collisions with other helium atoms, exchange metastability providing nuclear polarization of the ground ^{3}He state. Polarizing systems allow obtain large quantities (liters per hour) of high polarized (up to tens of percents) ^{3}He or ^{129}Xe for medical (Magnetic Resonance Imaging – MRI) and scientific applications. The unique MEOP polarizer, working in a high magnetic field and at elevated pressure of ^{3}He also will be presented. This system can produce hyperpolarization of noble gas inside a superconducting magnet used for clinical MRI [2].

[1] T. Pałasz, B. Tomanek. *Optical Hyperpolarization of Noble Gases for MedicalImaging*, Chapter 10 in *"Gas Phase NMR"*, Ed. K. Jackowski, M. Jaszuński, Royal Society of Chemistry 2016, ISBN: 978-1-78262-161-4.

[2] G. Collier, T. Pałasz, A. Wojna, B. Głowacz, M. Suchanek, Z. Olejniczak, T. Dohnalik. *A high-field ^{3}He metastability exchange optical pumping polarizer operating in a 1.5T medical scanner for lung magnetic resonance imaging.* Journal Of Applied Physics **113**, 204905 (2013).

The proton spin puzzle

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Proton is a mysterious particle: understanding its spin (and its radius) seems to be a major problem. It was noticed almost 30 years ago, that the proton components, fermionic quarks and bosonic gluons do not built its spin. Since then the particle physicists all over the world, also at CERN, are engaged in solving the puzzle of the proton spin; as a result new research fields have emerged: the helicity and transversity aspects of the proton structure are investigated. But is the proton spin puzzle solved yet ?

Space-time duality for optical quantum information processing

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Quantum mechanical properties of atomic-scale objects are of importance both for understanding the fundamental principles that govern the world around us, and for their potential practical application. A photon is a quantum mechanical object whose properties are interesting from the telecommunications and metrology perspectives, to name just a few. Out of the photon's degrees of freedom its spectral-temporal properties are particularly appealing from the experimental point of view. Here we investigate the spectral-temporal degree of freedom of single photons and develop tools for its active manipulation.

Our experimental tools are derived from the optical space-time duality: the formal analogy between spatial diffraction of paraxial optical fields and propagation of optical pulses in media with group velocity dispersion [1]. The analogy has been very fruitful in various areas of classical optics and photonics, for example leading to concepts such as temporal imaging. Here we demonstrate the use of its tools for actively modifying the spectral-temporal modes of non-classical states of light. By employing fast electro-optic phase modulation we realize temporal analogues of prisms and lenses, which we use to shift the spectrum of single-photon pulses [2] and to compress their spectral bandwidth (Figure 1) [3]. We experimentally verify the preservation of quantum properties of light upon manipulation. Our results pave the way towards the use of spectral-temporal degree of freedom of light for encoding quantum information and towards optical interfacing of single quantum objects.

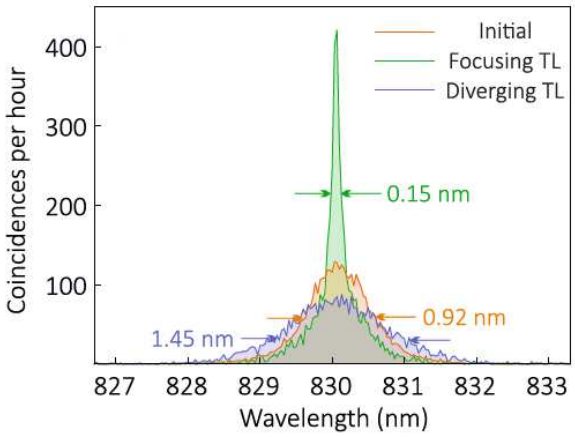

Figure 1: Spectral compression and expansion of single-photon pulses. Spectral intensities of single photon pulses after passing through dispersive medium combined with a focusing or diverging electro-optic temporal lens (TL).

[1] B. Kolner, *Space-time duality and the theory of temporal imaging*, IEEE J. Quant. Electron. **30**, 1951 (1994).
[2] L. J. Wright, M. Karpiński, C. Soeller, B. J. Smith, *Spectral shearing of quantum light pulses by electro-optic phase modulation*, arXiv:1605.00640 (2016).
[3] M. Karpiński*, M. Jachura*, L. J. Wright, B. J. Smith, *Bandwidth manipulation of quantum light by an electro-optic time lens*, arXiv:1604.02459 (2016).

Nuclear reactions at astrophysical energies with γ-ray beams

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A newly built Extreme Light Infrastructure – Nuclear Physics (ELI-NP) facility in Bucharest-Magurele, Romania will provide monochromatic, high-brilliance γ-ray beams that will allow to study key nuclear reactions in modern astrophysics by means of the inverse photo-dissociation process [1].

One of the benchmark reactions to be studied at ELI-NP is the $^{16}O(\gamma,\alpha)^{12}C$ photo-dissociation process that can shed more light in explaining carbon-to-oxygen abundance ratio observed in the Universe. In order to measure this and other (γ,α) or (γ,p) reactions of astrophysical interest, an active-target gaseous Time Projection Chamber (ELITPC) is being developed by the University of Warsaw, IFIN-HH / ELI-NP and the University of Connecticut [2].

The ELITPC detector has an active volume of about 35 × 20 × 20 cm^3 that is centered around the axis of the gamma beam. The working gas mixture, rich with target nuclei to be studied, is kept at a lower-than-atmospheric pressure (~100 mbar) in order to optimize 3D kinematical reconstruction of the events. The ionization electrons from tracks of charged particles emerging from photo-dissociation reactions drift in a uniform electric field towards several *Gas Electron Multiplier* (GEM) structures before reaching the segmented readout anode. The detector will employ fast digitizing front-end electronics developed by the *Generic Electronics for TPCs* (GET) collaboration for middle-size experiments in nuclear physics [3]. The readout anode is constituted from interconnected pads that are arranged in three arrays of strips, which form a redundant three-coordinate *u-v-w* system. About 10^3 electronic channels are envisaged in the full-scale ELITPC detector. A scaled demonstrator detector operating at atmospheric pressure was constructed and tested with an alpha-particle beam at the IFIN-HH Tandem facility Romania [4].

An overview of the project and the status of the development will be presented.

[1] D. Filipescu et al., *European Physical Journal A*, **51**, 185 (2015).
[2] O. Tesileanu et al., *Romanian Reports in Physics*, **68**, S699 (2016).
[3] E. Pollacco et al., *Physics Procedia*, **37**, 1799 (2012).
[4] M. Cwiok, *Acta Physica Polonica B*, **47**, 707 (2016).

Poster contributions

Measurement of β-delayed proton emission from ^{27}S and ^{26}P with Optical Time Projection Chamber

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Experimental studies of β-delayed proton emission from ^{27}S and ^{26}P have been performed at the ACCULINNA separator, JINR, Dubna, in December 2015. The goal of the experiment was to search for, so-far unobserved, low-energy protons emitted after β decay of these nuclei. This goal was reached by applying the Optical Time Projection Chamber (OTPC) to record charged particles emitted by nuclei of interest implanted in its active volume. This experimental technique was developed in the Institute of Experimental Physics of University of Warsaw. The preliminary results of this experiment will be presented.

Study of neutron-deficient Ge and Zn isotopes

A. A. Ciemny [1], W. Dominik [1], T. Ginter [2], R. Grzywacz [3,4], Z. Janas [1], M. Kuich [1], C. Mazzocchi [1], K. Miernik [1], M. Pfützner [1], M. Pomorski [1], D. Bazin [2], T. Baumann [2], A. Bezbakh [5], B. P. Crider [2], M. Ćwiok [1], S. Go [3], G. Kamiński [5,6], K. Kolos [3], A. Korgul [1], E. Kwan [2], S. N. Liddick [2,7], S. V. Paulauskas [2,3], J. Pereira [2], K. P. Rykaczewski [4], C. Sumithrarachchi [2], Y. Xiao [3], F. Zarzyński [1]

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Due to the large Q-value available for β decay, nuclei lying close to the proton drip-line are characterised by several exotic decay modes: ground-state proton- and two-proton decay and β-delayed (multi-) proton emission. As the branching ratios for these decay channels are often very small and the isotopes of interest are extremely difficult to produce and observe, many of them have still not been investigated yet.

In an experiment performed at NSCL (MSU) several neutron-deficient isotopes were studied by means of a gaseous time projection chamber with optical readout (OTPC) [1]. For the first time, not only was ^{59}Ge identified [2], but also the β-decay properties of ^{60}Ge were measured [3]. The results of the analysis of the decay of neutron deficient germanium and zinc isotopes produced in this experiment will be presented.

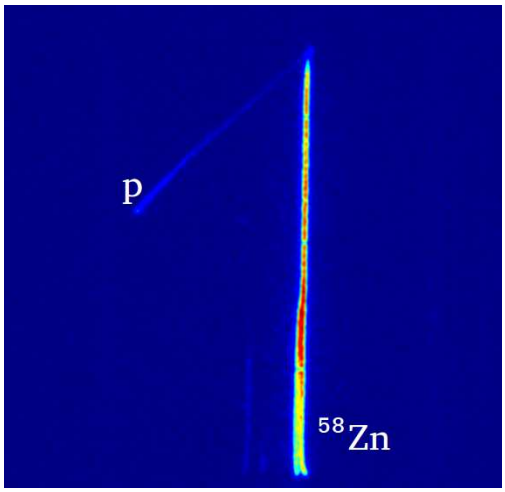

Figure 1: An example event of the β-delayed proton emission form ^{58}Zn. The trajectory of the ^{58}Zn ion stopped in the active volume if the OTPC detector as well as the track of the emitted proton are visible.

[1] M. Pomorski et al., Phys. Rev. C 83, 014306(R) (2011)
[2] A. A. Ciemny et al., Phys. Rev. C 92, 014622 (2015)
[3] A. A. Ciemny et al., Eur. Phys. J. A 52, 89 (2016)

Quest for mimics of m^7GMP as molecular probes to monitor cN-IIIB enzyme activity in cell

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Human cytosolic 5' nucleotidase, cN-IIIB, belongs to the family of eight enzymes catalyzing the hydrolytic dephosphorylation of non-cyclic nucleoside monophosphates to nucleosides and orthophosphate. As a one of catabolic enzymes, it contributes to the regulation of nucleotide levels in living cells, however, its exact role in the cell has not been established so far. Due to the distinctive activity towards m^7GMP, it has been assumed that cN-IIIB participates in mRNA decay, and protects cells against undesired salvage of m^7GMP and its incorporation into nucleic acids. We envisaged that a properly designed inhibitor or chemical probe could aid in the elucidation of biological roles of cN-IIIB. The choice of a suitable compound for cN-IIIB activity modulation or monitoring is crucial to ensure selectivity, especially in biological samples where additional, interfering 5' nucleotidase activities are present. Considering m^7GMP as a hallmark of substrate specificity of cN-IIIB we prepared a synthetic library of fifty nucleoside monophosphates, analogs of m^7GMP, to investigate the hydrolysis and inhibition of cN-IIIB enzyme, either by monitoring the reaction progress by HPLC with detection at 254 nm or by determination of the released phosphate using malachite green. The most potent compounds were subjected to further modification and evaluation. Such approach will allow to understand the basis of cN-IIIB selectivity for substrates as well as to design unnatural inhibitors of the protein which could be used in the future as molecular probes to track the enzyme activity in cells.

Trace gas detection with ultrasensitive absorption spectroscopy

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Trace substances detection is very important for many applications. Absorption laser spectroscopy provides opportunity for easy, quick, non-invasive, and accurate determination of selected gases amount.

Trace matter detection is based on determination of light extinction tuned to specific spectral line of compound of interest [1] Ultrasensitive absorption spectroscopy techniques such as multipass spectroscopy (MPASS), and cavity ring-down spectroscopy (CRDS) are applied to increase sensitivity. Combining these methods with wavelength modulation spectroscopy (WMS) leads to noises reduction and additional improvement of the detection limit.

We developed optoelectronics sensors for measurement of water vapor distribution in atmosphere. High H_2O concentrations and its large gradients that occur at lower atmosphere require a fast (10 ms) detector for aircraft measurements. For upper troposphere we built another gauge based on CRDS method, with the detection limit of about 10^{12} cm^{-3}.

In order to monitor disease biomarkers, which can occur in human breath, the optoelectronics detectors presented in Tab. 1 were built.

Tab.1: Disease biomarkers and their detection limits.

Biomarker	Concentration in healthy human breath [ppb]	Diseases	Detection wavelength [μm]	Technique	Detection limit [ppb]
Ammonia	< 2 000	uremia	1,527	MPASS	1 000
Methane	10 000	intestinal problems	2,2536	MPASS	100
Nitric oxide	< 50	asthma, angina pectoris	5,263	CRDS	5
Carbon monoxide	< 10 000	oxidative stress, respiratory infections and asthma	2,3337	MPASS	400
Carbonyl Sulfide	< 30	liver-related diseases	4,875	CRDS	1
Ethane	< 12	cancer, cystic fibrosis, vitamin E deficiency	3,348	CRDS	3,5

[1] B. Buszewski, D. Grzywinski, T. Ligor, T. Stacewicz, Z. Bielecki, J. Wojtas, *Detection of volatile organic compounds as biomarkers in breath analysis by different analytical techniques*, Bioanalysis, vol. 5, pp. 2287 – 2306, (2013).

Exfoliation of semiconductor microcavity containing three (Cd,Zn,Mn)Te quantum wells

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Monocrystalline substrate is a key component for grow a thin layers by molecular beam epitaxy (MBE). The choice of the substrate is typically determined by the lattice constant and crystalline structure of designed layer. However physical properties of some substrates may significantly affects measurements of grown epitaxial layers, e.g. opaque substrate limits measurements of light transmission and absorption.

The problem of opaque substrate can be solved by exfoliation of epitaxial layers. The purpose of this experiment was to develop and verify the method of producing free-standing microcavity containing three (Cd,Zn,Mn)Te quantum wells (QW).

On the black GaAs substrate we have gown the 1 μm thick CdTe buffer and 1 μm hygroscopic MgTe layer. Next we have grown 22 pairs of Bragg mirror based on (Cd,Zn,Mg)Te with 40% and 10% of Mg in low and high refractive index layers respectively. The width of layers was optimized to reach cavity resonance at emission wavelength of (Cd,Zn,Mn)Te quantum wells (about 760 nm). Inside cavity we have grown three (Cd,Zn,Mn)Te quantum wells containing 1% of manganese. Finally we have grown 22 pairs of top Bragg mirror.

Such a structure was stable in atmosphere. Reflectance at both room and helium temperature showed characteristic stopband with sharp cavity mode. The photoluminescence measurements at helium temperature revealed narrow spectral line at 760 nm corresponding to QWs energy.

To separate epitaxial layer with microcavity from the rest of the structure, the sample was attached to a scotch tape and immersed in deionized water for 5 days. After rinsing, MgTe layers was removed by water and the tape with microcavity containing QWs was exfoliated from the substrate. Images of the sample on the scotch tape showed continuous surface of area more than 1 mm^2. At low temperature we observed photoluminescence of QWs and characteristic reflectivity of microcavity what confirms that Mg in Bragg mirror and cavity was not harmed despite long contact with water.

Only after exfoliation it was possible to measure optical transmission through the microcavity. This measurement gives complementary information to reflectivity spectra, but also it opens possibility of experiments on superfluidity of exciton-polaritons with magnetooptical properties enhanced by presence of Mn in quantum wells.

Raman investigations of hexagonal boron nitride

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Raman spectroscopy is one of the most popular methods of characterization of two-dimensional materials. Its result reveal a broad spectrum of information about various qualities such as crystallographic structure, density of defects or electronic structure of investigated surfaces. In particular, Raman spectroscopy might be used for estimation of number of atomic layers in complex graphene structures [1].

The relation between the phonon structure and number of atomic layers can also be observed in case of hexagonal boron nitride (h-BN) [2]. Contrary to graphene, h-BN is a wide band-gap semiconductor, which, in combination with its atomic-flat surface, makes it a very attractive substrate for other materials or an insulating layer in hybrid structures. Because of this investigating the properties of the layered h-BN structures is vital for understanding the processes occurring in more complex hybrid structures such as graphene/h-BN/graphene system [3]. This aspect, however, is often omitted during experimental investigations.

In this presentation a method of estimation of number of atomic layers of hexagonal boron nitride by Raman spectroscopy will be shown. The samples of h-BN exfoliated onto SiO2/Si substrate have been investigated. The thickness (number of layers) in studied crystals was estimated using both optical microscopy and atomic force microscopy. Microraman experiment conducted with submicron spatial resolution has shown a correlation between the thickness, which relates to number of layers) and characteristic G band (Raman shift of about 1365 cm-1). The results may be interpreted as an interaction between single atomic layers of hexagonal boron nitride.

[1] A. C. Ferrari, J. C. Meyer, V. Scardaci, C. Casiraghi, M. Lazzeri, F. Mauri, et.al, Phys. Rev. B. 97 (2006) 187401
[2] R. V. Gorbachev, I. Riaz, R. R. Nair, R. Jalil, L. Britnell, B. D. Belle, et.al., Small 7 (2011) 265-268
[3] J. Gasekel, L. Eaves, K. S. Novoselov, A. Mischenko, A. K. Geim, T. M. Fromhold, et.al., Appl. Phys. Lett. 107 (2015) 103105

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Role of the phase matching in the four-wave mixing process

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Non-degenerate four-wave mixing in a four-level configuration is a simple and robust process yet offers extensive possibilities. For example it enables conversion of light to telecom wavelengths which is very useful in information transfer. Nowadays quantum memory in atomic vapors based on four-photon light-atom interface is researched [1]. This solution would allow us to build multimode quantum memory where writing and reading information could be carried out using telecom photons. However to do this we need to better understand the four-wave mixing process.

Since atomic vapors are dilute in comparison to solid matter a unity refractive index for all contributing beams is assumed when considering the phase matching condition, thus making the propagation effects trivial. This approach corresponds to a simple single-atom perspective, and all phase relations throughout the ensemble are neglected.

However it turns out, that these assumptions are not correct close to atomic resonance and in a dense atomic vapor where the four-wave mixing is most effective. There was many experiments where we can see some effects, such as shifting of nonlinear susceptibility resonance or strong modifications of expected spectrum, but they was misunderstood.

Here we show that a vast majority of observed effects may be described by a simple model of spatial propagation and phase matching. We use our results to engineer the spatial configuration of the beams and find that four-wave mixing may be enhanced if the phase matching is taken into account. We also demonstrate direct effects of rapidly-varying refractive index on position of resonance, direction and shape of emitted light.

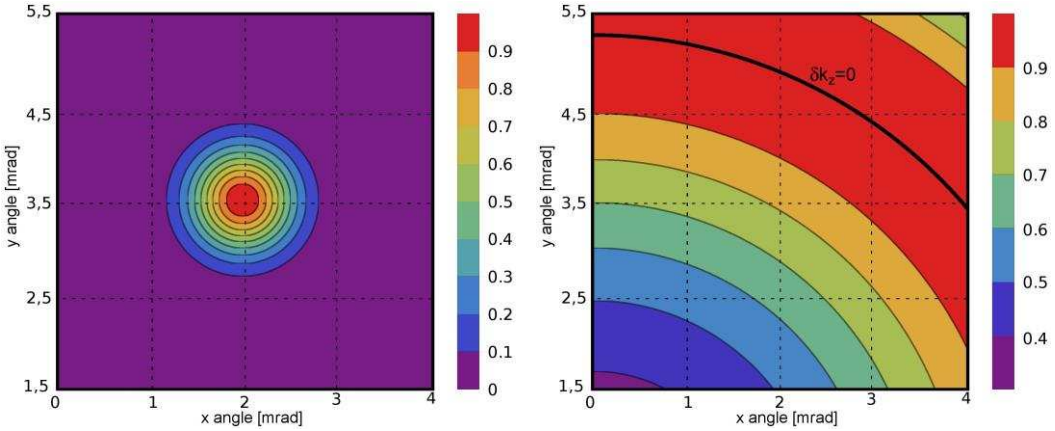

Figure 1: Exemplary theoretical prediction of intensity angle distribution of four-wave mixing signal. At the left side the result without takin phase-matching into account is presented. At the right side it is shown the phase matching factor.

[1] M. Parniak, A. Leszczyński, W. Wasilewski, Physical Review A 93, 053821 (2016)

WSe_2 based light-emitting tunneling van der Waals heterostructures in magnetic fields

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The toolbox of available two-dimensional (2D) crystals comprises a variety of materials with different electronic properties (metallic, semiconducting and insulating). By vertically stacking different types of 2D crystals one can create more complex systems, which are referred to as van der Waals heterostructures (vdWs) [1]. Lately, vdWs were fabricated using ultrathin layers of graphene, hexagonal boron nitride (hBN) and transition metal dichalcogenides. The first successful demonstration of devices like field-effect tunneling transistors [2] or light-emitting tunneling diodes [3] highlight the great versatility of the approach.

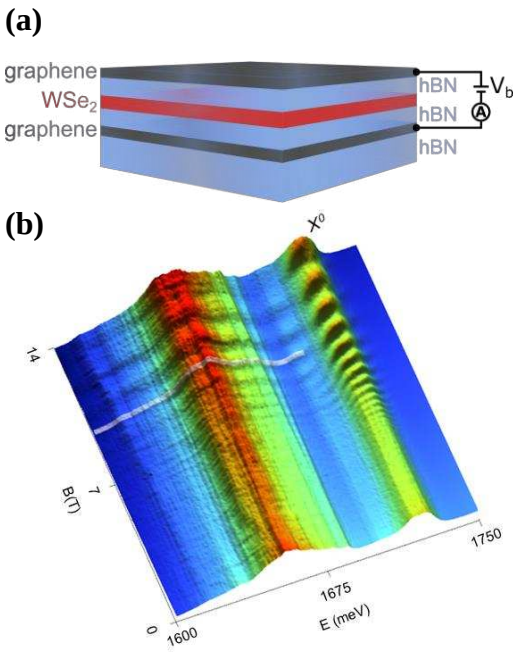

Figure 1: (a) sample structure, (b) 3D false color plot of the EL of the vdW as a function of magnetic field

Here, we report on magneto-optoelectronic measurements of a light-emitting tunneling structure based on a WSe_2 monolayer (ML) as the active emission material. The actual stacking sequence for the samples was hBN / graphene / hBN / WSe_2 / hBN / graphene (Fig. 1 (a)). Remarkably pronounced magneto-oscillations were observed for the electroluminescence (EL) of the free exciton emission line (X0) of the WSe_2 ML (Fig.1 (b)). The results can be interpreted in terms of a modulation of the tunneling injection processes into the WSe_2 caused by the Landau quantization of the graphene electrodes. These oscillations can be used to deduce an effective valence band offset for the graphene / WSe_2 / hBN system. Surprisingly, the EL signal was registered even at sub-bandgap voltages, which can be explained by taking into account tunneling into exciton states, which are situated well (~ 0.4 eV) below the bandgap of the WSe_2 ML. These findings indicate the great potential of vdWs for optoelectronic applications. The sheer number of materials and combinations for vdWs should allow to tailor many more device schemes suitable for a plethora of applications.

[1] A. K. Geim et al. *Nature* **499**, 419 (2013).
[2] L. Britnell et al. *Science* **335**, 947 (2012).
[3] F. Withers et al. *Nature materials* **14**, 301 (2015).

Potential fluctuations in InGaN/GaN quantum wells as function of In composition.

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The topic of In segregation in InGaN quantum wells is important for understanding the optical properties of nitride optoelectronic devices. The influence of In content on variations of composition was studied in number of works. However, in most of publications the investigated samples of different In content were grown in different processes. In our work, a single sample containing few regions with slopes of different angles has been used. The miscut was below 1 degree in respect to wurzite c axis. The scheme of our samples is shown on Fig. 1.

Since In composition depends on miscut angle [1], using such approach we can obtain controlled change of indium content in selected sample's region.

Temperature – dependent time - resolved photoluminescence measurements were performed in regions with different miscut angles. The samples were excited by third harmonic (300 nm) of Ti:Saphire laser. The diameter of the light beam was about 10 μm.

The QW emission energy was between 3.1 eV and 3.3 eV depending on the In content. Taking into account constant width, the observed energies correspond to In content between 4% and 6%. During heating, the QW PL energy increased at temperatures below 75 K and then decreased (see Fig. 1A). So called S - shape behavior is interpreted as effect of diffusion and relaxation of excitons in fluctuating potential. This dependence was examined using model introduced by Li et al. [2]. Such approach allows us to estimate the amplitude and the size of potential fluctuations caused by formation of In – rich regions.

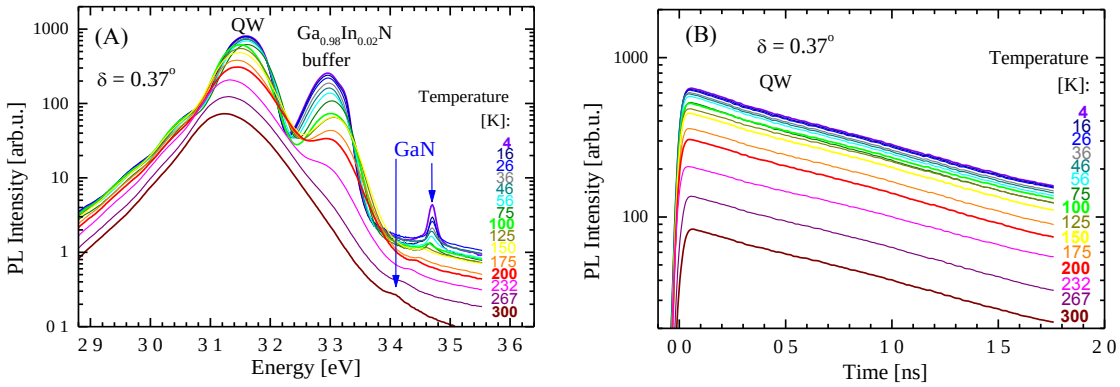

Figure 1: A) Photoluminescence spectra and B) PL decays measured in different temperatures

[1] M. Sarzyński, T. Suski, G. Staszczak, A. Khachapuridze, J. Z. Domagała, R. Czernecki, J. Plesiewicz, et al. *Appl. Phys. Express* **5**, 021001 (2012)
[2] Q. Li, , S. J. Xu, M. H. Xie, and S. Y. Tong, Europhysics Letters **71**, 994 (2005)

Coevolution in the model of social interactions: getting closer to real-world networks

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In the 90s Robert Axelrod have proposed the canonical model of social interactions [1] explaining one of possible and important mechanisms of dissemination of culture. He found that depending on initial conditions the system can end up in one of two states: ordered with global culture or disordered with many small subcultures. The dynamics of this model captured complexities of real interactions between people, but the square lattice which was considered is far from satisfying reflection of real-world social networks. Others have studied Axelrod's model deeper on complex networks and it turned out that the structure can have fundamental influence on the behavior of the system. Maxi San Miguel et. al. [2] made the next step by exploring the model of social interactions on coevolving random networks and finding two phase transitions with interesting properties. Unfortunately social networks are as far from randomness as from regularity. In our work we introduce four extensions changing the mechanism of edge rewiring. The models are intended to catch two kinds of interactions - preferential attachment in scientist or actors collaborations and friendship formation in everyday relations. Numerical simulations show that proposed dynamics can lead to the power-law degree distribution and high value of the clustering coefficient, still retaining the small-world effect in three models. All models are characterized by two phase transitions of different nature. We find new and universal characteristics of the second transition point - abrupt increase of clustering coefficient, due to the formation of many small complete subgraphs inside the network.

[1] R. Axelrod, The dissemination of culture, J. Conflict Res. 41, 203 (1997)
[2] F. Vazquez, J. C. Gonzalez-Avella, V. M. Eguíluz, M. San Miguel, Time-scale competition leading to fragmentation and recombination transitions in the coevolution of network and states, Phys. Rev. E 76, 046120 (2007)

Structural Investigations of Graphene Layers Grown on 4H-SiC - Buffer Layer Engineering

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Intercalation of the various elements or compounds into the few layer graphene structure shows the way for future graphene electronic applications. That also includes functionalized graphene which may be suitable for the specific applications like bio-sensors, liquid and gas sensors etc. X-ray diffraction and X-ray reflectometry measurements presented here regarding few layer graphene structures are based on standard laboratory X-ray source equipped with parallel beam Bragg reflection mirror and standard Phillips diffractometer [1]. Samples were grown either by Chemical Vapor Deposition (CVD) or sublimation methods at 1600^{o}C under an argon laminar flow in an Aixtron VP508 hot-wall reactor. Graphene growth was preceded by H_2 etching of the SiC substrate. SiC surface was atomically stepped [2], although substrate was nominally on-axis (0001) oriented. Graphene intercalated with hydrogen [1], oxygen [3], and nitrogen, together with graphene oxide are prime examples of such graphene treatments which can led to specific graphene properties necessary for the wide spectra of applications. We have shown that in all samples investigated one can observe presence of non intentional water layers between the SiC and first carbon layer. Positioning and type of bonding of the intercalate, within the few layer graphene structure, is a crucial aspect of the whole functionalization. Using X-ray laboratory setup we have measured standard diffraction pattern as well as low angle reflectometry signal allowing for the precise evaluation of the buffer region above SiC substrate. We have shown that one can manipulate the positioning and presence of the intercalates, within the graphene structure, by thermal treatment and UV light. We have also observed a clear resistance changes upon UV illumination. This may be connected with the presence of water layers within the buffer volume. It will be shown that hydrogen, oxygen and nitrogen intercalate differently and positions itself at completely different lattice sites within the layer. X-ray measurements are compared with Raman spectroscopy, and ATR measurements to cross-reference the presence and positions of the intercalate.

[1] Tokarczyk, M. et al., *Appl. Phys. Lett*. **103**, 241915 (2013)
[2] Grodecki, K. et al., *Appl. Phys. Lett*. **100**, 261604 (2012)
[3] Kowalski, G et al. *J. Appl. Phys*. **117,** 105301 (2015)

Study of parity doublet structure in ^{147}La

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At the moment there are about 3000 known nuclei, but only a small percentage of them has a spherical symmetry, most of them are deformed The problem of nuclear deformation was first investigated by the A.A. Bohr in 1952.[1] He suggested that atomic nuclei can acquire shapes other than spherical through a process called spontaneous symmetry breaking (SSB). Because the shapes of atomic nuclei largely depend on the interactions between nucleons, nuclear deformation studies can provide valuable information on nuclear forces. Residual interactions are responsible for acquiring non-spherical shape. In case of octupole deformation, studied in this work, residual interaction correlates nucleons moving on orbits which diffier by three units of angular momentum (l = 3), and have different parities. If the Fermi level of the nucleus is between these levels, we have to deal with octupole deformation. This occurs for a particular number of protons and neutrons called "octupole magic numbers" (N, Z = 34, 56, 88, 134). Because the wave functions describing octupole deformed nuclei do not have well-defined parity in the intrinsic frame, in the laboratory frame one can observe specific scheme of excited states, called a parity doublet.

The aim of the study was to investigate the presence of octupole deformation in ^{147}La nuclei. These nuclei were produced in spontaneous fission of ^{252}Cf and the measurements were done by using GAMMASPHERE array. Collected data were sorted into three-dimensional arrays. Taking as a starting point schemes proposed in previous works ([2] and [3]) new scheme of excited states has been proposed in which levels and transitions were arranged in a parity doublet structure. Four new transitions has been found with energies 558.8, 436.5, 421.4 and 414.25 keV In addition, the energies of all transitions and levels were recalculated with greater accuracy. In order to determine the spin and parity of levels, angular correlation technique has been used. Intensities of transitions allowed to determine the dipole moments and gyromagnetic coeficients.

Finding new transitions, and analysis of angular correlations allowed to present the scheme of excited states in ^{147}La in form of doublet parity. In addition, the fact that obtained values of dipole moments and gyromagnetic coeficients are consistent with other octupole deformed nuclei around ^{147}La allows to conclude that the ^{147}La nuclei is octupole deformed.

[1] A. Bohr, Mat. Fys. Medd. Dan. Vid. Selsk. 26, (1952).
[2] W. Urban *et al.,* "Octupole correlations in the neutron-rich, odd-A lanthanum nuclei", Phys. Rev. C 54, 945 (1996).
[3] S. J. Zhu *et al.,* "Octupole correlations in the neutron-rich ^{145,147}La nuclei: Coriolis-limit-coupling bands with aligned $h_{11/2}$ proton", Phys. Rev. C 59, 1316 (1999)

Studies on protein-ligand interactions using ^{1}H-^{1}H STD NMR

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Saturation transfer difference (STD) NMR [1] is one of the most popular magnetic resonance-based techniques useful for studying biomolecule-ligand interactions. ^{1}H-^{1}H STD NMR allows to detect transient binding of small molecule ligands to biomolecular receptors, usually proteins, by observation of magnetization transfer from receptor to ligand.

The experiment is carried out by selective saturation of the protein protons that resonate in the spectrum region free from ligand protons (usually achieved by irradiating the protein CH_3 groups). Due to spin diffusion, the saturation quickly spreads across the protein. If a protein-binding ligand is present in the solution, the saturation spreads also onto the ligand, thereby attenuating its signal. Subtraction of the resulting ^{1}H NMR spectrum from the reference spectrum recorded without protein saturation yields the STD spectrum.

STD NMR technique is often applied by bioorganic and medicinal chemists to ligand screening, mapping of binding moieties (group epitope mapping, GEM), and determination of the dissociation constants (K_D) for protein-ligand complexes.[2,3] The technique is very popular because it is robust, uses relatively small amounts of proteins and does not require isotopic labeling of proteins with ^{13}C and ^{15}N.

The Division of Biophysics at the Faculty of Physics UW has recently acquired a 500 MHz NMR apparatus with automatic sample exchanger which enables high-throughput ^{1}H-^{1}H STD measurements. Here, we would like to present our first results obtained from ^{1}H-^{1}H STD NMR experiments for two model proteins and their corresponding small molecule ligands: Human Serum Albumin (HSA) with aminoacid ligand and cNIIIB phosphatase with nucleotide ligand.

[1] Mayer, and Meyer, J. Am. Chem. Soc., 2001, 123 (25), 6108–6117
[2] Viegas et al. J. Chem. Educ., 2011, 88 (7), 990–994
[3] Angulo et al. 2010, Chem. Eur. J. 2010, 16, 7803 – 7812

Exploring fragmentation pathways of mononucleotides by ESI MS/MS: towards improved identification of nucleotide analogues

Dominika Strzelecka[1], Sebastian Chmieliński[2], Sylwia Bednarek[1], Jacek Jemielity[2], Joanna Kowalska[1]

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Synthetic analogs of nucleotides and nucleic acids are useful research tools and an emerging class of modern therapeutics. Mass spectrometry is an invaluable tool in identification and quantification of natural nucleotides, nucleotide-based drugs, and their metabolites. However, the fact that many nucleotides and their synthetic analogs are isomeric or isobaric compounds with similar chromatographic mobility, significantly impairs such analyses. We used our 'in-house' collection of nucleotide analogs modified in the phosphate chain, nucleobase, and within ribose moiety to perform a broad study on fragmentation pathways of modified nucleotides. The modifications involved the substitution of hydroxyl groups with various substituents and/or the introduction of the additional groups such as phosphorothioate, phosphoroselenoate, phosphoroamidate, boranophosphate, fluorophosphate, methylenebisphosphonate and imidodiphosphate. In total, we tested over 200 nucleotides with different modifications. We also used isotope labelling with ^{2}H, ^{18}O and ^{13}C and MS^{n} fragmentation to gain insight into fragmentation pathways. Based on the results we proposed general rules for nucleotides fragmentation that may be helpful in MS/MS spectra prediction and identification of unknown compounds based on their fragmentation spectrum. The results of MS/MS were collected in a form of data base which, will be freely available in public domain. The presentation will focus on selected examples demonstrating how MS/MS analyses can be applied to distinguishing between structurally similar isomeric and isobaric nucleotides and to quantification of selected biologically-relevant nucleotides such as mRNA cap metabolites.
We hope that the results of our research and the database will be useful to researchers focused on investigation of nucleotide-based drug and prodrug metabolism, discovery of new natural nucleotide modifications in biological samples, as well as chemical synthesis of nucleotide analogs. Development of methods for quantification of mRNA cap metabolites can provide better understanding of degradation pathways of mRNA.

Optical phase locked loop for long-term stabilization of broad-line DFB lasers frequency difference

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Long-term laser frequency difference stabilization is required in many applications such as coherent control of atomic spins, laser cooling or frequency comb metrology. Commonly applied methods such as Mach–Zehnder type interferometer using coaxial cable delay lines [1] or analog low-pass filter frequency-to-voltage converter [2] do not provide simple tuning mechanism and offer very limited feedback loop bandwidth. On the other hand optical phase locked loops (OPLL) provide excellent stabilization yet require very narrow line lasers and state-of-the-art, well calibrated electronics.

We present an experimental realization of an OPLL applied in an unconventional regime of long-term frequency difference stabilization of broad-line DFB lasers. The presented design is real time, digitally tunable, simple, robust, and compatible with basic, commercially available, slow laser current control modules. We present a simple model and a quick method to optimize the loop for given hardware using only simple measurements in time domain and approximate laser linewidth.

Example of such optimization is given for DFB lasers offset by 1-6 GHz. Loop characteristics measurements showing the loop bandwidth, phase variance and loop stability are presented and adhere to our theoretical model.

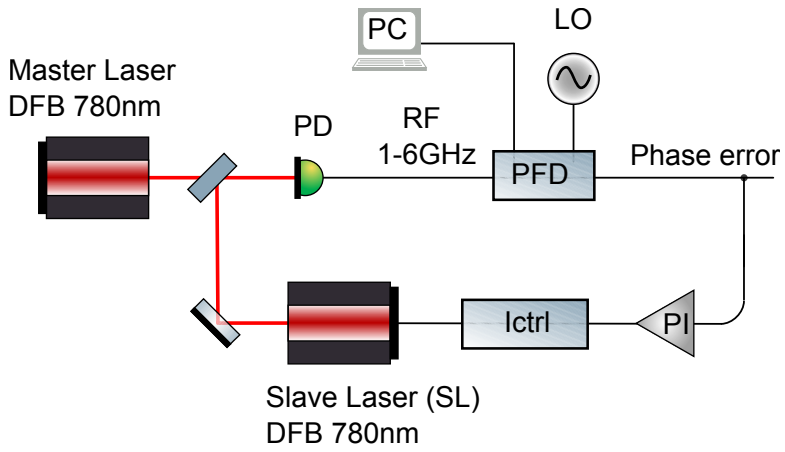

Figure 1: Experimental setup. Broad line (~10MHz) DFB Master laser (ML) and slave laser (SL) frequency difference (RF) is measured as a beat note on fast photodiode (PD) and fed to a programmable ADF41020 phase frequency detector (PFD) where it is compared with a reference local oscillator (LO). Phase error signal is fed through proportional-integral controller (PI) to slow laser current controller (Ictrl) closing the feedback loop.

[1] U. Schünemann, H. Engler, R. Grimm, M. Weidemüller, M. Zielonkowski, Rev. Sci. Instrum. **70**, 242 (1999)
[2] G. Ritt, G. Cennini, C. Geckeler, M. Weitz, Appl. Phys. B **79**, 363 (2004)

Synthesis and properties of fluorescent nucleotide derivatives

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"Click chemistry" allows synthesizing larger molecules on the way of coupling smaller ones using simple, rapid and efficient chemical reactions. The main representative of click reactions is copper-catalysed azide-alkyne Huisgen cycloaddition (CuAAC), in which the azide and alkyne moieties form 1,4-substituted-1,2,3-triazole. CuAAC has been used in many fields of chemical synthesis and biogonjugation, including nucleotide chemistry.
To provide new possibilities of nucleotide labelling and bioconjugation using CuAAC, we synthesised novel nucleotides with phosphate chain modified by the presence of an alkyne handle (Fig.1a), which can be reacted with azide-containing compounds. [1]
After CuAAC reaction (Fig. 1e) with various fluorescent dye azides we obtained a series of nucleotides exhibiting fluorescence properties. We characterized the fluorescent properties for each of the synthesized compounds. In the next step, we performed enzymatic experiments in which we studied activity of pyrophosphatases (SVPDE, DcpS), by observing changes in fluorescence emission spectra of the compounds upon enzymatic reaction. We found that our fluorescent nucleotide analogues can be used as fluorescent molecular probes for studying enzymatic activity in real time

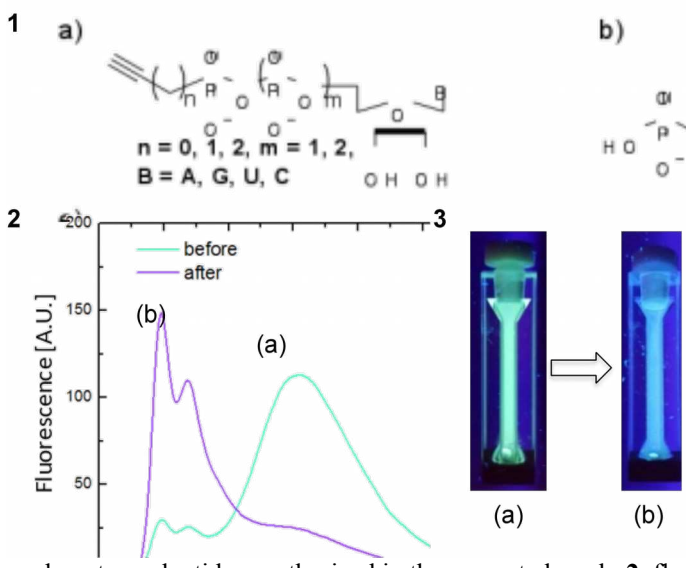

Figure 1: **1.** C-phosphonate nucleotides synthesized in the presented work. **2.** fluorescence spectra before (a) and after (b) enzymatic reaction. **3.** Fluorescence also can be seen with naked eye - fluorescence before (a) and after (b) enzymatic reaction.

[1] **Ethynyl, 2-Propynyl, and 3-Butynyl C-Phosphonate Analogues of Nucleoside Di- and Triphosphates: Synthesis and Reactivity in CuAAC,** Przemyslaw Wanat, Sylwia Walczak, Blazej A. Wojtczak, Monika Nowakowska, Jacek Jemielity, and Joanna Kowalska, *Organic Letters* 2015 *17* (12), 3062-3065, DOI: 10.1021/acs.orglett.5b01346

Study of interactions between fluorescently tagged cap analogues and gold nanoparticles

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The goal of my project was to create a molecular probe for study of cap analogues enzymatic degradation by DcpS enzyme[1]. 5' cap is a nucleotide structure on the 5' end of eucariotic mRNA chain, consiting of guanosine methylated on 7 position and connected to mRNA via 5'-5' triphosphate chain. I was able to synthesize an orthogonally functionalised mononucleotide cap analogue. Cap moiety was then tagged with Cyanine 5 fluorescence dye. It was also conjugated with lipoic acid on the terminal phosphate group of the 5'-triphosphate chain - this enabled attaching cap moieties to the surface of gold nanoparticles. Gold nanoparticles have unique abillity to quench fluorescence of nearby chromophores, in radiative and nonradiative manner[2]. In my project I used this phenomenon to observe first quenching of fluorescence of Cy5 dye attached to cap moieties assembled on gold nanoparticle surface, and then increase in fluorescence intensity when DcpS enzyme hydrolysed cap's 5'-triphosphate chain.

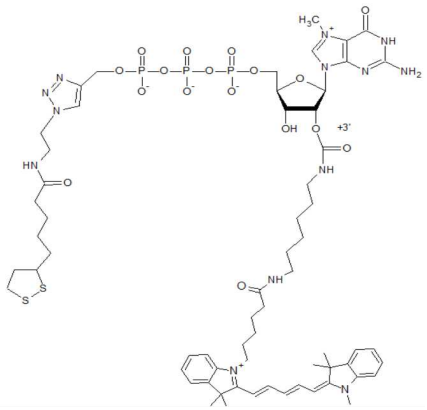

Figure 1: Orthogonally functionalised mononucleotide 5' cap, fluorescently tagged and conjugated with lipoic acid.

[1] M. Gu, C. Fabrega, Shin-Wu Liu, H. Liu, M. Kiledjian, Ch. D. Lima, *Insights into the Structure, Mechanism, and Regulation of Scavenger mRNA Decapping Activity,* Mol. Cell, 2004, 14 (1), 67-80
[2] E. Dulkeith, A. C. Morteani, T. Niedereichholz, T. A. Klar, and J. Feldmann, *Fluorescence Quenching of Dye Molecules near Gold Nanoparticles: Radiative and Nonradiative Effects*, Phys. Rev. Let., 2002, 89, 203002

Penning trap-assisted studies of β-decay of ^{88}Se

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The study of the neutron-rich nuclei with mass number A < 92 and proton number Z < 38 is motivated by the question about the structure of those very exotic nuclei. They are located near the path of the astrophysical r-process and close to ^{78}Ni, which is expected to be a doubly magic nucleus. In particular, it is of interest to study the development of collectivity close to ^{78}Ni, which may influence the r -process path by increasing binding energies.

On the poster we would like to present new results from a Penning trap-assisted measurement of the decay of ^{88}Se, which are a continuation of our recent studies of N=53 isotones [1]. In the experiment neutron-rich ^{88}Se ions were produced in fission induced by a 30 MeV proton beam irradiating the natural uranium target. The ion samples were on-line separated with the Ion Guide Isotope Separator On-Line (IGISOL) facility [2] and double Penning trap setup, JYFLTRAP [3]. The radiation of the ^{88}Se ions was registered by the γ spectrometer consisted of five Broad-Energy, germanium (BE-Ge) detectors, used to register low energy radiation, two large germanium detectors with relative efciency of 70 % to register high energy radiation and a β counter.

As an outcome of analysis the poster will present low-spins structure of excited levels in odd-odd ^{88}Br interpreted with a large scale shell-model calculations [4].

[1] M. Czerwiński, et al., Phys. Rev. C 92, 014328 (2015).
[2] J. Äystö, Nucl.Phys. A 693, 477 (2001).
[3] T. Eronen and J. C. Hardy, Eur. Phys. J. A 48, 46 (2012).
[4] K. Sieja et al., Phys. Rev. C 79, 064310 (2009).

The kinetics of the formation of a loose encounter complex of xanthone and naphthalene-2 acid. Triplet - triplet energy transfer.

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Formation of a loose encounter complex of ligand and receptor molecules is usually an initial step of biological processes. A quantity which characterizes the rate of formation of such complexes is the encounter rate constant. There are many methods for the experimental determination of rate constants. One of them is nanosecond laser flash photolysis spectrometry. I will present application of this method in the study of the xanthone - naphthalene-2 acid system. I utilize the energy of the excited triplet state of xanthone, which acts as a donor, to excite naphthalene-2, the acceptor in this process. This effect is called triplet - triplet energy transfer (TTET). The results obtained from the experiments are analyzed numerically using Dynafit, which enables the determination of the mechanisms of the processes and allows for the calculation of their rate constants. The conducted computational research consists of constructing molecule models and of simulating formation of encounter complex using Brownian dynamics.

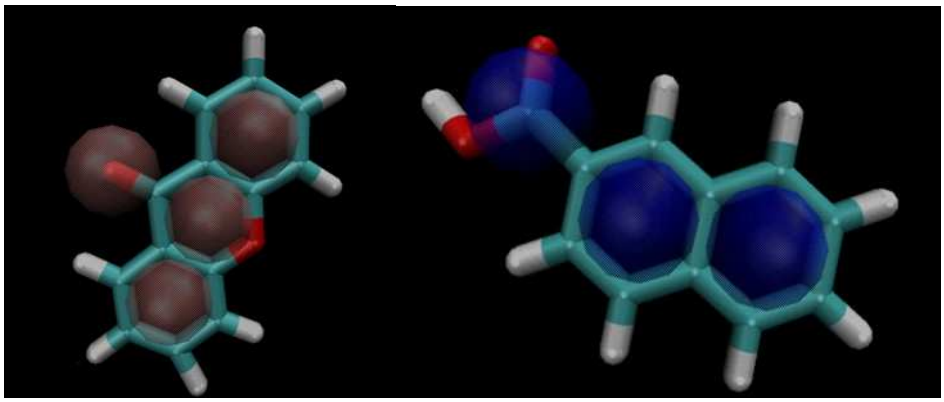

Figure 1: Structural models of the tested compounds: xanthone (left) and naphthalene-2 acid (right). Visualization by using the VMD (Visual Molecular Dynamics).

[1] A. Khalid, Abdullah and Terence J. Kemp, *J. Chem. Soc., Perkin Trans. 2, 1985*, 1279-1283
[2] E. Klimtchuk, M. A. J. Rodgers, D. C. Neckem, *J. Phys. Chem*., 1992, 96 (24), 9817–9820.

β-decay fast-timing study of ^{138}Xe

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The nucleus ^{138}Xe belongs to a class of nuclei positioned in a close vicinity to the doubly-magic ^{132}Sn, which is characterized by a crossing of the major neutron (N=82) and proton (Z=50) shell closures. With some approximation, ^{138}Xe can be described as a simple nuclear system with 2 neutron and 4 proton particles outside the core comprised of ^{132}Sn The presence of 6 particles outside a closed core represents a challenge to the shell model description.

Measurements of nuclear level half-lives provide direct insight into the nuclear structure, as they allow to extract essential information about transition matrix elements. This way, predictions of nuclear structure models can be verified, which is of great importance for investigation of the structure of nuclei located at double shell closures, particularly those with large neutron excess.

We have measured the half-lives of the low-lying states in ^{138}Xe populated in the β decay of ^{138}I. Experiment was performed at the OSIRIS fission-product mass separator at Studsvik in Sweden. The separated mass A=138 was continuously extracted from the fission target located near the reactor core. The advanced time-delayed β-γ-γ(t) method [1] was employed ensuring picoseconds precision. Two fast-response detectors with BaF_2 crystals were used in coincidence with fast β detector. In order to select desired decay branch with high energy resolution, experimental setup was complemented by Ge detectors. Timing information was obtained from β-γ(t) delayed coincidences between events registered in β detector and BaF_2 scintillator.

The half-lives of $T_{1/2}$=8.2(32) ps, 25(6) ps and 9.5(32) ps were obtained for the 2^+_1, 4^+_1 and 2^+_2 states, respectively, which provided information about reduced transition probabilities. These results allowed to examine the model predictions for this nucleus, which in general predict much higher collectivity for the 2^+_2 state.

[1] H. Mach *et al.*, Nucl. Instrum. Methods Phys. Res. A 280, 49-72 (1989).
[2] B. Fogelberg *et al.*, Nucl. Instrum. Methods Phys. Res. B 70, 137-141 (1992).

Non–fluorescent mutant of Green Fluorescent Protein sheds new light on the chromophore formation mechanism

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The Green Fluorescent Protein and its mutants have numerous applications in biological and medical research[3]. One of the reasons of such widespread use is the unique ability of GFP to form a chromophore without the assistance of external enzymes or cofactors, except for molecular oxygen. In the wild-type GFP the chromophore is spontaneously created from the three residues: serine 65, tyrosine 66 and glycine 67, and it is situated in the middle of the β–barrel in the folded GFP structure (Fig.1, left). Interaction of the chromophore with its local environment has a great influence on the spectral characteristics. This fluorescence is mediated by amino acids close to the chromophore in the tertiary structure[4]. Two mechanisms for the chromophore maturation were proposed[1] (Fig.1, right): one as cyclization–dehydration–oxidation (Mechanism A) or another as cyclization–oxidation–dehydration (Mechanism B).

We have generated the non–fluorescent mutant of GFP, S65T/G67A-GFP. Lack of fluorescence originates from the presence of non–functional chromophore, and indicates that the chromophore maturation process is interrupted. The data obtained by mass spectrometry revealed that in this mutant chromophore formation follows only mechanism A, however the oxidation reaction is suppressed. Among the pool of examined GFP mutants this result is unexpected, as for the wild-type GFP there is a strong support for the mechanism B[1][2].

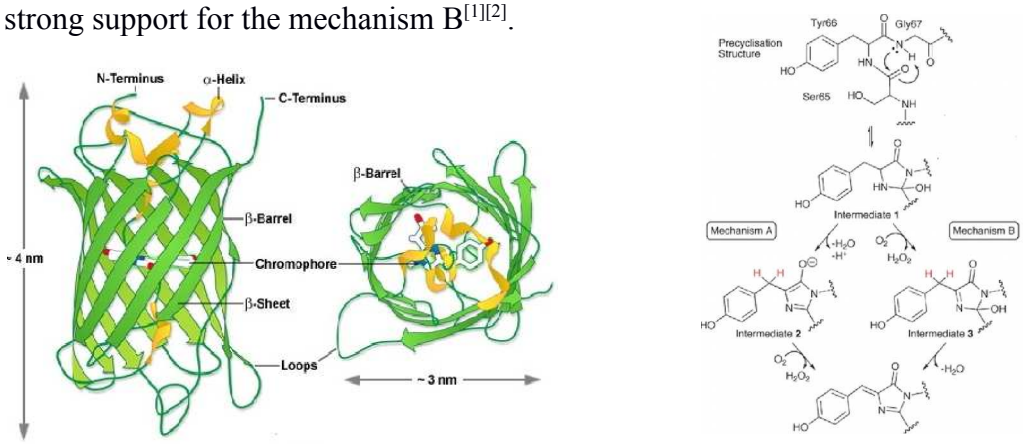

Figure. 1. Left: The tertiary structure of the wild-type GFP, overall view of the β–barrel and the top view showing the chromophore. Right: Two proposed mechanisms of the chromophore maturation[1]

[1] Craggs, T. D., Green fluorescent protein: structure, folding and chromophore maturation, Chemical Society Reviews 2009; 38, 2865-2875
[2] Tsien R.Y., The Green Fluorescent Protein, Ann.Rev.Biochem. 1998; 67, 509-544
[3] Su, W. W.: Fluorescent proteins as tools to aid protein production, Microb. Cell Fact., 2005, 4, 12–17
[4] Reid, B. G., Flynn, G. C., Chromophore Formation in Green Fluorescent Protein, Biochemistry 1997, 36, 6786-6791

Analysis of the enzymatic activity of the mammalian Nudix proteins towards dinucleotide 5'mRNA cap analogs.

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Eukaryotic mRNAs bear at their 5'end a cap structure, consisting of 7-methylguanosine linked by a triphosphate bridge to the first transcribed nucleotide (m^7GpppN), and cap removal is a critical step in multiple mRNA degradation pathways. Dcp2 and Nudt16 enzymes, that belong to the NUDIX protein family are the best studied players in the decapping process. However, recent analysis of known mammalian NUDIX hydrolases revealed mRNA decapping activity also for other proteins, including Nudt3 and Nudt12 [1][2].

Interestingly, next to the mRNA decapping properties, Nudt16 and Nudt12 enzymes possess also activity towards m^7GpppG and GpppG - the dinucleotide analogs of the cap structure [1]. Hydrolysis of dinucleotide cap analogs was up to date assigned to the DcpS enzyme, in the mRNA 3'-5' degradation pathway. Thus it raises a question, whether Nudt16 and Nudt12 may play a role similar do DcpS in a final degradation of dinucleotide caps present on a specific RNA transcripts.

Using analytical reverse-phase HPLC and fluorescence measurements methods we extended substrate specificity analysis of Nudt16 and Nudt12 enzymes on a series of unmethylated (GpppG, GpppA), monomethylated (m^7GpppA, m^7GpppG) and trimethylated ($m_3^{2,2,7}$GpppA, $m_3^{2,2,7}$GpppG) cap analogs. Obtained results showed for the first time, for example, that Nudt12 in addition to previously reported monomethylated and unmethylated substrates, effectively hydrolyses trimethylated cap analogs (preferred $m_3^{2,2,7}$GpppA) and seems to be most active on GpppA dinucletide. Detailed comparison of the Nudt12 and Nudt16 substrate specificity, and preliminary data of kinetic analysis of these enzymes will be presented.

Acknowledgments. This work was supported by the grant from the National Science Centre (Poland) UMO-2013/08/A/NZ1/00866

[1] Song MG., Bail S. and Kiledjian M. Multiple Nudix family proteins possess mRNA decapping activity. RNA 2013, 19(3):390–399
[2] Grudzień-Nogalska E., Jiao X., Song MG., Hart RP., Kiledijan M. Nudt3 is an mRNA decapping enzyme that modulates cell migration. RNA 2016, 22(5):773-81

New molecular probes based on pyrene fluorescence – synthesis and cap-protein interactions studies

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Pyrene and its derivatives have characteristic fluorescence properties, therefore are commonly used in fluorescent labelling. Pyrene fluorescence strongly depends on environmental conditions, hence, pyrene-labeled nucleotides can be used as molecular probes or biosensors. Using S-alkylation reaction we synthesized three mRNA cap analogs m^7GDP, m^7GTP and m^7GpCH_2pp labeled with acetylpyrene. As a control for fluorescence and biological studies we labeled two non-methylated analogs (GDP, GTP) and thiophosphate. Pyrene fluorescence can be influenced by its chemical modifications, such as nucleotide incorporation. The synthesized cap analogs showed wide fluorescent band, which was present even at low concentrations. Conversely, the non-methylated guanine nucleotides labelled with pyrene showed very weak fluorescence. To explain the difference in the fluorescent properties of m^7G and G pyrene-labelled nucleotides, the concentration, temperature and pH dependence of the emission spectra was extensively studied, as well as the influence of temperature on ^{1}H NMR spectra. The results indicate that the presence of N1-protonated form of m^7G results in a significant enhancement of pyrene fluorescence. This finding indicates that the new analogs are potentially useful for studying cap-binding proteins and enzymes responsible for cap degradation. An example of such reaction is cap degradation by DcpS enzyme which is therapeutically relevant process - inhibitors of DcpS enzyme are known as a potential drugs in SMA treatment[1]. We used our method to calculate IC_{50} parameters of selected DcpS inhibitors. Another tested application were biosensors for determination of the concentration of eIF4E protein (a tumor marker[2]) (Fig. 1).

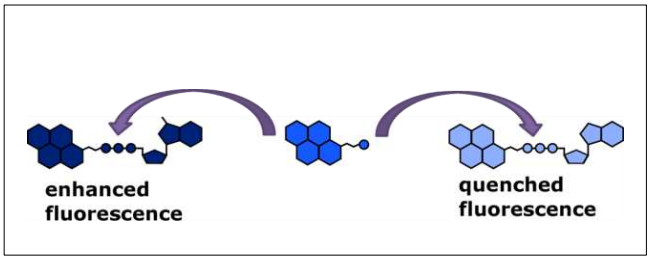

Figure 1: Scheme showing the nucleobase influence on acetylpyrene fluorescence.

[1] J. Singh, et. al. *ACS Chem. Biol.* vol. 3, pp. 711-722, 2008.
[2] A. Lazaris-Karatzas, et. al. *Nature* vol. 345, no. 6275, pp. 544-547, 1990.

Correlation steerin in the angularly multimode Raman atomic memory

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We demonstrated [1] the possibility of steering the direction of correlations between the off-resonant Raman scattered photons from the angularly multimode atomic memory based on warm rubidium vapors. In write-in process the Stokes photons are created in random direction together with atomic collective excitations. During the readout this excitations are converted to anti-Stokes photons. According to phase-matching conditions the wave-vector of anti-Stokes photon is correlated with driving beams and Stokes one. Using acousto-optic deflectors (AOD) driven by different modulation frequencies we experimentally change the angle of incidence of the laser beams on the atomic ensemble. Performing correlations measurements for various deflection angles we verify that we can choose the anti-Stokes light propagation direction independently of the correlated Stokes scattered light in the continuous way. As a result we can select the spatial mode of photons retrieved from the memory, which may be important for future development of quantum information processing, especially for photon generation.

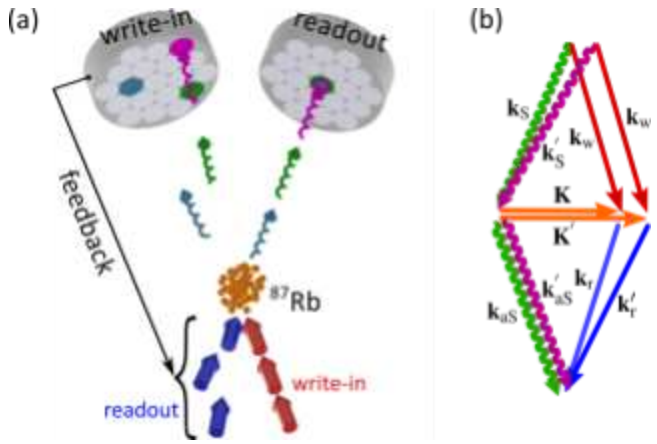

Figure 1: Redirecting heralded photons into the same mode in warm rubidium vapors atomic memory. (a) Photons are scattered at random directions during the write-in process. By redirecting readout beam we can launch the readout photon into the same fiber each time. (b) Phase-matching in the Raman scattering process.

[1] Mateusz Mazelanik, Michał Dąbrowski, and Wojciech Wasilewski, "Correlation steering in the angularly multimode Raman atomic memory," Opt. Express 24, 21995-22003 (2016)

Influence of chemical modifications within cap structure on activity of m^7G-binding proteins

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m^7G-binding proteins play a key role in mRNA metabolism by interacting with the cap structure (m^7GpppN_n) present at the 5' mRNA end or its hydrolysis products. Methylation at the N^7 position is the characteristic feature of the cap. It introduces a positive charge required for specific interaction with biomacromolecules. The m^7G-binding proteins are specific regulators of mRNA metabolism and their activity is under tight control in the cells. [1] Consequently, the specific m^7G-protein interaction influences gene expression processes such as pre-mRNA splicing, translation and mRNA degradation.

m^7G-binding proteins are also known therapeutic targets. eIF4E takes part in the translation initiation process. Elevated level of eIF4E has been found in many types of tumor cells resulting in selective increase in the translation of mRNAs connected with malignant transformation. [2] The therapeutic strategy in anticancer treatment uses eIF4E high affinity ligands to limit the active pools of protein available for mRNAs.

The second protein which is also the object of our studies -DcpS enzyme - hydrolyses cap structures released after 3' to 5' mRNA decay. It has been suggested that DcpS plays also a more general role in the control gene expression, as it has been independently linked to spinal muscular atrophy, intellectual disability and regulation of miRNA processing. [3,4] DcpS is a therapeutic target for Spinal Muscular Atrophy (SMA), which is an autosomal recessive disease caused by deletion or mutational inactivation of the SMN1 gene.

Finding high affinity, specific ligands for target proteins and using them as tools in biochemical experiments is one way for better understanding of protein function and mechanism. Fluorescence based techniques are commonly used for fast and simple inhibitor identification. Among advantages of fluorescence techniques are: high sensitivity, short analysis time, easy experimental setup and non-expensive reagents.

Here, we present different class of compounds which were studied as ligands for eIF4E protein or DcpS enzyme. The characterization of the compounds was performed using fluorescence-based techniques such as: fluorescence quenching titration, fluorescence polarization and enzymatic activity-dependent activation of fluorogenic probe.

[1] I. Topisirovic, Y. V. Svitkin, N. Sonenberg, A. J. Shatkin, WIREs RNA, 2011, 2, 277.
[2] Y. Jia, V. Polunovsky, P. B., et al., Medicinal Research Reviews, 2012, 32, 786.
[3] S. Bail, M. Kiledjian, et al., RNA Biology, 2008, 5, 216.
[4] C.K.L. Ng, M. Shboul, V. Taverniti, C., et al., Hum. Mol. Genet., 2015, 24, 3163.

Magneto-optical studies of natural quantum dots formed in GaN nanowire-UV-LED

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Semiconductor nanowires provide a number of possibilities for the design of various sophisticated heterostructures and, as a consequence, enable development of advanced electronic and optoelectronic devices. They are both efficient light harvesters and emitters, which makes them suitable building blocks for production of solar cells as well as light emitting diodes (LED) and lasers. It is known that incorporation of quantum wells, which enables quantum carrier confinement, improves the efficiency of light emitting devices.

In this communication we present our research on GaN-nanowire-UV-LED devices with built-in quantum wells. Our sample is grown by plasma-assisted molecular beam epitaxy (PAMBE) on the n-type Si substrate, and consists of two sections. The bottom section is composed of n-type AlGaN nanowires with AlN composition gradient from 0 to 15 %. The sample's top part consists of fully-coalesced p-type $Al_{0.2}Ga_{0.8}N$ nanowires forming a p-n junction. Three GaN quantum wells with width of 3.5 nm separated by 15 % AlGaN barriers are built in the active part of the structure.

The sample was studied using electroluminescence and photoluminescence spectroscopy. Low-temperature micro-photoluminescence spectra are dominated by emission in the energy range 3.50 – 3.65 eV, which originates from AlGaN barriers with different Al concentrations. Interestingly enough, a number of sharp lines with halfwidths of about 0.25 meV appear at random energies in the spectrum. These lines are clearly visible for rather small excitation powers and saturate for high power excitations. As shown in Fig. 1, they display unusual behavior in the magnetic field. The observed magnetic field evolution shall be discussed in terms of the emission from natural quantum dots formed within the investigated structure.

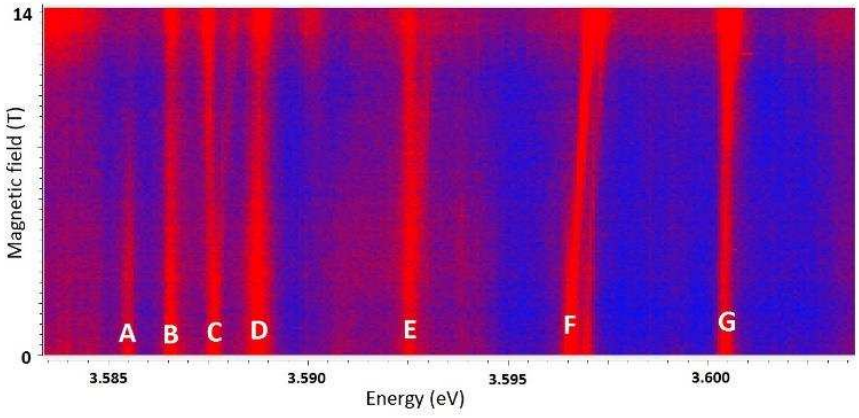

Figure 1: Exemplary luminescence spectrum evolution of several quantum dots in the magnetic field.

Dependence of Tissue Inhomogeneity Correction Factors on Nominal Photon Beam Energy

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Introduction: Before the first clinical use of the treatment planning system the commissioning of the dose calculation algorithms must be performed. One of the most difficult task is to check the accuracy of calculations in the inhomogenious abosrber. Several results of so called inhomogeneity correction factors were published but it is not clear if they might be used for the user beam due to differences in beam energies.

Purpose: The aim of the study was to check how much the correction factors depend on the energy of the beam.

Materials and Methods: The Batho correction method, which is the ratio of powers of Tissue Air Ratios (TAR) was used for calculation of the set of correction factors for lung. The TAR factors for wide range of energies were calculated using the depth doses described by the Gerbis' formula and peak scatter factors by the Li's formula. The correction factors were calculated for lung of 0.25 g/cm3 density for several beam sizes and for points lying at several depths below of lung. Calculated correction factors were then compared with AAPM TG-85 and treatment planning system (TPS).

Results: The maximum difference among $TPR_{20/10}$ for 38 6 MV Linear accelerator is 4.2% and for 15 MV is 2.2%. The 10% difference in energy ($TPR_{20/10}$) lead to changes of CF of 0.7% and 1.3% for 6 & 15 MV respectively for 2 cm lung. Whereas for 8 cm lung, CF were changed to 3% and 3.6 for 6 & 15 MV respectively.

As a result of comparison of calculation and data from AAPM TG-85 and TPS shows a deviation of less than 2%.

Conclusion: Little linear dependence of correction factors on energy were found. Correction factors decreased with increase the field size. The larger lung thickness, the larger differences between the correction factors were obtained.

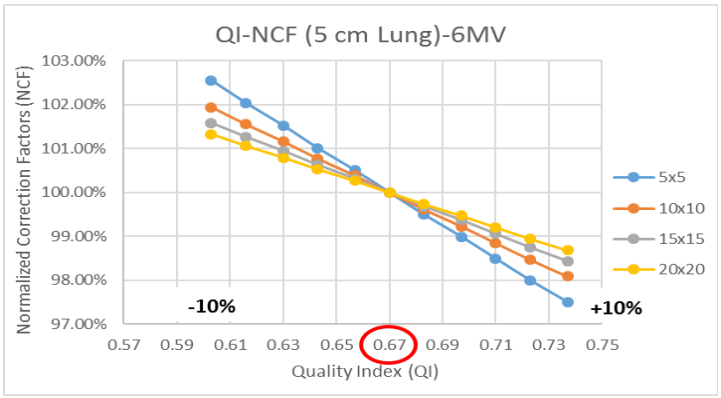

Figure-1 Normalized correction factors as a function of beam quality index at 5 cm depth below of 5 cm lung for 6 MV X-rays with field sizes of 5x5, 10x10, 15x15 and 20x20 cm²

References:

[1] AAPM Report No. 85, Tissue inhomogeneity corrections for megavoltage photon beams, August, 2004

[2] Bruce J. Gerbi, A mathematical expression for %DD accurate from Co-60 to 24, MV, Med. Phys. 18, 724 (1991)

[3] X. Allen Li, Peak scatter factors for high energy photon beams, Med. Phys. 26, 962 (1999)

[4] Marc R. Sontag and J. R. Cunningham, Corrections to absorbed dose calculations for tissue inhomogeneities, Med. Phys. 4, 431 (1977)

Synthesis and Properties of mRna Cap Analogs Designed For Electron Spin Resonance Experiments

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Molecular tools allowing for specific monitoring of enzymatic activity and association processes *in vitro* and *in vivo* are crucial for improving our understanding of cell functioning and elucidating origins and bases of a wide range of diseases, stemming from damages of these processes. For instance, overactivity of DcpS (Decapping Scavenger) enzyme worsens the symptoms of Spinal Muscular Atrophy and overexpression of translational factor eIF4E in cells results in expression of oncogene products what has tumor-promoting effects [1,2]. Both proteins, DcpS and eIF4E are 5'mRNA cap–binders. Thus, inhibition of DcpS activity and cap-dependent translation where eIF4E is involved, can be accomplished using 5'mRNA cap analogs [3].

Spin labeled probes suitable for ESR (Electron Spin Resonance) experiments emerge as new molecular tools to investigate enzymatic activity and association [4]. They hold several advantages over extensively used FRET-based probes, including less sterically demanding labels, high sensitivity and specificity since paramagnetic centers are not widespread in the cell, and avoidance of potential radiation-induced sample damages.

Our goal was to synthesis mono- and bis- spin labeled 5'mRNA cap analogs and test their potential for ESR experiments. We developed two types of probes modified with one or two TEMPO radicals. One type was a dinucleotide 5'mRNA cap analogue functionalized with a carboxyl group at the N6 position of the second nucleotide allowing for attachment of one TEMPO radical using NHS strategy. The second type was a mononucleotide analogue functionalized with two alkyne-substituents allowing for attachment of two TEMPO radicals in a click reaction. We employed both compounds to study their binding to eIF4E and their enzymatic hydrolysis by DcpS. From acquired data we extracted information about dynamics of investigated processes as well as changes of the local environment of the probes.

We obtained nucleotide analogues mono- or bis- labelled with TEMPO radicals that are suitable for ESR studies of enzymatic hydrolysis or binding to selected targets. We successfully studied binding of compounds to eIF4E and their enzymatic hydrolysis by DcpS. We are confident that this ESR-based detection of protein–ligand association and hydrolytic activity could be applied to other cap- and nucleotide binding proteins.

References:

[1] A. De Benedetti *et al.*, Oncogene. **23,** 3189 (2004)
[2] J. Singh *et al.*, ACS Chem. Biol. **3,** 711 (2008)
[3] J. Kowalska *et al.*, RNA. **14,** 1119 (2008)
[4] S.M. Hacker *et al.*, Chem. Commun. **50,** 7262 (2014)

Strong Photoluminescence Fluctuations In Laser-thinned Few-layer WS_2

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Transition metal dichalcogenides (TMDs) have recently become a worldwide subject of intensive optical studies [1]. One of the astonishing properties of these materials is that their band structures undergo a transformation from indirect bandgap to direct bandgap when decreasing the number of layers in the crystal lattice, which is accompanied by a substantial increase of the photoluminescence intensity. Since up to now there are no well-established procedures of synthesizing large-area TMD monolayers, a very desirable would be an efficient and reliable method of fabricating them from bulk TMD flakes. In this communication we present our results of μ-Raman and μ-photoluminescence (μ-PL) study of few-layer WS_2 flakes that have been locally thinned down by a focused laser beam. It was found that the luminescence spectra measured outside the laser-thinned region were quite stable. Enormous increase of intensity in laser-thinned region was found along with transitions which characterize WS_2 monolayer [2]. Interestingly, huge intensity fluctuations were detected at the boundary between the 3-layer area of the flake and the laser-thinned region (Fig. 1). Similar effects were found at the edges of a WS_2 bilayer flake, which has not been subjected to laser thinning. The origin of the observed time evolution of the PL response will be discussed in terms of electrostatic potential fluctuations resulting from light-induced changes of the charge states of defects present in the laser-thinned area.

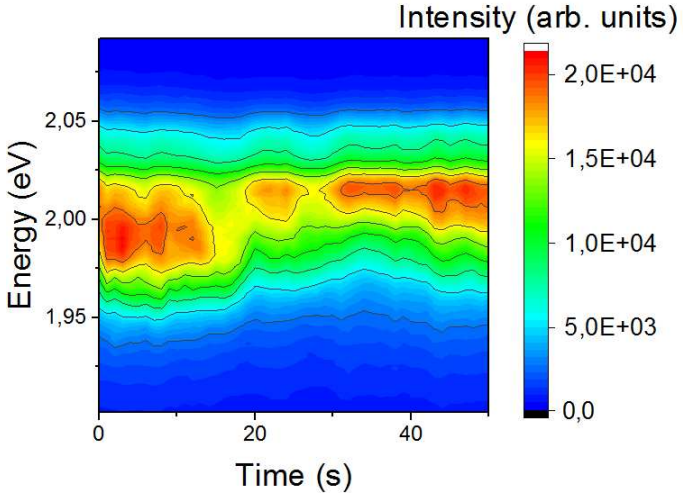

Figure 1: Subsequent photoluminescence spectra measured with 1 s acquisition time for laser excitation spot positioned at the boundary between the 3- and 1-layer parts of the investigated WS_2 flake.

[1] Wang, Qing Hua et al., *Nature nanotechnology* 7.11 (2012): 699-712.
[2] Plechinger, Gerd, et al., *physica status solidi (RRL)-Rapid Research Letters* 9.8 (2015): 457-461.

(Oligo)nucleotides containing a fluorophosphate moiety – synthesis and application in 19F NMR studies on biological processess

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To broaden the scope of existing methods for nucleotide ^{19}F-labeling we synthesized a library of fluorophosphate (oligo)nucleotide analogs containing an O to F substitution at the terminal position of the (oligo)phosphate moiety and evaluated them as tools for ^{19}F NMR studies.

We first synthesized over 30 fluorophosphate-containing (oligo)nucleotide analogs varying in nucleobase type, oligophosphate chain length and presence of additional phosphate modifications. To achieve this, we developed three synthetic methods that provide access to a variety fluorophosphate-containing (oligo)nucleotides. The first approach (A) employs substituting the imidazole leaving group of an activated nucleotide by fluoride anion. The second approach is similar but the fluorophosphate anion is used as a nucleophile (B). The third approach (C), which is particularly useful for the synthesis of either highly polar nucleotides (e.g. tetraphosphate analogs) or those bearing a modified oligophosphate bridge, exploits the use of a fluorophosphate unit activated as an electrophile. In all cases the presence of either $ZnCl_2$ or $MgCl_2$ as Lewis-acid catalyst is required. Using method (C) we also synthetized ten oligonucleotides carrying 5'-fluorodiphosphate moiety. Subsequently, the compounds were thoroughly characterized by ^{19}F NMR and evaluated as ^{19}F NMR molecular probes based on δ_F and J_{F-P} changes. Due to high sensitivity of δ_F to local environment changes the fluorophosphate-containing probes were suitable to studying both oligonucleotide hybridization and enzymatic monitoring of pyrophosphatase catalysed reactions (including snake venom phosphodiesterase (PDE-I), RNAse T2, and decapping enzyme (DcpS). We also applied fluorophosphate mRNA cap analog as a ^{19}F NMR reporter ligand to monitor ligand exchange process in the cap-binding site of translation initiation factor 4E (eIF4E), a protein responsible for the recognition of the mRNA 5′ cap during the initiation of translation process. This allowed us to determine the dissociation constants of eIF4E with various non-fluorinated cap analogs. Finally, we found that several nucleotide-specific phosphohydrolases can cleave P–F bonds in substrate analogues containing a fluorophosphate moiety to release fluoride ions. By employing a fluoride-sensitive molecular sensor, we harnessed this cleavage reaction to develop a fluorescence assay to screen for phosphohydrolase inhibitors (hDcpS and PDE-I)[1,2]

[1] Baranowski et al. J. Org Chem., 2015, 80 (8), pp 3982-3997
[2] Baranowski et al. Org. Biomol. Chem., 2016, 14, pp 4595-4604

Synthesis of propargyl-modified analogs of the 5' mRNA end structure for fluorescent labeling with CuAAC

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Cap structure is present on 5' end of eukaryotic mRNAs. It consists of 7-methylguanosine bound by a 5',5'- triphosphate bridge to the first transcribed nucleotide. Cap is involved in many RNA-related processes, for example, interaction with eIF4E (eukaryotic translation initiation factor 4E) in the translation initiation process. The presence of cap modulates also transcript stability by protecting it from the 5'-exonucleolytic activity. Only specific hydrolases such as DcpS (Decapping Scavenger) can cleave the cap structure [1], therefore fluorescently labeled cap analogs are useful tools for investigation of cap-specific proteins and cap-related processes.

Here, we present the synthesis of a series of dinucleotide cap analogs modified with a propargyl moiety. The propargyl moiety is attached either to guanosine (N1 position) or adenosine moiety (2'-O position). These positions were rationally selected to provide tools useful for various biological applications. Some of the analogs were additionally modified at the bridging or non-bridging positions of the triphosphate chain to modulate affinity to specific proteins and confer resistance towards decapping enzymes. The analogs were characterized by HRMS and ^{1}H and ^{31}P NMR spectroscopy.

The usefulness of the cap analogs in an azide moiety by copper catalyzed alkyne-azide cycloaddition (CuAAC) reactions was demonstrated by reacting them with several azide-containing labels and tags. The resulting fluorescent cap analogs can be used in various biological tests with cap-binding factors as well as to conduct cap degradation experiments.

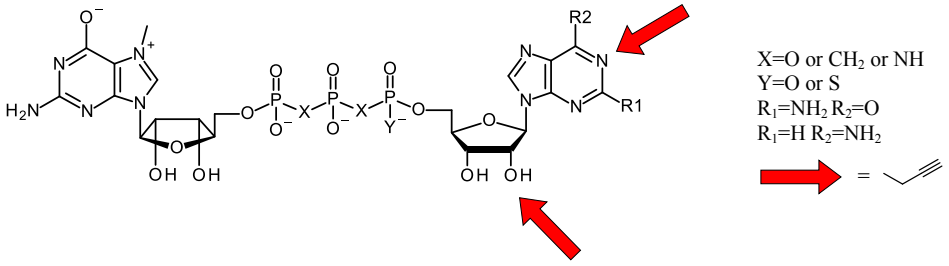

Figure 1: Structure of obtained cap analogs.

[1] M. Ziemniak, M. Strenkowska, J. Kowalska, J. Jemielity, Future Med. Chem., 2013, 5, 1141-1172

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Optical properties of thermotropic liquid crystal with trapezoidal mezogenic core

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The mesogenic metal complex attract attention because of their optical, photoconductive and paramagnetic properties. [1] Commonly, the liquid crystalline properties are observed either by rod-like, or disc-like molecules, forming smectic or columnar phases, respectively. The trapezoidal shape – the molecules of intermediate shape are less studied [2,3]. We synthesised enaminoketone Ni(II) complexes trapezoidal shape and show that such molecules depending on number, size and and distribution of substituents can build smectic or/and columnar phases. The polarizing microscopy, x-ray diffraction and differential scanning calorimetry were used to characterize the mesophases.

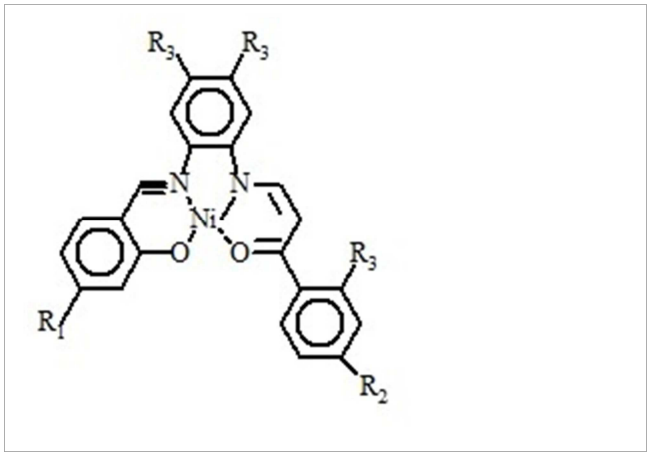

Figure 1: Trapezional mezogenic core molecule, R1, R2, R3 were different type substitutes.

[1] B. Donnio, D. Guillon, R. Deschenaux and D. W. Bruce, in Comprehensive Coordination Chemistry II, ed. J. A.McCleverty, J. J. Meyer, M. Fujita and A. Powell, Elsevier, Oxford,2003, vol. 7, p. 353.
[2] Richard J. Bushby, Owen R. Lozman, Current opinion in Solid State and Materials Science, Elsevier, 2003, vol.6, p.569.
[3] Agata Głębowska, Krystyna Kamieńska-Trela, Adam Krówczyński, Damian Pociecha,
Jadwiga Szydłowska, Jacek Szczytko, Andrzej Twardowski, Jacek Wójcik and Ewa Górecka, the Royal Society of Chemistry - Journal of Materials Chemistry, 2008, vol. 18, p.3419.

Reconstruction of tracks in the mini eliTPC

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The poster will describe the eliTPC detector – a time projection chamber with a novel type of planar readout in which readout strips has varying width. The detector will be used in newly developed research facility - Extreme Light Infrastructure – Nuclear Physics (ELI-NP) in Romania in day-one experiment. The poster will describe algorithm of reconstruction and its application to the data collected during the beam tests in IFIN-HH, Magurele, Romania and during laboratory tests in Warsaw.
The Extreme Light Infrastructure – Nuclear Physics is a new laboratory which will deliver brilliant monochromatic gamma beam $\Delta E_\gamma \sim 3$ % of energy up to 20 MeV and high intensity (10^8 Hz) [1]. The measurement of the cross section of astrophysical nuclear reaction proposed by University of Warsaw in collaboration with University of Connecticut and ELI-NP was chosen as a day-one experiment. Among the research programme there is so called holy grail of nuclear astrophysics – measurement of cross section of $^{12}C(\alpha,\gamma)^{16}O$ reaction.
The mini eliTPC detector is a working in normal pressure reduced setup of the eliTPC. The eliTPC will be an active target, low pressure detector. The gaseous medium containing CO_2 will be a source of oxygen for photodissociation reaction $^{16}O(\gamma,\alpha)^{12}C$. Low pressure in the chamber will extend the range of products of the reaction. The novel readout is made of interconnected pads which forms three arrays of strips. Such organisation of readout structure allows to significantly decrease number of required channels, with comparison to the pixel readout. An initial algorithm of reconstruction from the redundant system of coordinates *uvw* was developed [2], [3]. The algorithm is still developed and the further version is presented in [4].
The mini eliTPC was constructed on Faculty of Physics, University of Warsaw, as a part of R&D for the eliTPC detector. In October 2015 and in April 2016 the detector was tested on the beam line at IFIN HH, Magurele, Romania. The detector was placed on the 15 MeV α beam from the 9 MV, Tandem Van de Graaff accelerator. The poster will show recorded beam particles as well as beam scattering on the gas.
The poster will be an extended summary of the results discussed in [4].

[1] D. Filipescu et al, Eur. Phys. J. A (2015) 51: 185
[2] J. Bihałowicz, Bachelor thesis, Faculty of Physics, University of Warsaw 2014
[3] J. Bihalowicz et al, Proc. SPIE 9290, 9290C (2014)
[4] J. Bihałowicz, Master thesis, Faculty of Physics, University of Warsaw 2016

Ultrafast single-photon camera

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Single-photon detection with spacial resolution is a quite new method used in quantum optics. It enables deriving a benefit from single-photon spacial correlations in quantum information processing (e.g. in cryptography or quantum metrology).

Up to now commonly used cameras measuring that correlations (iCCD, isCMOS) [1] have low repetition rate (<< 1 MHz), which impose some constraints on experiments that can be performed. We present a 100 px single-photon camera made of a fiber bundle with repetition rate up to 80 MHz. Each fiber has a different length, so we obtain space-time mapping [2]. An average difference in time between neighboring time bins is 85 ps. Optical signal from the fiber bundle is then transferred to the single-photon detector.

We have conducted imaging of an object of a known shape to proof the utility of such a camera for further experiments. This camera will be applied in experimental realization of quantum-enhanced imaging.

[1] R. Chrapkiewicz, W. Wasilewski, K. Banaszek, Opt. Lett. 39, 5090-5093 (2014)
[2] K. Goda, K. K. Tsia, B. Jalali, Nature 458, 1145-1149 (2009)

ENA detection vs heliosphere numerical models

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Charge exchange on interstellar He dominates properties of the neutral solar wind in the downwind (interstellar wind) hemisphere[1]. During charge-exchange collisions there are produced ENAs (energetic neutral atoms) which are detected to image the interaction of the heliosphere with interstellar medium [2]. Measurements are performed by two ENA imagers, IBEX-Hi in energy band ~0.5 to 5 keV [3] end IBEX-Lo in energy band ~0.1 to 2 keV. Every 6 months data are gathered into sky maps (Figure 1). First attempt to numerically model the interaction between solar wind and interstellar medium was by solving hydrodynamic equations of counter-flowing fluids, via solving inviscid Euler equation. Since then many numerical models were developed to determine the basic structure of the heliosphere. The local interstellar medium velocity vector and temperature originally determined through the velocity and temperature of the interstellar He flowing in the inner heliosphere and measured by the GAS instrument on Ulysses [4,5,6] recently have been challenged by new measurements by the Interstellar Boundary Explorer (IBEX). In this work we discuss results of global modeling of the heliosphere regarding the interstellar bow shock and measurements of the He flow.

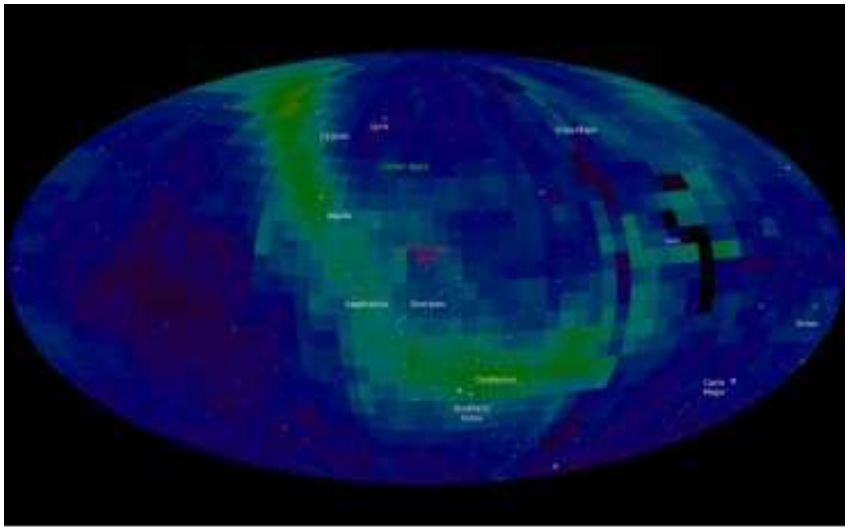

Figure 1: In 2009, NASA's Interstellar Boundary Explorer (IBEX) mission science team constructed the first-ever all-sky map of the interactions occurring at the edge of the solar system, where the sun's influence diminishes and interacts with the interstellar medium.A giant ribbon of energetic neutral atoms – shown here in light green and blue - streaming in from that boundary. Source: NASA/Goddard/Scientific Visualization Studio

[1] M. Gruntman, The neutral component of the solar wind at Earth's orbit, Cosmic Research, 18, 649-651, 1980.
[2] D. McComas, et al., Global observations of the interstellar interaction from the Interstellar Boundary Explorer (IBEX), Science, 326(5955), 959–962, 2009.
[3] H. Funsten et al., The Interstellar Boundary Explorer High Energy (IBEX-Hi) neutral atom imager, in The IBEX Mission, edited by D. J. McComas, N. A. Schwadron, and G. Zank, Springer, Dordrecht, Netherlands, in press, 2009
[4] M. Witte et al., Advanced Space Research, 34, 61, 2004.
[5] M. Witte, Astronomy and Astrophysics, 426, 835, 2004
[6] E. Moebius et al. Astronomy and Astrophysics, 426, 897, 2004.