# Annual Report

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| **Funding Programme:** | **Helmholtz Joint Research Groups** |
| **Project ID No.:** | HRJRG-400 |
| **Project Title:** | Application of 3D ellipsoidal cathode laser pulses for high brightness photo injector optimization |
| **Principal Investigator:** | Dr. Mikhail Krasilnikov (Helmholtz PI)<br>Prof. Efim Khazanov (Russian PI) |
| **Report Period (=Calendar Year):** | 01/2014-12/2014 |

## 1) Group Structure

*Please report briefly on the structure and personnel development of your group.*

Helmholtz Association group (Germany):

DESY, Zeuthen site:

- Dr. Mikhail Krasilnikov (PI), general coordination, beam dynamics simulations, PITZ run coordination;
- Dr. Frank Stephan (senior scientist), head of the accelerator activity in Zeuthen and PITZ group leader, general coordination, scientific supervision;
- Dr. Martin Khojoyan (postdoc at PITZ, DESY), beam dynamics simulations for various shapes of the photocathode laser pulse, optimization of the PITZ setup for the new laser shape, tolerances studies;
- Dr. Tino Rublack (postdoc at PITZ, DESY), photocathode laser expert, responsible for the PITZ laser room reconstruction, responsible for the new laser system tuning from DESY side;
- Dr. Matthias Gross, photocathode laser expert; simultaneous operation of two photocathode laser systems at PITZ;
- Prach Boonpornprasert (PhD student at PITZ, DESY), Investigations on the capabilities of THz production at the PITZ facility. Start-to-end beam dynamics simulations for various shapes of the cathode laser pulse;
- Another PhD student (funded by the project) was still not employed in 2014, (the selection procedure was finished, the candidate started on 01.03.2015)

Russian participants:

IAP, Nizhny Novgorod:

- Prof. Efim Khazanov (PI), general coordination, scientific supervision;
- Dr. Anatoly Poteomkin (senior researcher), scientific supervision, laser amplifiers, beam transport lines, nonlinear optics, general scheme of  the laser;
- Dr. Sergey Mironov (scientific researcher), general coordination, numerical simulations of the laser pulse properties, harmonics (SH and UV)  generation, harmonics (SH and UV) generation, modelling of cross-correlator operation;
- Ekaterina Gacheva (PhD student), Multipass broadband Yb:KGW amplifier, delivery system of the diode pump, laser system assembling and adjustment, system of beam diagnostic;
- Victor Zelenogorsky (scientific researcher), laser pulse shaper, automation of the pulse shaping algorithm, cross-correlator for 3D shape diagnostics, spatio-temporal measurements;
- Dr. Maryana Kuzmina (scientific researcher), laser pulse shaper.

JINR, Dubna:

- Dr. Evgeny Syresin (group leader), beam dynamics, formation of high power electron beam in FELs, diagnostic of electron bunches in FEL;
- Dr. Sergej Kostromin (scientific researcher), developing of accelerator technique;
- Roman Makarov (engineer), development of diagnostic technique for FEL;
- Dmitry Petrov (engineer), development of undulator system applied for longitudinal shape of ellipsoidal electron bunches.

**2) Network/ Meetings**

*Please describe how the group works together. Have there been any international meetings organized by or attended by the group? What is the contribution of the group to the networking of international partners and the Helmholtz Centre?*

2nd ARD ST3 workshop, HZDR, Dresden-Rossendorf, 26-27.02.2014, Talk of M. Krasilnikov "Advanced photo cathode laser pulse shaping for ultimate XFEL photo injector performance" (Activities at PITZ in the frame of ARD-ST3 "ps – fs Electron and Photon Beams")

HRJRG Workshop, March 3, 2014, Moscow. Talk of M. Krasilnikov "Development of a photo cathode laser system for quasi ellipsoidal bunches at a high brightness photo injector"

PITZ collaboration meeting, DESY, Zeuthen, 27-28.05.2014,
Talk of T. Rublack "Installation of 3D ellipsoidal laser system"
Talk of P. Boonpornprasert "Beam Dynamics Simulations for Undulator Radiation of IR/THz Source Project at PITZ"

IPAC 2014, June 18, 2014, Dresden, Poster of T. Rublack "Development of a Quasi 3-D Ellipsoidal Photo Cathode Laser System for PITZ"

IPAC 2014, June 18, 2014, Dresden, Poster of M. Khojoyan "Studies on the application of the 3d ellipsoidal cathode laser pulses at PITZ"

Laser Optics 2014 (16th International Conference on Laser Optics), St. Petersburg, Russia, 30.06-04.06.2014, Invited talk of S. Mironov "Laser system for generation 3D ellipsoidal UV pulses"

4th German-Russian Young Researchers Forum, St. Petersburg, Russia, July 9, 2014, Talk of T. Rublack "Development of a quasi 3D ellipsoidal laser system at IAP RAS for the high brightness photo injector at PITZ"

FEL 2014, August 28, 2014, Basel, Poster of T. Rublack "Design of a spatio-temporal 3-D ellipsoidal photocathode laser system for the high brightness photoinjector PITZ"

FEL 2014, August 28, 2014, Basel, Poster of M. Khojoyan "Optimization of the PITZ Photo Injector Towards the Best Achievable Beam Quality"

PITZ collaboration meeting, DESY, Zeuthen, 2-3.12.2014,
Talk of S. Mironov "Laser system for generation 3D ellipsoidal UV pulses"
Talk of M. Khojoyan "3D ellipsoidal laser pulses: summary of electron beam studies"
Talk of P. Boonpornprasert "Start-to-End Simulation of THz FEL with Actual PITZ Beamline"

**Collaboration meetings between IAP RAS and PITZ experts at IAP RAS:**

02.06. – 06.06.2014 T. Rublack, DESY (PITZ), Zeuthen, Germany,
A. Andrianov, E. Gacheva, E. Khazanov, S. Mironov, A. Poteomkin, V. V. Zelenogorskii, IAP/RAS, Nizhny Novgorod, Russia

04.08. – 09.08.2014 T. Rublack, J. Good, DESY (PITZ), Zeuthen, Germany,
A. Andrianov, E. Gacheva, E. Khazanov, S. Mironov, A. Poteomkin, V. V. Zelenogorskii, IAP/RAS, Nizhny Novgorod, Russia

**Installation work at PITZ done by IAP RAS and PITZ experts:**

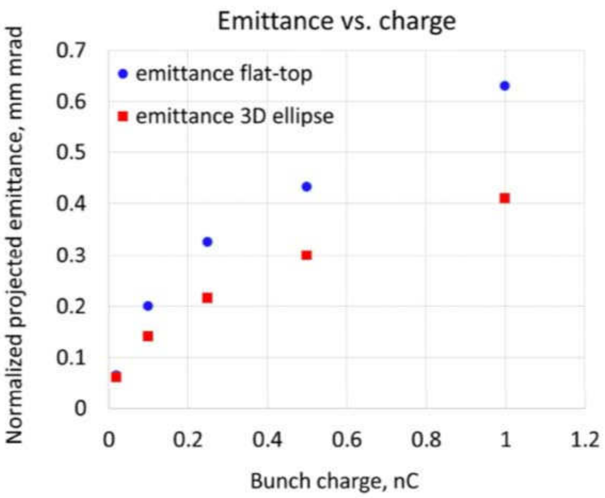
06.10. – 07.12.2014 T. Rublack, M. Gross, J. Good, DESY (PITZ), Zeuthen, Germany,
A. Andrianov, E. Gacheva, E. Khazanov, S. Mironov, V. V. Zelenogorskii, IAP/RAS, Nizhny Novgorod, Russia

## 3) Scientific Progress / Milestones

*How has your work plan progressed? What important milestones could be achieved during the report period? Is the progress of your work in accordance with original planning or has the work plan been changed?*

**Helmholtz Association – DESY, Zeuthen site:**

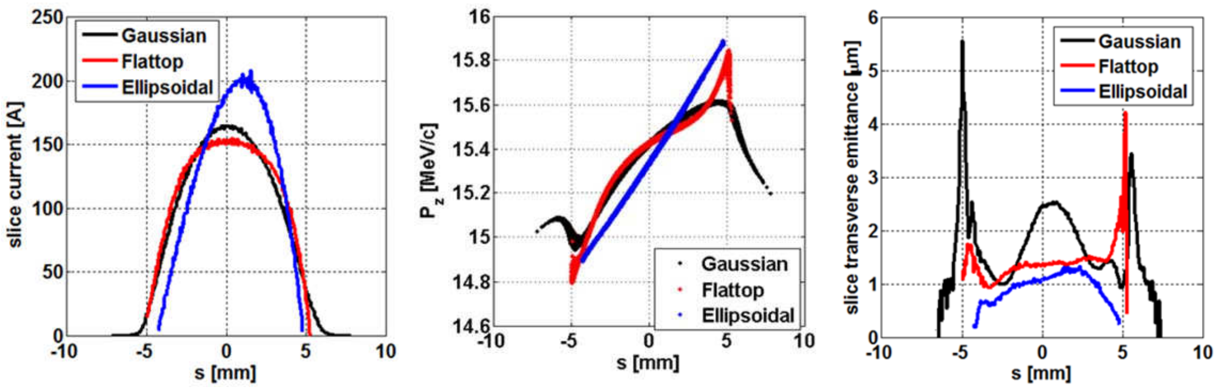
Beam dynamics simulations (WP3) were performed for the PITZ setup applying various shapes of photocathode laser pulses. The detailed studies of the 3D ellipsoidal laser pulse case have revealed a necessity of CDS booster position optimization. It resulted in a new booster position which is ~40 cm upstream of the beamline (towards the rf gun). Besides the projected emittance reduction the obtained optimum setup has less sensitivity to the machine parameter variations and thus is expected to be more stable in operation. According to these results the corresponding hardware beamline modifications have been done at PITZ. The beam dynamics simulations were performed for the updated setup as well as for the flattop temporal profile of the photocathode laser pulse (currently the nominal shape at PITZ). These simulations have been done for a wide range of bunch charge: from 20 pC to 1 nC. The results are shown in the plot below:



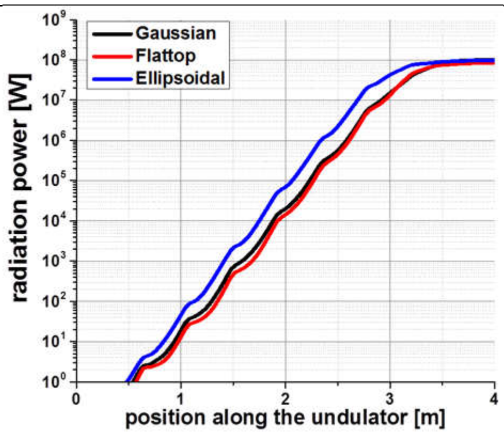
Results of the beam dynamics simulations including optimization of the booster position and tolerance studies were summarized in the report (milestone H-MS1) M. Khojoyan, M. Krasilnikov, F. Stephan "3D ellipsoidal beams for ultimate performance at the high brightness photo injector PITZ" and reported at several conferences [5, 7].
Based on the results of these simulations corresponding modifications in the PITZ linac (namely, the CDS booster shift by 40 cm upstream) have been realized. In terms of the PITZ run schedule it meant a big shutdown of about 10 weeks with significant reconstruction work. As a result of the work, which was not originally planned, a delay in the PITZ measurement program including the realization of this project was caused.

Studies of the possibility to produce high power IR/THz radiation (wavelength range 5 – 100 μm) were continued. Since the time structure of electron bunches at PITZ is identical to those at the European XFEL, the PITZ accelerator is being considered as a proper machine for the prototype development of a THz source for pump and probe experiment of the European XFEL. The start-to-end simulations (S2E) of Self-Amplified Spontaneous Emission Free-Electron Laser (SASE FEL) radiation were performed assuming an APPLE-II type undulator installed at the end of the PITZ beamline. One of the major highlights in that work which is part of a PhD thesis is the usage of electron bunches produced by 3D ellipsoidal photocathode laser pulses to generate the synchrotron radiation. From the remarkable properties of such electron bunches, improvement of the radiation properties can be expected, especially for the SASE FEL case.

A bunch charge of 4nC was applied for the simulations in order to produce a high peak current of the electron beam. The plots below show the sliced profiles of the optimized beams.
The profiles of the ellipsoidal bunches show higher peak current and lower slice transverse emittance as well as more linear longitudinal phase space. Beam current profile (left), longitudinal phase space (middle) and the slice emittance (right) are shown for various shapes of the photocathode laser pulses.




Beam dynamics S2E simulations for the IR/THz SASE FEL based on the PITZ injector have been performed [8]. Power growth curves of the FEL radiation from the optimized beams are shown in the plot below.

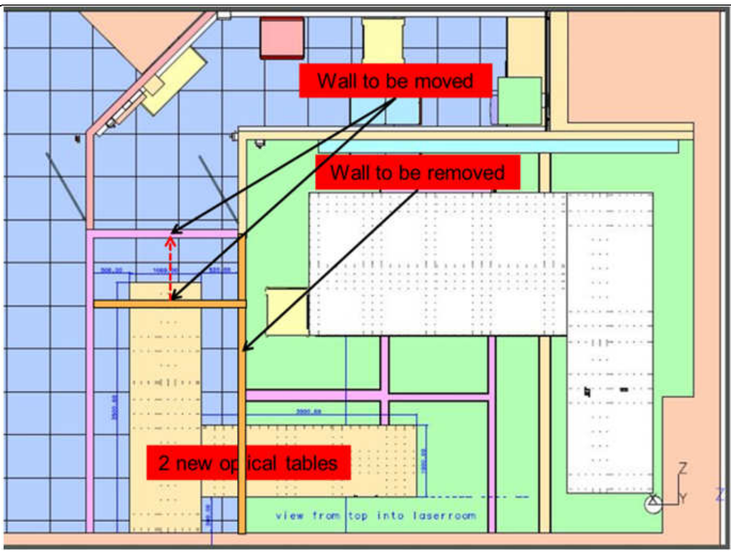



From this plot higher gain of the FEL is expected for the 3D ellipsoidal pulses. It should be mentioned that all these results were obtained for a case without bunch compressor. The implementation of a bunch compressor has to be considered as well in order to increase the bunch peak current and intensify the SASE FEL radiation. The longitudinal phase space of quasi-ellipsoidal bunches is expected to be more proper for these purposes.

Another aspect of the possible IR/THz source at PITZ is its usage as an electron beam diagnostic tool (WP5). Theoretical and simulation work on this subject is ongoing in close collaboration with DESY, Hamburg and JINR colleagues (see below in JINR-subsection).

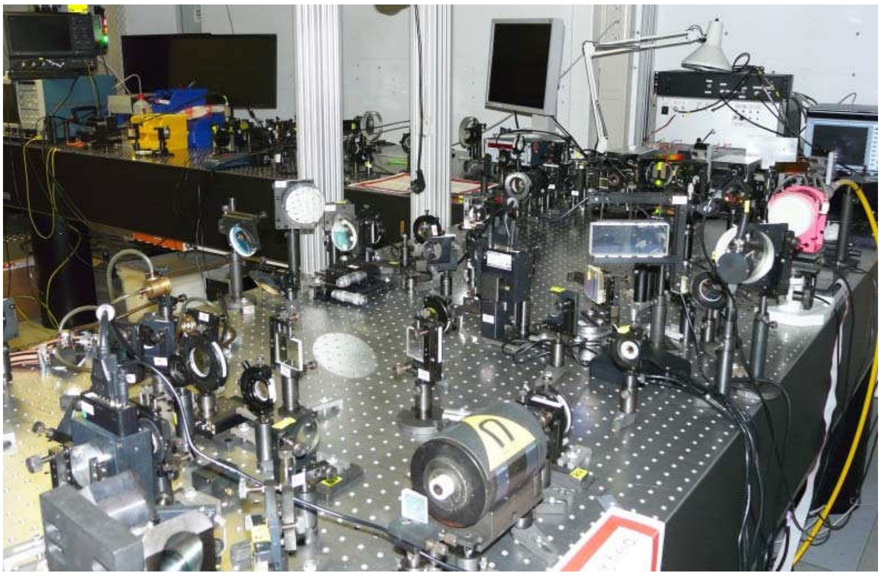
Experimental photo emission studies at PITZ have revealed a discrepancy between the measured extracted charge and the one expected from beam dynamics simulations (ASTRA) for the same RF gun and laser parameters. This discrepancy has been found for the nominal (cylindrical) shape of the cathode laser pulse with various temporal profiles (from Gaussian to flattop). Dedicated experimental and theoretical investigations are ongoing at PITZ. Detailed understanding of the photoemission of space charge dominated beams in presence of high RF field at the cathode is of great importance also for the production of 3D shaped electron bunches (milestone H-MS2). These investigations are planned to be extended for the new laser system.

One of the main issues to fulfill the WP6 tasks – parallel operation of two photo cathode laser systems – was the redesigning of the laser hut. Thereby, it was necessary to maintain attention to the “old” laser system as the operation of this system had to be ensured also for the future to allow one to one comparisons of the electron beam performance for both laser pulse shapes (flattop and 3D ellipsoidal). Therefore, an extension of the laser hut was the only option. To achieve that goal the wall between the laser hut and the former “Streak-camera room” had been removed. In addition a second wall between the “Streak-camera room” and the anteroom of the laser hut was relocated. An engineering drawing of the reconstructed laser hut can be seen in the scheme below.




In the drawing also the positions of the new laser tables are shown. The installation of the laser tables had been done synchronized to the reconstruction work of the laser hut.
Due to the new design of the laser hut and the elimination of the “Streak-camera room” a new design for the existing Streak-camera system had to be found and implemented into the new surroundings. This work is almost done, only small adjustments are planned for 2015.

In October the installation of the new laser system capable of producing quasi 3D ellipsoidal laser pulses has started. The installation was done in close cooperation between the IAP RAS and PITZ experts. In December the first UV laser pulses could be produced. The characterization of the (non-shaped) laser pulses showed similar behavior as seen before the dismounting of the laser system at IAP RAS. The following photo shows the installed laser system at PITZ.

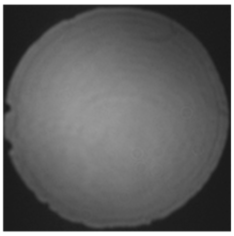


An important point is the integration of the new laser system into the same laser transport beamline to the photocathode as the “old” (MBI) laser system uses. Therefore, a concept was developed that allows to couple in and out the beam of the new laser system into the existing beam line using a hydraulic displaceable mirror.

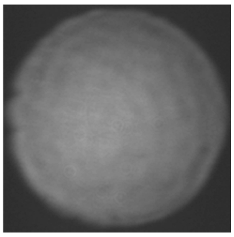
**IAP:**

Before the photocathode laser system in September 2014 was delivered to DESY, Zeuthen site, the final tuning and characterization of the system were performed at IAP.
The laser system has to generate 3D-ellipsoidal micropulses at the wavelength of 255-260 nm with an energy of 10-15 µJ (which should be sufficient to produce 1 nC electron bunches), rms duration of ~7 ps and repetition rate of 1 MHz. The pulse shaper based on spatial light modulators (SLMs) is capable of introducing spatial-time correlations into the laser micropulses enabling the 3D shape of the laser pulses. The identical micropulses will be grouped into macropulses with a duration of 300 µs and at a repetition rate of up to 10 Hz.

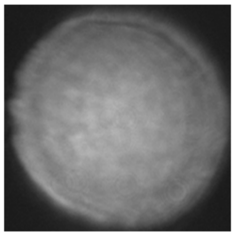
Experimental studies conducted at IAP in 2014 resulted in a pulse energy of up to 70 uJ for the 28 ps IR micropulse. Diffraction distortion effects in the amplifier optical scheme have to be considered seriously. The figure below shows the transverse distribution of laser radiation in imaging planes: before the amplifier (left); after a single full pass of the amplifier (middle) and after two full passes of the amplifier (right). These images were obtained with switched off diode pump.



At the input



After the 1st pass of the Amplifier (~16 m propagation)

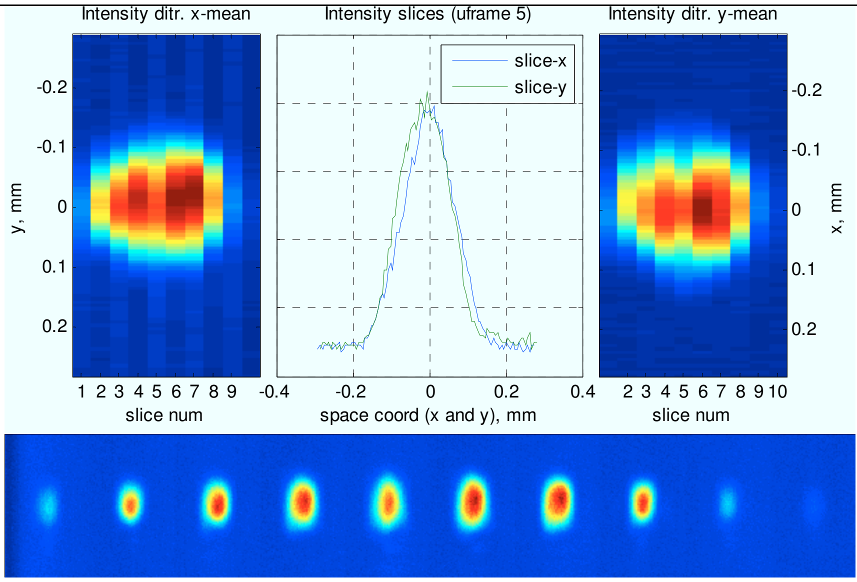


After the 2nd pass of the amplifier ( ~32 m propagation)

Optimization of the multi-pass amplifier is based on the concept to profile a train of micropulses (macropulse). A rectangular pulse train can be achieved by adjusting the time delay of the diode pump (LDM 2000).

The optimization of the second and fourth harmonics generation (WP1) yields efficiencies of 50% and 20%, correspondingly. An LBO crystal of 4 mm thickness has been used for the second harmonics generation. The fourth harmonics generation was realized using a 4 mm BBO crystal. The concept of angular chirped laser pulses was applied to the optimization of the nonlinear conversion processes. Numerical simulations demonstrated that the angular chirp allows an increase of the frequency conversion efficiency. At the same time this technique preserves a quasi-ellipsoidal shape of the micropulse. Experimental investigations resulted in an energy of the UV micropulse of up to 5 uJ. Detailed numerical studies show the possibility of further improvement of the fourth harmonics generation. Corresponding experimental studies are ongoing and planned to be held in 2015. It should be figured out, that for more realistic modeling of the fourth harmonics generation thermal effects and formation of color centers have to be taken into account.

One important part of the laser system is the diagnostics of the 3D shape of the micropulse. A scanning cross-correlator was developed and put into operation in order to measure the spatial-temporal distribution of the generated laser pulses before second and fourth harmonics generation [1]. A fast CCD camera detects up to 10 slices – transverse cuts within a micropulse, by making use of the 300 us pulse train. Corresponding results are shown in the figure below where 10 cuts within one micropulse are shown together with reconstructed side views of the quasi-ellipsoidal laser pulse.



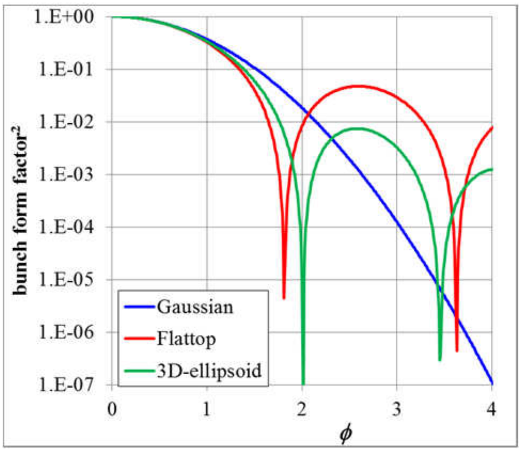

Within WP4 a transport laser beam line from the laser table to the photocathode was calculated. The optical system images the BBO crystal (used for the fourth harmonics generation) onto the plane of the beam shaping aperture (BSA) in the PITZ tunnel – used for the nominal photocathode laser system at PITZ. This allows common usage of the further telescope system for both lasers by imaging the BSA plane onto the photocathode surface. Optimum parameters of optical elements – mirrors and lenses (aperture, material, radius of curvature, anti-reflection coating, etc.) - have been defined. This should provide optimum transport of quasi-ellipsoidal pulses to the photocathode and be compatible with the corresponding PITZ infrastructure.

**JINR:**

The JINR develops a project of a superconducting linear accelerator complex for applications in nanoindustry, mainly for extreme ultraviolet lithography using a kW-scale Free Electron Laser (FEL) light source. The superconducting linear accelerator with electron energy of 0.7 GeV will produce coherent FEL radiation for extreme ultraviolet nanolithography at a wavelength of 13.5 nm and an average radiation power of 0.7 kW. The peak radiation power corresponds to 34 GW, the macropulse radiation energy is equal to 68 J, the micropulse radiation energy is 8.5 mJ. The accelerator complex involves a dedicated channel for extreme ultraviolet lithography with a few nanoscanners operating simultaneously in a processing line with 22 nm, 16 nm and beyond using FEL radiation at a wavelength 13.5 nm.
The project is based on the technology realized on FEL FLASH facility at DESY. FLASH has produced several GW powers for EUV radiation with a wavelength of 13.5 nm, a target goal for the next generation lithography. The present analysis shows that this technology holds great potential for increasing the average power of a linear accelerator and the efficiency of conversion of electron kinetic energy into light.
JINR creates a test bench for a high power laser driver applied for a high average power FEL radiation mode. The JINR-IAP collaboration constructed a powerful laser driver applied at the photo injector of the FEL linear accelerator which can be used for EUV lithography. To provide FEL kW-scale EUV radiation the photo injector laser driver should provide a high macropulse repetition rate of 10 Hz, a long macropulse time duration of 0.8 ms and 8000 pulses per macropulse. The laser driver operates at a wavelength of 260-266 nm, the forth harmonic in the mode locking on base of Nd-ions or Yb-ions. The laser driver micropulse energy of 1.6 uJ should provide the formation of electron beams in the FEL photo injector with bunch charges of about 1 nC. High average power FEL simulations and tests applied for extreme nanolithography are being performed within WP7. Main results of these studies (milestone R-

MS4) are summarized in [9].

JINR proposes a THz wiggler for measuring the longitudinal structure of 3D ellipsoidal electron bunches. Simulations of the ellipsoidal bunch form-factor and the magnetic structure of the THz wiggler were done. The bunch form factor (squared) for the three electron bunch shapes mentioned before is shown in the figure below as a function of the normalized frequency $\phi=\omega\sigma_z/c$ (where $\sigma_z$ is the rms bunch length, $c$ is the speed of light).




The results of these studies (milestone R-MS5) have been reported at the IPAC2014 conference [3] and are published [10].

In general the progress of the work is in accordance with our original planning, there is a good chance to achieve the project goals. Due to some technical reasons (e.g. reconstruction works in the PITZ linac) it is necessary to extend the project period until end of 2016.

**4) Financial Plan / Time Schedule**
*Can you comply with the financial plan and time schedule or do you see a need for adjustment?*

The installation of the new photocathode laser system at the Photo Injector Test facility at DESY in Zeuthen (PITZ) was mainly completed in December 2014. There are still missing works on the laser beam transport to the photocathode and on the synchronization with RF phase of the accelerator. These works have to be coordinated with the experimental program at PITZ, which is currently strongly involved in the preparation of the European XFEL (EXFEL) photo injector including urgent tests and runs for conditioning and characterization of the main and spare RF guns for the EXFEL. Due to this factor and due to some technical problems (e.g., broken crystals had to be replaced) there is a general delay of about 5-6 months with one of the important milestones – photoelectron production using the new cathode laser system.

The experience gained from the installation and first tests of the new laser system at PITZ shows that there are several critical issues which are planned to be fixed within this project. It was found that a new laser pulse train oscillator has the possibility to improve the laser pulse performance significantly. A modification of this part (or design/ordering of a new laser pulse train oscillator) is rather expensive (estimated 150 kEuro), its re-design and optimization will take definite time. The pulse shaping technique based on SLMs needs more detailed studies with probable modification afterwards as well. All these considerations make it necessary to shift the investment costs to 2016 in order to accumulate the needed amount of money. Also the experience which will be gained in 2015 will help to optimized the design and therefore to reach best performance of the laser system within the given resources. Additionally, market research will need a couple of month.

We ask to move the consumables (~35 kEuro, the rest of 2014) to 2016, whereas keeping the 2015 planned consumables (which are planned for the laser transport beamline, improvement of installation and ordering of spare parts) as it is foreseen originally. In order to test and characterize the new components (purchased until the end of 2016) another half of the year is required. Based on these considerations a prolongation of the project until middle of 2017 is necessary whereas the overall sum remains as it was originally planned.

One of two PhD student positions funded in frames of the project was offered to Prach Boonpornprasert and he has started this job in middle of 2014. Another position was still opened in 2014, but the selection procedure is finished, the candidate (James Good) started on 01.03.2015. It is necessary to modify the spending plan to adjust with the time line of these two PhD positions (P. Boonpornprasert until 31.05.2017, J. Good until 30.06.2017).

## 5) Publications of the Group

[1] V.V. Zelenogorskii, A.V. Andrianov, E.I. Gacheva, G.V. Gelikonov, M. Krasilnikov, M.A. Mart'yanov, S.Yu. Mironov, A.K. Potemkin, E.M. Syresin, F. Stephan, E.A. Khazanov, “Scanning cross-correlator for monitoring uniform 3D ellipsoidal laser beams”, Quantum Electronics 44 (1) 76 – 82 (2014) LASER APPLICATIONS AND OTHER TOPICS OF QUANTUM ELECTRONICS

[2] M. Krasilnikov, M. Khojoyan, T. Rublack, F. Stephan, A. Andrianov, E. Gacheva, E. Khazanov, S. Mironov, A. Poteomkin, V. Zelenogorsky, E. Syresin, “Development of a photo cathode laser system for quasi ellipsoidal bunches at a high brightness photo injector”, HGF Brochure "Structure of matter".

[3] E. Syresin, S. Kostromin, N. Morozov, R. Makarov, D. Petrov, Joint Institute for Nuclear Research, Dubna, Russia, M. Krasilnikov, DESY, Zeuthen, Germany, “Possibility of application of THz wiggler in low energy FEL for measurements of electron bunch longitudinal structure”,Proceedings of the fifth International Particle Accelerator Conference, Dresden, Germany, 2014, WEPRO093

[4] T. Rublack, M. Khojoyan, M. Krasilnikov, F. Stephan, DESY Zeuthen, Zeuthen, Germany I. Hartl, S. Schreiber, DESY Hamburg, Hamburg, Germany, A. Andrianov, E. Gacheva, E. Khazanov, S. Mironov, A. Poteomkin, V. V. Zelenogorskii, IAP/RAS, Nizhny Novgorod, Russia E. Syresin, JINR, Dubna, Moscow Region, Russia, “Development of a quasi 3-d ellipsoidal photo cathode laser system for PITZ”, Proceedings of the fifth International Particle Accelerator Conference, Dresden, Germany, 2014, TUPME074

[5] M. Khojoyan, M. Krasilnikov, F. Stephan, DESY, Zeuthen, Germany, “Studies on the application of the 3d ellipsoidal cathode laser pulses at PITZ”, Proceedings of the fifth International Particle Accelerator Conference, Dresden, Germany, 2014, TUPME074

[6] T. Rublack, J. Good, M. Khojoyan, M. Krasilnikov, F. Stephan, DESY, Zeuthen, Germany I. Hartl, S. Schreiber, DESY, Hamburg, Germany, A. Andrianov, E. Gacheva, E. Khazanov, S. Mironov, A. Poteomkin, V. V. Zelenogorskii, IAP/RAS, Nizhny Novgorod, Russia, E. Syresin, JINR, Dubna, Russia, “Design of a spatio-temporal 3-d ellipsoidal photocathode laser system for the high brightness photoinjector PITZ”, Proceedings of the 36th International Free Electron Laser Conference, Basel, Switzerland, 2014, THP060.

[7] M. Khojoyan, M. Krasilnikov, F. Stephan, G. Vashchenko, DESY Zeuthen, Zeuthen, Germany, “Optimization of the PITZ photo injector towards the best achievable beam quality”,

Proceedings of the 36th International Free Electron Laser Conference, Basel, Switzerland, 2014, THP006.

[8] P. Boonpornprasert, M. Khojoyan, M. Krasilnikov, F. Stephan, DESY, Zeuthen, Germany, B. Marchetti, E. Schneidmiller, M. Yurkov, DESY, Hamburg, Germany, S. Rimjaem, Chiang Mai University, Chiang Mai, Thailand, “Start-to-end simulations for IR/THz undulator radiation at PITZ”, Proceedings of the 36th International Free Electron Laser Conference, Basel, Switzerland, 2014, MOP055.

[9] N.Balalykin, M.Nozdrin, G.Shirkov, E.Syresin, G.Trubnikov, E.Gacheva, E.Khazanov, G.Luchinin, S.Mironov, A.Potemkin, V.Zelenogorsky, JINR powerful laser driver applied for FEL photo injector, IPAC14, Dresden, Germany,2014, THPRO022, p.2906.

[10] E. Syresin, S. Kostromin, M. Krasilnikov, R. Makarov, N. Morozov, D. Petrov, THz Wiggler Applied for Measurements of Electron Bunch Longitudinal Structure in FEL, Physics of Particles and Nuclei Letters, 2015, Vol. 12, No. 1, pp. 118–121.

[11] S. Mironov, E. Gacheva, A. Andrianov, V. Zelenogorsky, E. Khazanov, A. Poteomkin, M. Krasilnikov, F. Stephan, and M. Martyanov, "Laser System for Generation 3D Ellipsoidal UV Pulses," in Advanced Photonics, OSA Technical Digest (online) (Optical Society of America, 2014), paper JM5A.30.

## 6) External Funding

The development of the photocathode laser system was initialized within the BMBF project (05K10CHE) “Developing a laser system for experimentally investigating the possibility to achieve quasi 3D ellipsoidal laser pulses” in the framework of the German-Russian collaboration "Development and Use of Accelerator-Based Photon Sources". After the system has been assembled and tested at IAP it was delivered to DESY, Zeuthen site, and installed in the PITZ laser room. The costs of the laser room reconstruction were covered from the BMBF project and from the PITZ internal funding.
IAP (Russia) and PITZ (DESY) are providing laser and accelerator infrastructures for the advanced laser system developments and tests including manpower for installation works.
The participants form the Helmholtz Association side - PITZ staff (M. Krasilnikov, T. Rublack, M. Khojoyan, F. Stephan and M. Gross) contribute part of their working time to the project.
For the beam dynamics and IR/THz radiation simulations the computing capacities of DESY (funded by the internal PITZ sources) were used.
IAP is actively using the existing infrastructure and available manpower for the project developments.
The works at JINR on a test bench for high power laser driver applied for an FEL high average power radiation mode are funded from internal sources of the institute.

## 7) Patent Applications

*No. of pending/granted patents*

none

## 8) Awards received by Group Members

S. Mironov, Stipendium of President of Russian Federation for young Russian scientists (SP-1566.2012.2)

E. Gacheva, PhD stipendium of regional Ministry of Education (academician G. A. Razuvaev’s stipendium 2013-2014)