



FP7-REGPOT-CT-2011-285912 - project FOTONIKA-LV

The FOTONIKA-LV conference

“Achievements and Future prospects”

(The FP7-REGPOT-2011-1, Nr. 285912 project FOTONIKA-LV “Unlocking and Boosting Research Potential for Photonics in Latvia – Towards Effective Integration in the European Research Area”)

Riga, 23-24 April, 2015

Venue: Latvian Academy of Sciences

Dedicated to the 5th Anniversary of Association FOTONIKA-LV

BOOK OF ABSTRACTS



**INTERNATIONAL
YEAR OF LIGHT
2015**

**Supported by FP7 project
Unlocking and Boosting Research Potential for Photonics in Latvia –
Towards Effective Integration in the European Research Area (FOTONIKA-LV)
FP7-REGPOT-CT-2011-285912**

Conference section Chairs:

Dr. Arnolds Ubelis

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Dr. Mats Nordlund

Vidvuds Beldavs

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PROGRAMME

April 23

10.00–10.15	Welcome. Welcome words from invited honoured guests – Members of Saeima (Atis Lejins, Veiko Spolitis, Ivars Zarins); Minister for Economics Dana Reizniece-Ozola, Chair of SSC of the project and the Chair of Latvian Council of Science Andrejs Silins, Vice President of the Latvian Academy of Sciences Juris Ekmanis, Vice-rector for Research of the University Indrikis Muiznieks
10.15–11.30	Key note lectures session, Chair Dr.Phys. Arnolds Ubelis Advances in quantum sciences and space sciences
10.15–10.50	Advances in Quantum Sciences. Invited keynote speaker: Dr. Arthur Matveev, Max Planck Institute for Quantum Optics, Munich, Germany
10.50–11.25	Advances in Space sciences. Invited keynote speaker: Dr. Andris Vaivads, Swedish Institute of Space Physics, Sweden
11.30–12.00	COFFEE BREAK
12.00–14.00	1st Plenary, Chair: Prof. Andrejs Silins Photonics – Key enabling technology in the EU Photonics related science and technology domains in Latvia
12.00–12.30	Carlos Lee. Photonics – Key Enabling Technology for Europe
12.30–13.00	Arnolds Ubelis. Summary of Outcomes of the Project: FP7-REGPOT-2011-1. FOTONIKA-LV, Nr. 285912, Unlocking and Boosting Research Potential for Photonics in Latvia – Towards Effective Integration in the European Research Area
13.00–13.30	Arnolds Ubelis, <u>Janis Alnis</u> , Ilgmars Eglitis, Gunars Silabriedis. Photonics, Quantum Sciences, Space Sciences and Related Technologies in Latvia – Contribution of FOTONIKA-LV Project and the Capacity of Research Structures in the Domain in Latvia
13.30–14.00	<u>Vidvuds Beldavs</u> , Aigars Atvars. Photonics, Quantum Sciences, Space Sciences and Related Technologies in Latvia – Capacity of Research Driven SMEs – Contribution of FOTONIKA-LV Project to Applied Research Activities
14.00–15.00	LUNCH BREAK
15.00–16.00	2nd Plenary, Chair: Dr. Mats Nordlund Photonics – EU key enabling technology in Estonia and Lithuania
15.00–15.40	Arnolds Ubelis, Aigars Atvars Insight in Photonics, Quantum Sciences, Space Sciences and Related Technologies in Estonia and Lithuania: Contribution from Academy and Industry
15.40–16.00	Discussion: How to intensify collaboration inside Baltics photonics community and how to extend cooperation across Baltic sea region and across EU borders.
16.00–17.15	TRAVEL TO BALDONE ASTROPHYSICAL OBSERVATORY
17.15–19.00	Poster session on the Project outcomes, Chair: Dr.Phys. Janis Alnis (in Baldone Astrophysical Observatory)
19.00–22.00	SOCIAL EVENT
22.00–23.00	RETURN TO RĪGA

April 24

10.00–11.45	3rd Plenary, Chair: Vidvuds Beldavs Photonics and space sciences – advancements in Latvia – contribution of FOTONIKA-LV project
10.00–10.15	Ilgmars Eglitis. Baldone Astrophysical Observatory: Upgrade, Progress and Results in Observation and Research
10.15–10.30	Kalvis Salmīns, Jorge del Pino, The Capacity Of Upgraded SLR LS-105 System Station (ILRS Code Name 1884 Riga). Results Of Observation and Research
10.30–10.45	<u>Maris Abele</u> , <u>Elina Rutkovska</u> , Janis Vjaters, Andris Treijs. Design of Multipurpose Instrument for Ranging of Satellites and Space Debris and for Remote Sensing in Atmosphere
10.45–11.00	Janis Balodis, Ansis Zarins, Augusts Rubans, Diana Haritonova, Janis Kaminskis. Digital Zenith Camera – a new Astrometric Instrument for Precision Measurements in Geodesy
11.00–11.15	Gunars Silabriedis, Janis Balodis. Geodesy and Geoinformatics in Latvia
11.15–11.30	Vladislavs Bezrukovs. Radio Astronomy in Latvia
11.30–11.45	Ilgonis Vilks. Decades Long Science Communication at Institute of Astronomy based on High Level Science
11.45–12.15	COFFEE BREAK
12.15–14.15	4th Plenary, Chair: Dr.Phys Aigars Atvars Advances in photonics and quantum sciences – contribution of REGPOT FOTONIKA-LV project
12.15–12.30	N.Porfido, S.Birindelli, F.Tantussi, F.Fuso, Nikolay Bezuglov, Martins Bruvelis, and <u>Aigars Ekers</u> . Nonlinear Effects in Optical Pumping upon Resonant Excitation of Ultra-slow Beam of Cold Cs Atoms
12.30–12.45	<u>Teodora Kirova</u> , Arturs Cinins, Martins Bruvelis, D. K. Efimov, Kaspars Miculis, Nikolay Bezuglov, Aigars Ekers, Marcis Auzins and I. I. Ryabtsev. Consequences of Multiple Dressed States Formation in Atomic Nondegenerate Hyperfine Levels
12.45–13.00	U. Berzinsh, J. Blahins, A. Apsitis, J. Klavins, A. Rieba, D. Hanstorp, O. Windelius, J. Å. Wieman, A. K. Saxena. A Status Report of GRIBA (Gothenburg Riga Ion Beam Apparatus)
13.00–13.15	Roman Viter, Arnolds Ubelis. Development and Application of Photonic Materials for Optical Sensors/Biosensors
13.15–13.30	Janis Alnis, Ilja Fescenko. Quantum Optics Laboratory
13.30–13.45	Janis Blahins, Aigars Apsitis, Viesturs Silamikelis, Arnolds Ubelis. Contribution of the Project to the Development of Assets for Applied Research to Ensure Collaboration with Research Driven SMEs within the Photonics Domain
13.45–14.00	<u>Janis Alnis</u> , Arnolds Ubelis, Ilja Fescenko, Janis Blahins, Aigars Apsitis, Viesturs Silamikelis. Advances in quantum sciences – source for the initiatives in sophisticated applications
14.00–14.15	Karlis Gross. Multidisciplinary collaboration in biomaterial research
14.15–15.00	LUNCH BREAK
15.00–17.00	Concluding session with roundtable, Chair: Vidvuds Beldavs

15.00–15.20	Arnolds Ubelis. Readiness and capacity of FOTONIKA-LV in the implementation of HORIZON 2020 mission and participation in relevant calls for proposals
15.20–15.40	Mats Nordlund. How to extend cooperation across EU borders Director, Innovation Advisory Partners, http://www.innovationadvisorypartners.com/ Dr. Nordlund has a unique background from executive positions in > academia and industry in Europe, USA, and Russia. He spent 15 years in industry, first as Director of Corporate Technology Strategy and Acquisition at Saab AB, a major aerospace company, and later as Director of Research and Development for Emerson Process Management – Level and Marine. In his academic career, Dr. Nordlund recently served three years as Vice President of Research Programs at Skoltech, a new university being established in Moscow in partnership with MIT. In the 1990s, he launched and managed the System Design and Management (SDM) program at MIT. Dr. Nordlund has also served on several national and international (EU) panels in innovation and research, including > the High Level Expert Group that in 2005 laid the ground for the ERC.
15.40–17.00	Round table discussion
18.00–19.00	RECEPTIONS

<i>Conference Local Organising Committee</i>	<i>Scientific Program Committee</i>
Dr. Arnolds Ubelis – Chair	Prof. Andrejs Silins – Chair
Dina Berzina – Head of the Conference Secretariat	Dr. Maris Abele
Darta Ubele – assistant	Dr. Janis Alnis
Sandra Smalina	Prof. Andris Ambainis
Aigars Apsitis	Prof. Dainis Dravins
Dr. Aigars Atvars	Dr. Aigars Ekers
Vidvuds Beldavs	Dr. Ludwig Grunwaldt
Dr. Ilgmars Eglitis	Prof. Dag Hanstorp
Kalvis Salmins	Dr. Sune Svanberg
Dr. Gunars Silabriedis	Dr. Arnolds Ubelis
Edgars Smalins	Dr. Janis Balodis
Dr. Ilja Fescenko	

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FOREWORD

This booklet of the FOTONIKA-LV conference “Achievements and Future prospects” (The FP7-REGPOT-2011-1, Nr. 285912 project FOTONIKA-LV “*Unlocking and Boosting Research Potential for Photonics in Latvia – Towards Effective Integration in the European Research Area*”) has a mission to highlight the scientific achievements of the Association FOTONIKA-LV in the implementation of REGPOT project which was supported by the financial instrument of the Seventh Framework programme: FP7-REGPOT-(2007-2013)-1 Unlocking and developing the research potential of research entities in the EU’s convergence regions and outermost regions. REGPOT was a **key instrument of FP7 to allow excellent research institutes in convergence regions all over the EU to become an active member of the European Research Area**. All six REGPOT calls were extremely competitive (FP7-REGPOT-2007-1_2008-1_2009-1_2010-1_2011-1_2012/2013-1) with success rates 9,62%, 7,32%, 5,26%, 5,26%, 6,87%, 10,9% accordingly to annual calls. Our FOTONIKA-LV project FP7-REGPOT-2011-1, Nr. 285912 was ranked the second with score 15 from 15 in the FP7-REGPOT-2011-1 call where in total 291 project proposals were submitted and only 20 were financed.

In total for all FP7- REGPOT-(2007-2013) calls hundreds of excellent research structures from 25 countries submitted 1885 project proposals and 23 countries succeeded with at least one financed project. Only 149 were financed and resulting success rate was 7,9%. Besides, 48 project proposals were put on reserve list and in total 690 project proposals were marked above quality threshold.

The research community of Latvia was very active in this top level competition to achieve recognition, label of excellence and programme funding. In the first call (FP7-REGPOT-2007-1) project proposals from the Latvian State Institute of Wood Chemistry and the Research Institute of Biotechnology and Veterinary Medicine “Sigra” of the Latvian University of Agriculture received about 1 M€ financing and were recognized for excellence. The project proposal submitted by Daugavpils University in the second call (FP7-REGPOT-2008-1) received high scoring, was put on the reserve list, but failed to be financed. The next success for Latvia came in 2011, when the project proposal submitted by the Association FOTONIKA-LV at the University of Latvia get 15 points from 15 and was financed with a grant of 3.75 M€. In the last REGPOT (FP7-REGPOT-2012_2013-1) call Latvia won two financed projects one from the Latvian Institute of Organic Synthesis (4.7 M€) and the second from the A. Kirchenstein Institute of Microbiology and Virology, of Riga Stradins University (2.05 M€). The project proposed by the Institute of Physics at the University of Latvia also received high marking and was on the reserve list, but failed to be financed. Statistics of the participation of the research community of Latvia in REGPOT competition is provided in Table 1. In total Latvia succeeded with 5 highest grade excellence labels for its research institutes bringing a total of about 12.75 M€ investments in research to Latvia from the FP7 Budget. Approximately 4 M€ of this funding will land in the state budget of Latvia through taxes.

Table 2 provides information for 16 more successful countries in REPPOT competition where Latvia is ranked in 11 place in terms of absolute numbers. One need to keep in mind, that Latvia with about 3600 researchers according to EUROSTAT has a much smaller research community than other countries listed in table 2. That is an impressive result of the highly motivated research and innovation community in Latvia despite its “*hostile to science*” environment – the words said by former President of Latvian Academy of Science Academician Janis Stradins and present President Academician Ojars Sparitis. The same

conclusion was identified by TECHNOPSIS group in their evaluation report of Latvian research and innovation policy in 2014¹, from page 37:

The difficult financial climate, short-term planning within the state, insufficient administrative capacity and the low political priority of innovation and research and a heavily bureaucratic tradition all make it hard to implement research and innovation policy in Latvia.

From page 38 of the same report explains why the success of excellent national research structures has been neglected by the state and by university decision makers and administration²:

... But the most powerful reason behind these issues of implementation seems to be a lack of political commitment to the idea that research and innovation are important drivers of development and growth....

Unfortunately the reaction of policy makers and state administration to the success of the research structures having European Research Area scale label of excellence was **counterproductive**. Instead on providing national level support to the five REGPOT winners the policy seemed to be to exploit the EU financing as much as possible for the state budget. The first blow was incorrect VAT taxation applied to project purchases, which is illegitimate according to the Commission rules. That was the major reason why the first REGPOT project winner from Latvia "SIGRA" having no state budget funding to cover the disallowed VAT taxation went bankrupt after the end of the project. Success and EU level recognition of the institute was ignored and one excellent institute in the nationally and internationally vital topic was terminated. The same blow come to the next winner – the Latvian State Institute of Wood chemistry but luckily the Institute survived. In addition to VAT issues miserable institutional funding from the state budget is a problem for years in Latvia being in absolute numbers below 10 M€ for the whole research community annually in the country.

The success of the Association FOTONIKA-LV at the University of Latvia was also neglected. Three institutes of the University joined together voluntarily in 2010 – five years before the Ministry of Education and Science issued (2015) top down consolidation orders. TECHNOPSIS experts highlighted the Association as a good example. Having a REGPOT project and other FP7 projects the Association contributed about 1.00 M€ to the state budget during the last 3 years but the level of institutional funding coming from the state budget is far below 0.1 M€ annually -- this for a team of about 100 highly qualified researchers plus 30-40 students annually. As a result many researchers receive miserable salaries and frequently face the threat of unemployment. Unfortunately, there are no signs of change in Latvia RTD policy, stagnation will continue and FOTONIKA-LV will in the future face a desperate struggle for survival!

This booklet and the conference reports will clearly demonstrate that the researchers of Association FOTONIKA-LV used the REGPOT project resources **with maximum persistency and a lot of voluntary and unpaid inputs** to get maximum scientific outcomes published in peer review journals and presented in prestigious international conferences; to restore capacity to be in service and keep duties for several international scientific networks (*like International Laser Service Network led by NASA*), and has impressive number of competitive project proposals to HORIZON 2020 calls and various other financing sources, but as the TECHNOPSIS report warns³: ...

¹ Latvia. Innovation System Review and Research Assessment Exercise: Final Report, TECHNOPSIS, April 20, 2014

² Ibid, pg. 38

³ Ibid, pg. 22

Low relative levels of institutional funding are normally argued to undermine continuity, the ability to invest in facilities and equipment and therefore ultimately quality. **A degree of institutional funding stability is also a requirement in order to establish good links with industry.** Without this, it is hard to be a credible research partner for the longer term”.

The implementation of the project resulted in the transformation of the Association FOTONIKA-LV into the “*de facto*” National Science Centre FOTONIKA-LV in the domain of photonics, quantum sciences, space sciences and related technologies with clear visibility, partnerships and competitiveness in the European Research Area.

The implementation of the project resulted in the transformation of the Association FOTONIKA-LV into the National Science Centre “*de facto*” in the domain of photonics, quantum sciences, space sciences and related technologies with clear visibility, partnerships and competitiveness in ERA.

The Association FOTONIKA-LV has marshaled a bottom-up proposal calling to select “Photonics, Quantum Sciences, Space sciences and Related Technologies” as domain for smart specialization in Latvia and on the Pan Baltic level. The task is to overcome conservative thinking of the administration of the University of Latvia to formalize NSC FOTONIKA-LV “*de jure*” as an international recognized center of research excellence. The challenge is to provoke transformational change in national research and innovation strategy towards knowledge based economy with high added value production as main source for the welfare in the country.

Table 1. Participation of Latvia in FP7-REGPOT-(2007-2013)-1 calls

	<i>REGPOT call, deadline Nr and short names of financed projects</i>	<i>Project proposals on reserve list</i>	<i>Number of project proposals above quality threshold (except financed and reserve list)</i>	<i>Project proposals below quality threshold</i>	<i>Total number of eligible proposals</i>
1	Call identifier: FP7-REGPOT-2007-1 Deadline: 24/04/2007 1. 203459 / WOOD-NET, 2. 205079 / BALTFoodQUAL	0	1	3	6
2	Call identifier: FP7-REGPOT-2008-1 Deadline: 14/03/2008	1	1	2	4
3	Call identifier: FP7-REGPOT-2009-1 Deadline: 13/02/2009	0	2	1	3
4	Call identifier: FP7-REGPOT-20010-1 Deadline: 17/12/2009	0	1	2	3
5	Call identifier: FP7-REGPOT-2011-1 Deadline: 07/12/2011 1. 285912 / FOTONIKA- LV	0	3	1	5
6	Call identifier: FP7-REGPOT-2012-1 Deadline: 1. 316149 / InnovaBalt 2. 316275 / BALTINFECT	1	3	2	8
Σ	5	2	11	11	29

Table 2. 16 more successful countries in all FP7-REGPOT – 2007-1_2008-1_2009-1_2010-1_2011-1_2012/2013-1 calls

	Country	Number of financed REGPOT projects	Project proposals on reserve list	Number of project proposals above quality threshold (except financed and reserve list)	Project proposals below quality threshold	Total number of eligible proposals
1	Greece	35	10	142	124	311
2	Poland	21	5	90	115	231
3	Chroatia	9	2	44	42	97
4	Bulgaria	8	5	43	60	116
5	Turkey	8	8	118	249	383
6	Estonia	7	2	20	10	39
7	Czech Republic	7	1	20	14	40
8	Spain	7	2	19	34	62
9	Romania	7	1	21	72	101
10	Serbia	7	4	75	57	143
11	Latvia	5	2	11	11	29
12	France	4	0	7	3	14
13	Hungary	4	0	10	9	23
14	Italy	4	1	18	28	51
15	Germany	3	0	7	7	17
16	Lithuania	3	0	9	8	20

Dr. Phys. Arnolds Ubelis
The coordinator of the REGPOT-2011-1, Nr. 285912 project
Scientific Secretary of Association FOTONIKA-LV

Photonics – Key Enabling Technology for Europe

C. Lee

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EPIC, the European Photonics Industry Consortium (www.epic-assoc.com) is the industry association that promotes the sustainable development of organisations working in the field of photonics in Europe. More than 200 members foster a vibrant photonics ecosystem by maintaining a strong network and acting as a catalyst and facilitator for technological and commercial advancement. EPIC is the voice of the industry, creating a range of highly popular seminars and other extremely valuable membership benefits, reaching out to both the industry and policy makers and of course in establishing and growing a real photonics community within Europe. EPIC publishes market and technology reports, organizes technical workshops and B2B roundtables, coordinates EU funding proposals, advocacy and lobbying, education and training activities, standards and roadmaps, pavilions at exhibitions.

The European Commission has recognized photonics as one of the six Key Enabling Technologies (KETs) of Europe. Photonics has a substantial leverage effect on the European economy and workforce: 20-30 % of the economy and 10 % of the workforce depend on photonics. Photonics is a very dynamic and vibrant industrial sector in Europe that holds the potential for huge market growth. The expected compound annual growth rate for photonics over the coming years is 8 %, clearly demonstrating the rapid growth of this key technology sector [1].

It has been extensively documented in various reports that photonics technologies provide competitive advantages to the vital manufacturing industries in Europe. Photonics is everywhere around us: from communications and health, to lighting and photovoltaics and to everyday products like DVD players and mobile phones. Photonics is a rapidly growing sector, with a global market of around € 350 billion, projected to reach over € 600 billion by 2020. Europe has established a strong position with an overall total share of approximately 18 % (€ 66 billion in 2012)[2]. The European photonics industry employs more than 377000 people directly, many of these in the over 5000 photonics SMEs often organized in national and regional innovation clusters which represent a highly educated workforce [3].

References

- [1] Commission Communication “Preparing for our future: Developing a common strategy for key enabling technologies in the EU” COM(2009)512; ‘A European strategy for Key Enabling Technologies – A bridge to growth and jobs’ COM/2012/0341 final
- [2] EPIC/TEMATYS Report “Photonics Ecosystem in Europe”, April 2013
- [3] Towards 2020 – Photonics driving economic growth in Europe , Photonics Multiannual Strategic Roadmap 2014-2020: http://www.photonics21.org/download/Brochures/Photonics_Roadmap_final_lowres.pdf

Summary of Outcomes of the Project: FP7-REGPOT-2011-1. FOTONIKA-LV, Nr. 285912, Unlocking and Boosting Research Potential for Photonics in Latvia – Towards Effective Integration in the European Research Area

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The project aimed at unlocking and boosting Latvian R&D potential for photonics at the University of Latvia (LU) with activities contributing to the realization of the full research potential on the national scale for the enlarged Union and vision of Innovative Union 2020. The direct beneficiary of the project is the Association FOTONIKA-LV formed in April 24, 2010 by a bottom up initiative of three well recognized institutes of the University of Latvia – Institute of Atomic Physics and Spectroscopy – www.asi.lv, Institute of Astronomy – www.astr.lu.lv/, and the Institute of Geodesy and Geoinformatics – www.ggi.lu.lv.

The 10 laboratories, departments and observatories of the member institutes (9 counted when project started and the laboratory of Quantum Optics opened during the implementation of the project) involve more than 100 researchers: including 4 Professors, 45 with PhD degrees, more than 10 skilled technicians, more than 30 PhD candidates and MSc level students. Enhancement of research and outreach activities covered basic and applied sciences of photonics domain: optics, optoelectronics; in atmosphere and space; Earth geodesy; laser ranging and remote sensing; atomic and molecular physics; laser spectroscopy and plasma light sources and bio-photonics. The outcomes of the project implementation resulted in transformation of association FOTONIKA-LV in to the National Research centre FOTONIKA-LV at the University taking national leadership in quantum sciences, spaces sciences and related technologies under the framework of photonics.

The 10 laboratories, departments and observatories of the member institutes (*initially 9 when the project started plus the laboratory of Quantum Optics that was opened during project implementation*) involve more than 100 researchers: including 4 Professors, 45 with PhD degrees, more than 10 skilled technicians, more than 30 PhD candidates and MSc level students. Enhancement of research and outreach activities covered basic and applied sciences of the photonics domain: optics, optoelectronics; atmosphere and space sciences; Earth geodesy; laser ranging and remote sensing; atomic and molecular physics; laser spectroscopy and plasma light sources and bio-photonics. The outcomes of the project implementation resulted in transformation of Association FOTONIKA-LV into the emerging National Science Centre FOTONIKA-LV at the University taking national leadership in quantum sciences, spaces sciences and related technologies under the framework of photonics

Moreover, NSC FOTONIKA-LV “*de facto*” being unique in Latvia and in the three Baltic states is promoting a bottom-up initiative to elevate pan-Baltic regional smart specialization in the domain Photonics, Quantum Sciences, Space Sciences and Related Technologies. All three countries has excellent research outcomes in the domain and a community of more than 60 research driven SMES in the sector with turnover in 2014 close to 150 M € with historical and forecast growth in the range of 15% annually.

Objectives and tasks implemented during the project include the following:

A) Collaboration, sharing of knowledge and skills:

- 10 named in project proposal strategic partnerships with leading research centers in Finland (1), Sweden (3), Germany (4), Spain (1), Lithuania (1) were further activated via exchanges of know-how during more than 50 secondment visits, joint research efforts and participation in consortium's of project proposals for FP7 and HORIZON 2020;
- In addition 21 more partnerships were intensified via secondment financial instruments and successful FP7 IRSES projects with partners in Germany (3), Austria (3), France (2), Sweden (1), Poland (1), Finland (1), Lithuania (1), Russia (4) Ukraine (2), Belarus (1) ; Australia (1), Canada (1);
- Special attention was devoted to collaboration and assistance to the industry in the domain. More than 20 research-driven SMEs are on the list with which FOTONIKA-LV cooperates.

Figure 1 illustrates partnerships intensity for the research community of FOTONIKA-LV

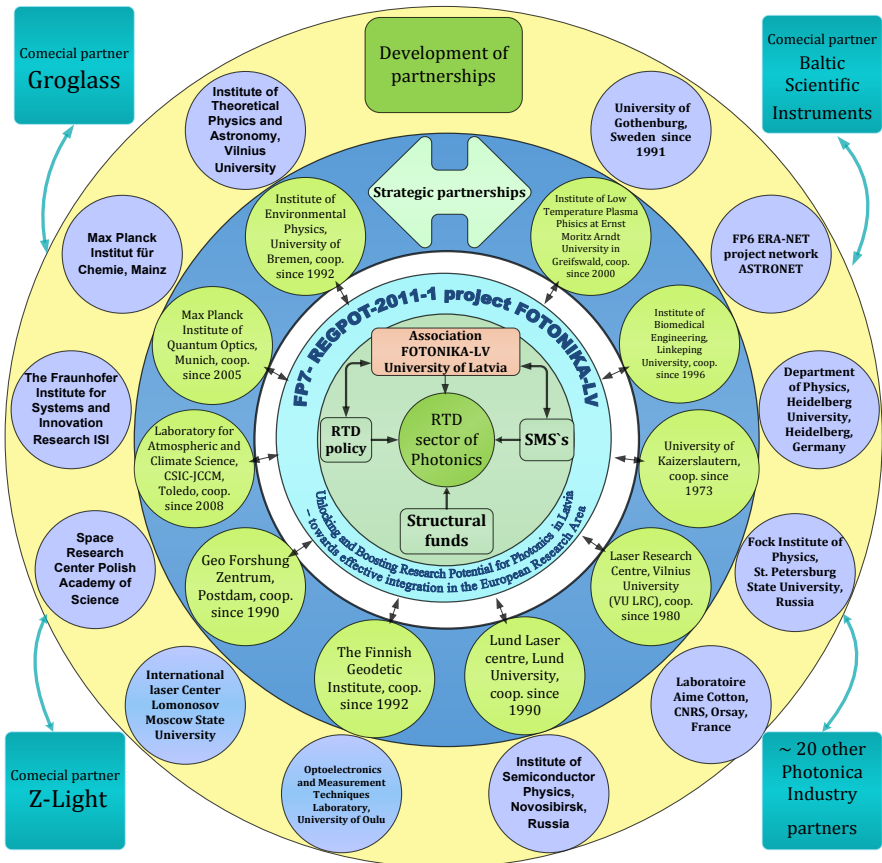


Figure 1. Collaboration Network within FOTONIKA-LV project.

Among many, a particularly noteworthy joint research achievements and synergy outcomes resulting from the “critical mass” achieved by FOTONIKA-LV cross disciplinary teams is the mobile negative ion beam instrument GRIBA that was built via joint efforts of research teams from FOTONIKA-LV and Gothenburg University during secondment visits. It is the first next generation instrument in ion beam technologies in the world (in value more than 500 000 euro). GRIBA is a significant contribution to EU research infrastructure and due to its reduced size and its portability. The instrument could be used in various laboratories where large scale facilities of powerful light and synchrotron radiations sources are present;

B) Publication in peer reviewed journals, conference reports, organization of conferences and workshops and thesis defended:

- The project resulted with 66 publications in peer review journals and more than 20 articles in preparation;
- The project financed participation in 33 conferences but in total research community of FOTONIKA-LV presented research results in close to 100 international conferences with more than 100 oral or poster presentations;
- During the course of the project four large scale conferences, two summers schools and 2 exhibitions for SMEs and one strategy planning foresight workshop were organized. The project supported organization of 2 more conferences;
- 10 PhD theses were defended and several more pending

C) New project design:

- Five project proposals prepared for FP7 calls were retained for financing and in two of them FOTONIKA-LV is a coordinator;
- 16 project proposals (12 in the role of coordinator) prepared for FP7 calls (*but not retained for financing will be further elaborated and resubmitted to HORIZON 2020 calls or elsewhere*);
- Membership in the consortium of 17 project proposals (among 17 proposals coordination of consortium for 4 proposals) raised for HORIZON 2020 calls and one financed (14 not retained will be further elaborated and resubmitted to the next HORIZON 2020 calls or elsewhere. two are pending for evaluation).

The more important HORIZON 2020 project proposals from the total of 17 that have been prepared are:

- Financed project H-2020 INFRAIA-1-2014-2015 (*Advanced Research Networks “EUROPLANET 2020”*);
- Two proposals to H2020-FETOPEN-2014-2015-RIA (*one marked 4.5 from 5, but not financed and another one pending for evaluation*);
- Two proposals to H2020-MSCA-ITN-2014, (*one marked 80 from 100, but not financed and another one pending for evaluation*);
- Submitted project to WIDESPREAD 2014–1 TEAMING call in the role of coordinator, but not financed and will be submitted to the next call;
- Two projects submitted to WIDESPREAD 2014–1 ERA-Chairs, but not financed and will be resubmitted.

In summary these activities resulted in systematization a lot of information for the resubmission or new project design.

Additionally 7 proposals are in preparation for coming H-2020-M-S-C RISE calls with deadline on April 28 and fellowship calls.

The proposal writing team contributed to the corporate mission of the FOTONIKA-LV and substantially assisted five photonics related research-driven SMEs in Latvia to develop 7 project proposals for the HORIZON-2020 – SME Instrument (*about 15% from total number of SME proposals from Latvia*). Three of the proposals received excellent marks (*above 12.4 from 15*), but were not financed, one project proposal was financed and three are pending for evaluation.

7 excellent project proposals were submitted to the Latvian Science Council call with international per review evaluation for basic research activities. The lowest scores were 68 and 71, but the highest ones were 84, 80, 79 and 78 from 90 as maximum. Unfortunately success rate in this national competition was about 7% and proposals from FOTONIKA-LV teams failed to receive financing.

D) Applied research initiatives towards commercialization of outcomes:

- Applied research activities during the implementation of the FOTONIKA-LV project resulted in active contacts with SMEs in Latvia. Besides mentioned project proposals for H-2020 calls there are more than 10 commercially oriented initiatives in various stages of readiness – from prototypes to elaboration stages above 6-8. Unfortunately miserable institutional funding from the national budget does not allow the authors further elaboration towards technology readiness above stages 6-8, to perform feasibility studies and relevant IPR search discouraging the formation of spin-offs.
- This is a problem painful to Latvian science community and was highlighted by the TECHNOPOLIS expert team that was invited to perform an international evaluation of Latvian science where the reviewers highlighted the quality of the association FOTONIKA-LV as well as the quality of three associated institutes:

Latvia. Innovation System Review and Research Assessment Exercise: Final Report, TECHNOPOLIS, April 20, 2014, see page 22:

“Only 17% of research funding is institutional (ERAWATCH Country Report, 2011), making Latvia’s one of the most highly ‘contested’ systems in the world. While there is no clear international benchmark for what the proportion of institutional funding should be, there is some consensus that 50% is the minimal viable level. The Finnish Research and Innovation Council recently observed that the share of competitive funding in the university research system has recently approached that value and that to do any further would be dangerous

*Low relative levels of institutional funding are normally argued to undermine continuity, the ability to invest in facilities and equipment and therefore ultimately quality. **A degree of institutional funding stability is also a requirement in order to establish good links with industry.** Without this, it is hard to be a credible research partner for the longer term”.*

E) International evaluation of the institutes of Association FOTONIKA-LV and its institutes by TECHNOPOLIS expert group – Latvia: Research Assessment Exercise, Report Panel M: Natural Sciences and Mathematics, Technopolis January 2014, See text in page 75:

“In April 2010, three institutions of the University of Latvia (Atomic Physics and Spectroscopy, Astronomy and Geodesy and Geoinformatics) established the association FOTONIKA –LV with the aim to take responsibility for sustainable advancement of the sector of photonics in Latvia. The association submitted an ambitious FP7 project of basic and applied research in traditional and innovative fields of photonics: REGPOT– 2011-1 which was eventually granted €3.8million. Other laboratories should follow this example”.

TECHNOPOLIS experts view on the Institute of Atomic Physics and Spectroscopy, see on page 29-31

Overall Score

Citation: *“The overall score of this laboratory (4) is justified by a very good level of basic and applied research, the initiative to federate three Laboratories in the association FOTONIKA-LV with the goal of a sustainable development of photonics in Latvia and the submission of an ambitious project to the FP7 call of proposals REGPOT and obtaining 3.8million LVL. In addition the institution has good links with the emerging industry, a large development potential and a dynamic management”.*

Quality of research

Citation: *“The basic research is well integrated into various applied research fields of multidisciplinary nature. The research in photonics is highly relevant at national and international level. The importance of the work span from national research areas including the development of devices for pollution control (Hg), and development of optical fibers; regional cooperation in EU funded projects as well as wider international level in areas spanning from theoretical background studies in laser pulse interactions”.*

TECHNOPOLIS experts view on the Institute The Institute of Astronomy, see pages 25-28 in above referred report. Citations:

“The Institute of Astronomy performs research on stars and interstellar medium, microwave sources at Sun and asteroids in the Solar System. It updates and maintains General Catalogue of Galactic Carbon Stars. The Institute runs a satellite laser ranging system (SLR, which has been in substantial part designed on the site) and a permanent GPS station. SLR and GPS stations, working with high accuracy, are involved in international service, define the origin of the Latvian national geodetic coordinate system and tie it to international reference frames. The Institute provides design of small optical systems, and software support and construction of laser ranging equipment for its own use, and also for international collaborators....

.... The Institute shows a good level of scientific research, especially in the field of navigation which is an area important both for Latvia and the international community. It should increase its internal visibility by stronger use of its potential (good infrastructure and skilled scientists) for extending research portfolio to more up-to-date research topics. Current international exchange and activity in attracting national funds are not satisfactory. The REGPOT 'FOTONIKA-LV project and Latvia's accession to the European Space Agency create perspectives for further development of the Institute

... As already mentioned above, a very strong side of the Institute is its experimental base and especially skills in calculation and design of equipment for laser ranging systems, spectrographs and optical components for telescopes. In the past high precision instruments designed and constructed by scientists from the Institute were used for observatories in many countries. These traditional skills have been used recently in construction of scientific equipment for Germany, Japan and Finland.....”

TECHNOPOLIS experts view on the Institute of Geodesy and Geoinformation see citation on page 33:

Citation: *“Both the quantity and the quality of the research, measured in term of the publication output, are insufficient, resulting in limited impact on the scientific discipline. The activities are largely focused on market oriented research projects and short-term contracts”*

Quality of research

Citation: *"The numbers of research staff and funds allocated are insufficient to perform research of interest to the international research community..."*

Impact on the scientific discipline

Citation: *"Although a group is small, it has experience that can be exploited by numerous research groups within the national and international research communities. Complementary knowledge available for earth observation studies as well as environmental studies in general should further be exploited. The involvement of the research group in networks has proven to be effective and useful (for example EUPOS). But because of the meager publication record and obscure publication fora, the Institute has not had any impact on the scientific discipline."*

F) Reversing "brain drain" into the "brain gain":

The project succeeded substantially in reversing "brain drain" into the "brain-gain":

The project succeeded substantially in reversing "brain drain" into a "brain-gain":

- Dr. Hab. Uldis Berzinsch has been repatriated from Sweden to Latvia. He has excellent expertise in basic research and 10 years expertise in research labs in industry. His contribution in the design of mentioned above ion beam instrument GRIBA was substantial and two peer-review publication resulted from his research activities. Unfortunately illness prevented him to be active during the last year of the project;
- Dr. Aigars Ekers repatriated back to Latvia for the second time. He was the first M-C fellow from Latvia and in his first return founded the Laser Center at the University. He was pressed to leave Latvia for the second time during the crises years and was back for year February 1, 2012 to April -2014 and headed the Institute of Atomic Physics and Spectroscopy. Now he is recruited by the Saudi Arabia. He accepted financially very favorable offer facing uncertainty for future and lack of recognition of his contribution to the development of research activities and research infrastructure from the State Authorities, the Ministry of Science and Higher Education and University administration. Facing such attitude his choice is reasonable – having family with four children and wife with Dr degree who was not able to find relevant employment position in Latvia
- Dr. Janis Alnis (*having two M-C fellowship grants*) was repatriated back from the Max Plank Institute of Quantum Optics in Munich where previously he was associated with the team of Nobel prize winner prof. Theodor Hänsch. Dr. Janis Alnis founded the Quantum Optics Laboratory at FOTONIKA-LV;
- High level technician Janis Blahins was repatriated back from Israel and his contribution to applied research initiatives are impressive;
- An additional four experienced researchers were repatriated: D. Phys. Ilja Fescenko, industrial researcher Dr. Phys Mikelis Svilans(P), planetary scientist Dr. Amara Graps and futurist Vidvuds Beldavs who initiated the International Lunar Decade initiative that is picking up increasing international support. 11 foreign researchers were recruited for the work in FOTONIKA-LV labs from Russia (1), Ukraine (2), Cuba(1), Bulgaria (2), South Africa(1), India (1) and Lithuania (3).

G) Development and upgrade of research infrastructure:

- Upgrade and updates of research infrastructure resulted in restoring experimental capacity and related infrastructure resulted in the creation of new experimental apparatus for value of 2-3 M€ and two observatories – (*Astrophysical Observatory in*

- Baldone and Fundamental Geodynamical Observatory of Riga*) in real value more than 10 M€. The two observatories are members of international networks and provide globally relevant services and during the course of the project were upgraded with instrumentation, renovated physically and returned to regular observations and data supply to relevant international networks.
- Large or specifically targeted purchases of up to date equipment, instrumentation and components allowed to keep leadership in four fundamental research domains and to build advanced instrumentation for negative ion and molecular and ionic cluster research (*mentioned above GRIBA*) in:
 - Experimental research of sophisticated phenomena in molecular physics using molecular beam instrumentation;
 - Research in quantum optics domain;
 - UV and vacuum UV, spectroscopy targeting basic research on atomic and molecular physics;
 - Ground segment of space technologies and astrophysical research (Renovated and upgraded SLR station. Prototype for new generation of SLR stations designed. Renovated the Baldone wide field Schmidt system type telescope (*one of 10 largest in Europe, largest in Baltic region*)).
 - Advanced Zenith telescope designed combining resources with structural funds project;
 - In future research on negative ions having astrophysical interest and ionic clusters concerning atmosphere physics problems;
 - In future research on negative ions having astrophysical interest and clusters concerning atmosphere physics problems;
 - Strong efforts were made and relevant resources used to restore previously lost basis for industrial oriented research:
 - Electron-beam and resistive evaporation of dielectric, semiconductor and metal;
 - multilayer achromatic optical coating installation – VU-2M with simultaneous photometric layer testing;
 - High quality small and cost effective clean room is build for sputtering experiments and for other technology needs;
 - Development of inductively coupled plasma technologies for basic and fundamental research;
 - Capacity of optomechanical (*as well as quartz-glass technologies*) workshop restored for the needs of technologically complicated experiments.

H) The Public-access Riga Photonics Centre is opened, has run programs for schools throughout Latvia and is planning a Year of Light event with the City of Riga in September. The Photonics Center provides support to the SME community with exhibitions, conferences, training events, and consultations on HORIZON 2020 calls specifically targeting the Horizon 2020 SME Instrument but also to other Horizon 2020 programs appropriate for research supporting industry.

Photonics, Quantum Sciences, Space Sciences and Related Technologies in Latvia – Contribution of FOTONIKA-LV Project and the Capacity of Research Structures in the Domain in Latvia

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In the introduction would like to write some words about “Photonics and Quantum Optics”: Optics can be divided into three parts: geometrical optics, wave optics and quantum optics. Quantum optics is the most recent part of optics and started in the beginning of 20-th century with discovery of a photon that is a quantum of light. It is necessary to mention wave – particle dualism of a photon: it can be detected as a click on photon counter and it also manifests as a wave in interference situations. Main driving horse of quantum optics are lasers as they allow to control emitted wavelength, have short pulse length, reach high light intensities and directionality. In the 1930-ies Dirac said that it will never be possible to see a single atom. Now it is possible to see a single atom and ion thanks to laser cooling and trapping techniques that presently contribute to the most precise optical clocks in the world that tick with astonishing 18 digits of precision. Picosecond lasers and single photon detection are essentials of satellite laser ranging having long traditions in Latvia.

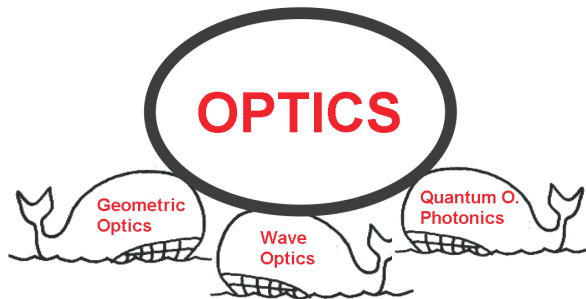


Fig. 1. Artistic view on the foundations of optics.

In Latvia during years 2012-2015 we realized European Regpot project FOTONIKA-LV with a motto “Unlocking and Boosting Research Potential for Photonics in Latvia”. It is in cooperation between University of Latvia divisions:

- Institute of Atomic Physics and Spectroscopy
- Institute of Astronomy
- Institute of Geodesy and Geoinformatics
- Baldone Observatory
- Riga Laser Centre

Photonics, Quantum Sciences, Space Sciences and Related Technologies in Latvia – Capacity of Research Driven SMEs – Contribution of FOTONIKA-LV Project to Applied Research Activities

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National Science center FOTONIKA-LV has been providing cluster support services to SMEs involved in photonics in Latvia from the start of the [FP7-REGPOT-2011-1, project Nr. 285912](#) project whose goal is to unlock and boost Latvia's photonics R&D potential. The project has provided funds for conferences, exhibitions and workshops involving the photonics industry in Latvia, that is essentially for the cluster with more than 30 SMEs and a lot of academic research teams involved. Photonics is a leading one among 6 Key Enabling Technology selected by European Commission to reach 2020 goals and frames sciences and technologies involving control of photons including quantum sciences, space sciences and related technologies. The FOTONIKA-LV research team has developed know-how and capabilities through participation in Framework program projects (FP5, FP6, FP7, and Horizon 2020) making it a valuable partner for research organizations and industry in Latvia and throughout the European Research Area. FOTONIKA-LV is taking actions to strengthen the entire "Photonics, Quantum Sciences, Space Sciences and Related" cluster as a bottom up initiative towards photonics becoming regional smart specialization for Latvia and eventually pan-Baltic via involvement of community of photonics in Estonia and Lithuania.

Latvian science is struggling with the lack of adequate state financing. Consequently, the knowledge and skills to prepare project proposals to Horizon 2020, ESA and other EU wide funding sources is extremely important for researchers and research centres in Latvia as well as for research-driven SMEs that must also compete for grant-based project funding. The largest opportunity for funding scientific excellence is the Framework program Horizon 2020 where active participation is expected. Latvian industry, particularly research-driven SMEs, are challenged by the shortage of high quality scientific personnel capable of developing funding proposals and managing complex industrial research projects.

Scientific education in Latvia is challenged to develop an innovation ecosystem and technical competence in industry that fosters adoption of new technologies, the development of innovative products, and the formation of new business ventures with jobs for new specialists.

A coordinating hub is needed for such an innovation ecosystem to be optimally effective that can orchestrate research, industry, education and civic society to work together for the economic development of the region. The FP7 Regpot project funding enabled FOTONIKA-LV to fulfil such a role during the course of the Project. Now, NSC FOTONIKA-LV is taking actions and contribution to activities to institutionalize its role as the hub of the photonics innovation ecosystem in Latvia. FOTONIKA-LV, has been successful in collaboration with SMEs in preparation of proposals for several Horizon 2020 SME Instrument calls. FOTONIKA has run photonics popularization seminars for school students as well as for the general public at the Riga Photonics Center. Several attempts have been made to expand public outreach activities at the Riga Photonics Center as well as at the Geodynamics Observatory at the Botanical Garden and the Baldone Astrophysics Observatory. Initiatives are also being planned, including the White Night project in

collaboration with the Riga City Council, within the context of the International Year of Light for which FOTONIKA-LV is a national contact point.

We have conducted a study of publically funded research and private industry in Latvia's photonics cluster that consists of research centers and research-driven SMES involved with photonics that frames quantum sciences, space sciences and related technologies.

Study of publically funded and private industry in Latvia's photonics cluster

Results

Latvian science shows the following parameters of publicized scientific papers on section that can be under the umbrella of "Photonics, Quantum Sciences, Space Sciences and Related Technologies". These data are derived from SCOPUS database.

Table 1. Number of Scientific publication from scientific institutions of Latvia.

No.	section	Search keyword in SCOPUS	No of scientific papers in 2004-2014	% of scientific papers of Latvia 2004-2014	No of scientific papers in 2012-2015*	% of scientific papers of Latvia 2012-2015*
1	Photonics	Optic* OR Spectr* OR Photon* OR Laser* OR Light*	2805	35	1339	32
2	Atomic, Molecular physics and quantum sciences	Atom* OR Molecul* OR Quantum*	2497	31	1206	29
3	Photonics, Atomic, Molecular physics and quantum sciences	Optic* OR Spectr* OR Photon* OR Laser* OR Light* OR Atom* OR Molecul* OR Quantum*	3820	48	1870	45

* As on 15.04.2015.

Scientific units of Latvia which can be included under umbrella of "Photonics, Quantum Sciences, Space Sciences and Related Technologies" cluster (main research units mentioned):

Photonics:

1. Institute of Atomic Physics and Spectroscopy of University of Latvia, www.asi.lv
 - 1.1. Biophotonics laboratory, leader – Dr. Prof. J. Spigulis
 - 1.2. Laboratory of Theoretical Physics, leader – Dr. E. Karule-Gailite,
 - 1.3. Laboratory of high-resolution spectroscopy and light source technology, leader – Dr. A. Skudra
 - 1.4. Laboratory of atomic and atmospheric physics and photochemistry, leader – Dr. A. Ubelis
 - 1.5. Quantum Optics Laboratory, leader – Dr. J. Alnis

2. Lasercentre of University of Latvia, <http://www.lasercentre.lv/>
 - 2.1. Atomic and Molecular Physics Laboratory, leader – Dr. Prof. M. Auzinsh
 - 2.2. Molecule Optical Polarization Laboratory, leader – Dr. Prof. R. Ferber
3. Institute of Solid State Physics of University of Latvia, <http://www.cfi.lu.lv/eng/>
 - 3.1. Laboratory of Optical Spectroscopy, leader – Dr. M. Springis
 - 3.2. Laboratory of Semiconductor Optoelectronics, leader – Dr. B. Polyakov
 - 3.3. Laboratory of Solid State Radiation Physics, leader – Dr. L. Grigorjeva
 - 3.4. Laboratory of Amorphous Materials Spectroscopy, leader – Dr. L. Skuja
 - 3.5. Laboratory of Optical Recording, leader – Dr. J. Teteris
 - 3.6. Laboratory of Radiation Physics, leader – Dr. J. Berzins
4. Division of Radiation Engineering Physics, Institute of Technical Physics of Riga Technical University, leader – Dr. A. Ozols, <http://www2.ktf.rtu.lv/TFI/>
5. G. Liberts' Innovative Microscopy Centre, Daugavpils University, leader – Dr. E. Tamanis, http://du.lv/en/about_university/faculties/dmf/institutes_centres/imc

Space Sciences:

1. Institute of Astronomy of University of Latvia, <http://www.lu.lv/eng/general/administrative/institutes/scientific/institute-of-astronomy/>
2. Institute of Geodesy and Geoinformatics of University of Latvia, <http://www.lu.lv/ggi/eng/>
3. Laboratory of Astrospectroscopy, Laser Center of University of Latvia, leader – Dr. L. Zacs
4. Ventspils International Radio Astronomy Center, <http://virac.venta.lv/en/>

Quantum sciences (some excellent group is mentioned):

1. A group of Quantum Computing, University of Latvia – Dr. Prof. A. Ambainis (a well recognizable scientific leader, mathematician in quantum computing, received ERC grant, full member of Academy of Science in Latvia), <http://home.lu.lv/~ambainis/>
2. A scientific group of Dr. Assoc. Prof. V. Kashcheyevs on quantum physics (a recognized researcher, member of Academy of Sciences in Latvia)

Significant infrastructure in Space Sciences:

- Schmidt telescope in Baldone, <http://www.baldonesobservatorija.lu.lv/>
- Riga Satellite Laser Ranging Station of Institute of Astronomy of University of Latvia,
- Large Raditelescopes in Ventspils International Radioastronomy center.

Main SMEs from Latvia which can be included under umbrella of “Photonics, Quantum Sciences, Space Sciences and Related Technologies” cluster are given in Table 2.

Table 2. List of major internationally visible enterprises (SMEs) in Latvia in Photonics, Quantum Sciences, Space Sciences and related technologies domain [1]

No.	Name, WEB page	Employees in 2013	Annual turnover, M€				Profit after tax 2013, M€	(Profit after tax) Turnover, 2013, %
			2010	2011	2012	2013		
1	2	3	4	5	6	7	8	9
1	GroGlass, Ltd. www.groglass.com	94	2.234	4.036	9.945	9.207	0.437	4.75
2	Z-LIGHT, Ltd. www.Z-Light.lv	89	5.998	6.664	7.407	9.175	2.206	24.04

1	2	3	4	5	6	7	8	9
3	Sidrabe, Ltd. www.sidrabe.com	78	3.410	5.585	3.704	9.410	0.786	8.35
4	BIOLITEC, Ltd. www.biolitec.com/biolitec_ag.html	92	3.113	4.311	7.224	7.224 (in 2012)	0.171	2.37
5	DARDEDZE HOLOGRAFIJA, Ltd. www.dardedze.lv	122	4.540	5.009	5.378	5.265	0.338	6.42
6	ISP Optics Latvia, Ltd. www.ispoptics.com	59	2.930	3.680	3.689	3.572	0.002	0.06
7	Baltic Scientific Instruments, Ltd. www.bsi.lv	64	2.179	3.073	3.564	2.676	0.073	2.73
8	OPTRON, Ltd. www.optron.lv	20	1.591	1.955	1.975	2.135	-0.104	-4.87
9	OPTILAS, Ltd. optilas.lv/lv.html	2	1.255	2.245	1.277	1.522	0.047	3.09
10	ENVIROTECH, Ltd. www.envirotech.lv	24	0.542	1.266	1.182	1.463	0.115	7.86
11	GeoStar, Ltd. www.geostar.lv	11	0.535	1.000	0.964	1.170	0.084	7.18
12	EUROLCDs, Ltd. www.eurolcds.com	9	0	0.032	0.147	0.468	-0.688	-147.01
13	Clusterpoint, Ltd. www.clusterpoint.com	6	0.191	0.097	0.136	0.231	-0.412	-178.35
14	TOPOPROJEKTS, Ltd. topoprojekts.lv	4	0.050	0.099	0.186	0.206	0.035	16.99
15	FUSH, Ltd. www.fush.lv	4	0.130	0.127	0.205	0.165	0.008	4.85
16	BurgerMetrics, Ltd. www.burgermetrics.com	3	0.057	0.016	0.036	0.149	-0.008	-5.37
17	Difraks Sol, Ltd. www.difraks.lv	12	0	0	0.119	0.146	0.024	16.44
18	Baltic Embedded, Ltd. www.baltic-embedded.com	0	0	0.002	0.065	0.113	-0.119	-105.31
19	Eventech, Ltd. eventechsite.com/en/	1	0	0	0.046	0.113	0.049	43.36
20	SensoTech, Ltd. sensotech.lv	2	0.108	0.072	0.025	0.074	0.011	14.86
21	HEE Photonic Labs, Ltd. www.heephotonic.eu	1	0.027	0.137	0.023	0.039	-0.023	-58.97
	Total	697	28.890	39.406	47.297	54.523	3.032	5.56
				Annual Growth rate				
				2011	2012	2013		
				36%	20%	15%		

References

[1] Data obtained from database of enterprises in Latvia – www.lursoft.lv (financial and legal data).

Insight in Photonics, Quantum Sciences, Space Sciences and Related Technologies in Estonia and Lithuania: Contribution from Academy and Industry

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Estonia and Lithuania both are strong in quantum sciences and space sciences. Each will be covered in the sections below.

Estonia

In Estonia the portal for professionals, scholars and students –**Research in Estonia** [1] highlights the main players and domains.

In the subdivision Astrophysics currently one can find the following information:

Estonian astrophysicists have made great strides in mapping galaxies and researching cosmic microwave background radiation. Driven by the desire to understand the make-up of the Universe, from its large-scale structure to subatomic level here on Earth. To pursue this knowledge, Estonia in 2013 launched EstCube, its first-ever satellite, and participates actively in CERN.

- Tartu Observatory. A research paradise filled with curious minds just like yours. Departments include astrophysics, cosmology, atmospheric physics, space technology with ongoing projects both domestic and international.
- University of Tartu Institute of Physics. 14 labs, five departments, various fields of physics from experimental to theoretical, biophysics to materials science.
- National Institute of Chemical Physics and Biophysics. Fundamental and applied research with an eye on new horizons in materials sciences, gene and biotechnology, environmental technology, and computer science.

The another subdivision „**Nonlinear processes and optics**” highlight the following research institution related to quantum sciences:

- *Researchers explore complex systems, atmosphere and sea waves, heart muscle* University of Tartu Institute of Physics. 14 labs, five departments, and various fields of physics from experimental to theoretical, biophysics to materials science.

The platform **Research in Estonia** also highlights two Centers of Excellence in the domain:

Dark Matter in (Astro)particle Physics and Cosmology Theoretical and experimental particle physics meet cosmology and computing to find dark matter in terrestrial and satellite-based experiments and to explain its origin and properties. It's amazing what an inquisitive scientific mind can work on in Estonia.

Theory and Applications of Mesosystems (MESO) also known as MESO, this research cooperation project between three universities explores mesosystems that exist between the macroworld and atomic dimensions. MESO research into coherence, dynamics and structures has exciting implications for innovation in fields such as optoelectronics, informatics, photonics, diagnostics, and sensorics.

There is a comprehensive publication about the Institute of Physics of University of Tartu [2] describing in the details the achievements of this leading institute in Estonia in the domain of photonics, quantum sciences, space sciences and related technologies.

Lithuania

The impressive quality of academic sector of Lithuania in quantum sciences indirectly highlights the fact, that two ERC grant holders originated from Vilnius Laser centre and are holding their grants in Austria at Vienna University of Technology:

- ERC grant holder BALTUSKA Andrius: CyFi – Cycle-Sculpted Strong Field Optics;
- ERC Starting Grant holder Aleksandr Ovsianikov. Laser Technologies to create microstructures with embedded living cells.

Both researchers originated from the Department of Quantum Physics and Laser Research Centrum [3] at the Faculty of Physics at the University of Vilnius which alongside with the Institute of Theoretical Physics and Astronomy and Department of Quantum Electronics endow the University a leading role in quantum physics and laser technology in Lithuania.

In the Table 1. below summarizes SCOPUS statistics on publications in the photonics and quantum sciences domain in Latvia, Estonia and Lithuania. Tables 2 and 3 shows industry activities in Lithuania and Estonia.

In summary it's evident that three Baltic States demonstrate impressive capacity in basic research in quantum sciences, spaces sciences and related technologies in the frame of photonics which is recognized as a Key Enabling Technology by the European Commission.

Table 1. Comparing number of scientific articles in SCOPUS on Photonics, atom, molecular and quantum sciences in Baltic countries.

		Latvia		Estonia		Lithuania	
Articles total in 2010-2014		6207		11228		11881	
Affiliations total		41		62		64	
No.		Articles Scopus 2010-2014	% of articles in 2010-2014	Articles Scopus 2010-2014	% of articles in 2010-2014	Articles Scopus 2010-2014	% of articles in 2010-2014
1	Photonics (*)	1958	32	3914	35	4382	37
2	Atom and Molecular Physics, quantum sciences (**)	1715	28	3698	33	3548	30
3	Photonics, Atom and Molecular Physics, quantum sciences (***)	2703	44	5520	49	5482	46

(*) Number of articles obtained by searching SCOPUS with a search words "Optic* OR Spectr* OR Photon* OR Laser* OR Light*"

(**) Number of articles obtained by searching SCOPUS with a search words "Atom* OR Molecul* OR Quantum*"

(***) Number of articles obtained by searching SCOPUS with a search words "Optic* OR Spectr* OR Photon* OR Laser* OR Light* OR Atom* OR Molecul* OR Quantum*"

Table.2. List of major internationally visible enterprises in Lithuania in Photonics, Quantum sciences, space sciences and related technologies domain [4]

No.	Name of a company, WEB page	Number of employees, 2014	Annual turnover in 2012, M€ (range – from... to)	
			from	To
1	Šviesos konversi, Ltd. www.lightcon.com	113	8.689	14.481
2	EKSPLA, Ltd. www.ekspla.com	121	8.689 (in 2011)	14.481 (in 2011)
3	STANDA, Ltd. www.standa.lt	130	5.792	8.689
4	ALTECHNA, Ltd. www.altechna.com	50	5.792	8.689
5	Optolita, Ltd. eksmaoptics.com/news	39	2.896	5.792
6	PRECIZIKA, Ltd. www.precizika.lt www.soletpv.lt/?language=LT	74	2.027	2.896
7	Anykščių kvarcas, Ltd. www.akvarcas.lt kvarcas@res.lt	50	1.448	2.027
8	“Via Solis”, Ltd.	20	0.579	0.869
9	OPTIDA, Ltd. www.optida.lt	43	0.579	0.869
10	EKSMA, Ltd. www.eksma.lt	8 (in 2011)	0.290	0.579
11	ELAS, Ltd. www.e-lasers.com	10	0.145	0.290
12	Precizika-Met Sc, Ltd. www.premet.lt/index.php?lang=en	11	0.145	0.290
13	Modernios E-Technologijos, Ltd. www.met.lt/index2.php	30	0.145 (in 2011)	0.290 (in 2011)
14	“Saulės energija”, Ltd. www.saulėsvejoenergija.lt	5	0.145	0.290
15	TERAVIL, Ltd. www.teravil.lt/fiber.php	6	0.087	0.145
16	Optronika, Ltd. www.optronika.lt	6	0.087	0.145
17	Optonas, Ltd.	3	0.087	0.145
18	Astuonetas, Ltd. www.astuonetas.lt	7	0.087	0.145
19	TERAVIL, Ltd. www.teravil.lt	6	0.087	0.145
20	Optines dangos, Ltd.	4	0.029	0.058
21	GEOLA, Ltd. www.geola.comt	XX	0.014	0.029
22	Brolis Semiconductors, Ltd. www.brolis-semicon.com	13	0.014	0.029

23	Lidaris, Ltd. lidaris.com	5	0.014	0.029
24	Integrated Optics, Ltd. integratedoptics.eu	8	0.014	0.029
25	Baltic Solar Solutions, Ltd. balticsolar.com/en/bss	64	0.003	0.014
26	Baltic Solar Energy , Ltd. balticsolar.com/en/bse	15	0.003	0.014
	Total	841	37.887	61.459

Table 3. List of major internationally visible enterprises in Estonia in Photonics and Quantum Technologies domain

No.	Name, WEB page	Number of employees in 2013	Annual turnover in 2012, M€	Annual turnover in 2013, M€
1	Ldiamon, Corporation http://ldiamon.eu/	9	1.427	1.345
2	Laservisioon LTD http://www.laservisioon.ee	6	0.961	0.811
3	INTERSPECTRUM,LTD http://www.interspectrum.ee/	8	0.549	0.291
4	Laser Diagnostics Instr., Corporation http://www.lidi.ee/	22	0.511	0.120
5	Estla, Corporation http://www.estla.com/	5	0.162	0.134
6	HOHENHEIDE, LTD http://www.hohenheide.ee/	1	0.031	0.013
7	IKO SCIENCE, LTD http://www.ikoscience.ee/	2	0.022	0.011
	Total	53	3.663	2.726

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- [4] Data obtained from the directory of Lithuanian companies, <http://rekvizitai.vz.lt/en/> – (financial data on: 2012 turnover (range from...to); actual workforce count on 2014).

Baldone Astrophysical Observatory: Upgrade, Progress and Results in Observation and Research

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Baldone Astrophysical observatory of Institute of Astronomy, university of Latvia is the largest observation base in Latvia in optic. There is the twelfth largest Schmidt type telescope in the world. The diameter of main mirror of telescope is 1.2 m, aperture 0.8 m and focal length 2.4 m. The size of field is $4^{\circ} 46'$. Telescope is installed with 4 degree objective prism.

Classical research field of observatory is the stars in late evolution stage, especially carbon stars – photometrical in B, V, R, I passbands, low resolution ($\lambda/\Delta\lambda=500$) spectral investigations and high resolution ($\lambda/\Delta\lambda=65000$) spectral analyses with model atmospheres and synthetic spectra methods. In the last years observatory take part in investigations of Solar system small bodies.

Main results:

- More than 350 new carbon stars are discovered, their photometric characteristics are investigated;
- Five monographs, including the “General catalogue of Galactic carbon stars”;
- 70 novae in Andromeda galactic are discovered, they photometric characteristics were studied and they were identified as soft x-ray sources;
- 42 new asteroids are discovered including Centaur, Apollo, Trojan -types. Five asteroids were named as “Baldone”, “Ikaunieks”, “Blumbahs”, “Canders” and centaur “Orius”.
- Project Fotonika-LV give possibilities upgraded observatory with five and seven core computers, A3 format flat bed scanners Epson Expression 10000XL, mirror and lenses to solving the problem connected with curved focal plane of telescope and flat plane of CCD; to solve the problem with crash of telescope quartz clock; two globes of 55 cm telescopes pavilion were coated.
- Upgrades give possibilities installed Schmidt telescope with new large 16 megabit CCD which increased the effectiveness of telescope four times in comparing with previous CCD.
- New computers and scanners will allow digitized 22000 astronomical photo plates of Schmidt telescope archive. Some fields of sky in Cygnus, Perseus, Cassiopeia were regularly observed in time range more than 35 years. Many clusters were observed in U, B, V, R, I passbands.
- IRAF and Ramafot software were optimized to processing the scans of plates. The mean squared error $\pm 0,07$ of coordinates and $\pm 0,05$ magnitude in photometry are obtained .
- Mini planetarium was created in Schmidt telescope pavilion. It gives possibility to popularize the success in astronomy and Fotonika-LV project. For example in 2014 in observatory were 2800 visitors.

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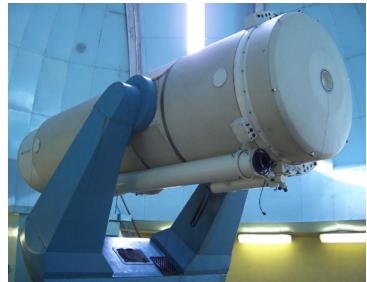


Fig.1. Baldone Schmidt telescope.

The Capacity Of Upgraded SLR LS-105 System Station (*ILRS Code Name 1884 Riga*). Results Of Observation and Research

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The Riga 1884 is one of the oldest continuously operating SLR stations in the world, currently the only operating SLR system in Northern Europe on the Baltic region and with the longest and consistent data set of measurements in the area.

Keeping the long series of measurements for geodetic satellites as Lageos, Lageos-2, Lares, Starlette and similar ones is necessary for keeping the station as an international space geodesy reference point contributing to the **ITRF (International Terrestrial Reference Frame)** and for studying the long-term geodynamical variations.

At the time of start of Fotonika-LV project several key SLR subsystems – time and frequency standard, testing, measuring and telescope control equipment – were using technology from the Soviet Era close to collapsing or below the current standards. The efficiency of the system was decaying in an alarming rate. As a result the number of measurements for the LAGEOS satellites was falling down to very low number

In late 2012/early 2013 Riga was not even able to get returns from LAGEOS 1 & 2.

New technologies which has become standard in the SLR community as aviation traffic monitoring (ADS-B) were missing, and the hardware/software available was a limiting factor to reach the maximum observational potential of the SLR Riga 1884.

The modernization and upgrading has been carried out in the following areas:

- 1.Replacement of obsolete equipment – the old time and frequency standards were replaced with GPS steered rubidium clocks with the option to transfer reference frequency and time signals over optical fiber lines.
- 2.Introduction of new technologies to improve the operational capabilities and to agree with international security requirements: ADS-B receiver for air traffic surveillance monitoring, All-Sky camera and wide field TV Camera on telescope.
- 3.Upgrading the calibration and test equipment to control the system performance: laser power meter, signal generators, oscilloscopes, digital tiltmeter with 1" accuracy, laser diodes for telescope optical system alignments and laser line interference filters.
- 4.Improving the operating conditions at the SLR building (heating, lightning, etc)
- 5.New computers and supplementary equipment, secondary meteo station.
- 6.Recovering and updating operational know-how and methodologies (SLR optical alignment)
- 7.Upgrading the SLR hardware (calibration loop, Laser-Telescope optical coupling, dew control at the Telescope Mirrors)
- 8.Full experimental analysis of the Receiver Chain
- 9.Improvements on the current SLR control and operational software (new calibration and data filtering software, control of observations done), also new software for the laser operation and parameter monitoring is being written.
- 10.Calibration against external standards (Time service against Cs-Clock, meteo station against Standard Barometer)
- 11.Not a part of the SLR but an important upgrading for the observatory: A new IGS/EUREF GNSS receiver with GPS/Glonass/Galileo capability.

During this time the station is not working regularly.

After a round of modifications a short observation campaign is done to insure that the SLR is working properly, and then stops for the next round of tests/modifications.

The official status of the Riga 1884 station at the International Laser Ranging Service is on **upgrading mode** marked as **active/quarantine**. That means that the test data is accepted and analyzed but the final release of all the data will be done once the regular tracking starts and sufficient amount of new LAGEOS data is delivered.

The upgrades are interconnected in the sense that, for example, any modification of the SLR control software cannot and will not be carried out until all the new telescope hardware components and associated electronics are installed, tested and operationally available.

Main results:

- The SLR internal calibration stability is improved and its single calibration RMS reduced to about 60% of the previous value by using a new single-mode optical fiber loop and improving its optical coupling and thermal stability^[4].
- The reference time and frequency standard has been upgraded, its operation is simplified, and its performance was compared and calibrated with a primary Cs time standard in collaboration with GFZ-Potsdam^[3].
- The new test and measurement equipment allowed measuring the signal delay between the Time Service and the SLR building and its temperature dependence, diagnose and improving the optical channel commutation electronics and evaluating the receiver channel performance.
- The updating of the mount model and the improved optical alignment gives a better satellite pointing stability.
- The telescope and monument stability was verified.
- Once all the new hardware, electronics and software became operational, regular shadow and day observations and to the GPS-like satellites will be possible, increasing the station productivity.

Reporting in Conferences:

- During this period, two International Laser Ranging Workshops has been carried out, the 18th in Fujiyoshida, Japan (2013) and the 19th in Annapolis, USA (2014). The Riga Team and partners presented 3 oral presentations and 5 Posters.
- On the 1st International Conference Nocturnal Atmosphere and Laser Ranging, Riga 2014 one oral presentation was carried out.

The following presentations and Posters were directly related to the SLR Upgrading:

1. K. Salmins, J. del Pino Preserving history and technical „know-how“ – experience at SLR station Riga, 18th International Workshop on Laser Ranging, Fujiyoshida, Japan, Nov 11-15, 2013
2. K. Salmins, M. Abele, J. del Pino Riga SLR station upgrade and status report, 18th International Workshop on Laser Ranging, Fujiyoshida, Japan, Nov 11-15, 2013
3. E. Hoffman, K. Salmins, J. del Pino, A. Meijers Modernization and Characterization of the Riga SLR Timing System, 19th International Workshop on Laser Ranging, Annapolis, US, Oct 26-31
4. J. del Pino, K. Salmins, A. Meijers Upgrading the Calibration Chain at Riga SLR Station, 1st International Conference, Nocturnal Atmosphere and Laser Ranging: NOCTURNAL – Riga 2014

Design of Multipurpose Instrument for Ranging of Satellites and Space Debris and for Remote Sensing in Atmosphere

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The Association FOTONIKA-LV in cooperation with HEE Photonic Labs Ltd has an objective to work towards the new design of multipurpose instrument for ranging of satellites and space debris and for remote sensing in atmosphere – advancement of technologies contributing to the Earth sciences. The progress in the designing the ground multipurpose instrument is shown.

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Digital Zenith Camera – a new Astrometric Instrument for Precision Measurements in Geodesy

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Detailed knowledge of local geoid surface has become increasingly important in order to fully use the potential of accurate geocentric positions, provided by GNSS. Recent advances in a number of scientific and technological fields – accurate astrometric reference star catalogs; development of digital imaging technology; high accuracy tiltmeter technology; and geocentric coordinate availability using GNSS – have made it possible to use astrometric methods for accurate, fast and automated determination of vertical deflections. Such measurements can give important contribution in determination of local geoid properties [1].

Zenith cameras for this kind of measurements have been developed by several research groups. However, accessibility to these instruments is limited. The institute of Geodesy and Geoinformatics of the University of Latvia has engaged in a project to develop its own digital zenith camera [2] that is portable and reliable using off-the-shelf components as much as possible.

All digital zenith cameras share a number of construction principles that includes an imaging system that is pointed to the zenith, and are equipped with a precision biaxial tiltmeter. In order to exclude alignment inaccuracies and tiltmeter zero-point uncertainty, the mount can be rotated around the vertical axis. Within our project a simple experimental prototype device was used to develop measurement methodology and design control and data processing software. The experimental camera has a 20 cm catadioptric telescope with a 1390 mm focal distance, imaging device with 1350×1024 6.45 mkm pixels, covering field of 0.35×0.27 dg (resolution 0.95" per pixel). Telescope assembly is supported by 3 small precision bearings, rolling on a flat horizontal support surface. Rotating and leveling of assembly are manual. Design of the improved version uses slightly bigger optics (a 8" catadioptric telescope with focus distance of 2000 mm) and a 3300×2500 pixel imaging device (5.4 mkm pixels; 0.56"/pixel; 0.5×0.39 dg field). Computer-controlled stepper motors are used for rotation and leveling of assembly. Rotating part includes on-board battery power source and embedded control computer, operator control is done via wireless remote desktop connection.

Stars of brightness up to 13^m-14^m (for 0.1 sec exposure) are found on obtained



Fig.1. Integration of components and tests of control equipment are now underway.

images, generally ensuring presence of at least 10-20 reference stars per frame. A subset of NOMAD astrometric position catalog [3] and NOVAS software package [4] are used for astrometric reduction of star coordinates. Reference star identification is done automatically [5].

CCD shutter pulse time tags, produced by GNSS receiver's event timing mechanism, are used to determine frame exposure moments. Timing accuracy of obtained star images is estimated to be within a few milliseconds.

Measurement session includes a series of imaging system frames together with tiltmeter readings, obtained within about 10 second interval around exposure moment. In order to minimize effects of tiltmeter scale and orientation uncertainties, assembly is leveled with sub-arcsecond accuracy in each measurement position. Assembly is rotated after a group of frames is obtained, any rotation position can be used. Optimal composition of measurement sessions is yet to be found out.

Presently accuracy of vertical deflection values, measured by the instrument, is expected at about 0.1". However, actual values of accuracy remain to be found.

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Geodesy and Geoinformatics in Latvia

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Geodesy and geoinformatics in Latvia are developed with the same methodology as in other EU countries by applying advanced measuring and computing technologies. Geodesy and geoinformatics play an important role in global and national economies by supplying and monitoring global and national Terrestrial Reference Frames (TRF), environmental studies, mapping and cadastre information etc. The Institute of Geodesy and Geoinformatics (GGI) is primarily involved in space related technologies [39] used for the monitoring of TRF and on geomatics [20,26,35,38,47,48]. During the FOTONIKA-LV project the institute has participated in 3 EU Regional Development Fund projects. Two of them are still in progress – one concerning design of a new multi-purpose optical tracking system with SLR capability [4,6,7,10], the other – utilizing levelling, gravimetric and vertical deflection measurements to calculate local geoid model parameters [1,3,8,9,15, 25,27,30,32,33,44]. The digital zenith experimental camera [24] was designed within a previous project. The new camera is now completed and is used for vertical deflection measurements. GGI conducts studies of vertical and horizontal motion of the Earth's crust in Latvia using analysis of GNSS observations at the LatPos and EUPOS-RIGA permanent station networks [5,11,-14,16,18,19,21,29,31,40,42]. GGI participates in a several international cooperation projects: EUPOS[®] – European Position Determination System (www.eupos.org) [12,22,28,34,37,46], in cooperation project with ESA "EUPOS[®] contribution to GOCE mission" (Id 4307) [17,43,45] and cooperation project with ETH Zurich, Switzerland (www.lu.lv/ggi). Three doctoral theses have been developed on the basis of GGI research [1-3] plus multiple bachelor or master's theses [23,36].

The FOTONIKA-LV project has made possible a number of research visits by foreign specialists to GGI. Additionally funding has enabled participation in international conferences for many GGI researchers and also provided funding for substantial purchases of equipment necessary to improve technical capabilities of the institute.

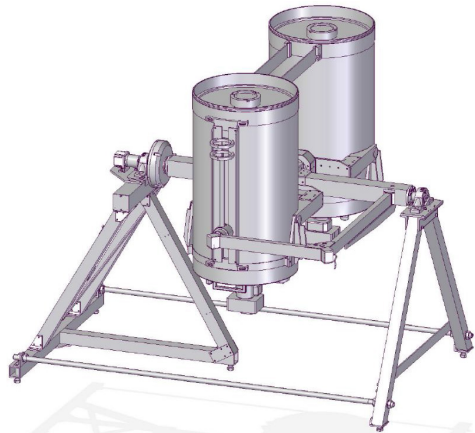


Fig.1. Project of multi-purpose optical tracking system [4].

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Radio Astronomy in Latvia

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Ventspils International Radio Astronomy Centre was established in 1994 by the decision of Latvian Academy of Sciences with the aim to develop the research directions in radio astronomy and astrophysics. The instrumental base for the centre comprised two fully steerable parabolic antennas, RT-16 and RT-32 (i.e. with the mirror diameter 16 m and 32 m), fig. 1. The telescopes were built in the 60-es of the last century and used for military purposes. By the time of VIRAC establishment, both the antennas had been in completely inoperable state. The reconstruction and instrumental refurbishment carried out by the VIRAC engineering team made it possible to use radio telescope RT-32 for the international scale fundamental and applied research in the field of radio astronomy. The most important aspect of this work is participation of RT-32 in the VLBI (Very Long Baseline Interferometry) international experiments [1, 2].

Since 2010, the VIRAC staff together with various international subcontractors has been heavily involved in the upgrading activities related to refurbishment of the RT-32 and RT-16. After reconstruction works both antennas will be equipped with completely new drive control system and fitted with appropriate VLBI receiving and recording equipment. Antenna backup structure, antenna surface and internal rooms of the radio telescope RT-32 will be fully renovated. In the RT-16, besides of same internal modernization, steerable part of antenna will be replaced with modern carbon fibre surface, which brings news live to this telescope and increase potential working frequency up to 22 GHz. Reconstruction works should be finished in the end of 2015 and both telescopes will be available for international radio astronomy community.

Currently, VIRAC radio telescope RT-32 is involved in the following research areas:

- investigation into the motion parameters of objects in the near-Earth space (space debris, satellites, asteroids) and planets;
- studying the Earth's ionosphere;
- studying the solar radio emission;
- observations in the international VLBI-networks, including the European VLBI network (EVN).
- To achieve these objectives it is possible to use the following receiving systems:
- 327 MHz (92 cm, P band) – primary focus;
- 1.6 GHz (18 cm, L band) – secondary focus;
- 4.5-8.8 GHz (C – X band receiver) – secondary focus;
- 6.9 – 9.3 GHz (3.7 – 4.2 cm) – secondary focus;
- 12 GHz (2.3 cm, X band) – secondary focus [2].

In September 2014, two cryogenic broadband receivers (4.5-8.8 GHz) are designed and delivered by "TTI" company. Each include two channels (Right and Left Circular Polarizations), intermediate frequency convertors, local oscillators, noise diodes and phase calibration units (fig. 2). Measured system temperature for this receiver installed on the RT-32 is in the order of 30 K. It is assumed that, after modernization of the both RT-32 and RT-16, 4.5-8.8 GHz receivers will be primary instrument for the VLBI and single dish observations.



Fig.1. VIRAC radio telescopes RT-32 with antenna diameter 32- m (left) and RT-16 with antenna diameter 16 m.

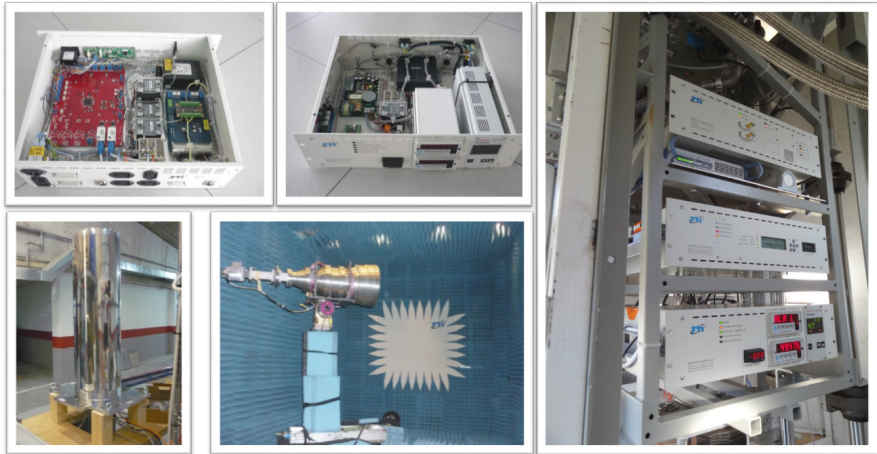


Fig.2. VLBI cryogenic broadband 4.5-8.8 GHz receiver installed in the radio telescope RT-32.

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Decades Long Science Communication at Institute of Astronomy based on High Level Science

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Science communication has been an important part of educational activities at the Institute of Astronomy, University of Latvia for 70 years. During these years science communication has taken different forms. After the Second World War there was an emphasis on publishing popular science books and giving lectures to broad audience. Latvian Astronomical Society was founded in 1947. Popular science magazine *Starry Sky* has been published since 1958. Scientists of Institute were involved in work with Riga planetarium. Research on asteroid orbits has been recognized by the scientific community, and several asteroids were named after Latvian places and astronomers. Scientific observatories of Institute have received many visitors during these years. In 1986 the Astronomical Tower – a public observatory opened in Riga. School pupil contests, astronomy summer camps and other science communication activities were also organised by Institute scientists. A small planetarium is now available to visitors of Baldone observatory and new asteroids are named after Latvian scientists.

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Nonlinear Effects in Optical Pumping upon Resonant Excitation of Ultra-slow Beam of Cold Cs Atoms

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We present the results of a combined experimental and theoretical study of nonlinear population dynamics of the $6^2P_{3/2}$ state upon resonant excitation of Cs atoms. The particular focus of this study is the very long interaction time limit ($\sim 180\mu\text{s}$), which is achieved by crossing a cold and slow beam of Cs atoms out of a pyramidal MOT (see [1, 2] for more detail on such beams) with an excitation laser beam, while the excited state population is probed via photoionization. The experiment shows marked differences in the dependence of the excited state population on the excitation laser power for excitation from the same lower level $F''=4$ in the $6^2S_{1/2}$ state but to different levels $F'=3, 4$, or 5 in the excited state.

We show that under such conditions the onset of nonlinear effects in the population dynamics and optical pumping occurs at excitation laser intensities much below the respective saturation values of the transitions, whereby for a given interaction time τ_{tr} the critical Rabi frequency Ω_{cr} at which the population redistribution via optical pumping can lead to significant changes in the excitation spectra is given by

$$\Omega_{cr} = \Omega_{sat} \sqrt{\frac{2\tau}{\tau_{tr}(1-I)}}$$

where τ is the excited state lifetime, Ω_{sat} saturation value for Rabi frequency for the respective transition and I is the branching ratio. We show that there is a huge increase (100 times!) of the ratio of $F''=4 \rightarrow F'=5$ and $F''=4 \rightarrow F'=4$ excitation signals as the excitation laser power is increased from $3\mu\text{W}$ to 10mW (see Fig. 1).

We invoke numerical simulations of optical Bloch equations for the involved Zeeman sublevels and demonstrate that the features observed in the experiment are explained by the presence of "bright" and "dark" resonances that lead to power-dependent effective branching coefficients. For example, the laser induced mixing of Zeeman sublevels can lead to population retrieval from dark states or to inhibition of optical pumping if bright states are present. The interplay between the various factors can lead to significant and intuitively unpredictable variations in hyperfine level populations, which may become particularly pronounced in cold atom experiments even at low laser intensities.

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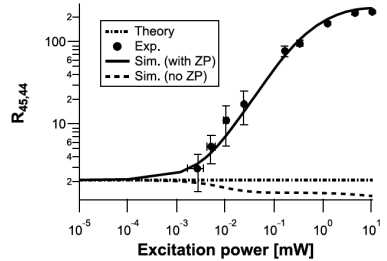


Fig. 1. Ratio of probe signals upon excitation of the $F''=4 \rightarrow F'=5$ and $F''=4 \rightarrow F'=4$ hyperfine transitions as a function of excitation laser power. The dashed-dotted line shows the ratio of the respective line-strengths, the dashed line shows the simulated result neglecting Zeeman pumping, while the full line shows accurate simulations of density matrix equations.

Consequences of Multiple Dressed States Formation in Atomic Non-Degenerate Hyperfine Levels

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We conduct theoretical studies of the formation of laser induced adiabatic states in a multilevel two-state quantum system with hyperfine (HF) splitting which is essential in observing laser-matter interaction phenomena under experimental conditions. For that purpose, two theoretical models were independently developed: the first model was based on solving the Schrödinger's equation, while the second one- on the Optical Bloch Equations using the Split Propagation Technique. Both models included the interaction of all laser fields with all HF- and Zeeman sub-levels in the system and produced similar results, which gave us confidence in the validity of our predictions. The effect of the HF structure on the architecture of the Autler-Townes (AT) [1] excitation spectra was shown to be radically different depending on whether the number of HF levels in the two laser-coupled states is equal or different. The latter is in full agreement with the predictions from the Morris-Shore (MS) [2] transformation which allows for the explicit description of "dark" and "bright" states in degenerate 2-level systems.

We studied the excitation schemes $3S_{1/2}(F''=2) \rightarrow 3P_{1/2} \rightarrow 5S_{1/2}$ and $3S_{1/2}(F''=2) \rightarrow 3P_{1/2} \rightarrow 4D_{3/2}$ in Na where the intermediate state is coupled by a strong laser field to the final $5S_{1/2}$ (or $4D_{3/2}$) state, creating the laser-dressed states which are then probed by a weak laser field scanned across the resonance between the ground $3S_{1/2}(F''=1, 2)$ and intermediate state. If the number of HF levels in the two strongly coupled states is equal (e.g., in the excitation scheme $3S_{1/2}(F''=1, 2) \rightarrow 3P_{1/2} \rightarrow 5S_{1/2}$), a sufficiently strong coupling was shown to result in full resolution of the M_F Zeeman sublevels. However, in the case of different number of HF levels (e.g., excitation scheme $3S_{1/2}(F''=1, 2) \rightarrow 3P_{1/2} \rightarrow 4D_{3/2}$), the increase of the coupling field strength, compared to the separation between the atomic HF components, leads to a rapid decrease (and eventually vanishing) of the intensity of all AT peaks except the two side ones. Using our theoretical models to describe the formation of "bright" and "dark" states, extensive numerical simulations were performed for a number of three-level ladder schemes in sodium. In addition, the evolution of dressed state energies upon variation of coupling field Rabi frequency was studied in order to correctly predict, interpret, and assign the rich spectral features. Our numerical data for a specific excitation ladder scheme $3S_{1/2}(F''=2, 1) \rightarrow 3P_{3/2} \rightarrow 4D_{5/2}$ exhibited noticeable peculiarities of the architecture of the AT spectra, namely, the death of not only "dark" but also some "bright" fluorescence peaks, as demonstrated in Fig.1 (left frame). The selection rules for transitions between different HF magnetic sublevels, which cause different coupling are shown in Fig 1 (right frame). By matching the positions of the fluorescence peaks with the values of the adiabatic states energies (Fig 1. (d)) we were able to unambiguously identify the origins of each spectral component in the AT spectra. Tracing down the origin of this AT spectrum pauperization, our theoretical treatise revealed a number of nontrivial moments in the manifestation of

HF adiabatic states depending on the coupling laser intensity: (i) At intermediate coupling field Rabi frequencies the HF operator is comparable to the coupling one, which results in noticeable mixing between different orthogonal adiabatic wave functions, in particular, between individual sets of “bright” and “dark” states. This mixing leads to the population of dressed states which are decoupled from the excitation scheme, e.g. “grey” states, and gives rise to a number of extra AT multiplets.

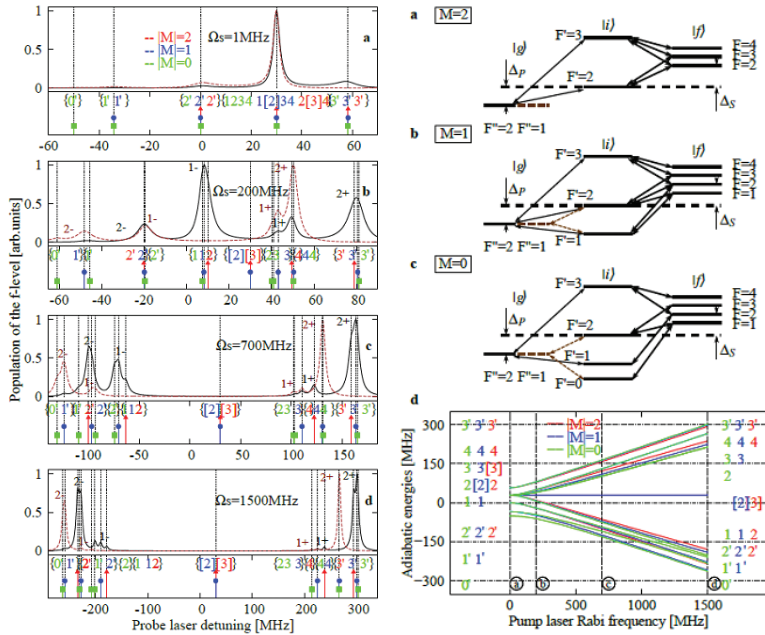


Fig1. Left frame: Population of the upper level in the $3S_{1/2}(F''); M)3P_{3/2}(F'; M)4D_{5/2}(F; M)$ ladder scheme for different coupling Rabi frequencies in the second excitation step. Excitation sequence with $F''= 2$ (black solid curves) and $F' = 1$ (brown dashed curves). Coupling strength in the first step is 1MHz. **Right Frame:** Excitation linkage patterns for Zeeman sequences (a) $M = 0$, (b) $M=1$ and (c) $M=2$; (d) Energies of adiabatic (dressed) states vs the coupling field Rabi frequency.

(ii) At large coupling field strengths, the HF atomic operator is treated perturbatively; the number of “bright” and “dark” states and their explicit representations is found from the classical MS transformation. Multiple “dark” states are created from the “grey” ones, while some “bright” AT components gradually die with the increase of coupling laser power. As shown in Fig. 1, the AT spectrum is composed of two independent sets of lines, originating from probing from the ground state HF sublevel $F''=2$ or $F''=1$. These multiplets are complementary to each other, i.e. at high coupling field powers the probe laser populates different orthogonal configurations of adiabatic states depending on the HF-channel ($F''=2$ or $=1$). In terms of applications this opens, for instance, nontrivial perspectives to form a two-component bichromatic polariton: a single strong control laser can drive the independent propagation of two uncoupled quantum probe fields.

While studying the dressed states formation, our extensive numerical simulations led us to the investigation of an additional ladder excitation configuration in atomic sodium. Somewhat unexpected, the excitation scheme $3S_{1/2}(F'' = 1, 2) \rightarrow 3P_{3/2} \rightarrow 5S_{1/2}$ appears to be most interesting for the purposes of developing new methods for quantum state control applications. In this case the main feature of the AT spectrum consists in preserving the bare states at the initial ($3S_{1/2}$) and final ($5S_{1/2}$) steps, as illustrated in Fig.2 (right frame).

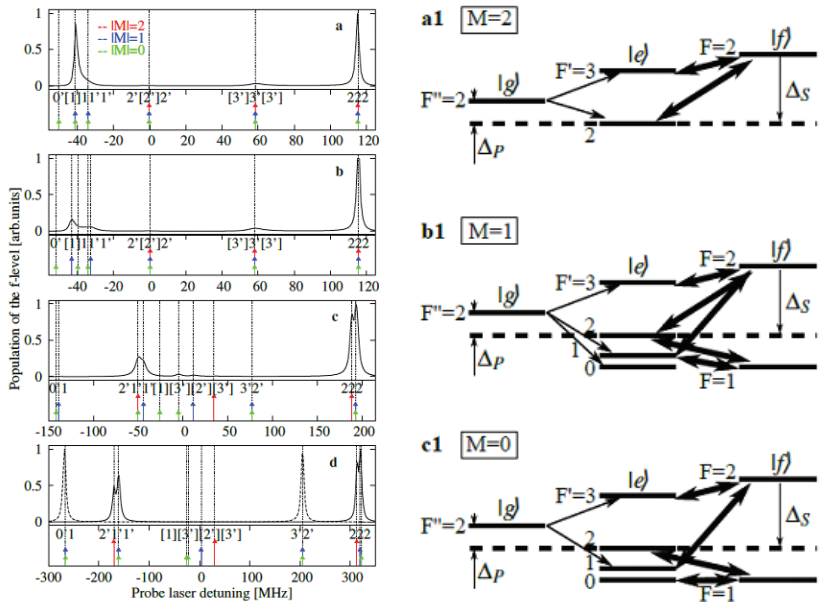


Fig 2. Left Frame: Population of the upper level in the $3S_{1/2}(F''); M)-3P_{3/2}(F'; M)-5S_{1/2}(F; M)$ ladder scheme for coupling Rabi frequency in the second excitation step (a) 1 MHz; (b) 25 MHz; (c) 450 MHz, (d) 1000 MHz. Coupling strength in the first step is 0.87 MHz. Excitation sequence with $F''=2$ (black solid curves) and $F''=1$ (black dashed curves). **Right Frame:** Excitation linkage patterns for Zeeman sequences (a1) $M=2$, (b1) $M=1$ and (c1) $M=0$.

The selection rules for transitions between different HF magnetic sub-levels, which cause different coupling patterns are shown in Fig. 2(left frame). Based on analysis of our results, an interesting observation was made: the excitation process $3S_{1/2}(F'') \rightarrow 5S_{1/2}(F)$ is going via a number of partial two-photon pathways with varying intermediate HF levels, which leads to destructive interference between the respective probability amplitudes and hence to creation of an artificial selection rule $\Delta F \equiv 0$ for the two-photon transition. Such destructive interference is the reason for the observed singlet structure in the left frame of Fig.2. This opens practically important perspectives for artificial construction of desired selection rules in many-photon interactions, both to manipulate quantum states and to achieve specific addressing of HF components in atoms and molecules.

The works were carried out within the EU FP7 Centre of Excellence project "FOTONIKA-LV-FP7-REGPOT-CT-2011-285912". Partial support by the EU FP7 IRSES project COLIMA, as well as the trilateral grant of the Latvian, Lithuanian and Taiwanese Research Councils are acknowledged.

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A Status Report of GRIBA (Gothenburg Riga Ion Beam Apparatus)

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In this presentation, we report the project which is based on collaboration between us and group of Professor Dag Hanstorp in University of Gothenburg. This collaboration was very successful during about 10 year period in 1990 when it resulted to number of publications [1-4]. It was restarted in frame of project "Unlocking and Boosting Research Potential for Photonics in Latvia- Towards Effective Integration in the European Research Area" [5].

The design and building of transportable Negative Ion Beam accelerator was completed in Gothenburg, and then GRIBA (Gothenburg-Riga-Ion-Beam-Apparatus) was transported to Riga and ready for the first experimental tests. Now it can be used for experimental studies of simple molecular ions of astrophysical interest, and for design and studies of ion sources for scientific and industrial applications. The graduate and undergraduate students have an advantage of having hand on practice on GRIBA. And if necessary, apparatus can be transported to other facilities for more complex experiments.

At the moment the hot filament plasma ion source [6] is installed on apparatus. The ions are extracted from discharge chamber through small pinhole and accelerated with about 3-5 kV potential. By applying the "+" or "-", the beam of anions or cations is formed. Then ions are mass selected in (Colutron) Wien mass/velocity filter, and then passing the Cesium (Cs) vapour chamber. If it is filled with Cs vapour the positive ions are converted to negative ions by two step charge transfer in collisions with Cs atoms. Then beam is passing the electrostatic quadrupole where beams of anions, neutrals, and cations are separated from each other. This line is built as separate module and can be transported as one unit. At the one end of beam line the rare gas is leaked in ion source in order to support discharge there. The beam is shaped and steered by set of deflection plates and electrostatic lenses. The vacuum along the beam line is hold in 10^{-7} mbar level by set of Edwards oil diffusion pumps in two first chambers while the turbomolecular pump is attached to quadrupole chamber and vacuum there is about one order of magnitude better. The high vacuum is critical for negative ions, since they are neutralised very efficiently in collisions with residual gas molecules.

The experimental chamber is built as separate module and attached with 90° angle to the beam line. The main object of this chamber is time of flight spectrometer what is used for detection and energy analysis of electrons created in the photodetachment process. [7] The crossed laser beam and the ion beam both enter the spectrometer through the small apertures. The electrons are focused and decelerated inside the the spectrometer tube and finally detected by a microchannel

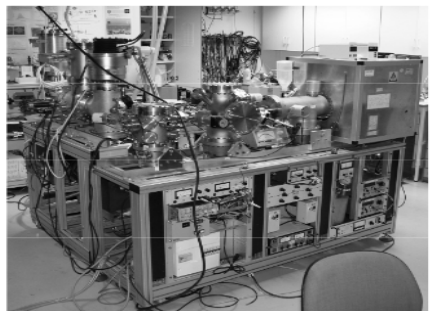


Fig.1. GRIBA under tests in Gothenburg.

plate detector. In order to control the ion current the Faraday cup is used at the end of beam line. The ultra high vacuum in the experimental chamber is obtained by help of turbo pump and by the ion pump the as main pump, and it is better than 10^{-9} mbar.

The laser beam enters and exits the experimental chamber through windows perpendicular to ion beam line. The laser is placed on separate table and can be substituted with another laser as module. Now we use the EKSPLA SL212 NdYag picosecond laser. We use it without pulse compressor and it generates 10 nsec long pulses up to 50 Hz repetition rate. The second harmonics with 532 nm wavelength can be generated and separated for experiments. The laser polarisation of laser light can be gradually rotated by Double Fresnel Rhomb before it enters the experimental chamber.

In this configuration the GRIBA can be used for the measurements of beta parameters in photodetachment process for number of negative ions, and it can be good training opportunity for undergraduate and graduate students, see as example [9].

We are working on development of the ion sources more suitable for molecular ions which are based on other plasma excitement methods. One of them is radiofrequency excitation [10], or alternatively hollow cathode discharge [11]. In presentation we'll report on our first samples of radiofrequency source.

Another possible application of GRIBA is pulsed the ultrasonic shock nozzle cluster source [12] attached to our experimental chamber in order to study the ion cluster collisions. This is our recently started collaboration with Dr A Saxena from Space Agency of India.

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Development and Application of Photonic Materials for Optical Sensors/Biosensors

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Novel 1-D ZnO nanostructures have been developed and studied for gas and biosensor applications.

Polyacrylonitrile (PAN)-ZnO core-shell nanostructures have been prepared using electrospinning and atomic layer deposition (ALD) technique. The PAN nanowires were coated with ALD-deposited ZnO thin layers with thickness varying from 2.5 nm to 30 nm.

XRD, SEM, TEM and photoluminescence (PL) measurements were performed. The PL was excited by solid state laser (355 nm, 10 mW). The ZnO-PAN nanostructures have shown the enhanced PL signal in UV and Vis range in comparison to the samples, deposited on Si.

Gas sensitivity tests of ZnO-PAN (ZnO 30 nm) samples were performed for ethanol detection using PL method. The changes of visible and UV emission bands of ZnO, induced by ethanol adsorption, have been observed [1].

ZnO Nanorods (NR) were deposited by gaseous-disperse synthesis [2]. XRD and SEM measurements were performed to study structural properties of ZnO NRs. The ZnO NRs were 460 nm in length and 60 nm in diameter. The PL spectra showed strong UV emission and weak visible peak, pointing to good crystallinity of the nanorods [2].

The deposited samples have been studied for optical biosensor applications, according to the method described by Viter et al. [2]. The ZnO nanorods were deposited on glass from 1 mg/ml ethanol solution, dried at room temperature and annealed in air at 400 °C for 1 hour. Bioselective layer was formed by immobilizing of specific antibodies on top of ZnO NRs. The obtained biosensor was used for photo luminescent detection of cancer cells (PA-1 line). Deposition of PA-1 cancer cells on the biosensor surface induced a decrease of the PL signal. The developed biosensor was sensitive to cancer cells concentration in the range of 10000-1000000 cells/ml.

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Quantum Optics Laboratory

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Quantum Optics laboratory was established at December 2013 at the Institute of Atomic Physics and Spectroscopy of the University of Latvia, Skunu street 4, Old Riga.



Research

- Precision optical frequency metrology with a femtosecond optical frequency comb.
- Development and improvement of optical frequency standards and comparison with radio-frequency standards.
- Development of ultra-stable resonators for laser line width narrowing.
- Free-space optical frequency transfer and distance measurements.
- Smart sensors, Internet of Things.

People

- **Dr. Janis Alnis, group leader**,
<https://scholar.google.lv/citations?user=kYt72h8AAAAJ>
- **Dr. Ilja Fescenko**, http://www.researchgate.net/profile/Ilja_Fescenko,
https://scholar.google.lv/citations?user=nLTU_OUAAAAJ
- **Dr. Christina Andreeva**, visiting scientists, Bulgaria
- **Dr. Asparuh Markovski**, visiting scientist, Bulgaria
- **Dr. Nikolay Bezuglov**, visiting scientist, Russia
- **MSc Inga Brice**, PhD student
- **MSc Aigars Apsitis**, technical assistance
- **Jāzeps Rutkis**, physics bachelor student

Main Publications

1. D.A. Cooke, P. Crivelli, J. Alnis, A. Antognini, B. Brown, S. Friedreich, ...Observation of positronium annihilation in the 2S state: towards a new measurement of the 1S-2S transition frequency, *Hyperfine Interactions*, 1-7 (2015).
2. I. Fescenko, A. Weis. Imaging magnetic scalar potentials by laser-induced fluorescence from bright and dark atoms, *Journal of Physics D: Applied Physics* 47 (23), 235001 (2014).
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Collaborations

- Precision spectroscopy of atomic hydrogen and optical frequency distribution over fiber link.
Prof. T. Hänsch group at MPQ, Garching, DE.
- Positronium spectroscopy. Dr. P. Crivelli group at ETH Zurich, CH. Preparing a 486 nm laser and 500 W build-up cavity. Building tellurium molecular reference in Riga for optical frequency measurements.
- Air quality measurements in laboratory and atmosphere, benzene, Hg, dust, CO₂ .
Prof. M. Knite at Riga Technical University, Dr. A. Ubelis, Dr. A. Skudra LU ASI.
- Coherence preserving ion crystals and spectroscopy using semiconductor diode lasers.
Prof. S. Svanberg, Prof. S. Kroll, Lund University, Sweden
- Laser spectroscopy of atoms, molecules, NV magnetometry.
Prof. M. Auzins and Prof. R. Ferber, Riga Laser Centre, University of Latvia.
- Spectroscopic imaging of magnetic field. Prof. A. Weiss Fribourg University. CH.
- Antihydrogen group at CERN lead by Prof. G. Gabrielse
- Frequency standards , PTB German Metrology Institute, Braunschweig, Dr. E. Peik, Dr. T. Mehlstäubler.
- Internet of Things technologies. Exploring new approaches for internet connectivity and global control. Electronics companies Farnell, Element14, Texas Instruments.

Financing

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Contribution of the Project to the Development of Assets for Applied Research to Ensure Collaboration with Research Driven SMEs within the Photonics Domain

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Even the best research ideas as well as the best knowledge and know-how, especially in the case of cooperating with industry, rather on the odd occasion provide a positive result, unless supplemented by a solid instrumentation basis making the implementation of the ideas and knowledge possible. Therefore, the relevant hardware has been of primary importance for the Fotonika project for research as well as collaboration with partners. Success stories to follow, have been promoted by the Fotonika-LV project.

Implants and BSI

Whereas our team was busy with GRIBA, a mobile ion instrument at the Gothenburg University (Sweden), the SME Baltic Scientific Instruments (BSI) being intrigued made an effort to collaborate with Fotonika-LV to build a small-size ion implanter for semiconductor crystals. From scientific standpoint there were three problems to solve – the gaseous forms of boron are extremely poisonous, the system demands frequent servicing, the mass selector magnet is drastically large, and the grid-less accelerator must work up to extremely high voltages. Experience with extremely volatile elements was useful making experiments with ionization of crystalline boron, which provided more details of how the plasma chamber must be made. A design was elaborated and an intriguing idea of how to suppress the freezing of boron on the inner walls of the plasma cell found. It is a magnetic radio-frequency accelerator unit – a linear induction engine rarely used in ion techniques, yet it simultaneously accelerates and squeezes ions in a plasma rope, called focusing in ion techniques. The experiment is pending – the effect has been observed but the appropriate computer modeling software imminent for further design to rely upon has not been found yet. The classical Sim-ion is too short for the task, LisaFea either, Maxwell didn't succeed, but Ansys is too expensive. So until now the search for better techniques or funding for elaboration of the exotic but powerful accelerator is going on. Instead of a magnet a four-rod RF-QMS mass selector could be used; however, it would not be reasonable to buy a mass-spectrometer class instrument for only taking out rods. For now no machining workshop of the required accuracy (ca +/- 0,5 to 1 micrometer) has been found for mass-selector of good enough transparency of the ion beam. Anyway, in the result it has been realized that such mini-size instrument may have a future market so it is worth the efforts, and the needs for producing the first demo apparatus have been formulated, the fate of the idea belonging now to writing successful fund-raising project.

Vacuum coating and VU2

A vacuum coating apparatus of good design with 70cm chamber, capable for work with filament sources and e-beam gun had the vacuum pumping system demolished and stayed unused. With support of Fotonika-LV and the efforts made to equip a place to exploit the machine all the necessary parts to refit it with turbo-pumps had been acquired. Soon the switch will be turned on to start collaboration with a potential partner – the Lithuanian laser producer Ekspla having a constant need for optical coatings. For better control of the processing accuracy Fotonika-LV had the chance to procure a

novel thickness meter detecting phase shift instead of detecting the quartz frequency shift. Ekspla is drawing the vision to possible collaboration as soon as Fotonika is ready to demonstrate the skills. The upgrade of the coating machine with a radio-frequency unit providing ability to make thick insulator-to-insulator coating layers is under way. Technical support for local R&D SMEs having ideas of innovative optical hi-tech devices that cannot be found in catalogs is another important task for the sputtering machine the mission of which will be providing small-series coatings to new demo devices.

The clean-room

As a rule, the smaller are the details that must be controlled at the coating process, the cleaner of dust must be the space. The cleaning factors and financial viability having been analysed a proper project of procurement work have been made to convert a 25 m² part of the basement into a high class clean-room. Since the works were not sponsored by Fotonika the construction has been much slower than expected, only now the clean-room is at the finish. It will boost high accuracy optical coatings in the whole Baltic region.

Multipurpose crystal growing

In collaboration with industrial partners Fotonika-LV has made efforts to grow the special sorts of selected semiconductor crystals. A borrowed apparatus for vacuum-growing by Chochralsky techniques has given nearly satisfactory results the problem being in the construction of the apparatus. Materials for a new crystal growing apparatus equipped with induction heater (sponsored together with the metal for stand by Fotonika-LV) have been purchased setting a good basis for cooperation.

GRIBA as test stand

In general the Gothenburg-Riga Ion Beam Apparatus has its place in the infrastructure for fundamental science. However, it has some application for practical use as well. It just allows for different methods of excitation of accelerated ion beams of different substances and preliminary mass analysis of the ion flux. Therefore, in cases such as with the BSI boron ion beam, this is the cheapest and most handsome way to test the purity and other parameters of the beam.

Astronomical mirrors

The contacts with the optics workshop of the Crimean Astronomical Observatory are interrupted by the change of the political situation and not available any more for high-accuracy services to renovate spherical mirrors. New projects of the Institute of Astronomy (LU-AI) and the Institute of Geodesy (LU-GGI) had to be suspended until the worn-out mirror coatings are renovated. By support from the Fotonika-LV funding the metal parts of a 1.35 m vacuum chamber have been acquired, complemented with decommissioned vacuum pumps and power sources to make a well-designed filament type vacuum metallization complex. In collaboration with a small commercial partner, HEE, a polishing stand will be delivered. A rough-carving machine is the third needed for the full service of spherical mirrors. Fotonika-LV capacities have been used to acquire a universal grinding machine for steel to modify for the purpose schedule after the project. A turning bench in relatively good condition of 82 cm diameter has been purchased at a bankruptcy sell-out for polishing support and customizing the vacuum vessel for science experiments. To accommodate the heavy-weight techniques requiring rather big place spare facilities at the premises of LU-AI in Baldone are going to be employed for general steelwork and glass-work. The workshop used by the three institutes and partners of the Fotonika-LV is expected to boost innovative inventions and design of instruments at the University and, hopefully, by R&D SMEs.

Baldone roofs

A spring hurricane had damaged the roof of the small telescope building in Baldone a year ago the rainwater beginning to cause rust on both the 70 cm telescopes (1.25m large telescope is still alive). Fotonika made a daring effort buying a barrel of epoxy resin and glass-textile a number of volunteer helpers making a capital repair to glass-plastic dome. The winter has shown that the expensive instrument under it is safe and water leaks have stopped. One of the minor telescopes is used for Solar science the other being reserved for future projects with SMEs.

Calcium 3-D printer

The chemical organization of a material to be inhabited by living bone cells and grown into natural bone is known. The problem of the revolutionary technique in traumatology is in a controllable heating to melt falling nano-droplets of calcite.

Earlier experiments with RF-ICP plasma bubble at near-atmospheric pressure have shown that ICP plasma generally fails to melt the mineral. The secondment schemes of the Fotonika-LV project have provided for hands-on learning at the Belorussian Heat and Mass Transfer Institute to find that the failure is due to choosing the wrong frequency. Increasing of frequency makes the plasma hotter. The microwave plasma torch being a simple solution the necessary specific microwave components have been ordered by another project and are on the way. If melting by the plasma torch is successful, it will be one more critical breakthrough facilitated by the Fotonika-LV project as the powerful booster of collaboration between science and innovative entrepreneurship.

Zvaigžņotā debess / The Starry Sky

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“Zvaigžņotā Debess” (ISSN 0135-129X) is the oldest popular science periodical in Latvia.

It is published four times a year (in March – Spring, June – Summer, September – Autumn and December – Winter) by the Latvian Academy of Sciences (LAS) and the Institute of Astronomy, University of Latvia (till 1997 the Radio-astrophysical Observatory of the LAS), the Publishing House “Mācību grāmata” (till 1996 the Publishing House “Zinātne”).

Editors-in-chief: Jānis Ikaunieks (1958-1969), Arturs Balklavs (1969-2005). [1]

Editorial Board: Dr.astron.h.c. of the LAS Dr.phys. Andrejs Alksnis, Corresp.memb. of the LAS Dr.habil.math. Agnis Andžāns (Editor-in-chief), Kārlis Bērziņš, Dr.sc.comp. Mārtiņš Gills (Deputy editor-in-chief), Ph.D. Jānis Jaunbergs, Dr.phil. Rihards Kūlis, Irena Pundure (executive secretary), Dr.paed. Ilgonis Vilks.

“Zvaigžņotā Debess” (“ZvD”, “The Starry Sky”) – popular science quarterly in Latvian (Contents in English). Since Autumn 1958, “ZvD” publishes surveys of seasonal astronomical phenomena, science news about the achievements of modern astronomy and space exploration (astronautics), articles on observatories and prominent scientists, philosophy and science history, folklore and Latvian world perception, and problems and solutions of astronomy, physics and mathematics olympiads for school youth. [2]

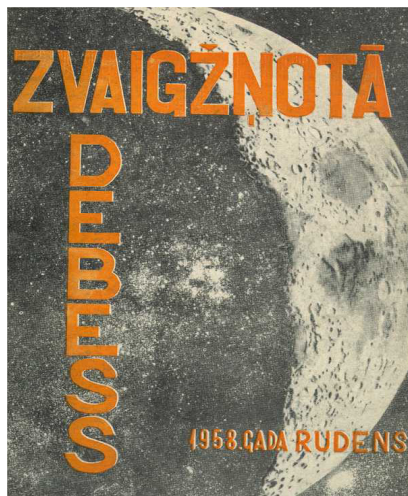


Fig.1. The Starry Sky, Autumn 1958. [3]

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Femtosecond Optical Frequency Comb

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The 2005 Nobel Prize for physics was awarded to J. Hall and T. Hansch for invention of the femtosecond optical frequency comb. Basically, they figured out an elegant method how to stabilize the pulse shape of fs laser, Fig. 1. Femtosecond optical frequency comb technology allows precise counting of optical frequencies to 14 digits in 1 s. In 2011, use of fs comb enabled optical frequency standards to surpass microwave frequency standards and re-definition of the Standard International second (SI) is anticipated. Presently the best optical frequency standards enable 18 digits of precision.

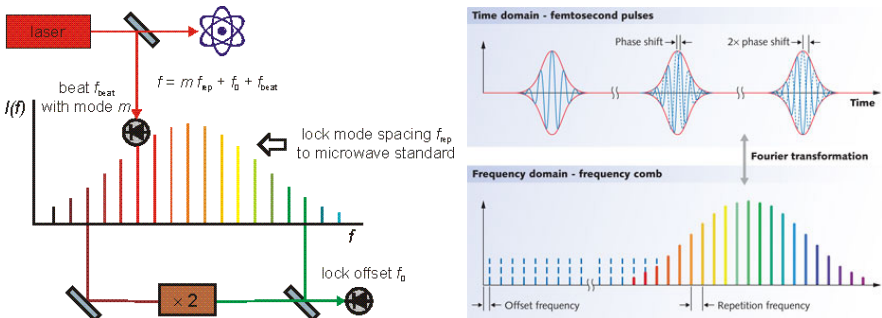


Fig. 1. Working principle of a stabilized fs frequency comb [1].

In Latvia within a Fotonika-LV project we have acquired a modern commercial femtosecond optical frequency comb system (Model FC1500-250-WG made by Menlo Systems, Germany) that can transfer frequency stability from the microwave region to the optical region.

Comb mode spacing is 250 MHz, wavelength range 35 nm centered at 1560 nm +/- 20 nm. Achievable accuracy of 10-14 or same as radiofrequency reference, whichever applies first.

The system contains a femtosecond fiber laser with integrated wedge for tuning of the CEO frequency, an EDFA amplifier, a highly nonlinear fiber for spectral broadening, a nonlinear f-2f interferometer based on a fiber-coupled waveguide, and the lock electronics to stabilize the repetition rate and the CEO frequency. User software, PC, and displays for system control and data acquisition are included.

The system includes a module to extend the stabilized comb of the FC1500-250 to the visible spectral range wavelength range 530 nm – 900 nm. The module contains a P250 PULSE-EDFA amplifier, a second harmonic generation unit, and a spectral broadening unit using a photonic crystal fiber.

It is a fully automated metrology system ready to measure. Telcordia GR-468-CORE qualified pump modules allow for 24h/7d operation. System requires a 10 MHz reference signal. We use GPS monitored Rb clock as frequency reference and achieve 11 digits of precision.

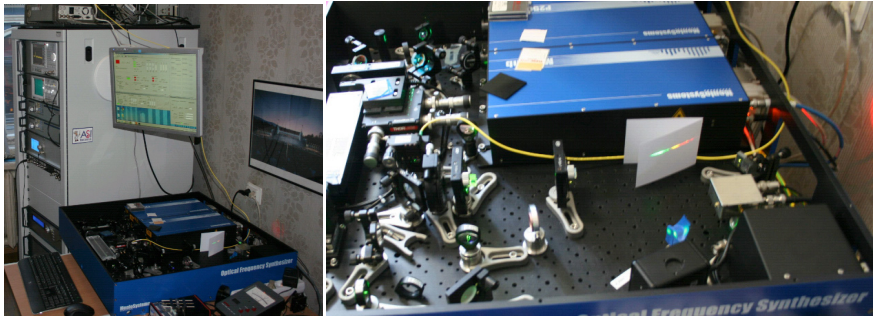


Fig. 2. Left: Optical frequency comb installed at the Quantum Optics Laboratory, LU ASI, Riga Skunu str. 4.
Right: Visible spectrum of the frequency comb.

As a first application we are practicing on the use of the system to re-measure precisely optical transition frequencies in Rb atoms and afterwards we will measure precisely positions of the Te molecular lines necessary for collaboration in laser spectroscopy of positronium at ETH Zurich.

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Project of Multi-purpose Optical Tracking System: Design and Deformations of Optical System's Transmitting Path

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The ESF-funded project of multifunctional optical tracking device is under construction in the Institute of Geodesy and Geoinformatics and Institute of Physics of the University of Latvia.

The planned result of the project is a functional prototype of newly designed multi-purpose optical tracking system for both positional and satellite laser ranging (SLR) observations with the additional capability to observe near-Earth objects (NEO).

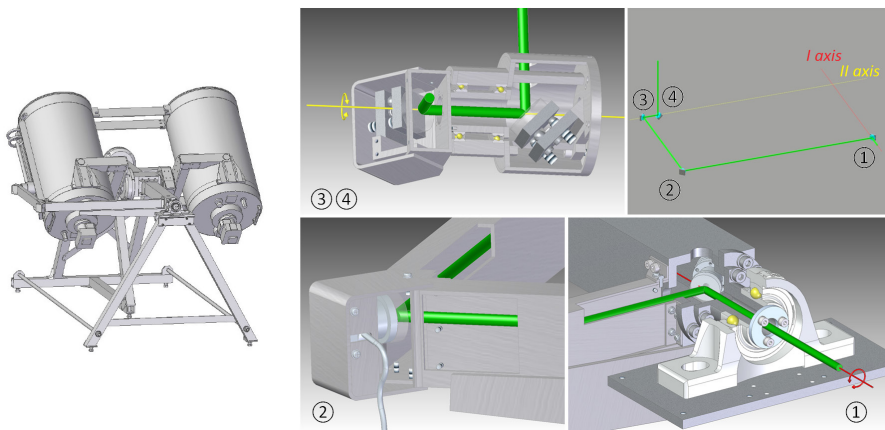


Fig.1. Design of device and separate optical units with laser path in beam turning mirrors' assembly.

This tracking system will be operating in both active (light-transmitting) and passive modes. In case of the active mode a pulsed laser (Nd:YVO₄, 50 Hz, 18 mJ, 28 ps) for SLR purposes or other light-emitting source for target illumination purposes can be used.

A novel optical scheme with three optical channels – one transmitter and two receivers, is being designed to provide precise pointing to support active more observations including daytime tracking.

The optical transmitter directs the laser beam through the system:

- the first two mirrors of laser path are equipped with actuators,
- each mirror reflects 99,5 % of laser beam light,
- laser beam turns at the mirrors with optimised performances at 532 nm wavelength,
- laser beam diameter is 6 mm,
- laser beam expander (10^x expansion presently).

Computer controlled high-performance tripod design actuators will be used for compensation of deformation effects in the beam path. Each actuator ensures beam deflection up to 2.4 mrad.

Deformation of system's first axis causes additional turning of the first mirror. To compensate for this additional turning a 3D actuator will be used that is associated with the mirror. As the actuator is fixed at the first axis, it must compensate displacements in two planes.

Tests will be performed after installation of montage with the aim to determine additional error sources which impact laser beam pointing. This will be achieved by star observations.

The research is funded by ESF Project:Nr.2013/0066/1DP/1.1.1.2.0/13/APIA/VIAA/059.

General Concept of Geoid Model Determination and its Verification using RTK

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Any kind of height data (geoid models, vertical deflections, normal heights, ellipsoidal heights) are used for precise geoid model determination. A mathematical tool within the general concept is the finite element model (FEM) surface approximation, which is used for the representation of the height reference surfaces (HRS). Combining ellipsoidal and normal heights with adapted geoid models Digital FEM Height Reference Surface is achieved using DFHRS program developed by Karlsruhe University of Technology. Vertical deflections are taken into consideration as an additional component of the concept for verification [1].

Ellipsoidal heights are computed using Bernese GNSS Software v 5.2, which is based on relative positioning. (Baseline between two points is determined, where one point is known and has precise coordinates). In this case only measurements from carrier phases are taken into account, because of their high accuracy. Double-difference solution of carrier phases is used. This method is considered to be the most precise as differences between both receivers and satellites are computed. Common formula for double-differences:

$$\phi_{AB}^{jk} t = \frac{1}{\lambda} \varrho_{AB}^{jk} t + N_{AB}^{jk}$$

where j, k – satellites, A, B – measured points, ϕ – double-difference, ϱ – distance between satellite and receiver, N – ambiguity parameters, λ – wavelength, t – time epoch [2].

Vertical deflections are determined using astrometric methods. The digital zenith camera developed by the Institute of Geodesy and Geoinformatics can be used for this purpose. At the moment this kind of data can serve as a verification of computed geoid heights deriving them and comparing with vertical deflections.

Another way how to check the geoid model is using RTK measurements on well-fixed points. Such points must be fixed somewhere in nature and should be as stable as possible to provide reliable accuracy of their coordinates and height component. If the above mentioned is fulfilled then such points can be used as reference e.g. for height geoid model verification. Of course, the level of accuracy of the verification is limited to accuracy of RTK measurements, which ordinarily under good conditions is approximately 1-2 cm in plane and 2-3 cm in height [3]. Therefore, it is recommendable to use such a method for raw verification only.

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Light Induced Diffusion Ionization of a Three Dimensional Hydrogen Atom

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One of the physical problems manifesting strong stochastic properties is a model of a Rydberg atom in an external microwave electric field $F_E(t) = F \cos(\omega t + \varphi)$ with the amplitude $E = F$ (atomic units are used). Under conditions of a dynamic chaos regime we consider a diffusion ionization of an Rydberg electron (RE) in the hydrogen atom. Applying external variable force $F_E(t)$ leads to chaotization of the RE motion under the condition when the force amplitude $|F|$ exceeds the critical value F_c . Electron states are specified by the principal n , orbital l , and azimuthal m quantum numbers [1]. The global chaos relates to threshold processes and occurs [2] provided

$$F > F_c \approx \frac{1}{n_0^4} \frac{1}{35(n_0^3 \omega)^{1/3} (1 - m^2 / l^2)^{1/2}}, \quad (1)$$
$$l \leq l_c \approx (3 / \omega)^{1/3}$$

The ionization rate of Rydberg atoms interacting with the microwave field is defined not only by one-dimension Rydberg electron (RE) energy dynamics, as it was assumed in earlier studies [2], but its angular momentum dynamics as well. We have improved split operator technique described in [3] for stationary systems having extended it to the important class of non-stationary problems – such as alkali atoms in alternating electric and magnetic fields. Split operator method and Floquet technique [4] allow us to perform numerical calculations with high accuracy in the case when standard methods of numerical integration of classical equations of motion, like Runge-Kutta method, appear to be unsatisfactory. Implementation of the Floquet technique allows one to find the optimal sequence of the atomic core and field (external perturbation) partial evolutions of the RE orbit for nonstationary Hamiltonian systems under the frame of the split operator technique. The latter makes it possible as well to redefine the effective Hamiltonian corresponding to the external field in an explicit form resulting in both the reduction of the error inherent in the method and in stabilization of the obtained solutions.

The presented results of the numerical experiment (Fig. 1. and Fig. 2.) exhibit the effect of an external microwave electric field influence on the RE orbital momentum L evolution for a hydrogen atom. It is well seen several characteristic types of the L dynamics. We revealed the unique orientation of the Runge–Lenz vector A_0 and the field polarization vector E_0 ($A_0 \parallel E_0$) for which the orbital momentum L ($L_0 = |L_0| = l_0 + 0.5$) remains almost constant (Fig. 2a). In the case of other configurations, a trend toward a significant change in L is clearly observed, i.e., in terms of the quantum theory, it occurs a noticeable mixing of states with different orbital quantum numbers l . Note that the aforementioned conclusion agrees with the results of [5]. Based on the multichannel quantum defect technique, it was demonstrated there a strong mixing in output reaction channels with different orbital momentums for reactions going via an intermediate collisional complex under the

presence of a complicated ramified structure with multiple self intersection of internal resonances. Nevertheless, our data do not cancel out the results of the one dimensional diffusion ionization approach [6, 7], which accounts for the chaotic RE migration only along the energy spectrum without regard to the change in L . In all numerical experiments performed here, momentum L does not reach the critical value L_c (1). Since both the critical field strength E_c value (1) and the diffusion coefficient [6, 7] weakly depend on L in the range $L < L_c$, statements of [8, 9] must keep their adequacy.

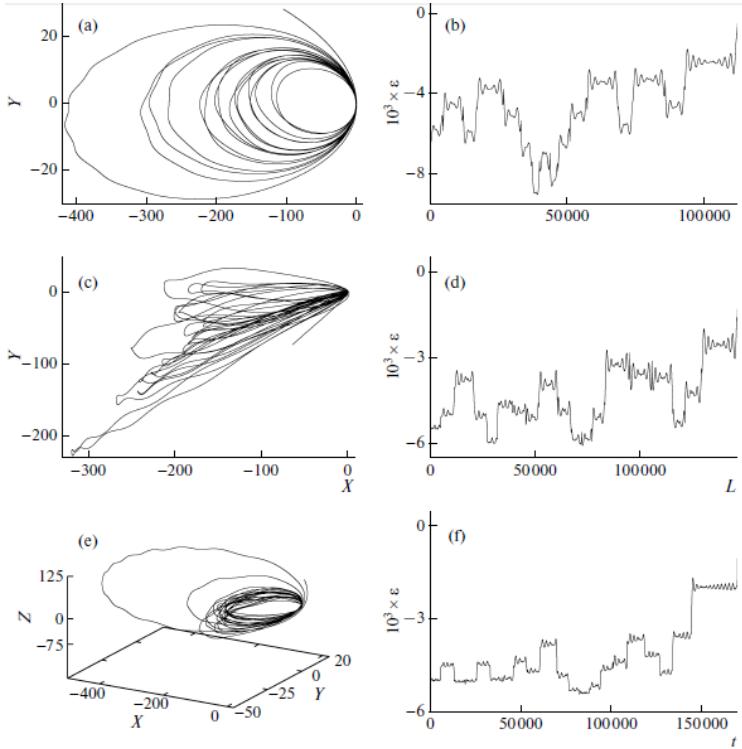


Fig. 1. (a, c, e) Electron trajectories corresponding to the 10P ($l_0=1, n_0=10$) state and (b, d, f) dependences of the electron energy on time. The upper (a, b) and middle (c, d) curves correspond to the case of plane motion ($E_0 \perp L_0$) with configurations $E_0 \parallel A_0$, $E_0 = -10/(49n_0^4)$ and $E_0 \perp A_0$, $E_0 = 16.4/(49n_0^4)$, respectively. Here, $E_0 = -F$ is the polarization vector of the external field. The lower (e, f) curves correspond to the case in which the vector of the field amplitude $E_0 = -12.9/(49n_0^4)$ lies orthogonally to the initial motion plane X, Y and is directed along L_0 (the Z axis). All quantities are given in atomic units.

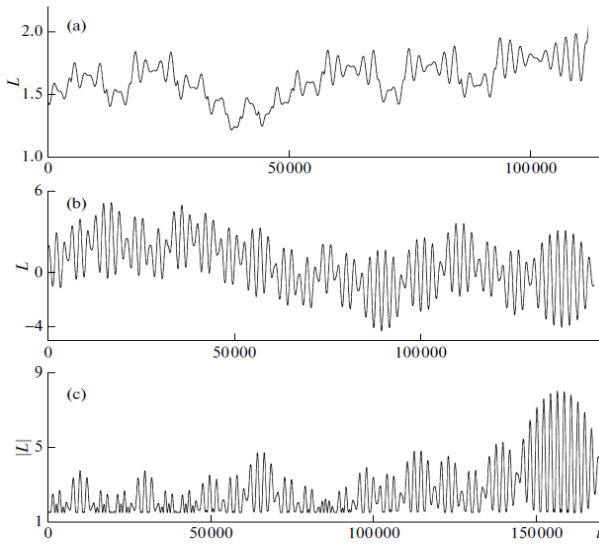


Fig. 2. Time dependence of RE angular momentum L . The sequence of plots and corresponding problem parameters are the same as in Fig. 1. In the case (a, b) of plane motion, amplitude $L = L_z$ is presented. For the three-dimensional motion (c), the modulus $L = |L|$ is shown. All quantities are given in atomic units.

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Advanced Beam Pulsing Hardware for Negative Ion Spectrometry

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Negative ions are atoms or molecules with an additional electron in their shell. Since early eighties of the last century the negative ions are subjects of interest for theoretical modeling in atomic and ion physics. As quantum systems they are interesting from a fundamental point of view, as an electron-electron correlation effects have large impact on the binding energy and structure of higher energy levels. Thus a comparison of spectroscopic experiments and theoretical calculations can give insight into this still not fully understood phenomenon.

It has been taken for granted that negative ions are very important in molecular processes of the interstellar media[1], but more massive efforts are needed and therefore progress in the development of more effective negative ion sources will be helpful.

The history of experimental research on negative ions is also counted in decades. Still in use an universal negative ion source has been proposed [2] and developed [3] by Middleton in 1974 and 1985 accordingly. Further developments are described in monographs [4], [5] published in 2004 and in 2005. The Middleton type negative ion source consists of a cathode, a heated ionizer electrode and an extraction electrode. It's limitation is the inevitable need to stop the experiment after (10-20) hours because cathode materials are sputtered away very rapidly resulting in the need to clean or to replace the cathode frequently. The other problem is a limitation to use possibly higher ion currents.

The paper describes the development and the results of new approach the idea is to adapt pulsed voltage (*techniques used in double-ring synchrotrons*) to pulse the sputtering and hence to increase the lifetime of the cathode (*no frequent cleaning or replacement is needed*) and therefore to get substantially increased continuous operational time for the experimental series. This is particularly useful for elements where the cathode lifetime is short and the properties of the cathodes is hardly repeatable from cathode to cathode. Pulse mode allows also to operate with higher ion currents in the beam.

Test and control experiments were performed at the Atomic Physics labs of the Gothenburg University on experimental installation in Gothenburg University – Negative Ion Laser LABORATORY (GUNILLA). This facility consists of a negative ion source, of an ion beamline with a mass selective dipole magnet and electrostatic ion optics – two electrostatic quadrupole deflectors Q1 or Q2 – which can direct ion beam towards two different interaction regions, where the ions can be merged with laser beams. Detailed technical description of GUNILLA is available in Anton O Lindahl's PhD thesis [6].

1. Experimental Method

1.1 The basic principle of classical Middleton sputter source

In ordinary experiments with negative ions the Middleton sputter source of negative ions consist of cesium oven (*reservoir of solid cesium*) emitting a beam of Cs atoms, *see Figure 1*. The evaporated atoms are hitting the concave surface of tungsten anode (*thermally ionizing electrode*) of the size of an inch (*with a tiny hole in the center*) where Cs atoms are thermally ionized and Cs⁺ ions are reflected to the cathode, holding the sample in it's hole. Bombardment of frontal surface of cathode and the sample in the hole results in production of negative ions from the sample substance by charge transfer.

Particularly for the GUNILLA, the cathode is made of a solid aluminum cylinder of diameter of 1cm. A pre-drilled hole of 5mm diameter is filled with needed sample substance to produce accordingly needed negative ions. In the traditional operational mode the cesium atoms from the Middleton sputter source form a layer on the front surface of the cathode acting as a donor of **electron cloud** into Cs thin layer around the cathode cavity. Any atom or molecule sputtered out of the cathode passes this layer and has the chance to absorb an electron. A guide how to design a cathode for production of various negative atomic ions most efficiently is described by R. Middleton [7].

The cesium oven is a grounded vacuum chamber with precisely controlled temperature (*saturated pressure of Cs vapor is in exponential dependence of temperature*) blowing a small diameter beam of Cs atoms toward the anode when heated. A high-voltage power supply ensures the potential of anode up ca. +3 kV against the cathode and oven. The anode is heated by a filament spiral cemented on backside of the concave disk and is brightly glowing. Neutral Cs atoms are transformed to Cs⁺ after hitting the heated anode (*thermal ionization*). Potential difference between the anode and cathode accelerates Cs⁺ ions to hit the target substance in the cathode where negative ions are created by the surface charge exchange. Upon exiting from the cathode, the negative ions specific to experimental substance in use are accelerated by the few kilowatts voltage applied to the concave extractor behind the anode toward the hole in the center of the anode. The negative ions passing the hole and emerging on the other side of the anode are attracted by the cone-shaped extractor electrode and are accelerated towards the system of ion optics designed to form the ion beam. It has to be noticed that due to Faraday cage effect there is no electric field inside the extractor. The sputtering gun is actually a part of the high voltage-platform (*Fig.2*) where the power is supplied in inverted way to the grounded extractor-vacuum chamber unit. All voltages of the electrodes of the high-voltage platform are shifted: the anode potential is negative with respect to the grounded extractor, the oven potential – negative with respect to the anode, potential of the target being the most negative.

In details the process of forming the negative ions on the cathode is the following:

- The bombardment of front surface of the cathode and the sample substance (*packed in the cup-hole drilled in the center of the cathode*) with the Cs⁺ creates neutral (*ca. 10 atomic layer thick*) cesium layer;

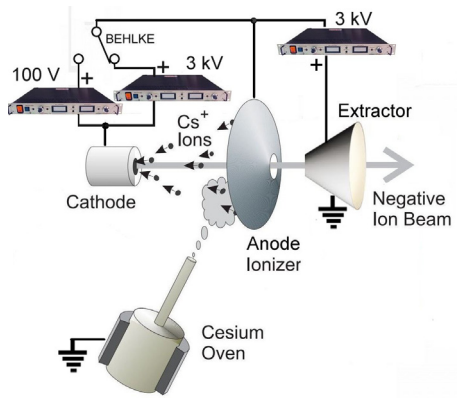


Fig.1. Pulsed mode Middleton type negative ion source with Voltage sources interconnections in it. For ordinary type of this source just unexist the 100V Voltage source at most left side and Behlke switch.



Fig. 2. Unused, pulsed sputtered and continuously sputtered cathodes (from left to right).

- Arriving Cs⁺ particles upon contacting the cathode surface are neutralized, still many Cs⁺ ions penetrate deeper into the sample substance sputtering it out of the cathode. The depth of sputtering depends on the energy of Cs⁺ ions, i.e. the potential difference. The cathode is water-cooled to allow condensation of cesium;
- Particles of the sputtered substance pass the electron-saturated Cs layer and obtain electron in the charge transfer from the layer or in collision with incoming cesium ions Cs⁺ and depart as negative ions, since the electron affinity of Cs is considerably lower compared with the affinity of typical experimental substances. In specific cases excitation of atoms or molecules of the sample substance may occur and negative ions are formed in an excited state rather than in the stable ground state [8].

Unfortunately in experiments with duration of 10-20 hours the Cs layer on the cathode becomes thicker due to various processes and the system needs to be cleaned up. Therefore, the concept of the pulsing high-voltage mode or the Gothenburg Pulsing Source was proposed, designed and tested, see chapter 1.3.

2 Experiments and results

Pulsing operational mode of the high-voltage mode was incorporated and applied to the GUNILLA experimental configuration described above and two types of test and control experiments performed:

- testing of the system in a routine (*ordinary*) negative ion experiment with eight various sample substances being used;
- test, control and comparison of cathode quality in two operational modes.

The experiments were performed with 6 ns scanning lasers pulses at 10 Hz repetition rate, which implies a duty cycle (beam in-use) of the experiments less than 10⁻⁷ which means that in case of constantly powered ion source the major fraction of the ion beam remains unused. In order to obtain a longer operational lifetime of the cathode, to avoid degradation as well as to increase the ion current a high-voltage switch was implemented in the sputter source and synchronized with the laser beam.

The detailed results of experiments was positive and will be more detailed shown at already written publication, which hopefully will publish the Atomic Physics Journal.

CONCLUSIONS

Solution of the sputter-source problem is adapted taking into account that in many experiments the ion beam is collided with short pulsed laser beam. Therefore for the investigation of interaction of both beams only small fraction of ion beam is needed with the length corresponding to the time of flight of negative ions in time frame of pulse of laser beam. Test experiments with GUNILLA experimental facility modified towards pulse mode operation of ion

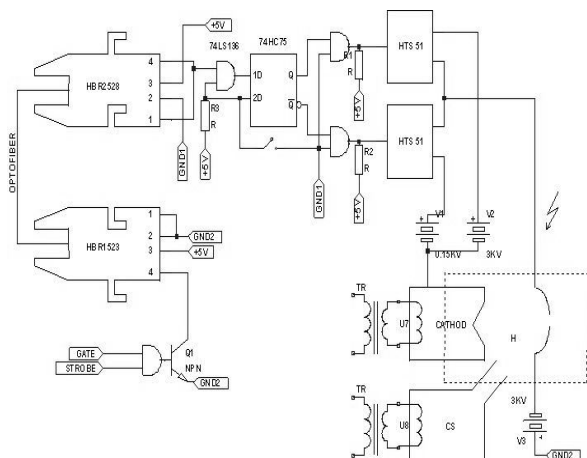


Fig.3. Electrical circuit of HV installation

beam demonstrated, that in case when ion sputtering is switched simultaneously with laser beam, experiments with a single sample substance for the needed ion beam may last longer to perform experiments without refilling the sample substance and cleaning the cathod, thus increasing the experiment active time-span and as consequence increasing the sensitivity and/or accuracy of results.

Acknowledgments

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TRIZ Knowledge for FOTONIKA-LV

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TRIZ is a theory for inventive problem solving that has been developed in Soviet Union by G.Altshuller and his team. Nowadays TRIZ is being applied worldwide for technical and non technical problem solving. In 2015 SCOPUS database shows more than 1380 documents when searched by keyword "TRIZ".

TRIZ master Dr. Alexander Narbut from Ukraine was recruited in Association FOTONIKA-LV, Institute of Atomic Physics and Spectroscopy, University of Latvia within a FOTONIKA-LV REGPOT project [1]. In February – April 2015 A. Narbut visited research laboratories and gave lecture course on TRIZ (more than 15 lectures). This introduced TRIZ methodology to FOTONIKA-LV and is expected to foster the development of innovations within this institution. A booklet of about 150 pages on TRIZ in English and Russian is publicized by A.Narbut for FOTONIKA-LV to ensure that TRIZ methodology is being used more widely within FOTONIKA-LV.

There are various resources on TRIZ available in English and Russian [for example, 2-7], yet preferred are resources published by founder of TRIZ – G.Altshuller.



Fig.1. A. Narbut giving lecture in Association FOTONIKA-LV in April 2015.

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