Self-report

Education:

PhD, *magna cum laude* 2002,

Institute of Physical Chemistry, PAS, Warsaw, POLAND.

Supevisor Doc. dr hab A. Mordzinski

MSc, *magna cum laude,* 1997

Dnepropetrovsk National University, Dnepropetrovsk, UKRAINE

Supervisor: Prof. V. Moiseenko

Employment history:

2009-present, Institute of Physical Chemistry, Warsaw, Poland, adiunkt.

2007-2008, University of Nevada, Reno, USA.

2002-2006, Montana State University, Bozeman, USA (several months per year).

1998-2002, Institute of Physical Chemistry, Warsaw, Poland, research assistant.

Research areas:

New methods and techniques in nonlinear optics, ultrafast spectroscopy and femtosecond laser technology.

Scholarships:

DAAD, Austria, Institute of Theoretical and Radiochemistry, Vienna University, 1999.

Research achievements

1. Scientific publications:
   overall number of scientific publications: **27**
   the number of publications in journals from Journal Citation Reports (JCR): **25**
2. Cumulative impact factor of scientific publications,
   IF - **74.352**
3. Number of citations according to the Web of Science database (WoS);
   561 (without self citations)
4. Hirsch index according to the Web of Science (WoS);
   10
5. International or national research projects management or participation in such projects:

a) principal investigator, grant KBN 7T09A00321 " Laser studies of isolated systems in supersonic jet beams and cold helium droplets", 2001-2004.

b) investigator, grant KBN 1P03B02926, „Parametric amplification of femtosecond light pulses", 2004-2006.

c) investigator, grant KBN N20201932/0698, "Parametric amplification of ultrashort light pulses, the role of the noncollinear geometry.", 2008-2010.

d) investigator, N62909-11-1-7024, grant Office of Naval Research Global, project in progress.

e) investigator, UDA-POIG.01.03.01-22-080/09-03, „Femtosecond laser system for materials micromachining", project in progress.

f) principal investigator, N R02 0019 10, development project NCBiR, „Femtosecond terawatt laser based on parametric amplification", project in progress

g) principal investigator, N62909-11-1-4045, Visiting Scientist Program, Office of Naval Research Global, project in progress.

6. Patent applications, granted patents, international or domestic,
   "The scheme and method of increasing of repetition rate of laser pulses" Switzerland DE700076, Poland P-391054, patent application
7. Foreign research centers cooperation:
   a. Montana State University, USA, prof. A. Rebane's group
   b. University of Nevada Reno (Nevada Terawatt Facility), Reno, USA.
8. Educational activity
   a. supervision of students undertaking students' practice in the Institute of Physical Chemistry
   b. a series of lectures on ultrafast pulses optics (summer school of quantum optics 2009)

Scientific work history

After the graduation in 1997 from Physics Department of Dnepropetrovsk National University (Ukraine), I enrolled in graduate studies in Institute of Physical Chemistry PAS in Warsaw. The main topic of my research during my graduate studies was high resolution laser spectroscopy of selected organic compounds and theirs complexes in supersonic jets and super cooled helium droplets. In my PhD thesis I presented the results of experimental measurements which give insight into first steps of micro solvation process. I presented the results of spectroscopic measurements of the molecular structure of

microclusters of several antracene derivatives with solvents molecules such as water, methanol, chloroform, carbon tetrachloride and benzene. All measurements were carried out by means of laser spectroscopy with optical and mass resolved detection. During my PhD studies I published 5 manuscripts in well recognized peer review journals from ISI Master Journal List.

After defending my PhD thesis (*magna cum laude*) in 2002 I changed the direction of my scientific activity. Ultrafast methods in laser spectroscopy, new methods of producing and characterizing ultrashort laser pulses, ultrafast nonlinear optics and physics of high peak power lasers attracted the most of my attention.

In 2003 I commenced collaboration with the group of prof. A. Rebane from Montana State University (USA), which continues till present days. During my stays in prof. Rebane's laboratory I developed new experimental system for two photon absorption (2PA) spectra measurements. The system was used for the precise measurements of two-photon absorption cross section of porphyrin and porficene derivatives – molecules required for several innovative applications, such as fluorescence three-dimentional (3D) microscopy, a photodynamic cancer therapy , micro- and nanofabrication or ahigh-density optical data storage.

As a result of this collaboration we published a series of manuscripts presenting detailed studies of two photon absorption spectra in the region of 800-1600 nm. Quantitative measurements of two photon cross sections of large number of tetrapyrrolic compounds, its oligomer and nano structures.
We also proposed a model which describes:

1. an effect of resonance enhancement of two photon absorption, common for most tetrapyrroles, which occurs if the excitation wavelength is close to the one photon allowed Q-transition
2. occuring of the strong two photon allowed gerade transition around Soret band in some substituted tetraazoporphyrins.
3. increasing of the 2PA cross section up to 1000 GM by means of the chemical modification of the bare tetrapyrroles.
4. possessing of large two photon absorption cross section by some porphyrin dimers in comparison to the parent monomers.

Below I present the list of my manuscripts together with theirs abstracts.

1. M. Drobizhev, **Y. Stepanenko**, Y. Dzenis, A. Karotki, A. Rebane, P. N. Taylor, and H. L. Anderson, "Understanding strong two-photon absorption in pi-conjugated porphyrin dimers via double-resonance

enhancement in a three-level model," Journal of the American Chemical Society 126, 15352–15353 (2004).

> We present the two-photon absorption (2PA) spectra of a series of conjugated porphyrin dimers and show that they possess extremely large intrinsic (femtosecond) peak 2PA cross sections, up to $\sigma_2 = 1 \times 10^4$ GM in the near-IR region; these are among the highest values measured for any organic molecule. Moreover, we demonstrate that the second-order perturbation theory applied to a simple three-level model gives a perfect quantitative description of the observed 2PA cross section. By comparing all the factors of the three-level model for dimers with those of corresponding monomer (for which σ_2 = 20 GM), we explain an 500-fold cooperative enhancement in σ_2 and find that the most important factor is the strength of excited-state transition. The matrix element of dipole moment of this transition amounts gigantic values of 30–40 D for conjugated porphyrin dimers, which can be accounted for a large delocalization radius (large electron–hole separation) in this state. We also demonstrate efficient generation of singlet oxygen upon one- and two-photon excitation of these porphyrin dimers, which can be useful for two-photon initiated photodynamic therapy of cancer.

2. M. Drobizhev, **Y. Stepanenko**, Y. Dzenis, A. Karotki, A. Rebane, P. N. Taylor, and H. L. Anderson, "Extremely Strong Near-IR Two-Photon Absorption in Conjugated Porphyrin Dimers: Quantitative Description with Three-Essential-States Model," J. Phys. Chem. B **109**, 7223-7236 (2005).

> Two-photon absorption spectra (2PA) of a series of conjugated dimers and the corresponding monomer were studied in the near-IR region. All of the dimers show very large peak cross section values, $\sigma_2 = (3–10) \times 10^3$ GM (1 GM = 1×10^{-50} cm^4 s), which is several hundred times larger than that obtained for the corresponding monomer in the same region. We explain such dramatic cooperative enhancement by a combination of several factors, such as strong enhancement of the lowest one-photon Q-transition, better resonance conditions in the three-level system, dramatic enhancement of the excited-state singlet–singlet transition, and parallel arrangement of consecutive transitions in dimers, as compared to perpendicular arrangement in the monomer. We show that the absolute values of the 2PA cross section in these molecules are quantitatively described by a quantum-mechanical expression, derived for the three-level model. We also demonstrate the possibility of singlet oxygen generation upon one- and two-photon excitation of these dimers, which makes them particularly attractive for photodynamic therapy.

3. M. Drobizhev, N. S. Makarov, **Y. Stepanenko**, and A. Rebane, "Near-infrared two-photon absorption in phthalocyanines: Enhancement of lowest gerade-gerade transition by symmetrical electron-accepting substitution," J. Chem. Phys. 124, 224701 (2006).

> This paper presents, to the best of our knowledge, the first study of two-photon absorption (2PA) spectra of a number of symmetrically substituted phthalocyanines in the excitation wavelength region from λ_{ex} = 800 to 1600 nm. The selected molecules vary by position of substitution (α or β), number of substituent groups (4, 8, or 16), and presence or absence of metal (Zn or Al) in the center. For all phthalocyanines we find a moderately strong ($\sigma_2 \sim$ 100–200 GM), pure electronic, gerade-gerade (g-g) 2PA transition, which shows up as a well-resolved relatively narrow peak in the energy region between Q and B bands (λex = 870–1100 nm). In metallophthalocyanines (MPcs) this lowest g-g transition is followed by the onset of other higher-frequency 2PA transitions. In some metal-free phthalocyanines (H2Pcs) we also reveal a second, broader 2PA transition at slightly higher frequency. In both MPcs and H2Pcs, we find a strong monotonic increase of integrated strength of the lowest g-g transition as a function of electron-accepting

ability of peripheral substituents, expressed as their aggregated Hammett constant. By using few essential states models (three states for MPcs and four states for H2Pcs) we demonstrate the primary role of excited-state transition dipole moment in this effect

4. M. Drobizhev, **Y. Stepanenko**, A. Rebane, C. J. Wilson, T. E. O. Screen, and H. L. Anderson, "Strong Cooperative Enhancement of Two-Photon Absorption in Double-Strand Conjugated Porphyrin Ladder Arrays," Journal of the American Chemical Society 128, 12432-12433 (2006).

> We present the two-photon absorption (2PA) spectra of a series of conjugated porphyrin oligomers containing N = 2, 4, 8, and ca. 13 monomer units, meso–meso connected with butadiyne linkers. We demonstrate that, in the coplanar double-strand arrays, self-assembled upon addition of 4,4'-bipyridyl, the conjugation length increases dramatically, leading to very strong cooperative enhancement of 2PA. We analyze the scaling of 2PA in both the double-strand and rotationally free single-strand arrays and show how the effective conjugation length in both cases is linked to the observed 2PA properties. By introducing a "conjugation signature" for the 2PA strength, we show that, in double-strand arrangement, the conjugation embraces the whole molecule up to the tetramer level, whereas in single-strand arrangement, it is always less than N, except for N = 2, but keeps increasing until N = 8. Our finding of extremely strong 2PA cross section, $\sigma_2 \approx 10^5$ GM, in double-strand oligomers peaking at 1.3 μm can find use for signal processing in fiber-optic devices.

5. M. Drobizhev, F. Meng, A. Rebane, **Y. Stepanenko**, E. Nickel, and C. W. Spangler, "Strong Two-Photon Absorption in New Asymmetrically Substituted Porphyrins: Interference between Charge-Transfer and Intermediate-Resonance Pathways," J. Phys. Chem. B 110, 9802-9814 (2006).

> We study two-photon absorption (2PA) in two series of new free-base porphyrins with 4-(diphenylamino)stilbene or 4,4'-bis-(diphenylamino)stilbene (BDPAS) attached via π-conjugating linkers at the porphyrin meso-position. We show that this new substitution modality increases the 2PA cross section in the Soret band region (excitation wavelength 750–900 nm) of the core porphyrin by nearly 2 orders of magnitude, from $\sigma_2 \approx 10$ GM for the meso-phenyl-substituted analogue to $\sigma_2 \approx 10^3$ GM for the ethynyl-linked BDPAS–porphyrin dyad. The 2PA properties are quantitatively described by considering two different and interfering 2PA quantum transition pathways. The first path involves virtual transition via intermediate one-photon resonance. The second path bypasses the intermediate resonance and occurs due to a large permanent dipole moment difference between the ground and the final electronic states. To our best knowledge, this is the first experimental observation of the combined effect of these two pathways on one particular two-photon transition, resulting in quantum-interference-modulated 2PA strength.

Another topic that I was involved to during my visits in prof. A. Rebane's group were studying of the quantum interference between one-photon and three-photon absorption pathways in an organic solid at room temperature. By illuminating a thin polimer foil with high three-photon absorption cross section chromophore we were able to observe a spatial interference pattern visible by the naked eye. Multiphoton absorption is usually very weak, therefore in order to observe quantum interference very sensitive and complicated methods of detection were used. Furthermore, the remarkably small

probability of absorbing of three photons at the same time demanded extremely high intensity excitation lasers in previous experiments. In order to increase the signal in our experiment we applied a new type of dendrimeric organic molecules which have the extraordinary high three-photon absorption cross section. One has to notice that in these molecules the maximum of one-photon transition overlaps with the maximum of three-photon transition indicating that the transition occurs between the same initial and final electronic states.

Abstracts of the quantum interference dedicated works are presented below.

1. A. Rebane, N. Christensson, M. Drobizhev, **Y. Stepanenko**, and C. Spangler, "Quantum interference in organic solid," Optics Express 13, 6033–6038 (2005).

> We demonstrate high contrast quantum interference between one-photon and three-photon absorption pathways in an organic solid at room temperature. Illumination of a thin polymer film activated with fluorescing dendrimer chromophores of large three photon absorption cross section with two simultaneous femtosecond pulses at near-IR frequency ω and its third harmonic UV frequency 3ω results in a spatial interference fringe pattern observable by eye.

2. A. Rebane, N. Christensson, M. Drobizhev, **Y. Stepanenko**, and C. W. Spangler, "Quantum interference between multi photon absorption pathways in organic solid," Journal of Luminescence 127, 28–33 (2007).

> We demonstrate spatial interference fringe pattern by simultaneous one- and three-photon absorption of UV and near-IR femtosecond pulses in thin film organic solid at room temperature. We use organic dendrimers that are specially designed to have strong fluorescence and very large three-photon absorption cross-section. High fringe visibility allows the quantum interference to be observed by eye.

I also applied considerable effort in developing new methods in the field of ultrafast spectroscopy. In collaboration with my colleagues from Warsaw University we have developed a method of recording of time resolved fluorescence spectra in the visible range. In order to increase the sensitivity and the time resolution of our method, we implemented a three-wave mixing process in a nonlinear crystal.

P. Fita, Y. Stepanenko, and C. Radzewicz, "Femtosecond transient fluorescence spectrometer based on parametric amplification," Appl. Phys. Lett. 86, 021909 (2005).

> We report an experimental proof-of-principle of a method for recording femtosecond, time-resolved fluorescence spectra in the visible range. The method is based on a noncollinear parametric amplification in a beta barium borate crystal and provides time resolution of the order of 100 fs. We demonstrate that with this method, transient fluorescence spectra as wide as 6000 cm^{-1} can be recorded in a single time-delay scan. Fluorescence decay dynamics and transient spectra of Coumarin 6 dye dissolved in aniline were measured to test the usefulness of the method.

In 2007 I established cooperation with Nevada Terawatt Facility (NTF), which is a part of University of Nevada Reno (USA), and specializes in high energy density physics reaserch as well as the studies of the behavior of matter at extremely high temperature and densities – under conditions similar to those taking place within stars or nuclear fusion reactors.

Single topic publication series representing the author's significant contribution to the development of a specific scientific discipline.

As my main scientific achievement I can indicate the development of the method of multipass parametric amplification of ultrashort pulses. In 2005 in collaboration with prof. Czesław Radzewicz from Warsaw University, we developed an effective method of laser pulses amplification to terawatt levels using parametric process and commercial pump lasers. In the same year we published our first manuscript on this topic.

Parametric amplification of light is a fast growing area in the field of ultrashort laser pulses production. These pulses are actively used in control and diagnostics of photo chemical reactions, a quantum control, frequency combs, materials microprocessing, multiphoton microscopy, a coherent deep UV production, laser particles accelerators and optical tomography. Optical parametric processes are well known and have been actively studied since the first high power lasers. When a nonlinear component of a dielectric polarization of a medium appears, enforced by the applied electric field, three-wave mixing processes occur in certain nonlinear crystals (such as KDP, BBO, BiBO, $LiNbO_3$). Parametric amplification process is one of the several possible three-wave mixing processes which involve two incident waves: the first high frequency wave, called the pump, and the other- a lower frequency one. During a nonlinear interaction in a nonlinear medium, the third signal wave is amplified, depleting the pump wave.

The first attempt on generation of ultraintense femtosecond pulses using an optical parametric amplifier was reported by the Lithuanian scientific group headed by A Dubietis Dubietisem (A. Dubeitis, G. Jonasauskas, A. Piskarskas, Opt. Commun. **88**, 437 (1992)).

In the first theoretical manuscript from this field of knowledge, which appeared 5 years later, I. N. Ross and his coworkers show that this technique is ideal for producing extremely high peak power laser pulses ($\geq$ 10 PW = 10^{16} W) and extremely high intensities. ($> 10^{23}$ W/cm^2) (I. N. Ross, P. Matousek, M. Towrie, A. J. Langley, J. L. Collier, Opt. Commun. **144**, 125 (1997)). In the same manuscript authors introduce the term OPCPA (Optical Parametric Chirped Pulse Amplifier) for the first time.

The CPA (Chirped Pulse Amplification) technique relays on the process of amplification of the weak laser pulse stretched in the time domain and its following recompression in the inverse dispersion setup. Time stretching of the pulse before its amplification is aiming to lower the high peak power, which could lead to a catastrophic damage of the amplifier.

In my first publication from the cycle, which was created in the Insititute of Physical Chemistry in collaboration with prof C. Radzewicz we proposed, and then successfully demonstrated, a new approach to the OPCPA methods, taking advantage of relatively cheap second harmonic radiation from a commercial nanosecond Nd:YAG laser as a source of pump pulses.

Y. Stepanenko and C. Radzewicz, "High-gain multipass noncollinear optical parametric chirped pulse amplifier," Appl. Phys. Lett. 86, 211120 (2005).

> We demonstrate a multipass noncollinear optical parametric chirped pulse amplifier seeded by pulses from a femtosecond Ti: sapphire oscillator and pumped by a commercial Q-switched, frequency doubled Nd: yttrium–aluminum–garnet laser. Amplification higher than 10^6 and pulse energy exceeding 1.7 mJ are achieved with four passes through a single b-barium borate crystal. Good beam quality and high gain, together with broad amplification bandwidth, make it an attractive alternative to Ti: sapphire chirped pulse amplifier systems..

In order to effectively amplify a stretched pulse (1 ns) by a relatively long (8 ns) pump pulse we used a novel multipass amplifier design. In the presented solution as well as in the methods used in ordinary laser amplifiers, the amplified pulse makes several passes through a nonlinear crystal. Each time the pulse exploits the gain produced by the subsequent parts of the long pumping pulse. Taking advantage of a parametric process in our case enforces the energy and momentum conservation relations for the pump and seed photons. Therefore, the angle between the pump beam and the amplified beam together with the angle between the pump and the optical axis of the nonlinear crystal stays the same in each pass through the nonlinear crystal. Consequently, each following beam of a seed laser must be located on the phase matching cone around the optical axis of the crystal. One must also bear in mind that a parametric process is instantaneous, thus in contrary to a laser crystal, a nonlinear crystal could not act as a storage medium, hence that space-time overlap between the pump and amplified pulses is playing a very important role. The requirement of the overlap place limits on the roundtrip time of the amplified pulse inside the amplifier cavity to the length of the pump pulse (8 ns).

We have shown that femtosecond pulses directly from the titanium-sapphire oscillator can be amplified in a single-stage amplifier with a BBO crystal by a factor of more than 10^7, while maintaining a wide bandwidth and high energy efficiency.

In the next work of the series we were able to demonstrate the possibility of a successful recompression of a pulse amplified in a multipass parametric amplifier. The temporal FWHM of 30 fs achieved for 4.5

mJ pulse is close to the Fourier-transform limit level of 29 fs. The total amplification gain of 1.8×10^7 is reached. We have also established the limits of the output pulse energy imposed by the amplification of the spontaneous parametric fluorescence.

Y. Stepanenko and C. Radzewicz, "Multipass non-collinear optical parametric amplifier for femtosecond pulses," Opt. Express 14, 779-785 (2006)

> We demonstrate a successful recompression of 4.5 mJ, 30 fs femtosecond pulses from a Ti:Sapphire oscillator amplified in a ring multipass optical parametric chirped pulse amplifier using β-barium borate crystal pumped by a commercial frequency doubled Nd:YAG laser. Pulses with duration close to the Fourier transform limit were obtained.pulse amplifier systems.

In order to increase the peak power of our amplifier, we were looking for new methods. The solution proposed by the Japanese theoretical group seemed to be ideal for this purpose (T. Harimoto, and K. Yamakawa, "Numerical analysis of optical parametric chirped pulse amplification with time delay," Opt. Express 11(8), 939–943 (2003)). In the next work of the series of manuscripts, we presented, for the first time, a demonstration of experimental possibility of two-stage parametric amplifier design with a time-shearing power booster stage.

P. Wnuk, Y. Stepanenko, and C. Radzewicz, "Multi-terawatt chirped pulse optical parametric amplifier with a time-shear power amplification stage," Optics Express 17, 15264–15273 (2009)

> We report on a compact and simple, broadband optical parametric chirped pulse amplifier system that amplifies femtosecond pulses directly from a titanium sapphire oscillator up to 2 TW power. Our system relies on a new technique - time shear - that improves the time overlap between the seed and pump pulses and, thus, improves the efficiency of the power amplification stage pumped with a ns laser. Parametric amplification was achieved in two stages: a multipass, noncollinear geometry preamplifier with a single β-barium borate crystal, and a power booster stage incorporating three β-barium borate crystals in the new time-shear design. Both stages were pumped with pulses from a commercial 10 Hz frequency doubled ns Nd:YAG laser. The system delivers 49 mJ pulses with a temporal width of 23 fs and its overall conversion efficiency after pulse compression of 10%.

We took advantage of a Nd:YAG laser with the pulse of a Gaussian temporal profile. We were able to reach 10% efficiency of the system with 2 TW peak power of amplified pulses. It is worth noticing, that our results have been commented by other scientific groups working on the same topics. The descriptions of our solutions have already been found in the textbooks of physics, lasers and laser spectroscopy (F. Träger, „Springer handbook of lasers and optics", 2007, Springer; W. Demtröder, „Laser Spectroscopy: Vol. 2: Experimental Techniques". Forth edition, 2008, Springer.

The next work is devoted to the methods of obtaining femtosecond pulses in the ultraviolet, which are essential eg in the ultrafast molecular spectroscopy.

P. Wnuk, Y. Stepanenko, and C. Radzewicz, "High gain broadband amplification of ultraviolet pulses in optical parametric chirped pulse amplifier," Opt. Express 18, 7911-7916 (2010)

> We report on a high gain amplification of broadband ultraviolet femtosecond pulses in an optical parametric chirped pulse amplifier. Broadband ultraviolet seed pulses were obtained by an achromatic frequency doubling of the output from a femtosecond Ti:Sapphire oscillator. Stretched seed pulses were amplified in a multipass parametric amplifier with a single BBO crystal pumped by a ns frequency quadrupled Nd:YAG laser. A noncollinear configuration was used for a broadband amplification. The total (after compression) amplification of $2.5 \cdot 10^5$ was achieved, with compressed pulse energy of 30 μJ and pulse duration of 24 fs. We found that the measured gain was limited by thermal effects induced by the absorption of the pump laser by color centers created in the BBO crystal.

Generating pulses in the UV is associated with several problems, such as low efficiency and a limited spectral bandwidth. Therefore, we used our method of a multipass parametric amplification of ultrashort pulses in the UV region where many important chemical and biological substances have their absorption bands. It becomes evident that using currently available nonlinear crystals and noncollinear geometry it is possible to amplify broadband pulses in the spectral region of 320-450 nm.

In the presented work we conduct research of the broadband noncollinear optical parametric chirped pulse amplifier (NOPCPA) with a BBO crystal working in the spectral region of 350-420 nm. As in the case of IR NOPCPA we took advantage of a commercially available Nd:YAG laser. We used the fourth harmonic of this laser (2660 nm, 8 ns) to pump the multipass amplifier. As a seed source we employed the second harmonic of the broadband titanium-sapphire oscillator.

Despite our best efforts the efficiency of all our parametric amplifiers were limited to the level comparable to this achievable in systems where titanium-sapphire crystal was used as an amplification medium. Maximum efficiency of energy transfer from the pump to a seed beam was on the level of 15%. The main reason of this was a low time overlap integral between two pulses possessing the Gaussian time profile. The methods of improvement of the spatiotemporal overlap are required to increase the efficiency of the amplifier. In the last manuscript in a series devoted to the parametric amplifier I analyzed the efficiency and stability of the multipass amplifier pumped by the square temporal profile laser pulse.

Y. Stepanenko, "On the efficiency of a multiterawatt optical parametric amplifier: numerical model and optimization," J. Opt. Soc. Am. B 28, 2337-2346 (2011))

> Numerical simulations and analysis of a very efficient and stable noncollinear optical parametric chirped pulse amplification (OPCPA) femtosecond system are presented. The system is optimized for a long (nanosecond), rectangular temporal profile and a flat-top spatial profile of the pump laser pulse. We show that a two-stage system consisting of a multipass preamplifier and a time-sheared power amplifier operating around 850nm and pumped by a 532nm pulse can achieve quantum efficiencies as high as 0.9. We also discuss practical schemes of the few-cycle

multiterawatt OPCPA systems employing different nonlinear crystals. The results of the Monte Carlo simulations are used to balance the stability and efficiency of the parametric amplifier system.

In this publication I developed and described a mathematical model of a multipass, multistage broadband parametric amplifier with high efficiency. The model allows reproducing the behavior of the amplified pulse in a real parametric amplifier consisting of a multipass preamplifier stage and a power buster stage. It also allows recovering of the spectral and spatial characteristics of the amplified pulse in real time. I also conducted an analysis of the sources of instability of the output pulse energy in such an amplification chain, and proposed practical schemes with efficiencies up to 50%-60% corresponding to the quantum efficiency of 75%-90%. I also presented some estimates and methods to improve the pulse contrast to the level of the amplified parametric fluorescence.

At present time I am a principal investigator of the development grant of the National Center for Research and Development for 2011-2013. The main goal of the grant is to build a highly efficient ultrashort pulse laser amplifier based on the innovative methods developed by me and my colleagues.

Warsaw, 08/12/2011

Y. Stepanenko