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FOTONIKA-LV
LATVIJAS UNIVERSITĀTES ZINĀTNISKO INSTITŪTU ASOCIĀCIJA

The 2nd FOTONIKA-LV conference

“Achievements and Future Prospects”

Two years after the end of the project:

FP7-REGPOT-2011-1, No. 285912, FOTONIKA-LV
“Unlocking and Boosting Research Potential for Photonics in Latvia –
Towards Effective Integration in the European Research Area”

Riga, 23–25 April, 2017

Dedicated to the 7th Anniversary of the Association FOTONIKA-LV,
50th Anniversary of Schmidt–Cassegrain telescope in Baldone

Riga, 2017

Conference Scientific Committee

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Dr. Ilgmārs Eglītis
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Preface

The 2nd FOTONIKA-LV conference ***"Achievements and Future Prospects"*** – Two years after the end of the project: FP7-REGPOT-2011-1, No. 285912, FOTONIKA-LV "Unlocking and Boosting Research Potential for Photonics in Latvia – Towards Effective Integration in the European Research Area" was held in Riga (April 23–25, 2017) exactly two years after the first one. April 24 is the birthday of the Association FOTONIKA-LV. In early spring seven years ago, the directors of three institutes signed a unique agreement in the history of Latvian science creating a framework in which research communities targeting quantum sciences, space sciences and related technologies are joining forces to challenge great tasks and large projects under the umbrella of photonics – the technology of the 21st century. Many leading EU member states have defined their own photonics strategies, and photonics is ranked among 6 Key enabling technologies.

The wisdom in founding the association was specifically highlighted on January 2014 in the report of international evaluators of Latvian science led by TECHNOPOLIS group[1]: *"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 € 3.8 million. Other laboratories should follow this example".*

From now on, the FOTONIKA-LV conference ***"Achievements and Future Prospects"*** is going to be a biannual tradition. It will provide opportunities to the community of FOTONIKA-LV via comprehensive efforts to highlight results of research activities in many cases jointly with partners in the EU and worldwide as well as to reveal plans and ideas for future.

The book of the 2nd FOTONIKA-LV conference is a collection of abstracts and articles related to the research activities and project life of the association FOTONIKA-LV; therefore it has the role of a business card for the emerging National Science Centre FOTONIKA-LV for the next 2 years until the 3rd conference.

Finally, worth to mention, Teams from research groups forming the emerging **NSC FOTONIKA-LV** have been contributing to **various research and technology developments** in Latvia since the early 1960s in photonics, quantum sciences, space sciences and related disciplines and technologies. Examples include:

- Quantum optics, laser spectroscopy, VUV spectroscopy, UV and visible light spectroscopy;
- Atomic, molecular and optical physics; molecular beam and ion beam physics; ICP plasma devices;
- Atmosphere physics and photochemistry and the development of atmospheric remote sensing devices;
- Observational astronomy, spectroscopy and astrophysics of galactic carbon stars as well as research on late evolution stars (*MS, S type*);

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[1] Latvia. Innovation System Review and Research Assessment Exercise: Final Report, TECHNOPOLIS, April 20, 2014: http://izm.gov.lv/images/zinatne/ZISI/Latvia-systems-review_2014.pdf

- Observation, and monitoring of small objects of the Solar System and Near Earth Objects with wide field Ø1.2 metres Schmidt type telescope in Baldone (*Code 0.69, valuable contributor to ASTRONET*[1]);
- Satellite laser ranging (SLR) instruments, including software and hardware components. Design of precision optical systems with apertures up to Ø35 cm for astronomy, laser ranging, remote sensing;
- The laser telescope LS-105, a world-class instrument, with which the Latvian astronomers have corporate obligations and have been serving to the International Laser Ranging Service Valuable for decades. This has been and continues to valuable to Earth geodesy and geodynamics measurements with (ILRS code name RIGL-1884, Riga) and planetary geodesy and Earth geodesy measurements;
- Biosensors, bio photonics for cardiovascular monitoring, and biomedical optics;
- Optical fibres technologies, in particular UV fibre optics;
- Vacuum-sputtering, quartz, glass and vacuum technologies.

Dr. Arnolds Ūbelis
The Chair of the Scientific Committee of the Conference
Scientific Secretary of the Association FOTONIKA-LV
University of Latvia

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[1] ASTRONET – www.astronet-eu.org (organised Forum on Astronomy in Latvia – 17 September 2014)

Agenda

The 2nd FOTONIKA-LV Conference "Achievements and Future Prospects"

Riga, 23–25 April, 2017

APRIL 23 Baldone – Astrophysical observatory

15.00–15.30	**WELCOME** **Welcome messages sent by invited honoured guests:** Members of Saeima: **Atis Lejiņš, Veiko Spolītis**; Former EU Commissioner **Andris Piebalgs**; Prof. **Anthimos Georgadis**, Leuphana University of Lüneburg, Lüneburg, Germany
15.30–17.00	**1st plenary: Astrophysics and Astronomy** Chairs: Dr. Phys. **Arnolds Ūbelis,** Dr. Phys. **Ilgmārs Eglītis**
	Dr. Andris Vaivads, ESA mission candidate THOR **Dr. Ilgmārs Eglītis**, Astrophysics and Planetary Sciences in Latvia **Dr. Ilgmārs Eglītis, Dr. Valdis Avotiņš**, Radio astronomy in Latvia
	Exhibition and invited poster session

APRIL 24 Institute of Atomic Physics and Spectroscopy, Šķūņu 4

10.00–12.00	**2nd plenary: Quantum Sciences and Technologies** Chair: Dr. **Teodora Kirova**
10.00–10.30	**Welcome words from invited honoured guests**
10.30–12.00	*Key note lectures:*
10.30–11.00	**Dr. Arnolds Ūbelis**, Summary of efforts during the last two years
11.00–11.30	**Dr. Jānis Alnis**, Major achievements in fundamental sciences
11.30–12.00	**Dr. Aigars Atvars**, Synergy between fundamental and applied sciences
12.00–12.30	Coffee Break
12.30–14.30	**3rd plenary: Space sciences, Geodynamics and related Technologies** Chair: Dr. **Ilgmārs Eglītis**
12.30–13.00	**Welcome words from honoured guests**
13.00–14.30	*Key note lectures:*
13.00–13.30	**Kalvis Salmiņš, Jorge del Pino**, Advances in Geodynamics research
13.30–14.00	**Dr. Māris Ābele, Jānis Vjaters, Andris Treijs**, SLR advancements
14.00–14.30	**Dr. Jānis Kaminskis, Dr. Jānis Zvirgzds**, Advances in space geodesy and geoinformatics
14.30–15.15	Lunch Break
15.15–17.00	**Poster Sessions** Chair: Dr. **Aigars Atvars** A. Quantum sciences and technologies B. Astrophysics, Space sciences and Technologies C. Applied and Industry research D. Disruptive Innovations and SMEs

APRIL 25 Institute of Atomic Physics and Spectroscopy, Šķūņu 4

10.00–12.00	**Open lecture session from invited guests**
12.00–13.00	**Short Communications** (upon requesting floor)
13.00	Closing

List of Exhibited Posters

23 April: Baldone – Astrophysical observatory;

24 April: Rīga – Institute of Atomic Physics and Spectroscopy

Nano Satellite imaging system design proposal	M. Abele, J. Vjaters, A. Treijs
Nano-Satellite FSO data Terminal design proposal	M. Abele, J. Vjaters, A.Treijs
Transportable FSO system Ground Terminal for flying platform: design proposal	M. Abele, J. Vjaters, A. Treijs
Optical clocks outperforming microwave clocks	J. Alnis
Photonics, Quantum Sciences, Space Sciences and Related Technologies – Cluster and Smart Specialization	A. Atvars
The project "Feasibility study of diode spectrometer" and preparation of project proposals for Horizon 2020 SME Instrument calls	A. Atvars, A. Ubelis, V. Z. Beldavs
Photonics in Horizon 2020	D. Bērziņa
Short historical compendium on RF ICP power sources circuitry	J. Blahins, A. Apsitis, J. Busenbergs
Effective Cooperation Project between LU ASI and KEPP Ltd.	J. Blahins, A. Bžiškjans, A. Atvars
Effective Cooperation Project between LU ASI and BSI Ltd.	J. Blahins, A. Ciniņš, A. Ūbelis
Towards WGM Resonator stabilized on Rb-5P transition lines	I. Brice, A. Pribitoks, J. Alnis
Interatomic Förster resonance and anomalous low spontaneous decay of p-series states in Na	A. Cinins, K. Miculis, K. N. Arefieff, N. N. Bezuglov, A. N. Klyucharev, A. Ekers
SLR Station 1884 Riga Upgrading the Station Calibration Procedures	J. del Pino, I. Liubich, S. Melkov, K. Frolkov, S. Horelnykov, K. Salmins
Trilateral grant of the Latvian, Lithuanian, and Taiwanese Research Councils "Quantum and Nonlinear Optics with Rydberg-State Atoms": first year achievements	T. Kirova, A. Cinins, M. Auzinsh, I. A. Yu
Selective Excitation of Uncorrelated Sets of Adiabatic States in Non-degenerate Hyperfine Level Systems	T. Kirova, A. Cinins, D. K. Efimov, K. Miculis, M. Bruvelis, N. N. Bezuglov, N. Auzins, A. Ekers
Latvia-France Partnership Program OSMOZE "Electromagnetic Field-Control of the Blockade/Antiblockage Effect in Rydberg Ensembles": first year achievements	T. Kirova, A. Cinins, N. K. Sandor, G. Pupillo
Designed of a pulsed negative ions source	T. Leopold, J. Rohlén, D. Hanstorp, J. Blahins, A. Apsitis, U. Berzins, A. Ubelis

Gaismas atstarošana	N. Lesiņa
Photodissociation of oxygen molecules upon the absorption in Shumann-Runge bands in various environments: modelling study	A. Pelevkin, K. Miculis, A. Ubelis, N. S. Titova, A. M. Starik
Fast mapping of four skin chromophores by double-snapshot technique	I. Oshina, J. Spigulis, U. Rubins
Control system of rotating mirrors of telescope TPL-1	V. Pap, Y. Hlushchenko
Estimation of optical fiber melting temperature from the Planck's law using a grating spectrometer	A. Pirktiņa, I. Brice, A. Atvars, J. Alnis
Thin RF Magnetron Deposited Antimicrobial HAP-0.4 Zn Coatings: Structure and Cellular Response *in vitro*	K. Prosolov, Yu. Sharkeev, K. Popova, E. Zschech, V. Hruschka, X. Monforte
Estimation the contribution of each electronic instrument in the overall measurement error	K. Salmins, V. Bespal'ko, I. Liubich, S. Melkov, K. Frolkov, S. Horelnykov
SLR Station Riga Status Report	K. Salmins, J. Del Pino
Modelling and building quasi-levitating melting zone crystal growth facility	V. Silamiķelis, A. Krauze, Ā. Krūmiņš, A. Apsītis
The project "Development of nanotechnology based biosensors for agriculture – BIOSENSORS-AGRICULT"	A. Ubelis
The project "NOCTURNAL ATMOSPHERE" – Secondary photochemical reactions and technologies for active remote sensing of nocturnal atmosphere	A. Ubelis
The project "The development and testing immune to electromagnetic interference high temperature sensor" and preparation of the common project proposal for Horizon 2020 SME Instrument Phase 2 call	A. Ubelis, A. Atvars, F. Pliavaka
Collaboration in the modification and development of ICP RF power generator and special sources adapted for usage in ROFLEX 2 instrument for measurements of Iodine and Bromine in atmosphere	A. Ūbelis, A. Saíz-Lopez
Upgraded MAXDOAS instrument for validation of atmospheric spectra sensors on Earth satellites platforms and independent tests of air quality in Riga	A. Ubelis, J. Vjaters

List of Short Communications

25 April: Rīga – Institute of Atomic Physics and Spectroscopy

The SLR Telescope EGLE mount	M. Abele, J. Vjaters
Geomagnetic storms and their impact on kinematic GNSS solutions	J. Balodis, I. Janpaule, D. Haritonova, M. Normand, G. Silabriedis
Cooperation in Space Technologies with Africa	V. Beldavs
International Lunar Decade 2020-2030: A Key Role for Europe	V. Beldavs
Rīgas Fotonikas Centra darbība un nākotnes plāni	V. Beldavs
Fabry-Pérot resonator for laser stabilization below 1 kHz line width with stability better than 100 Hz/s	I. Brice, A. Atvars, J. Alnis
STIRAP nonadiabaticity and optimal choice of experimental parameters	A. Cinins, N. N. Bezuglov
Baldone Schmidt Telescope	I. Eglitis
Horizon H2020 projects at the Institute of Astronomy	I. Eglitis
System for Control and Unwinding Telescope Cables	Y. Hushchenko, V. Pap, M. Aribzhanov
Recent state and vision for development of Complementary SLR (optical range) and radar-VLBI (radio range) near-space observation methods	N. Jekabsons, K. Skirmante, K. Salmins
Electronic module for the RON-series angle encoders	M. Medvedskyy
Bio-Sensing Antioxidant-Specific Biomarkers by Microwave Dielectric Whispering-Gallery-Mode Resonator	N. Naumova, N. Rostoks, H. Hlukhova, S. A. Vitusevich
Prospects of Hybrid Organic-Inorganic Photovoltaic Solar Cells	P. Smertenko, N. Roshchina, V. Naumov, G. Wisz, A. Ubelis
Bilateral LV-UA and LV-FR (OSMOZE) projects as long lasting collaboration between project partners of FP-7 project BIOSENSORS-AGRICULT (Project No.: 318520)	R. Viter

Plenary Reports

ESA Mission Candidate THOR

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THOR is a mission proposal, in response to the ESA M4 call, to address one of the most widespread and fundamental, but also one of the least understood, physical processes in the universe: turbulent energy dissipation and particle energization [1, 2]. In general, the dissipation due to the turbulent fluctuations is believed to be one of the main processes of plasma heating and particle acceleration in different astrophysical as well as laboratory plasma environments.

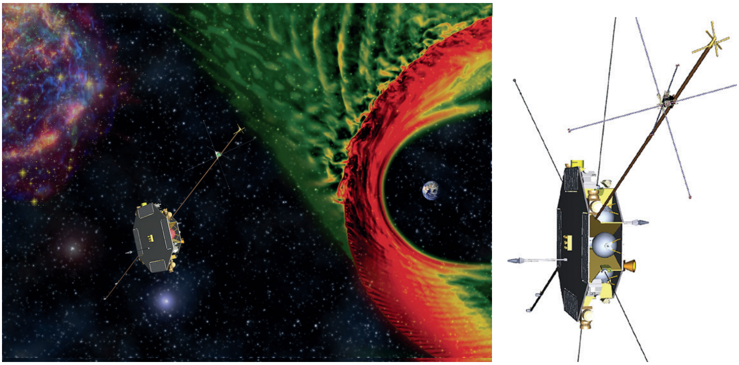

Fig. 1. *Left: THOR will explore the near-Earth space, the key science regions being pristine solar wind, bow shock and magnetosheath. Right: THOR will be slowly spinning sunpointing spacecraft with 10 instruments measuring plasma electromagnetic fields and charged particles. The particle instruments are mounted on the platform of the spacecraft, and the electromagnetic field measurements are made with sensors on two solid booms and four long wire booms*

THOR addresses the ESA Cosmic Vision question "How does the Solar System work?" and will answer the following science questions:

Q1: How are plasmas heated and particles accelerated?
Q2: How is the dissipated energy partitioned?
Q3: How does dissipation operate in different regimes of turbulence?

In comparison to earlier missions key required improvements are: accuracy and sensitivity of electric field measurements, sensitivity of magnetic field measurements, temporal resolution of mass-resolved ion measurements (H^+, He^{++}), temporal and angular resolution of pristine solar wind ion measurements, temporal resolution of electron measurements, wave and electron correlation up to electron plasma frequency. The nominal mission contains three one-year phases focusing on 1) bow shock and magnetosheath, 2) foreshock, 3) pristine solar wind.

In June 2015, THOR was selected by ESA as one of three missions to enter a 2-year study phase. ESA is expected to make the down-selection before the end of 2017.

References

[1] Vaivads, A., et al. (2016). Turbulence Heating ObserveR – satellite mission proposal, J. Plasma Phys., 82(5), doi: 10.1017/S0022377816000775

[2] http://thor.irfu.se

Space Research Visions at Baldone Observatory

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The research at Baldone Observatory is focused on four areas: investigations of carbon stars by B, V, R, I photometry and low, high resolution spectroscopy, monitoring of small bodies of the Solar system, digitising of the wide field 24300 plate archive of the Baldone Schmidt telescope and popularisation of astronomy.

In previous decades, more than 5% of carbon stars in the Milky Way Galaxy have been discovered. Main photometric characteristics of these stars were investigated. New type of variability of late stars – DY Per with irregular dimming by 2–5 magnitudes was selected.

"General Catalogue of Galactic Carbon Stars" has been prepared by astronomers of the institute in 2001.

Carbon stars are interesting not only from a stellar evolution point of view, but as it has been revealed in the first summarising studies they also delineate the spiral structure of the Galaxy. The results of searches done so far are summarised in the General Catalogue of Cool Carbon Stars (CGCS) [1] containing 6991 entries. Most of the findings have been made using objective prism spectra recorded on photographic plates in the visual spectral region by wide-field telescopes. However, the search could be done more efficiently in the near infrared region where the radiation maximum of carbon stars is localized and fainter objects come in reach.

A new prospect of the spectrophotometry of carbon stars at low resolution opens applying of CCD's – more sensitivity than photo-plates, providing possibilities of quantitative measurement of spectral details and reaching further in the infrared region. However, a serious drawback is the reduction of the field area. Searching for new carbon stars may overcome this obstacle using the 2MASS catalogue [2] containing J, H, and K magnitudes for thousands of very faint red stars. We take objective prism spectra with the CCD camera of all northern sky 2MASS objects brighter than $J = 10$ magnitude with colour index $(J - K) > 1.5$ magnitude, to check which of them may be new cool carbon stars. The limit on $(J - K)$ is chosen, to exclude prevalent numerous early M-type stars. As it is shown by [3], where colour index distribution of known carbon stars has been analysed, approximately this $(J - K)$ value is the boundary at which cool carbon stars come in light. For the search the range 550 nm – 900 nm has been exploited, where carbon stars are brighter than in blue. Further investigations reveal possibilities to obtain absolute magnitudes, distances and effective temperatures of carbon stars. From one side these studies allow to study the Milky Way structure, on the other side the study of the distribution of C stars in the Galaxy shows interesting concentrations of this type of stars and possibly will push development of the theory of evolution of the C stars.

Small bodies of the Solar system have been monitored at the Baldone observatory since 2008. Forty-eight new asteroids have been discovered, 11 have been numbered and labelled; 3511 astrometric positions of 826 asteroids have been calculated in cooperation with the Institute of Theoretical Physics and Astronomy, Vilnius University. Orb-Fit v. 4.0 program which takes into accounts the planets and Ceres, Pallas, Vesta perturbations, is used for ephemerides calculations in the case of Main belt asteroids, while Orb-Fit v. 4.2 taking into consideration perturbations of 25 objects applies to the Trojan and Centaurus asteroids.

The success of small solar system body characteristics research provides an opportunity to participate in projects related to this property of the practical applications – mining on the asteroids. Asteroid-monitoring is important from a safety point of view, too.

First results obtained from processing of the digitised data of the astronomical Archive reveals a high potential of further development. There are observations that upgrade Pluto orbit elements the observations of more than 87 asteroids, besides ephemeris of ten asteroids, have been obtained many years before discovery of the data.

Upgraded mechanics of the Baldone Schmidt telescope and upgrade of the optical system by fly-eye technologies allow looking forward to participating in projects of investigations of the phenomena of carbon stars and studies of small bodies of the Solar system.

With the active participation of the Institute of Astronomy is issued four times per year the popular science magazine "Zvaigžņotā Debess" ("Starry Sky"). The ongoing popular science lectures at the Planetarium of the Baldone Observatory remain popular. For example, the Baldone observatory had 3302 visitors in 2016.

References

[1] Alksnis, A., Balklavs, A., Dzervitis, U., Eglitis, I., Paupers, O., Pundure, I. (2001). Baltic Astronomy, 10, 1

[2] Skrutskie, M. F., et al. (2001). The Two Micron All Sky Survey (2MASS), AJ 131, 1163

[3] Dzervitis, U. Eglitis, I. (2005). Statistical Properties of a Complete Carbon Star Sample Based on 2MASS Infrared Photometry, Baltic Astronomy, 14, 167

Research Environment and Summary of Efforts During the last Two Years after the End of FP7, No. 285912, FOTONIKA-LV project

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The ending of the FP7 project, No. 285912, FOTONIKA-LV resulted in an excellent report for the Association of FOTONIKA-LV from evaluators about outcomes of implementation of the project. It is worth mentioning that only 5 projects from Latvia received funding in strong competition for the FP7-REGPOT calls for years 2007–2013. See the table below:

REGPOT call, deadline No. and short name of the financed projects	Project proposals on reserve list	Number of proposals above quality threshold (excluding financed and reserve)	Number of proposals below the quality threshold	**Total number of eligible proposals**
Call identifier: FP7-REGPOT-2007-1 Deadline: 24.04.2007 **1. 203459 / WOOD-NET,** **2. 205079 / BALTFOODQUAL**	0	1	3	**6**
Call identifier: FP7-REGPOT-2008-1 Deadline: 14.03.2008	1	1	2	**4**
Call identifier: FP7-REGPOT-2009-1 Deadline: 13.02.2009	0	2	1	**3**
Call identifier: FP7-REGPOT-20010-1 Deadline: 17.12.2009	0	1	2	**3**
Call identifier: FP7-REGPOT-20011-1 Deadline: 07.12.2010 **1. 285912 / FOTONIKA-LV**	0	3	1	**5**
Call identifier: FP7-REGPOT-2012-2013-1 Deadline: 03.01.2012 **1. 316149 / InnovaBalt,** **2. 316275 / BALTFINFECT**	1	3	2	**8**
Total	**2**	**11**	**11**	**29**

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

Latvia "per capita" was among the most successful nations in this competition where among 1885 project proposals only 149 were financed. Average success rate is 7.9%.

The information and both tables are from the Report on key players in convergence region [1].

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

Table 2. 16 most successful countries in all the FP7-REGPOT-(2007-2013)-1 calls

Reference to independent evaluators report

The project FP7-REGPOT-2011-1, No. 285912, FOTONIKA-LV "Unlocking and Boosting Research Potential for Photonics in Latvia – Towards Effective Integration in the European Research Area" was finalised on July 31, 2015 with the Ex-post Evaluation report submitted by three independent experts nominated by the EU Commission on the outcomes of three years of efforts. Two statements from the summary of this report envisage that the implementation of the project by FOTONIKA-LV community was very successful:

- *The evaluators discussed the progress of the project separately during each visit, which has been very good at every stage of the project.* ***Finally, all evaluators agreed that the FOTONIKA-LV project has fulfilled in an efficient way all its planned tasks. The project has accumulated all the elements in order to achieve excellence first at national and furthermore in European level, both in scientific and in organisational matters.*** *Moreover, FOTONIKA-LV will be reinforced in terms of new researchers and new equipment due to the FOTONIKA-LV project in combination with the presented strategic plan to establish a sustainable basis for advanced research in photonic systems. According to the proposed plan, the research of FOTONIKA-LV will focus on Photonics, Quantum Sciences, Space Sciences and Related Technologies and selected topics presented in this Report;*
- ***The evaluators strongly believe that FOTONIKA-LV has reached the level of a Centre of Excellence and its establishment at a national level will contribute to the sustainable long-term development of its activities in photonics, quantum & space sciences, and related technologies. Following the completion of this REGPOT project, FOTONIKA-LV is ready to be integrated into the regional and national Smart Specialisation activities and contribute significantly to the socio-economic growth of Latvia and the Baltic states.***

Unfortunately the landscape for research activities is hardly unfavourable due to acute problems of national RTD & Innovation policy identified by TECHNOPOLIS report in 2014 [2]; therefore, the research community of FOTONIKA-LV faced lots of problems *(including acute lack of national funding leading to a lot of unused opportunities, losses of revenues to national budget and smaller number of new project initiatives with industry and RTD institutions worldwide)* already during the implementation of the mentioned FP7. After the project, the situation only became worse.

Citations of statements of the TECHNOPOLIS report are provided below:

- ***Latvia face disastrous problems with institutional funding for research*** *(p. 22) –* *5.1.1 Structure of research funding: "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".*
- ***Latvia face problems with decision making and political will in the area*** *(p. 33, 34) –* *6.1.7 Difficulties in Implementation: "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… 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…"*
- *Sever problem for Latvia is lack of any constructive RTD and innovation policy (p. 41) – 7.4. Policy implications: "The biggest question is, as earlier indicated, the absolute lack of money. This is completely understandable in the current economic context. However, the plain fact is that you cannot build and sustain a modern economy without making a significant expenditure on research and higher education. If you fail to make this investment, the supply of high-quality human resources to society and industry is too small and those people who could be driving socio-economic development and growth tend to drift abroad. The production of knowledge is of course one very important reason for funding research; but the production of human capital is probably an even more important reason for doing so. Lack of human capital means not only that the country has difficulties in exploiting its own knowledge production but also, crucially, that it is hard to exploit the more than 99% of new knowledge that is generated abroad. Without these capabilities, the country will enter a declining spiral that infects the performance of the economy as a whole".*

Currently the research community of the Association FOTONIKA-LV is benefiting from excellent inheritance form the project FP7-REGPOT-2011-1, No. 285912, FOTONIKA-LV which ended in April 2015:

- Upgraded research infrastructure *(including two observatories)*, new quantum optics laboratory, new negative ion beam instrument, substantially upgraded molecular beam laboratory, clean room and various reshaped experimental set-ups and instrumentation. Value for money in total – up to 20 M€;
- Strong team of excellent repatriated and recruited scientists. In total 18 during the project run;

- Several hundreds of partnerships and collaborations in different countries worldwide via various FP7 and H2020 projects and project proposals initiated due to the implementation of FP7-REGPOT-2011-1, No. 285912, FOTONIKA-LV:

Country code	*No. of institutions*	***Country code***	*No. of institutions*	***Country code***	*No. of institutions*	***Country code***	*No. of institutions*
AR	1	**DE**	25	**IS**	1	**SE**	8
AT	6	**DK**	7	**IT**	10	**SI**	3
AU	3	**EE**	3	**KE**	1	**SK**	3
BE	6	**ES**	9	**KR**	1	**TW**	1
BG	1	**FI**	9	**LT**	7	**UA**	2
BR	1	**FR**	19	**NL**	16	**UA**	3
BY	2	**GR**	6	**NO**	3	**UK**	17
CA	1	**HR**	1	**PL**	11	**US**	1
CH	8	**HU**	4	**PT**	5	**ZA**	2
CN	4	**IE**	1	**RO**	6		
CV	1	**IL**	5	**RU**	6		
CZ	4	**IN**	1	**RS**	3	**Total**	**238**

Table. 3. Partnerships and collaborations due to the implementation of FP7-REGPOT-2011-1, No. 285912, FOTONIKA-LV

- Active relations **with a *'club'* of research driven SMEs** via bilateral collaboration projects, H2020 SMEs project proposal development and via joint participation in H2020 project consortiums aiming for H2020 Industry Leadership and particularly space related calls. More visible from the 'club' are fiber-optics companies ***Light Guide Optics International*** *Ltd* (turnover in €12.6M in 2015) and ***CeramOpt*** *Ltd* (€20.35M, 2015); short wave radiation detectors company ***Baltic Scientific Instruments*** *Ltd* (€3.44M in 2015), ***Keramserviss*** *Ltd* (€0.685M, 2016); and photonics related SMEs like ***RD ALFA*** *Ltd* (€1.28M, 2015), ***KEEP EU*** *Ltd* (€0.42M, 2015), ***GroGlass*** *Ltd* (€12.08M, 2015), ***NACO Technologies*** *Ltd* (€0,09M, 2015), ***Cryogenic and Vacuum Systems*** *Ltd,* ***FON.ONS*** *Ltd* (€0.6M, 2015), ***VIZULO SOLUTIONS*** *Ltd* (€5.75M, 2015) and ***VIZULO*** *Ltd* (€6.07M in 2015). The Institute of Astronomy has had a long-term collaboration specifically with space technologies related SMEs: ***HEE Photonics Labs*** *Ltd;* ***FOTONIC*** *Ltd,* ***EVENTECH*** *Ltd,* the former *Riga Optics Factory*, now ***ISP Optics*** *Ltd* (€7.3M, 2016); and several others. Up to now, there are only 3 foreign companies in the "club": ***DiGOS Potsdam*** *GmbH* from Germany and ***Thorlabs*** *Inc*. from USA and ***KURS*** *Ltd* from Ukraine. Several cooperative initiatives with SMEs have been turned into producible prototypes with TRL up to 6 or more – e.g. new Digital Zenith camera, next generations SLR station etc.

In order to survive after the end of mega FP7 project in conditions where institutional funding from the state budget was close to zero the project *"Task Force"* of FOTONIKA-LV made tremendous voluntary and unpaid efforts to raise new projects via writing a large number of project proposals to be submitted to various calls of HORIZO 2020, ERAF call of National part of EU Structural funds, University effective collaboration projects with various partners etc. The overall statistics are impressive. Visibility of the association FOTONIKA-LV research groups, laboratories and observatories acquired during the implementation of FP7-REGPOT project in many cases allow them to take the role of Coordinator. Challenged calls are rather competitive from one side and available resources for the design of the projects hardly sufficient. Therefore, success rate is not as good as could be, but for many projects there are still resubmission possibilities of improved versions.

During the last two years, the efforts of various teams from the FOTONIKA-LV community resulted in the following:

- Since the start of the FP7-REGPOT FOTONIKA-LV project more than 150 peer reviewed articles were published and more than 160 presentations delivered. Finalisation of many from the list was made during the last two years;
- During the implementation of the FP7-REGPOT FOTONIKA-LV project, 8 other FP7 projects were financed (4 coordinated). Among 16 not financed project proposals 5 were above quality threshold and 14 were submitted in the status of coordinator;
- Application to the HORIZON 2020 calls started already in the last years of FP7-REGPOT FOTONIKA-LV project and intensified during the last two years:
  - two projects financed;
  - 43 project proposals submitted;
  - 13 above quality threshold;
  - 21 in the status of coordinator;
  - 8 pending for evaluation;
  - three pending for resubmission.
- Besides H2020 calls, other opportunities were also used:

· ATO for Peace programme	1 project pending for evaluation
· COST programme	1 financed project
· ERDF EU National Structural Funds projects	2 financed from 7 submitted
· European Space Agency proposals	2 pending to be financed
· Industry – University effective collaboration	9 financed projects with SMEs
· INTERREG BSC region programme	1 financed project from 2 proposals
· ISLR (NASA) technical workshop	1 financed project
· LV – CH bilateral cooperation	1 financed project
· LV – FR bilateral OSMOZE project	2 financed projects
· LV – LT – TW trilateral cooperation	1 financed project from 2 proposals
· LV – UA bilateral cooperation programme	1 financed project
· Support to H2020 SMEs instrument	4 financed projects, 12 proposals pending for resubmission

In various ways, many of the ideas from the listed above projects are represented in the current conference booklet together with research efforts which will find outcomes in new projects development.

Finally, it should be highlighted that Dr. Ilgmars Eglītis, the head of Astrophysical Observatory in Baldone, has received the National prize in Science (2016) for his contribution to the research on small planets and asteroids of Solar system via monitoring of space of Solar system with Schmidt–Cassegrain telescope. Eight new asteroids were discovered and the orbits of 826 asteroids were fine-tuned. This contributed to the progress of the solution to Space Surveillance and Earth safety problems.

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Major Achievements in Quantum Optics Fundamental Sciences

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One of presently quickly progressing areas of Photonics is to develop technologies to miniaturise optics with the goal to put optics on the chip and create various sensors, faster telecommunication equipment, and ultimately, quantum computers on the chip. The work on optical micro-resonators has been recently started at the Institute of Atomic Physics and Spectroscopy.

The idea of the project arose from the 9 years (2004–2013) of post-doc experience of the project leader Dr. Janis Alnis at the Max Planck Institute of Quantum Optics in Germany, led by the 2005 Nobel Prize winner Theodor Hansch. J. Alnis is experienced in development of various Fabry-Perot resonators [1, 2]. But nowadays there is tendency to use much smaller resonators – Whispering Gallery Mode (WGM) resonators (size of 5 micrometres to 4 mm, compared to 15 cm Fabry-Pérot resonators). The actuality of micro-resonators reveals, for example, the fact that online version of journal Nature has special reference section on micro-resonators [3].

It was decided to proceed with research on WGM resonators as this is hot topic with many perspective applications, for example, for miniaturization for laser systems. WGM resonators are smaller and cheaper than Fabry-Pérot resonators therefore they are better candidates for future miniaturized optoelectronic systems.

J. Alnis has experience in the production and stabilization of WGM resonators [4, 5]. By this project J. Alnis will introduce the research on WGM resonators in Latvia and will advance this field, for example, by constructing a technology prototype where optical frequency standard is stabilized on WGM resonator and additionally on Rb saturation spectroscopy.

WGM resonators have applications as biosensors. Already in Germany J. Alnis faced this research in the team of Th. Hansch [6]. The current project will deal this topic too by the leadership of Roman Viter, who is experienced in optical biosensing.

It was decided to proceed with WGM resonators for biosensors as availability of expertise on R. Viter was available. This theme gives contribution on multidisciplinary of the project and opens medical/biological market for WGM sensors.

Potential cooperation partner in Latvia is Institute of Solid State Physics. Yet workload of potential group that would be able to make lithography was too high, therefore we could not find personnel to include in the project. Therefore, it was decided to make some WGM lithography as outsourcing and to make collaboration with small WGM resonator teams from abroad, for example, with T. Kippenberg team, with whom visits are planned.

The state of the art is that WGM resonators are produced in various configurations (ball, cylinder, toroid), from various materials (including those made of CaF_2 and MgF_2 [7, 8] crystals), and made in size of mm and micrometres (lithographic) [9] way to produce WGM resonators). This project will contribute to obtain the state of the art knowledge in this field by using glass, quartz, CaF_2 and MgF_2 as materials for WGM resonators and obtaining and testing samples of tenths micrometres size WGM resonators made by lithography (these samples will be bought). J. Alnis has an experience in producing MgF_2 micro-resonators [10] and will use this experience to make resonators with advanced form. Additionally, polystyrene balls [11] will be used as WGM resonator cores for biosensors.

Simulation of WGM resonators

Theory of micro-resonators and example simulations of WGM resonators will be used to make our own program pack that can simulate WGM resonator signals (by COMSOL, Mathematica, C++/Python) [8, 12, 13] and Rb spectroscopy. This will allow reaching state of the art in simulation capacity. Quality beyond the state of the art will be reached when simulation results will be obtained for special types of WGM resonators and specific experimental setups that will be used in the project.

Fig. 1. *LU ASI Quantum Optics lab WGM project team in 2017: the lab space has been recently renovated to make it suitable for work with optical biosensors*

Development of optical frequency standard, which is stabilized by WGM resonator and Rb saturation spectroscopy

The analogue for this system is reported in 2015 [14]. Our system will have additionally optical frequency comb system that will allow to obtain absolute frequency values, will involve optical fibre for directing laser light in the WGM resonator that will keep Gaussian form of laser signal, will include vacuum shell for WGM resonator, will involve various types of WGM resonators. Results will be described in publication and in technology rights (know-how). J. Alnis is experienced with stabilization of WGM resonators and Rb spectroscopy to reach state of the art results and beyond it. The construction of such system is not trivial. It is planned that at the end of the project the developed technology will reach Technology readiness level 4 (Validation of technology in laboratorial environment: basic technological components are integrated to establish whether they will work together in a laboratorial environment).

Development of biosensors based on WGM resonators

It is known that WGM biosensors are restricted to detected low size biomolecules [15]. Different ways of bio-functionalisation have been applied and they reduced the detectable size of the biomolecules to 15–20 nm [16]. In new core-shell WGM due to support layer (metal oxide, Au NPs, PANI etc.) we expect to develop novel approaches in sensitivity of WGM biosensors. For this polystyrene core balls with size of 5 micrometres will be used. It is planned that at the end of the project the developed WGM biosensors will reach

Technology readiness level 4 (Validation of technology in laboratorial environment: basic technological components are integrated to establish whether they will work together in a laboratorial environment).

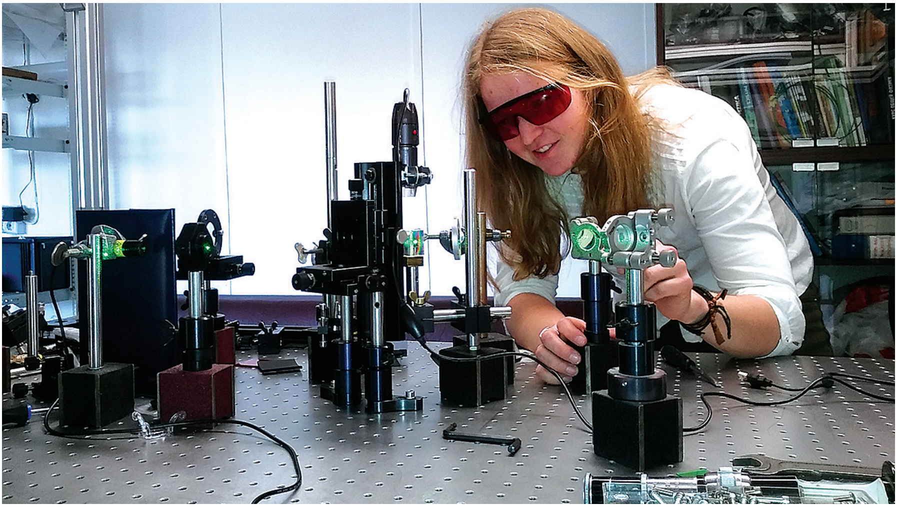

***Fig. 2**. Working on WGM micro-resonator setup at LU ASI QO*

Acknowledgment

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Synergy of Fundamental and Applied Sciences

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Association FOTONIKA-LV is realizing fundamental and applied research. In recent years FOTONIKA-LV collaborated actively with industry/SMEs in two directions:

- provision of assistance and guidance for SMEs in preparing proposals for Horizon 2020 SME Instrument Phase 1 and Phase 2 calls;
- implementation of common projects in the "Effective collaboration" program of the University of Latvia.

A. Horizon 2020 SME Instrument call

European Commission (EC) has opened a project call "SME Instrument" dedicated to new product development within SMEs [1]. Phase 1 project call supports the preparation of feasibility studies of new product development. The contribution of the EC to such project will be 50 000 EUR, which is 70% of eligible costs of the project. Duration of the project is 6 months. Phase 2 projects may receive support of up to 2.5 million EUR from the EC, which is 70% of eligible costs. In these projects their products have to be developed to market maturity within 2 years or less. The success rate for proposals within these calls is below 10%.

FOTONIKA-LV has contributed to the following companies in preparing the SME Instrument proposals:

- "Baltic Scientific Instruments", Ltd., www.bsi.lv. The company produces devices for X-ray and gamma-ray detection. The company received support for SME Instrument Phase 1 project [2] and is preparing for resubmission of Phase 2 project proposal;
- "HEE Photonics Labs", Ltd., www.heephotonic.eu, the company is developing space technologies based on the competence accumulated in Latvia since 1950-ies. The company received support for SME Instrument Phase 1 project [3] and is preparing for resubmission of Phase 2 project proposal;
- "KEPP EU", Ltd., www.keppeu.lv. The company is working in the field of silicon metallurgy. The company received support for SME Instrument Phase 1 project [4] and is preparing for resubmission of Phase 2 project proposal;
- "RD Alfa Mikroelektronikas departaments", Ltd., www.rdalfa.eu. The company is producing microelectronic components for defence and space industry. The company is preparing to resubmit SME Instrument Phase 1 project proposal and to submit Phase 2 project proposal;
- "KERAMSERVISS", Ltd., www.keramserviss.lv. The company is selling and producing different equipment for ceramic heaters. The company is preparing to resubmit SME Instrument Phase 1 project proposal and to submit Phase 2 project proposal;
- "FONONS", Ltd., www.fonons.lv. The company is producing and selling pumps and compressors, including ground source heat pumps. The company is preparing to resubmit SME Instrument Phase 1 project proposal.

B. Projects of "Effective collaboration"

FOTONIKA-LV has realized several projects of "Effective collaboration" with industry/SMEs. The calls were announced by the University of Latvia. Research groups could propose projects and receive up to 50% of project's costs as contribution from the

University of Latvia, if a project partner – for example, SME – will contribute the other 50%. In this scheme, the maximum contribution available from the University of Latvia for one project was 50 000 EUR. FOTONIKA-LV has realized or is implementing 9 such projects with the total contribution over 100 000 EUR from SMEs. Such projects strengthen ties of FOTONIKA-LV with industry. The projects are:

1. Project "Innovative Boron Ion source for the next generation ion implant devices". Collaboration partner: "Baltic Scientific Instruments", Ltd. Realisation period: 16.08.2016.–31.01.2017.
2. Project "Research on application of MHD levitation in large-size high-purity crystal growth". Collaboration partner: "Baltic Scientific Instruments", Ltd. Realisation period: 12.09.2016.–31.01.2017.
3. Project "Design of High-power electron beam source prototype for industrial application" Collaboration partner: "KEPP EU", Ltd. Realisation period: 16.08.2016.–31.12.2016.
4. Project "Joint research efforts of Z-LIGHT Ltd and FOTONIKA-LV (LU) towards application of fibre optics in biosensors and in devices based on quantum and plasma Technologies". Collaboration partner: "Light Guide Optics International", Ltd./ "Z-Light", Ltd. Realisation period: 16.08.2016.–28.02.2017.
5. Project "Upgraded MAXDOAS instrument for validation of atmospheric spectra sensors on Earth satellites platforms and independent tests of air quality in Riga". Collaboration partner: "HEE Photonics Labs", Ltd. Realisation period: 16.08.2016.–28.02.2017.
6. Project "The development and testing of high temperature sensor immune to electromagnetic interference high temperature sensor and preparation of the common project proposal for Horizon 2020 SME Instrument Phase 2 call". Collaboration partner: "Keramserviss", Ltd. Realisation period: 16.08.2016.–28.02.2017.
7. Project "Feasibility study of diode spectrometer and preparation of project proposals for Horizon 2020 SME Instrument calls". Collaboration partner: "BIPOLARS", Ltd. / "RD Alfa Mikroelektronikas departaments", Ltd. Realisation period: 12.09.2016.–31.01.2017.
8. Project "Development of mechanisms for stabilization of electron gun beam for silicon rod melting". Collaboration partner: "KEPP EU", Ltd. Realisation period: 01.04.2017.–31.12.2017.
9. Project "Collaboration in modification and development of ICP RF power generator and spectral sources adapted for usage in ROFLEX-2 instrument for measurement of Iodine and bromine in atmosphere". Collaboration partner: "Instituto de Quimica Fisica "Rocasolano"", IQFR, Spain. Realisation period: 01.04.2017.–31.12.2017.

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International Laser Ranging Service Network in Riga, Code RIGL-1884

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The paper presents a brief review of the main results after the started in 2013 modernisation of the Riga 1884 Satellite Laser Ranging (SLR) station. During the modernisation efforts, almost all the main subsystems have been refurbished or replaced including the 1 m main mirror, detector unit, the time and frequency system [1], system calibration [2] and the data processing software. The system range bias operational since December 2016 after modernisation, is now estimated being below 7 mm and calibration RMS about 8 mm. Another improvement is the tracking performance of high satellites like GNSS, which allows participating in dedicated experiments like GREAT: Galileo gravitational Redshift test with Eccentric sATellites [3] running from May 2016 to July 2017. The station also participated in space debris campaigns with the aim to determine rotational parameters of dysfunctional satellites Topex/Poseidon, Oicets and Adeos-2. Activities in near future will be focused on building a new telescope control system to implement closed loop tracking and to modernise timing electronics, particularly event timer RTS 2006 [4], which currently imposes some limits on working with fast photon detectors and range bias correction.

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SLR Advancements

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A short analysis of the development of satellite technologies shows that *10–15%* of the more than 900 orbiting satellites, especially those collecting the *Earth observation* data *should be monitored* and tracked [1] by means of different observation nets.

The trends of the space surveillance technology development show:

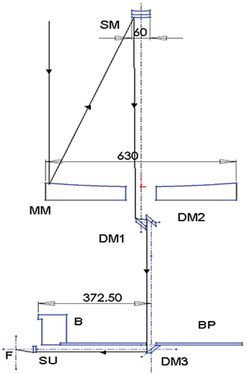
- The need for *enhanced Space Surveillance and Tracking (SST) capabilities* is becoming more recognised with several initiatives underway: both the ESA and the European Commission aim to support the development of the EU SST services, *upgrading the existing European infrastructure, observation sensors, as well as developing new assets* (*as part of the European Space Situational Awareness Programme* [2]*)*.
- All space-based systems *(especially collecting Earth observation data)* are managed and controlled by the corresponding *ground segment systems relying on specific services,* e.g. NORAD, International Laser Ranging Service (*ILRS*) [3] and others. Collected Ranging data are further *used by different services*, e.g. as the International Terrestrial Reference Frame, the International Earth Rotation and Reference Systems Service, etc. All *these services* use data obtained from either *direct space object observations* by different Earth-based equipment or by *satellite on-board instruments*.
- *Measurements of far space objects* by optical means *(e.g. by laser ranging)* from the Earth surface provide the most accurate data of distance and monitoring the motion of far space objects fixing (calculating) their geocentric positions in an absolute system available e.g. for the above-named and more other Services.
- *Nano-satellites* and *Space Debris* monitoring by optical means *(e.g. laser source with SLR)* is becoming more actual.
- Far distance *Free Space Optics* (FSO) communication systems are developing including space applications.

Some hardware advancements implemented in the SLR project "Egle" include:

- New design high *resolution* collimation *(afocal) achromatic diffraction* of the main optical system; conclusions:
    - *highly collimated* laser pulse radiation established in the *far zone*,
    - ability to radiate in a *wide spectral range.*
- The collimator is compensated for work outside in a *wide temperature range*.
- The main optical system has wide throughput (>1′) for *large aperture (energy) laser* source.
- New *reduced weight mounts* for the main telescopic system.
- New *achromatic diffraction resolution* completing field telescope for SLR apparatus coordinate system.
- New apparatus auto-collimator system for monitoring directions of the optical axes of the telescope optical systems and mechanical axes of the telescope mount.
- A new monitoring system of the directions of Earth gravity vector and Azimuth mark sensors.

SLR "Egle" main optical system technical solution (*not in scale*) in Fig. 1.

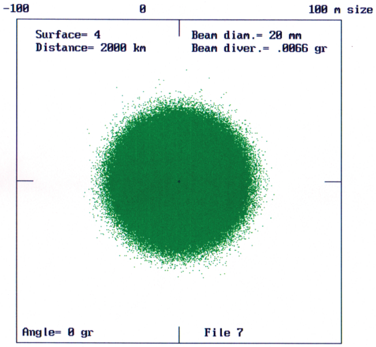
Analysis of SLR Telescope laser beam illumination in far zone were made for different laser sources at different distances, e.g. D = 20 mm *(high power)* laser beam at distance 2000 km gives di ~140 m (see Fig. 2).



MM – main mirror (parabolic)
SM – secondary mirror
(Mangin double lens)
DM1 – first diagonal mirror
DM2 – second diagonal mirror
DM3 – third diagonal mirror
SU – optical system shortening unit
F – focal plane
BP – base plate
B – telescope basement sketch
at β/2 = 0.01° = 0.6'

Ref. B. F. L.	56.452
Focal Length	5814.866
Apert. Ratio	9.23
Image Height	1.013

Fig. 1. *Main optical system technical solution for SLR "Egle"*

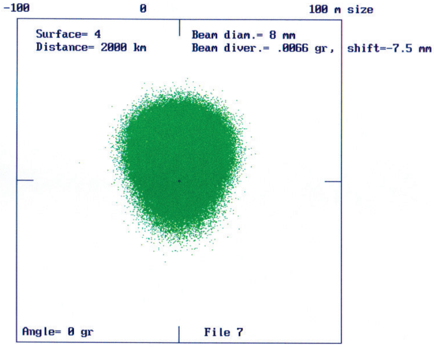


Ilumination di.= 139.6237 m
Energi= 3.772037E-4 E/m^2
Ilumination area. (file aa121).

Fig. 2. *Telescope laser beam D = 20 mm illumination at distance 2000 km*

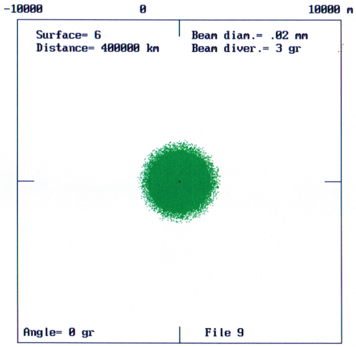
D = 8 mm *(high pulse frequency)* laser beam with shifted input place in transmitter channel (see Fig. 3). Telescope laser beam D = 8 mm illumination at distance 2000 km gives di ~120 m.

D = 0.02 mm laser (*semiconductor*) beam at distance 400 000 km gives di ~5.2 km (see Fig. 4). Telescope laser beam D=0.02 mm illumination at distance 400 000 km.



Ilumination di.= 128.389 m
Energi= 4.690424E-4 E/m^2
Ilumination area. (file aa121).

Fig. 3. *Telescope laser beam D = 8 mm illumination at distance 2000 km*



Ilumination di.= 5199.988 m
Energi= 1.78537E-7 E/m^2
Ilumination area. (file aa121).

Fig. 4. *Telescope laser beam D = 0.02 mm illumination at distance 400 000 km*

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Poster Abstracts and Contributions

Photonics as Smart Specialisation and Research Topic in European Programmes

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Review of existing and identifying of key enabling technologies (KET) relevant for enhancing future competitiveness and prosperity evolved in European Union (EU) member states as a response to economic recession in 2009. Based on global research and market trends and given their economic potential to solving societal challenges and knowledge intensity, European Commission has defined the most strategically relevant KETs predicting radical breakthroughs in a wide variety of economic sectors promoting different production technologies: *Nanotechnology* for development of smart nano and micro devices and systems; *Micro- and nanoelectronics* essential for intelligent control of all goods and services; *Photonics* as a multidisciplinary domain dealing with light, its generation, detection and management; *Advanced materials* facilitating recycling, lowering the carbon footprint, energy demand and limiting the need for raw materials; *Biotechnology* for sustainable industrial and agri-food operations [1].

Photonics is everywhere around us starting from lightening, communications, health and in daily used devices like mobile phones. As a field of science and technology, it was laid down in 1960 with invention of the laser, followed by the laser diode and, optical fibres for transmitting information. These inventions provided the infrastructure for the Internet in the late 20th century when research in the field of photonics flourished. According to the Photonics Industry Report, the predicted average growth rate for the photonics industry in the period 2011 to 2020 was estimated at 1.5 times of the global gross domestic product (GDP) and expectations for 2020 world market in photonics are set up to 615 billion EUR [2].

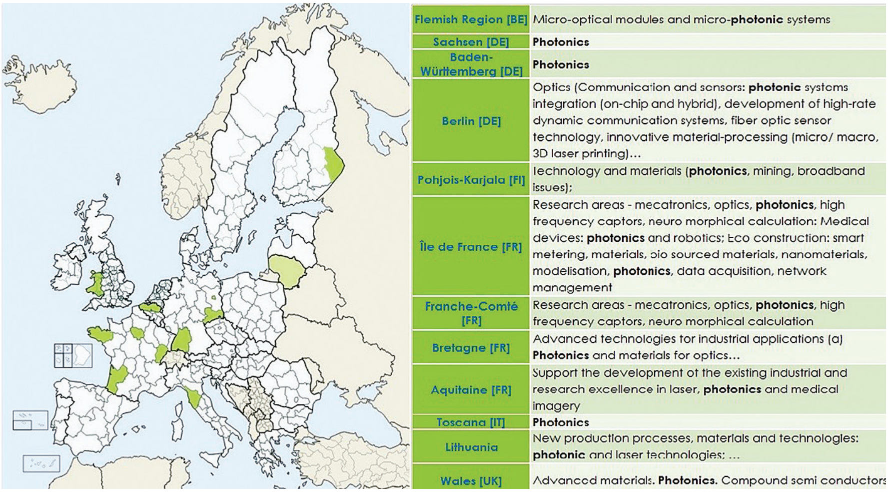
Research and Innovation strategy for Smart Specialisation (RIS3) is a strategic framework to align European, national, regional and private investments in each region or member state. In 2011 the European Commission launched the Strategies for Smart Specialisation Platform (S3 Platform: s3platform.jrc.ec.europa.eu/home) which currently provides information on smart specialisation strategies in all the 28 EU Member states as well as for associated countries Moldova, Norway, Serbia and Turkey. However, only 12 regions have defined Photonics or photonic systems as a smart specialisation: Flemish Region (BE), Sachsen (DE), Baden-Württemberg (DE), Berlin (DE), Pohjois-Karjala (FI), Île de France (FR), Franche-Comté (FR), Bretagne (FR), Aquitaine (FR), Toscana (IT), Lithuania, Wales (UK) (see Fig. 1).

Projects dealing with photon-related issues one can distinguish already since the first European framework programme for research (FP1), however nobody indicates 'photonics' as a key-word for that time. The trend is constant for FP1-FP3 (1984–1994) – about 35 projects signalise photon/photonics in the project's objective/abstract; however, at that time the photon is only a tool for research and not the research issue itself (see Fig. 2). A faint growth of interest continues up to FP7 (2007–2013) when photonics is announced as one of the KET's in the EU. Topic is included in the Work programmes and targeted research is undertaken by doubled interest in every next programme (see Fig. 3).

In FP6 (2002–2006) 27 Photonics projects were implemented by 17 different organisations (all of them having the word 'photonics' in the organisation legal name) in 9 countries (Denmark, France, Germany, Ireland, Netherlands, Portugal, Spain, Switzerland,

and United Kingdom). In FP7 also other organisations all around EU invested effort in 124 photonics research projects, including Latvia by participation to the ERA-net project on Biophotonics.

For the half-time of Horizon 2020 there have been 10 project applications with 32 applicants from Latvia dealing with Photonics, however only one organisation has succeeded – the Institute of Solid State Physics, University of Latvia (ISSP UL) with a 2-stage project under Spreading excellence and widening participation programme. The biggest project in the history of Latvian science to date, CAMART^2 [4], has been launched on 1 February 2017 bringing to Latvia more than 11 million EUR from European research funding which constitutes about 7.5% of the whole Horizon 2020 funding invested into photonics research.



Flemish Region [BE]	Micro-optical modules and micro-**photonic** systems
Sachsen [DE]	**Photonics**
Baden-Württemberg [DE]	**Photonics**
Berlin [DE]	Optics (Communication and sensors: **photonic** systems integration (on-chip and hybrid), development of high-rate dynamic communication systems, fiber optic sensor technology, innovative material-processing (micro/ macro, 3D laser printing)…
Pohjois-Karjala [FI]	Technology and materials (**photonics**, mining, broadband issues);
Île de France [FR]	Research areas - mecatronics, optics, **photonics**, high frequency captors, neuro morphical calculation: Medical devices: **photonics** and robotics; Eco construction: smart metering, materials, bio sourced materials, nanomaterials, modelisation, **photonics**, data acquisition, network management
Franche-Comté [FR]	Research areas - mecatronics, optics, **photonics**, high frequency captors, neuro morphical calculation
Bretagne [FR]	Advanced technologies for industrial applications (a) **Photonics** and materials for optics…
Aquitaine [FR]	Support the development of the existing industrial and research excellence in laser, **photonics** and medical imagery
Toscana [IT]	**Photonics**
Lithuania	New production processes, materials and technologies: **photonic** and laser technologies; …
Wales [UK]	Advanced materials. **Photonics.** Compound semi conductors

***Fig. 1**. Photonics declared as a Smart specialisation priority (S3) in Europe*

	FP1	***FP2***	***FP3***	***FP4***	***FP5***	***FP6***	***FP7***	***H2020***[1]
Total number of projects	32	34	36	140	135	264	921	458
with LV participation						2	2	5

Fig. 2. Term ‘photon/photonics’ in FP project abstract/objective [3]

	FP6	***FP7***	***H2020***[1]
Total number of projects	27	124	78
with LV participation		1	2

Fig. 3. Photonics as a key-word in the project [3]

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[1] Horizon 2020: half time of the programme (2014–2016)

Fabry-Pérot Resonator for Laser Stabilization below 1 kHz Line Width with Stability better than 100 Hz/s

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To demonstrate the results of creating a two-mirror Fabry-Pérot (FP) resonator that allows to achieve the width of a stabilized laser line below 1 kHz the FP has been mounted vertically mid-plane to reduced sensitivity to vibrations and enclosed in 2 shields inside a vacuum chamber to lower the temperature fluctuations. A Peltier element was used for temperature control at zero-expansion temperature point of low-expansion Zerodur spacer and broadband high-reflectance mirrors (99.85% in the range 630 to 1140 nm). The diode laser was stabilized to the FP resonator using Pound-Drever-Hall method and the stabilized light was compared with ultra-stable light (of line width about 1 Hz at 980 nm) to form a beat note signal. For the best performance the width of the beat note signal was below 1 kHz with a linear drift of about 23 Hz/s. The Allan deviation characterising relative frequency stability reached 1×10^{-12}.

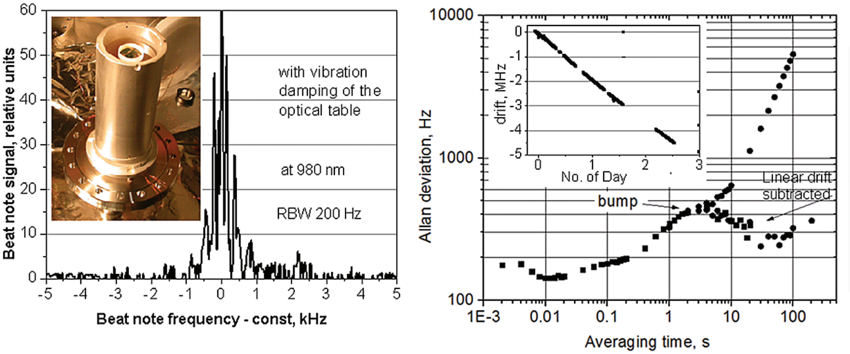

Fig. 1. *Photo of the resonator being assembled, optical beat note spectrum with another stable laser, Allan deviation and long-term stability graphs. Allan deviation reaches minimum of 1×10^{-12} at time scales between 10 ms and 1 s. Bump in the picture at few seconds time scale is due to parasitic interference fringes*

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Towards WGM Resonator Stabilised on Rb 5s-5p Transition Lines

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Frequency stability is regarded as absence of frequency drift or maintaining a single fixed frequency as long as possible. Precision play an important role in high speed communications, navigation, frequency standards, spectroscopy and in numerous other important applications [1].

Using femtosecond optical combs the absolute frequency of light can be determined. We use Erbium fibre based optical frequency comb synthesizer that covers a broad optical spectrum 530–1000 nm emitting 150 fs pulses with 250 MHz repetition frequency.

Together with a 780 nm ECFL diode laser and a Rb vapor saturation set-up we are attempting to measure precisely the hyperfine splitting of Rb atoms. The laser is slowly scanned across all the Rubidium saturation peaks to calculate the optical frequency. During different measurements inconsistencies and slight shifting of absolute frequencies of the rubidium lines were observed due to variations of power of the diode laser. This happens as a result of AC Stark shift. This leads to further investigations to observe the frequency depending on the laser power (see Fig. 1).

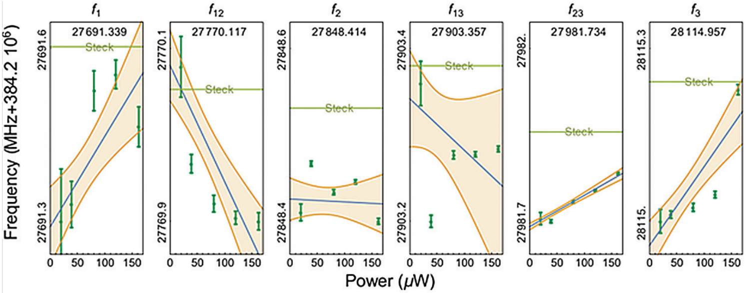

***Fig. 1**. Absolute optical frequency drift of the Rb87 D2 saturation lines and crossover peaks due to laser power*

Hereafter we want to combine the frequency comb and Rb saturation spectroscopy with the Whispering Gallery Mode Resonator (WGM) to compensate for thermal drift and improve the long-term stability. WGM resonators have a high Q factor and resonant frequencies are far apart from each other which provides resonant optical feedback to the laser. As a result the frequency noise and laser line width decreases and stability improves [2].

Acknowledgements:

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STIRAP Nonadiabaticity and Optimal Choice of Experimental Parameters

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Stimulated Raman adiabatic passage (STIRAP) is a splendid laser based method for near–lossless coherent transfer of population between different quantum states. Since it was first proposed about 26 years ago it has found multitude of applications in different fields of physics, chemistry and quantum information processing [1]. While STIRAP has been a subject for intense theoretical studies over the last years, very few models present analytical description of STIRAP dynamics [2]. Adiabaticity criterion in most cases, in particular for Gaussian laser pulses, has only qualitative or numerical representations [3].

The present research focuses on analytical assessment of nonadiabatic losses in STIRAP in two cases: (1) with Gaussian laser pulses, and (2) with exponential ramp laser pulses.

Nonadiabatic losses in STIRAP are caused mainly by the inevitable coupling between bright and dark states due to finite lengths of laser pulses. Integral representation of the dark-to-bright state coupling operator is used to outline the accuracy range of Sun-Metcalf approximation [4] in the case of exponential ramp pulses (see Fig. 1).

Saddle-point method [5] is used in obtaining asymptotes of STIRAP efficiency for Gaussian laser pulses. The analysis reveals the effect of additional saddle points, which are ignored in the commonly used Dykhne-Davis-Pechukas treatment [6, 7].

Predictions of the developed analytical model are tested against numerical simulation data, and, in the case of exponential ramp pulses, also against exact analytical predictions.

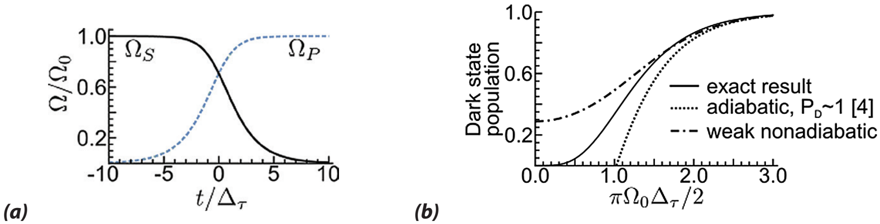

***Fig. 1**. Dynamics of STIRAP with ramp laser pulses can be solved analytically*
(a) Semi-infinite exponential ramp laser pulses. The generalized Rabi frequencies Ω_0 are identical for both pulses. Temporal overlap of the pulses is determined by the delay time Δ_τ
(b) Population of the dark state in a three level Λ excitation scheme is determined by the pulses overlap area $\pi\Omega_0\Delta_\tau/2$

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Trilateral Grant of the Latvian, Lithuanian, and Taiwanese Research Councils *"Quantum and Nonlinear Optics with Rydberg-State Atoms"*: First Year Achievements

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This collaborative project focuses on combined theoretical and experimental studies of interactions of laser fields with Rydberg atomic systems, motivated by the recent intense research in the fields of quantum computing, ultra-cold Rydberg-physics, and quantum simulation. Theoretically designed novel methods for control of Rydberg-Rydberg interactions via ac-Stark tuning of Förster resonances [1] will be experimentally demonstrated in a Riga-Hsinchu collaboration. The latter will bring complete understanding of the underlying physical processes and open new possibilities for control schemes in interacting atoms. Systematical experimental and theoretical works on Electromagnetically Induced Transparency (EIT) [2] of room-temperature Rydberg atoms is also undertaken, including the effects of coupling laser intensity, polarization configurations, principal quantum number, and orbital angular moment on the Rydberg-EIT spectra.

In the first year of the project joint work between the Riga and Hsinchu groups was initiated on **Task 1** involving theoretical studies of dipole blockade [3] parameters using Förster resonances in Rb atoms. Our aim is to find the best experimental parameters necessary to achieve large dipole blockade radius [4] and realize it in the Ultracold Atom Laboratory of Hsinchu group. For that purpose, we are deriving a general expression for the dipole-dipole interaction strength for an arbitrary Förster resonance transition, which will allow us to automatically find the best candidates among the multiple possible Förster resonances in atomic Rb. Significant progress was made also on **Task 2**, which aims to study EIT in Rydberg atoms at room temperatures. The Riga based team developed a numerical model for simulating the experimental data obtained in Hsinchu laboratory. The model is based on the density matrix equations of motion and accounts for the full Zeeman structure of the atomic energy levels, all possible relaxations mechanisms, as well as Doppler broadening effects. The challenge for the numerical modelling can be considered having in mind the rapidly growing number of equations which need to be solved as the complexity of the atomic levels system increases. The preliminary numerical calculations have partially succeeded in reproducing the experimental data for Rydberg EIT in room-temperature ^{87}Rb atoms.

The work is supported by the Latvian, Lithuanian, and Taiwanese (LLT) Research Councils trilateral grant "*Quantum and Nonlinear Optics with Rydberg-State Atoms*" project FP-20338-ZF-N-100.

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Selective Excitation of Uncorrelated Sets of Adiabatic States in Non-degenerate Hyperfine Level Systems

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The study refers to formation of adiabatic states upon strong laser coupling of two levels with non-degenerate hyperfine (HF) structure a typical Autler-Townes (AT) [1] type of experiment in the ladder excitation scheme $3S_{1/2}$–$3P_{3/2}$–$4D_{5/2}$ conveniently accessible by visible laser radiation sources being examined. The strong field couples the $3P_{3/2}$ and $4D_{5/2}$ states, creating adiabatic (laser-dressed) states [2] which are then probed by a weak laser field on the $3S_{1/2}$–$3P_{3/2}$ transition. Both laser fields are linearly polarized, implying the selection rule $\Delta M_F = 0$ for Zeeman sublevels, which allows us to consider each subset of mutually coupled HF levels with the same M_F as an independent multilevel system. The probe laser intensity is chosen week enough, in order to avoid optical pumping and mixing of the ground state HF components. Doppler broadening due to atomic velocity distribution is not taken into account, which is justified in laser-atom interactions in supersonic atomic beams [3].

We investigate numerically the population of state $4D_{5/2}$ as a function of the probe laser detuning for different values of the coupling field strength and detuning. Our numerical calculations are based on the Optical Bloch equations (OBEs) formalism [4] for the density matrix equations of motion. The system of OBEs for the diagonal (Zeeman coherences) and the off-diagonal (optical coherences) elements is readily solved numerically using the Split Operator Technique [5].

Analysis of the non-resonant adiabatic mixing of HF levels by the strong laser field reveals some intuitively unexpected features of the AT spectra. First, the intensities of the bright peaks diminish with the increase of the coupling field strength, such that the peak ratio is inversely proportional to the coupling Rabi frequency squared. Second, and most interesting for applications, it is possible to excite two uncorrelated (orthogonal) configurations of adiabatic states, by using the appropriate choice of probe laser detuning for excitation from F = 1 or F = 2 HF ground state components. Simultaneous use of two probe fields pulses leads to interesting perspectives to form a two-component biochromatic polariton [6], where a single strong control laser field can drive the independent propagation of the two uncoupled probe field pulses.

We acknowledge support from the EU FP7 Centre of Excellence FOTONIKA-LV and the Trilateral grant of the Latvian, Lithuanian, and Taiwanese Research Councils FP-20338-ZF-N-100.

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Latvia-France Partnership Program OSMOZE 'Electromagnetic Field-Control of the Blockade/Antiblockade Effect in Rydberg Ensembles': First Year Achievements

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The joint Latvia-France partnership program OSMOZE project *"Electromagnetic Field-Control of the Blockade/Antiblockade Effect in Rydberg Ensembles"* (2016–2017) focuses on theoretical studies of laser fields interacting with degenerate Rydberg atomic systems, and on the development of novel approaches for manipulation of quantum optics phenomena in Rydberg media. The need for such new schemes is evidenced by current scientific activities in the areas of quantum computing, ultracold Rydberg physics and quantum control [1].

We take two different and complementary approaches for achieving control of the Rydberg-Rydberg interactions:

- application of resonant or nearly resonant mw dressing field to tune the near Förster resonant states via the ac-Stark shift [3];
- far off-resonant coupling of the atoms to a Rydberg-molecular bound state.

The combination of these two approaches will allow us to achieve separate control of the atom-atom interaction on two significantly different length-scales.

Following the first approach, we are developing a theoretical model for control of Rydberg-Rydberg interactions by coupling of the Förster resonance states in Rb atoms by an ac-field. The ac-Stark shift is expected to bring the stated closer and thus increase the resonant dipole-dipole interaction. Therefore, our model involves two ladder excitation schemes in Rb atoms coupled by two laser fields in a ladder configuration. The atom-atom interaction between the two excited Rydberg states is included, as well as the interaction with the additional ac-field.

Using the second approach, a novel scheme was proposed [4] to efficiently tune the scattering length of two colliding ground-state atoms by off-resonant laser coupling to an excited Rydberg-molecular. For the s-wave scattering of two colliding ^{87}Rb atoms, the effective optical length of the Rydberg optical Feshbach resonance (OFR) can be tuned over several orders of magnitude, showing the usefulness of Rydberg ORFs to manipulate interactions in a cold dilute atomic gas. Currently we are extending the investigations of s-wave scattering in Rydberg OFRs to the case of a p-wave scattering.

This work was supported by the Latvia-France partnership program OSMOZE project "*Electromagnetic Field-Control of the Blockade/Antiblockade Effect in Rydberg Ensembles*" FP-20355-ZF-N-109.

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Development and Testing of Advanced Beam Pulsing Hardware for *Negative Ion Spectrometry*

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It has been taken for granted that negative ions are very important in molecular processes of the interstellar media, but the first negative ion, CH_6^-, has been observed [1] only in 2006. Since then related activities have been advanced in astronomical observatories and experiments in laboratories intensified [2] but more massive efforts are needed and therefore progress in the development of more effective negative ion sources will be helpful. Besides beams of negative ions are in demand for the accelerator mass spectrometry, ion implantation, SIMS *(secondary Ion mass spectrometry)* for material analysis, and in the field of atomic and molecular spectroscopy as well.

The history of experimental research on negative ions is also counted in decades. Still in use a universal negative ion source has been proposed [3] and developed by Middleton [4] in 1974 and 1985 accordingly. Further developments are described in monographs [5, 6] published in 2004 and in 2005. The Middleton type negative ion source consists of a cathode, a heated ionizer electrode and an extraction electrode. Its 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 report describes and the results of the developed new approach by adapting pulsed voltage *(techniques used in double-ring synchrotrons)* 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 experimental series. This is particularly useful for elements where the cathode lifetime is short and the properties of the cathodes are hardly repeatable from cathode to cathode. The pulse mode allows also operating with higher ion currents in the beam.

Test and control experiments have been 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 – that can direct the 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 [7].

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Photo-dissociation of Oxygen Molecules by 193.3 nm Laser Radiation and its Importance to the Intensification of Chain Reactions in Hydrogen–Air Mixture

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Photo-dissociation of molecular oxygen plays an important role in the photochemistry of the atmosphere and can be used for the initiation of combustion in different combustible mixtures due to production of highly reactive atomic oxygen $O(^1D)$ upon absorption of resonance laser radiation [1, 2]. The presence of O_2 molecules in the excited states and or photo-dissociation by UV radiation provides a greater reduction in the induction period and the decrease of ignition temperature compared to heating of the medium with a significantly greater value of energy supplied to the gas. Photo-dissociation and laser excitation of the O_2 molecule contribute to formation of reactive hydrogen atoms. The Photo-dissociation products $O(^1D)$ is part of chemical reaction $O(^1D)+H_2=OH+H$. The rate constant of this reaction is greater than in a similar reaction with oxygen ground state atoms $O(^3P)$. However, the laser-induced excitation of O_2 molecules makes it possible to ignite the mixture of H_2/O_2(*air*) at a lower temperature. For the analysis and modelling of photochemical processes both in the atmosphere and in the combustible mixtures it is needed to calculate the rate of photo-dissociation with rather high accuracy upon the exposure of the mixture to solar radiation or to resonance laser radiation at given wavelength. As is known, O_2 molecules strongly absorb the ultraviolet radiation in the Shumann-Runge and Hertzberg systems.

In order to estimate the photo-dissociation rate it is necessary to reproduce the ultraviolet spectrum of O_2 molecules in different mixtures at different temperature and pressure. The paper does address the calculations of the spectrum of Shumann-Runge bands in air and in H_2–O_2 (*air*) mixture as well as the estimation of the rate of photo-dissociation upon exposure of the mixture to ArF laser radiation at 193.3 nm wavelength. The variation of the composition of H_2–O_2 (*air*) mixture with temperature $T_0=700$–800 °K and pressure $P_0=0.5$–1 atm during the laser pulse ($\tilde{\iota}_p=40$ ns) is also calculated. It should be emphasized that applied methodology for the calculation of O_2 spectrum in the Shumann-Runge bands allows to reproduce the data reported on spectrum of the Shumann-Runge system [3] in the atmosphere with high accuracy. As an example, Fig. 1 depicts the

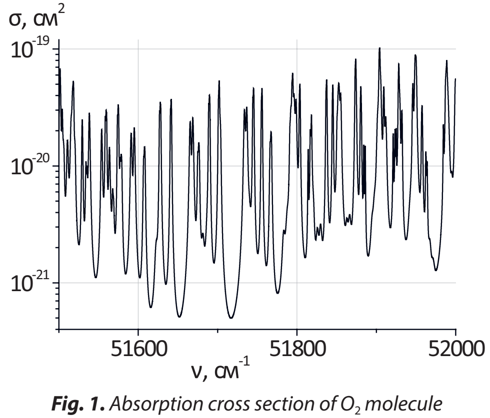

Fig. 1. *Absorption cross section of O_2 molecule in the range of wavelengths λ = 51500–52000 cm^{-1} for the stoichiometric H_2-air mixture at T_0 = 800 K and P_0 = 1 atm*

spectrum of O_2 molecule in the range of wavelength numbers $\lambda = 51500–52000$ cm^{-1} for the stoichiometric H_2–air mixture at $T_0 = 800$ °K and $P_0 = 1$ atm. On the basis of this methodology the values of photo-dissociation rate were calculated in different sections of the ArF laser beam propagating through the cell filled with the stoichiometric H_2–air mixture. The composition of the mixture in these sections was predicted by numerical simulation taking into account the detailed chemistry in the H_2–air system.

We acknowledge the support by the EU FP7 IRSES Project – NOCTURNAL ATMOSPHERE.

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The SLR Telescope EGLE Mount

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The report reflects the current state of the SLR Telescope EGLE project, specifically – the first results of a working model characteristic of the manufactured Telescope mount assembly.

The SLR Telescope EGLE with 630 mm main mirror has an Alt-Azimuthal mount. The telescope basement with azimuthal axis and walkway ring placed on the telescope basement has azimuthal bearing ring mounted coaxial azimuthal axis. The azimuthal platform's support bearings are based on the walkway ring at azimuth turning.

The walkway ring embedded in the telescope basement has been previously polished by a special-made rotary grinder fixed to the original azimuth bearing on the Azimuthal axis.

The measurements (see Fig. 1) refer to the angular displacement of the Azimuthal platform (*Azimuthal axis*) of the Telescope mount assembly of the working model in respect to the Azimuth angle.

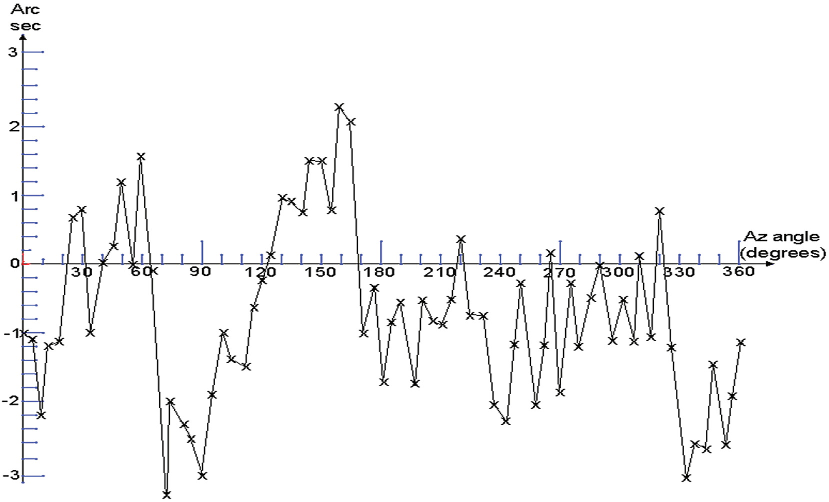

Fig. 1. *Angular displacement of the Azimuthal platform angular displacement*

Nano Satellite Imaging System

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A feasibility design of Low Earth Orbit (LEO) nano-satellite platform Imaging Spacecraft (IS) of high definition optical video sensors or Synthetic Aperture Radar (SAR) as the new generation Earth's surface exploration sensors has been made on the basis of the assessment of the technical capacity of the CubeSat platform within the framework of the project of our group. The design is part of a joint development of CubeSat platform pairs on the same orbit one of which (reviewed elsewhere) to be used for communication of FSO ST with the FSO Ground terminal (GT), the other – the IS – for independent operation of the on-board new generation Earth's surface exploration sensors. The pair of the IS and ST carrier platforms is connected by a High-speed data transmission radio channel described in the present paper.

Currently attainable pointing accuracy of the CubeSat satellite axes (e.g. Z-axis; ST telescope optical axis) in movement along the orbit during the whole pass were evaluated to reach better than 0.5 deg the pointing stability to a desired Ground Object being 0.1 deg/s achievable by satellite own means (on-board Reaction Wheels, Attitude Control System (ACS) with Global Navigation Satellite system/Global Positioning System (GNSS/GPS) in open loop mode. ACS includes STK (star trackers) with arcsec resolution. The same platform pointing accuracy is sufficient for precise aiming at a desired Ground object (e.g. linear aiming tolerance at Nadir of 600 km high gives +/– 2.6 km). The gimbal mount for the on-board Imaging system can further align the optical axis of the telescope to desired Ground objects within some 10 m.

The subtasks and structure of the IS have been evaluated, selected parameters of the IS Telescope with completed devices being optimised. The Telescope gimbal turning range at maximum input aperture up to 85/90 mm and the plane and overall length of the gimbal turning axes have been estimated (see Fig. 1).

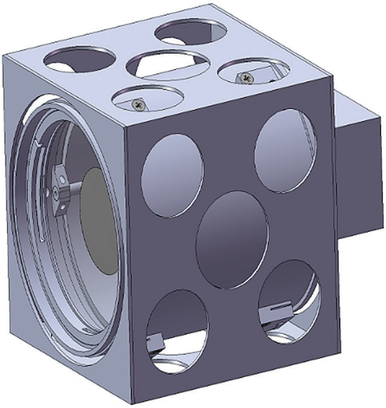


Fig. 1. *IS Telescope in CubeSat platform*

Installing the Imaging telescopes at the ends of spacecraft for easy day and night observations (only changing direction of the longest axis of the spacecraft to opposite) the overall length reaches ~400 mm (4U size), see Fig. 2.

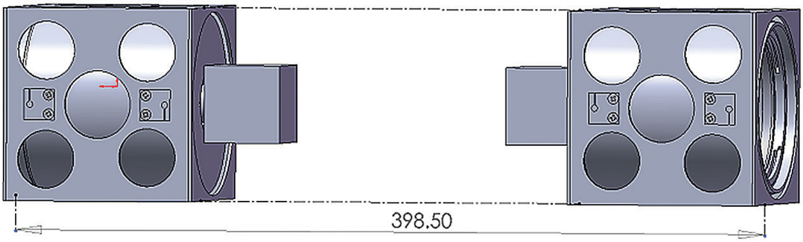
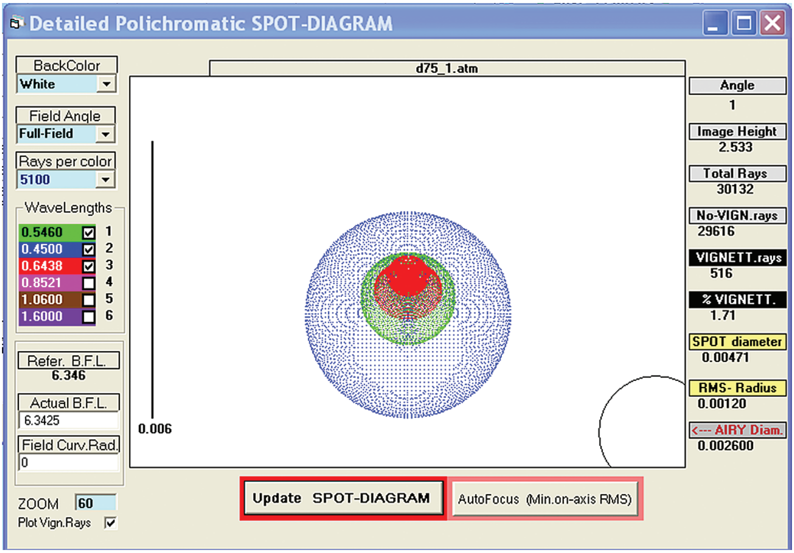


Fig. 2. *Installed Imaging Telescopes*

The Imaging Telescope optical features in the visible spectral range (see Fig. 3).



Detailed Polichromatic SPOT-DIAGRAM

BackColor: White
Field Angle: Full-Field
Rays per color: 5100

WaveLengths
0.5460 ☑ 1
0.4500 ☑ 2
0.6438 ☑ 3
0.8521 ☐ 4
1.0600 ☐ 5
1.6000 ☐ 6

Refer. B.F.L.: 6.346
Actual B.F.L.: 6.3425
Field Curv.Rad.: 0
ZOOM: 60
Plot Vign.Rays ☑

d75_1.atm
0.006

Angle: 1
Image Height: 2.533
Total Rays: 30132
No-VIGN.rays: 29616
VIGNETT.rays: 516
% VIGNETT.: 1.71
SPOT diameter: 0.00471
RMS- Radius: 0.00120
<--- AIRY Diam.: 0.002600

Fig. 3. *Imaging Telescope optical features in the visible spectral range*

Full-Field image at the field of view (FOV) = +/– 1° gives common SPOT dia better than ~4.7 µm for 3 different spectral bands; field half height h/2 = 2.532 mm; chromatic focal shift is present but less than 2 µm in the spectral range.

Imaging telescope resolution estimation shows, e.g.:

- at FOV β/2 = 0.5°; half field h/2 = 1.265 mm; SPOT dia = 1.05 µm; LFOV500 = 8.7 km; LGR = 3.6 m;
- at FOV β/2 = 1.0°; half field h/2 = 2.532 mm; SPOT dia = 2.1 µm; LFOV500 = 17.5 km; LGR = 7.2 m,

where LFOV500 – the ground linear field of view from 500 km height at Nadir and LGR – linear ground resolution from 500 km height at Nadir calculated from SPOT dia.

Nano-Satellite FSO Data Terminal

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Upon assessment of the technical capacity of the CubeSat platform being used as the carrier of on-board High-speed data SpaceTerminal (ST) the feasibility design of the Free Space Optics (FSO) Low Earth Orbit (LEO) nano-satellite (e.g. CubeSat) platform has been accomplished: the structure of the ST has been evaluated; selected Telescope parameters optimised, the turning range of the Telescope gimbal at maximum input aperture of up to 85 mm and the plane and overall length of the gimbal turning axes – estimated (see Fig. 1).

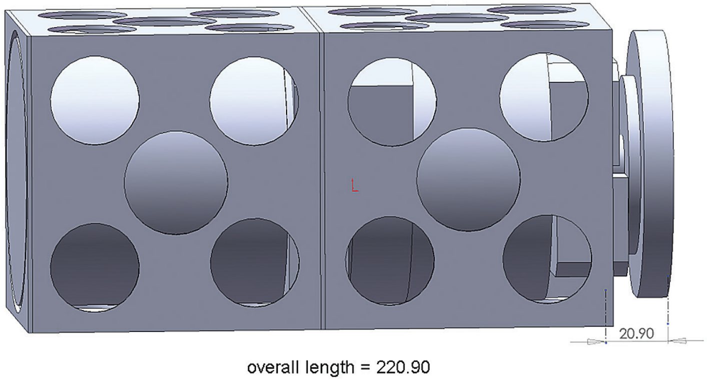


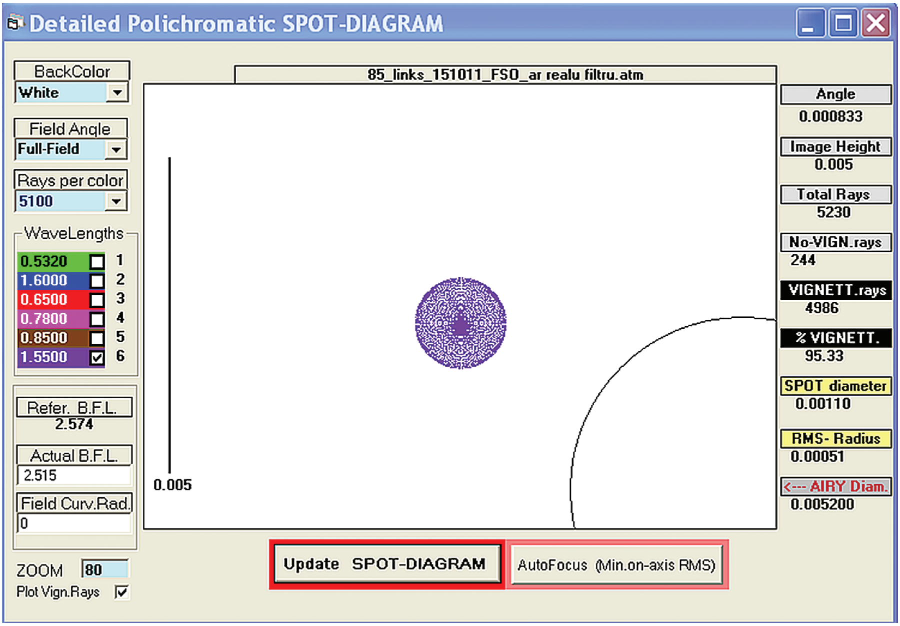
Fig. 1. *IS Telescope in CubeSat platform*

The currently attainable pointing accuracy of the CubeSat satellite axes (e.g. Z-axis; ST telescope optical axis) at moving along the orbit during the whole pass and pointing stability to FSO GT (Ground Terminal) achievable by on-board means (Reaction Wheels, ACS (Attitude Control System) with GNSS/GPS (Global Navigation Satellite system/Global Positioning System) in open loop mode have been estimated. The ACS includes STK (star trackers) of arcsec resolution.

Evaluations showed the need for a gimbal mount of the on-board FSO system to align further the optical axis of the ST telescope with the optical axis of the FSO GT system within desired tolerance of some arcsec in the close loop mode to track the beam coming up from the GT by the ST imaging sensor.

The optical features of the ST Telescope in different optical channel modes and different spectral ranges have been calculated: e.g., the Full-Field image of the ST Telescope for precise aiming of the data beam of wavelength $\lambda = 1.55$ µm (see Fig. 2).

The linear half height of the image (in the telescope focal plane) is calculated to be $h/2 = 5$ µm the incoming light beam being directed to Receiver Input (dimensions determined by the size of the ST Telescope aperture wheel diaphragm) and the FOV (field of view) of the Receiver channel made by spatial filtering to form the angular FOV of the Receiver equal to 6″ or FOV = +/− 3″. The calculated image SPOT of the optical system of the Telescope is of diameter of ~1 µm.



85_links_151011_FSO_ar realu filtru.atm

BackColor: White
Field Angle: Full-Field
Rays per color: 5100

WaveLengths

0.5320	☐	1
1.6000	☐	2
0.6500	☐	3
0.7800	☐	4
0.8500	☐	5
1.5500	☑	6

Refer. B.F.L. 2.574
Actual B.F.L. 2.515
Field Curv.Rad. 0
ZOOM 80
Plot Vign.Rays ☑

Angle 0.000833
Image Height 0.005
Total Rays 5230
No-VIGN.rays 244
VIGNETT.rays 4986
% VIGNETT. 95.33
SPOT diameter 0.00110
RMS- Radius 0.00051
<--- AIRY Diam. 0.005200

Fig. 2. *ST Telescope Full-Field image for data beam*

The ST Telescope receives the Data beam (from GT) passing through its focal plane diaphragm and spectral divider providing spectral filtering of the FSO Laser beam coming to the Receiver.

In our case the employed spectral divider is based on custom lens group chromatic aberration or a set of dispersive prisms, or others. The received Data beam is separated from the spectrum and focused on the FSO optical Receiver Input (e.g. the estimations show that the incoming Data beam at $\lambda = 1.55$ µm focused by the lens group chromatic aberration spectral divider onto the Receiver Input does not exceed drec < 16 µm determining the possible aperture of the Receiver sensor.

The Data transmitter channel with its emitting Laser must satisfy conditions of the existing optical joints with spectral divider: e.g. the active (emitting) surface of the Laser: dlas < 16 µm and Laser full radiant angle (estimated from lens group chromatic aberration spectra divider) of < 10° allow to minimise the illuminating laser beam geometric (and energy) losses.

The feasibility design is part of the joint development of a CubeSat platform pair closely orbiting on the same orbit and linked by High-speed data interchange radio channel – one for communication between the FSO ST and the FSO GT (Ground terminal), the other (reviewed in another article) – for independently operating new generation Earth's surface exploration sensors.

Transportable FSO System Ground Terminal for Flying Platform

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A feasibility design of the FSO (Free Space Optics) High-speed data Ground Terminal (GT) for communication with LEO (Low Earth Orbit) CubeSat nano-satellite platform has been accomplished on the basis of the results of assessment of the technical capacities of the on-board FSO Space and Areal terminals (ST and AT, respectively). The design of the GT includes a controlled Telescope mount on 2 axes with accessory systems to be assembled together with communication systems and operator workplaces on a transport vehicle.

Within the activities of implementation of the project our group has accomplished:

- evaluations of the energy balance between the Space and Areal Terminals and the Ground Terminal FSO systems, which together with solutions for a typical main optical system of the GT Telescope show that input aperture of the main Telescope should be at least 400 mm. The optical axis of the GT Telescope should be aimed at ST (AT) without tracking restrictions on the upper hemisphere of the sky (altitude: H = +/– 90°) in any apparent speed range (angular velocity: $\omega s < 3°/s$ – satellite; $\omega a < 10°/s$ – areal) limiting the mounting type choices of the GT Telescope to the Alt-Alt mount;
- assessments and calculations for a transportable (especially for areal applications) GT Telescope deploying a minivan or station wagon and a special cradle in transport mode mounted inside the vehicle in the operator compartment or on the roof. The Telescope is assumed to be mounted on one end of a sliding telescopic mast extendable in the working mode; the other end of the mast should rest on a supporting body laid on some foundation (earth) away from the vehicle. Supplementary systems and electronic subsystems of the GT are designed to use COTS (commercial off-the-shelf) products. The pointing accuracy of the optical axis of the GT Telescope during the whole pass of the ST and AT along the orbit should be better than some arcsec to be obtained by tracking the apparent AT spots on the sky (their laser sources) in the close loop mode;
- evaluation of the GT structure and optimisation of selected parameters of the GT Telescope completed with devices and controls;
- a feasibility design of the telescope mount and the optical system of the main telescope operating in a vast spectral (500 nm – 1650 nm) and vast outdoor temperature (–30 °C – +60 °C) range with optical subsystems and electronic subsystems and operator control of the ST/AT platform;
- a project of rebuilding transportable GT comprising a sliding mast and cradle for the telescope mount. The equipped GT telescope mounted in the cradle (the transport mode) is shown in Fig. 1.

Example of linear resolution for GT data Receiver is shown in Fig. 2.

The linear resolution of the spectral divider (Spot Diagram) of the main optical system at $\lambda = 1.6\ \mu m$ central and 1.55 μm/1.65 μm side bands (the wavelength of the data laser beam from ST/AT (also for tracking in the close loop mode) in the Focal plane of the Receiver (see Fig. 2) provides the estimated half field of the object image $h/2 = +/- 0.050$ mm at FOV (Field of View) = +/– 0.01° (the object at infinite distance >500 km, $F = \sim 10$ m).

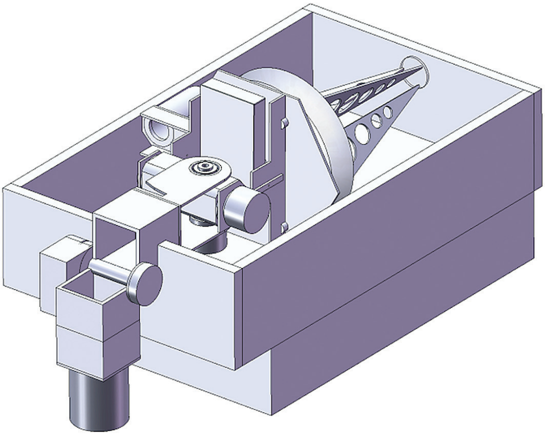
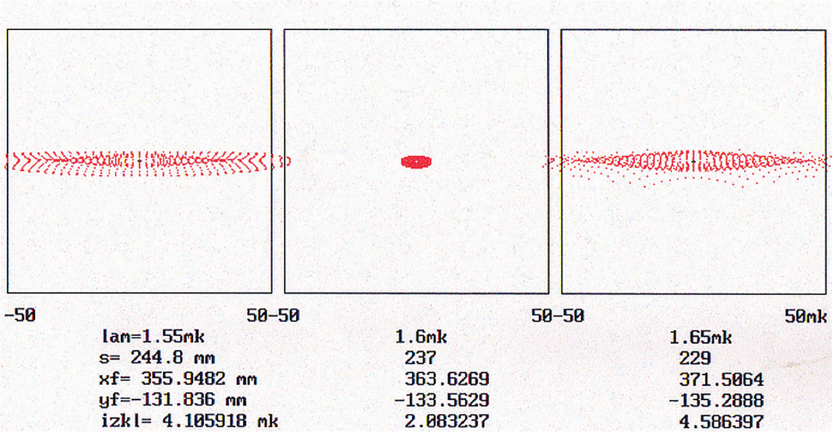


Fig. 1. *Equipped GT telescope mounted in cradle (in transport mode)*



```
lam=1.55mk          1.6mk           1.65mk
s= 244.8 mm          237             229
xf= 355.9482 mm      363.6269        371.5064
yf=-131.836 mm      -133.5629       -135.2888
izkl= 4.105918 mk    2.083237        4.586397
```

Fig. 2. *Example of linear resolution for GT data Receiver*

The size of the focused data laser image on the Receiver input is < 5 µm × 2 µm with spectral dispersion in the 1.55 µm – 1.65 µm range – better than 6 nm/mm.

The project proposal: 738910, ComLink "Free-Space optical communication link for flying platforms" is submitted on 15 June 2016 under the Horizon 2020's SME instrument phase2 call H2020-SMEInst-2016-2017 was successful in a highly competitive evaluation process and has been granted the Seal of Excellence.

Cooperation in Space Technologies with Africa

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The FOTONIKA-LV research association of the University of Latvia in collaboration with the Space Technologies Cluster of Latvia and the firm Space Technology and Science Group Oy based in Finland organized the conference International Conference on Collaboration in Space Technologies (ICCST) in Riga, Latvia June 5–6, 2014 [1]. The vision of the conference was that the Baltics, Central Europe together with the Nordic countries have developed a high level of space technology capabilities that can address critical needs in Africa. Conference participants included key people from the African Union Commission responsible for African Union space policy including Dr. Abdul Hakim Elwaer, Director Human Resources, Science and Technology Department as well as Dr. Mahamma Quedraogo, Head of Division, Human Resources, Science and Technology Department. Ethiopia, Nigeria, South Africa, and Zimbabwe also participated. Latvia, Czech Republic, and Finland participated as well as the European Commission and ESA. The Conference resulted in a Memorandum of Understanding signed between the African Union Commission and STSG. Several concrete projects have resulted from ICCST including projects to launch satellites as well as the development of a master's level program in space science. An additional project is to provide assistance to the African Union Commission to develop a space policy for the African Union. ICCST was opened by former President of Latvia Prof. Vaira Vīķe-Freiberga as well as with introductory remarks by Dr. Ina Druviete, Minister of Education and Science.

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International Lunar Decade 2020–2030: A Key Role for Europe

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The idea of an International Lunar Decade (ILD) germinated in work underway in the International Lunar Working Group (ILEWG) coordinated by ESA starting before 2000. Envisioned was an International Geophysical Year (IGY) inspired global collaborative undertaking to better understand the Moon, its origins and resources as a step towards lunar development and possible human settlement. By 2006 the ILD idea had evolved sufficiently that the ILEWG endorsed it and endorsement was also received from COSPAR [1] The Planetary Society under the leadership of Louis Friedman championed the ILD idea, received a grant from the Secure World Foundation to promote it at various conferences as well as to the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS). Friedman made a presentation about ILD to COPUOS in February, 2007 [2]. Despite positive interest in the idea no member state of COPUOS chose to promote it. The ILD agenda was adopted by ILEWG and largely fulfilled by the member space agencies in the decade from 2007–2014, but without UN endorsement as a global initiative.

In 2013 an idea for an International Lunar Decade took hold among a group of space activists that included ideas for an International Lunar Research Park [3], an International Lunar Geophysical Year and other elements including an article published by V. Beldavs in the Space Review on January 14, 2014 [4]. These various thought streams were brought to focus at the conference “The Next Giant Leap: Leveraging Lunar Assets for Sustainable Pathways to Space”, November 9–13, 2014 in Hawaii that resulted in the International Lunar Decade Declaration [3] and the formation of the working group (ILDWG) to promote implementation of ILD.

In 2015 numerous organizations and influential persons were approached and informed about the idea of a framework for international collaboration sustained over a decade to gain an understanding of the Moon and its resources and to develop the technologies and infrastructure that would make lunar development feasible. Presentations, posters and papers were presented at about a dozen conferences in 2015 and the idea of ILD continued to evolve. Where initially launch was anticipated in 2017 commemorating the 60th anniversary of the IGY and the of launch of Sputnik other possibilities have been discussed including launch on July 20, 2019 commemorating the 50th anniversary of the Apollo 11 landing. Current thinking is that the ILD will span the timeframe from 2020 to 2030 aiming towards achieving breakthrough to a self-sustaining space economy beyond Earth orbit. Key to this would be technologies for ISRU as well as markets for products derived from lunar resources and the policies that needed for private investment in lunar resource ventures. The international collaboration envisioned in ILD will coordinate action in lunar exploration, technology development and infrastructure construction and deployment in cislunar space and on the Moon to enable lunar operations, including manned facilities on the Moon as well as at E-M Lagrange points and facilities in Earth orbit.

The ILD concept is increasingly including consideration of specific building block elements such as the proposed energy, communication and navigation lunar utility [5]. ILD also provides a framework for coordination of major international projects such as NASA’s Journey to Mars and ESA’s Moon Village [6].

In 2016 it is anticipated that ILD will be presented at ten more conferences and that key organizations will include ILD in their plans. The ILD concept was presented to the UN Committee for the Peaceful Uses of Outer Space (COPUOS) on 22 February 2016 [7]. We anticipate worldwide celebrations commemorating the launch of Sputnik and the dawn of the space age in 2017. A major goal is that ILD become a theme of the UNISPACE +50 conference in 2018. The 50th anniversary of the landing of Apollo 11 on the Moon on July 20, 2019 will mark the launch of ILD itself marking the decade 2020–2030 as a paradigm shift from government-centric, budget driven deep space initiatives to a self-sustaining space economy with the expectation of significant expansion of space exploration along with profit-making space business.

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Baldone Schmidt Telescope

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Astronomers of the Baldone observatory (code 069) operate a 1.2-meter Schmidt-type Telescope (focal length = 240 cm, correction plate = 80 cm) installed with four-degree objective prism and two SBIG STX-16803 type CCD's covering two square degrees of the night sky. It is the twelfth largest Schmidt Telescope in the world, manufactured in Germany in 1966. The limit of U, B, V, R, I observations is 19 magnitude and 21 magnitude in the integral light.

Spectral resolution of the objective prism is 500 at Hα, the spectral range 4000–10 000 Å and brightness limit 14 magnitude.

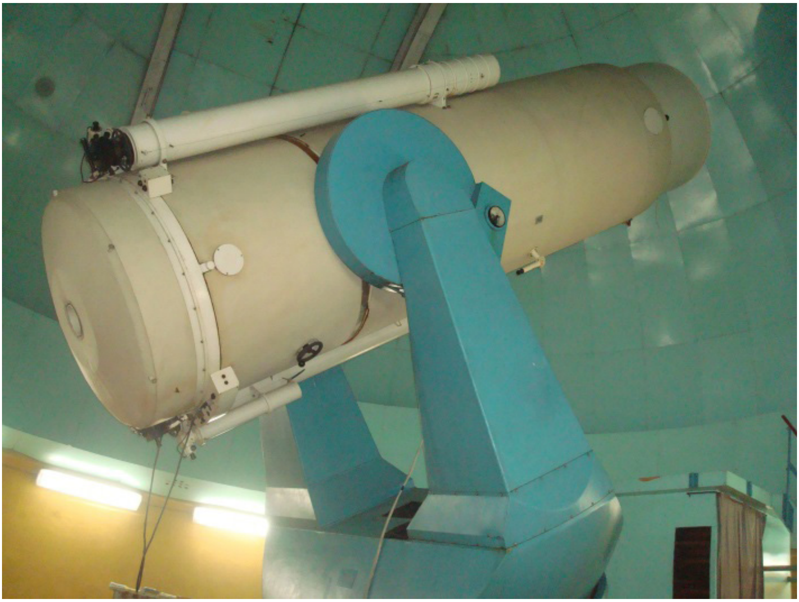

Fig. 1. *Baldone Schmidt Telescope*

Horizon H2020 Projects at the Institute of Astronomy

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Astronomical Institute is currently conducting of two EU projects. Those are:

- FP7-PEOPLES-IRSES-2013-2016-612691 in cooperation with the Institute of Atomic Physics and Spectroscopy;
- EUROPLANET 2020 Research Infrastructure, EPN 2020-RI, H-2020 INFRAIA-1-2014-2016-654208 "Upgraded hardware and software and looking forwards to participate in projects of investigation carbon stars' phenomena and studies of Solar system small bodies";
- INTERREG ESTLAT H-2020 "Training the next generation entrepreneurs with hands-on methods in space STEM (SpaceTEM)".

The Institute of Astronomy is a State Research Program performer as a subcontractor of the Ventspils University College "Multifunctional materials and composites, photonics and nanotechnology" (IMIS2) Project photonics and materials for photonics".

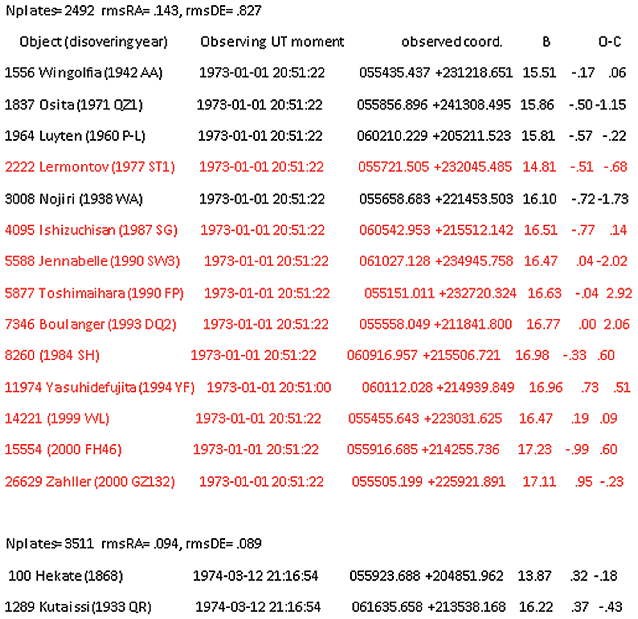
Revisit submission of the project application H2020, which was highly appreciated in 2015: H2020-MSCA-RISE-2015 "Towards Next Generation of SLR instrumentation and Advances in GEODYNAMICS" (NEXTSLR) submitted in 2016. Project is related to new technologies (femto-second laser) of satellite observations and to expand the SLR user network. There are five participants in the consortium: University of Latvia, Helmholtz Centre Potsdam (Germany), Institute for Space Research (Austria), National Academy of Sciences of Ukraine, Entoto Observatory and Research Centre (Ethiopia).

The Astronomical Institute intends to submit three H2020 projects associated with exploration of small bodies of the solar system:

- An Asteroid Database of the Baldone Observatory Plates (AST_DB);
- Obtaining astronomical data for practical application in asteroid mining programs (Obastap);
- Development of Fundamental SLR Stations for Advances in Geodynamics and Space Geodesy;
- Satellite Laser Ranging station signal detection and processing system.

Digital processing of photographic plates of star fields allows, in addition to the main tasks of a massive search for images of small bodies of the solar system and to determine their coordinates. From earlier observations, you can extract information about the locations of these bodies well before discovering them. We analysed the results of 20 observations of clusters in UVBR bands and 7 of Pluto observations made by the 1.2-m Schmidt telescope of the Observatory of the University of Latvia in Baldone. At the moment, there are identified 87 positions and magnitudes of asteroids weaker than 14.5 magnitude for 1967–1991. Among them 11 positions for 10 asteroids which at the time of observation was the earliest of the world's known observations of these asteroids, many years before discovering. The analysis was carried out to determine the accuracy of 2 to 7 scan results of plates. These studies show the great potential of the astroplate archive of the Baldone Schmidt telescope. An example of processing results of four astroplates is presented below.

The Earth science research will benefit from new accuracy level in distance measurements, more sophisticated laser technologies and data processing. Therefore, coordinated transfer of knowledge, training and joint research activities are foreseen and planed between participating teams in the EU (Riga, Potsdam, Graz and Kyiv – Ukraine SLR net).



```
Nplates=2492  rmsRA= .143, rmsDE= .827
   Object (disoveringyear)     Observing UT moment        observed coord.      B       O-C
1556 Wingolfia (1942 AA)      1973-01-01 20:51:22     055435.437 +231218.651  15.51   -.17   .06
1837 Osita (1971 QZ1)        1973-01-01 20:51:22     055856.896 +241308.495  15.86   -.50 -1.15
1964 Luyten (1960 P-L)        1973-01-01 20:51:22     060210.229 +205211.523  15.81   -.57  -.22
2222 Lermontov (1977 ST1)     1973-01-01 20:51:22     055721.505 +232045.485  14.81   -.51  -.68
3008 Nojiri (1938 WA)         1973-01-01 20:51:22     055658.683 +221453.503  16.10   -.72 -1.73
4095 Ishizuchisan (1987 SG)   1973-01-01 20:51:22     060542.953 +215512.142  16.51   -.77   .14
5588 Jennabelle (1990 SW3)     1973-01-01 20:51:22    061027.128 +234945.758  16.47    .04 -2.02
5877 Toshimaihara (1990 FP)    1973-01-01 20:51:22     055151.011 +232720.324  16.63   -.04  2.92
7346 Boulanger (1993 DQ2)      1973-01-01 20:51:22    055558.049 +211841.800   16.77    .00  2.06
8260 (1984 SH)               1973-01-01 20:51:22    060916.957 +215506.721   16.98   -.33   .60
11974 Yasuhidefujita (1994 YF)  1973-01-01 20:51:00    060112.028 +214939.849   16.96    .73   .51
14221 (1999 WL)               1973-01-01 20:51:22   055455.643 +223031.625   16.47    .19   .09
15554 (2000 FH46)            1973-01-01 20:51:22   055916.685 +214255.736   17.23   -.99   .60
26629 Zahller (2000 GZ132)     1973-01-01 20:51:22    055505.199 +225921.891   17.11    .95  -.23

Nplates=3511  rmsRA= .094, rmsDE= .089
 100 Hekate (1868)            1974-03-12 21:16:54    055923.688 +204851.962   13.87    .32  -.18
1289 Kutaissi (1933 QR)        1974-03-12 21:16:54    061635.658 +213538.168   16.22    .37  -.43
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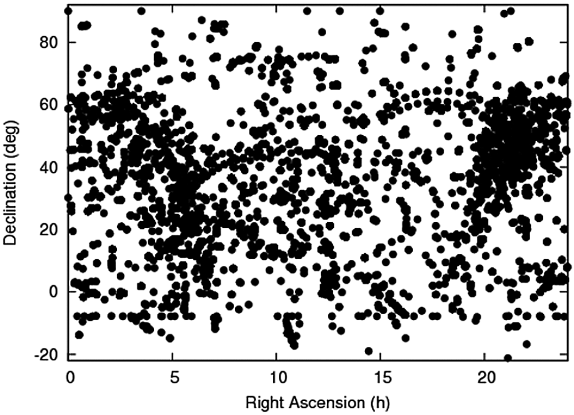

Fig. 1. *Distribution of the 22000 archive direct observations on the sky*

Intensification of existing scientific partnerships on new level are aimed in this project for a lasting synergy via enhancing scientific excellence in the whole network, in particular by cross-discipline and cross-generation exchange benefiting from impressive, more than half a century long expertise in SLR technology design, software and data processing developments in Riga and measurement results accordingly important for Earth sciences and Geodetic purposes.

The Riga team is making further progress and sophistication in SLR technology design promoting upgrade to new quality the existing inside this network and used SLR system with 1 m aperture telescope (LS-105) for experimental low altitude orbits (LEO) satellites class objects like nano-, micro satellites and space debris.

The Riga team benefit of unique experience in femto-second laser technologies is designed to perform in this project as well as novel atmosphere parameters and their changes during the satellite observation determination.

The project is designed to expand and develop the SLR user network by attracting, educating and training in the SLR technologies for space applications in third countries: Ethiopia – where these technologies will be used for the first time.

The current instrumentation and software of telescope controls and event time measurement is limited to night time observations only (LS-105). Other SLR systems allow for daylight and blind tracking. After upgrading the LS-105 system by optical and mechanical assemblies and controls with new nodes of advanced processors substantially altering electronic nodes and mechatronics development the functional performance of the SLR system management as well as accuracy of pointing and tracking space objects, the system calibration and range measurements will increase and remote control of the SLR system will be possible. To perform the LEO objects ranging, a different optical scheme will be implemented in Riga.

Stability and accuracy of the functional elements will be under scrutiny analysis: the azimuthal platform (azimuthal axis bearing, support ring and running mechanisms), the altitude platform (altitude axis bearing, support ring and running mechanisms), the main mirror support and reliever mechanisms, the secondary mirror support mechanism, adjustment systems of the diagonal mirrors, optical channel dynamic distribution system, optical channels (transmission, photo-electric receiver and visual), the drive mechanisms and control systems of the mount axis, measuring systems of the mount axis rotation angle, the laser beam telescope input mechanism, as well as performing their upgrade.

The upgrade must be standardized and done together with the standardization and related works on measuring devices set, calibration system and procedures, so that to make the instrument more efficient by increasing measurement precision and allowing for ranging at daylight as the result of these steps.,

Such an upgrade of the LS-105 telescope in SLR technologies evidently requires relevant theoretical assumptions and model experiments on the SLR telescope, its nodes and the joint measuring and calibration systems, as well as making use of earlier calculations. A new modular software package for upgraded SLR is developed and tested.

System for Control and Unwinding Telescope Cables

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The satellite laser ranging station "Kiev-Golosiev" is included in the international network ILRS (*ISLRS [1] code GLSL-1824*) and night ranging of artificial satellites. A large number of passages of satellites often leads to the telescope is making several turns around a vertical axis in one direction, which leads to breakage of connected cables. To increase the number of turns of the telescope, the cables were put at the top on the dome, after this modernisation the maximum number of turns is three as opposed to the previous one. In next stage of modernisation, the azimuthal frame was equipped with sensor that determines the number of times by using a starting reference point. The signal from the sensor is fed to an electronic unit near the working place of the observer, which outputs the number of turns on the scoreboard. Additionally, when the maximum quantity of turns will be achieved the sound signal is given. The unwinding of cables is possible by manually rotating the telescope by hand, and remotely using stepper motors. The telescope is equipped with stepper motors ShD-4, which move the telescope at 1 arcsecond in a single step. After research, it tur that the maximum operating frequency is about 15 kHz. This frequency corresponds to a speed of rotation of 4 degrees per second, allowing you to make a complete turnout of the telescope in less than 2 minutes.

This work was performed with partial support of the project SECONDARY PHOTOCHEMICAL REACTIONS AND TECHNOLOGIES FOR ACTIVE REMOTE SENSING OF NOCTURNAL ATMOSPHERE.

References

[1] The International Laser Ranging Service, https://ilrs.cddis.eosdis.nasa.gov

Recent State and Vision for Development of Complementary SLR (Optical Range) and Radar-VLBI (Radio Range) Near-Space Observation Methods

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The goal of this research is aimed to the achievement of the internationally agreed objective – the safe space. The concept of a safe space consists of multiple components including individual spacecraft trajectory control, space debris detection and their orbital element determination, and space debris growth mitigation up to active space debris removal for Kessler Syndrome avoidance as well as the general space awareness against possible future asteroid impacts. Technologies to prevent catastrophic NEO (Near Earth Objects) collisions with the Earth by means of space flight are possible [1]; however, they are only possible after the NEO path validation.

The method of Very Long Baseline Interferometry (VLBI), one of the most powerful instruments used in radio astronomy, allows high accuracy determination of coordinates of radios sources. Since 1980 VLBI method has been successfully applied for angular coordinate determination of artificial Earth satellites and interplanetary space stations with the precision 0.01–0.03 arc sec in single measurements. A promising field in coordinate research proves to be the combination of VLBI with range measurements method, such as radar-VLBI, laser ranging, and telemetric mode.

Satellite Laser Ranging (SLR) is a method of measuring distances to satellites using very short laser pulses. At the SLR station, a very short laser pulse is generated, transmitted to the satellite, and reflected back to the station, where it is detected. A high precision event timer – using time and standard frequency derived from a specially dedicated GPS receiver – or from primary time standard like caesium clock or hydrogen maser – measures the time of flight of the laser pulse with an accuracy of about 3 ps. Using the known velocity of light, one can thus determine the distance to the satellites – from a few hundred kilometres up to more than 20,000 km – with an accuracy of a few millimetres.

The combination of SLR and VLBI is a novel approach with large potential when NEO or geodetic areas are considered. The aim of this research is to explore this combination and possible applications in a more detail.

SLR and radar-VLBI observations of transmitting geodetic satellites (GPS and GLONASS) were carried out in 2016. The purpose of the observations was to work out observation procedures and data processing, using two different technologies: SLR and VLBI. GNSS satellites, such as Glonass and Galileo, were chosen as the main object of observations, due to perfect accessibility by both observation techniques. Thus, GNNS have a laser retroreflectors; they transmit radio signals with known properties. They also have a well-known high quality orbital data. The SLR station in Riga and three VLBI stations (radio telescopes RT-16 and RT-32 in VIRAC of VUC and UNN (RT2) in NIRFI) were used in NKA16 experiments and more than 25 GPS and GLONASS satellites were tracked. Work by data processing still continues.

Due to cloudy weather conditions, these first sessions were not truly simultaneous, although the same objects were observed. Renovation tasks of RT-32 and RT-16 radio telescopes limited time-windows for more observations in 2016. Year 2017 seems to be more suitable for further development of this method. It has to be stated, that for observation of NEO in relatively close Earth orbits by this method that a much smaller aperture than given by radio-telescopes is needed. Thus, mobile VLBI stations located near well-established locations of existing geodetic stations can be used in future when all the pros and cons of the method will be explored.

Further research directions and concept development: establish data formats, uniform NEO trajectory description, pointing software, common protocols and session schedule generation; continue work by data processing method development including Kalman type filters; and resolution of spatial directions. The mobile VLBI station is planned to be developed. Design of the mobile VLBI station will be based on the existing design for the ionosphere receiver already developed and deployed on VIRAC RT-32. Single beam-parking mode of operation is specified for the mobile station (no tracking). Live correlation of rVLBI data (reVLBI) is planned to be developed and implemented in complementary SLR and radar-VLBI system.

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Electronic Module for the RON-Series Angle Encoders

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Absolute optical encoders from HEIDENHAIN RON [1] series need an electronic module, which will match the sensor and control system. These sensors are mounted on the laser ranging station "RIGL-1884" of ISLRS service network [2]. As the azimuth and vertical axes have different sensors (with different resolution), a universal module has been developed, which is automatically programmed at the time of the power supply. The implementation of the module is provided with the maximum use of electronic means.

The module is a three-byte counter with automatic reversing direction changes depending on the direction of rotation, and it also contains two registers: a register code of maximum value (at 360°) and the register fixing angle.

The feature angle register simultaneously captures the state of the counter for all bits. This eliminates the angles read errors at high speeds of the telescope.

The angle fixing register allows you to send three bytes to the angle control system to directly address the segment register. A schematic diagram of the automatic portion of the circuit is shown in Fig. 1.

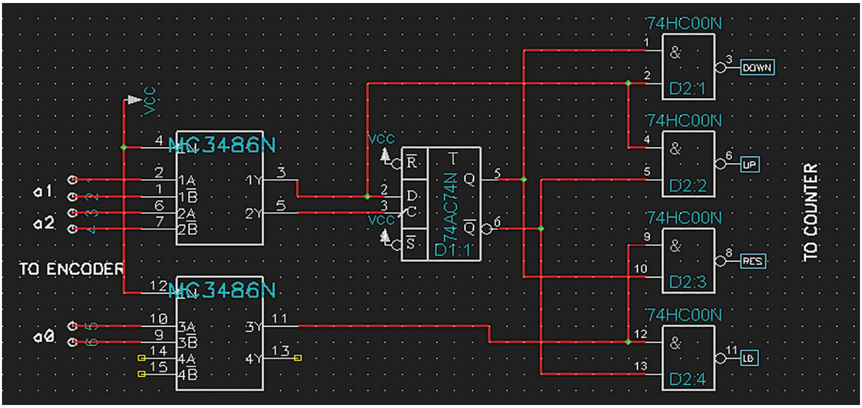

Fig. 1. *Schematic diagram of the automatic part*

This module has been tested together with the unit interface based on the ATMEGA16 microcontroller and PC. At speeds not exceeding permissible for sensor data loss from happening. This unit is recommended for use in the control system SLR station "Riga".

This work was carried out with the financial support of the project FP7-MCA-PEOPLE-IRSES-GA-2011-294949-NOCTURNAL ATMOSPHERE. Special thanks to Dr. Arnolds Ubelis and Kalvis Salmins.

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[2] The International Laser Ranging Service, https://ilrs.cddis.eosdis.nasa.gov

Control System of Rotating Mirrors of Telescope TPL-1

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The system with two rotating mirrors is established when the same optical channel is using for transferring and receiving laser impulses on a telescope. The first mirror, conditionally named transferring mirror, serves for a redirection of an impulse from a laser generator to a telescope and further to the satellite. This mirror rotates with a frequency repetition rate of the laser (10 Hz). At the moment of a laser impulse, it reflects a laser beam to the telescope and simultaneously, protects the receiving channel. The rest of the time (nearby 94 ms) this mirror passes a signal from the telescope.

The second mirror, conditionally named the receiving mirror, serves for switching of the signal accepted by a telescope between the receiver of laser impulses (PMT) and the electron-optical converter (or TV-chamber) for visualisation of the satellite. On defined with the help of ephemeris the moment when the mirror should reflect a signal on PMT, and all rest of the time a signal goes on the chamber.

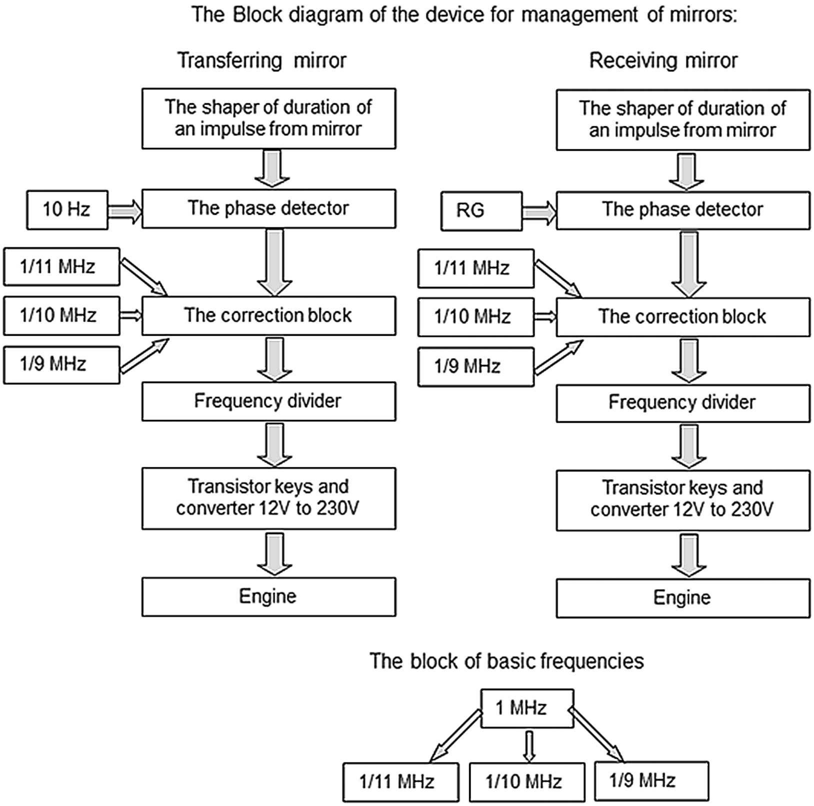

Fig. 1. *Block diagram of the device for management of mirrors*

For a successful satellite laser ranging both mirrors should rotate synchronously in regard the moments of laser impulses (signal 10 Hz). Thus, the second mirror should be shifted on a phase concerning the first mirror. The value of a phase also is double the distance to the satellite (signal RG – range gate). This value was obtained from ephemeris.

Both mirrors use rotating synchronous engines with a reducer 1 : 5.

The shaper of duration of an impulse does an impulse of necessary duration of a signal of the gauge of a mirror. Further, this impulse goes to the detector of a phase which compares time of arrival of an impulse from the mirror to an impulse of 10 Hz from the operating computer (for the receiving mirror from the operating computer undertakes impulse RG). Concerning what impulse has come first, the phase detector chooses the necessary frequency from the block of basic frequencies. Frequencies corresponds to modes to accelerate (1\11 MHz), to slow down (1\9 MHz), to continue (1\10 MHz).

Further, the chosen frequency shares on 2000 divider of frequency and moves on transistor keys, which swing the raising transformer. The quasi-sinusoidal pressure received from the transformer moves on the mirror engine.

In system management of a reception mirror of a signal from a new control system of telescope where instead of signal RG its 8-bit code moves is provided.

This device has been made and tested at the SLR station Riga and also can be used in others SLR station.

The development of device was executed within the project “Secondary photo-chemical reactions and technologies for active remote sensing of nocturnal atmosphere”.

The Project "*NOCTURNAL ATMOSPHERE* – Secondary Photochemical Reactions and Technologies for Active Remote Sensing of Nocturnal Atmosphere"

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The key objective of the FP7-MC-IRSES, "*NOCTURNAL ATMOSPHERE*", Nr. 294949 (04.02.2013–03.02.2017) project was to carry out coordinated transfer of knowledge measures between participating teams at the universities and research institutes in the EU (*Riga, Bremen and Mainz*), in the Ukraine (*Kyiv*) and Russia (*Moscow*). It was also done with the aim of restoring and strengthening scientific partnership: developing new collaboration for long lasting synergy; and enhancing the level of scientific excellence of participating early stage and experienced researchers and technicians. Joint theoretical exercises and laboratory research were performed in the important field of secondary photochemical reactions in the Earth's nocturnal atmosphere and in the development of breakthroughs in application of advanced satellite laser ranging technologies combining laser beam and white light beams in the single ranging telescope for active remote sensing technologies for night-time cartography of the troposphere and stratosphere. In total 125.5 personal months for secondment visits were used: 33 secondment visits were performed by technicians, 17 secondment visits were carried out by early stage researchers and experience researchers participated in 64 secondment visits. In summary, the joint efforts of the consortium resulted in: 17 publications in peer review journals, 46 reports in 10 International conferences, and 8 project proposals to H2020 calls to ensure sustainability of the Project (*one Project proposal for ERC call; one Project proposal to FET-open call; two Project proposals for MSCA-RISE call, one Project proposal to WIDENING Teaming call, one Project proposal to WIDENING Twinning call, one Project proposal to Researchers Nights call, and one Project proposal to COMPET call*).

Via joint efforts of researchers' teams from Riga and Kyiv, software and hardware of ILRS [1] station RIGL-1884 at the Fundamental Geodynamic Observatory was substantially improved. RIGL-1884 is now among the best performing stations in the network. The Project contributed to emergence of three disruptive innovations project proposals to H2020 SMS Instrument calls for Space Technologies topic. The project proposal to the 1st phase call received award of 50000 EUR. Two project proposals to the 2nd phase call were awarded with Seals of Excellence from European Commission and are pending to be financed from EU Structural funds in Latvia. The 1st International Conference "Photochemistry of Nocturnal atmosphere, Remote Sensing, Satellite Laser Ranging and Geodynamics", Riga 2014, 16–18 October, 2014, was organized complementary with training course for young researchers: Adventure of Nocturnal atmosphere – Advances in Remote Sensing, Satellite Laser Ranging and Geodynamics – Riga 2014, 20–22 October, 2014.

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[1] The International Laser Ranging Service, https://ilrs.cddis.eosdis.nasa.gov

Geomagnetic Storms and Their Impact on Kinematic GNSS Solutions

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The five-minute resolution GNSS observation coordinate results were computed in kinematic mode using scientific post-processing software. The results were obtained for the 30 continuously operating GNSS reference stations of the LatPos and EUPOS-Riga networks covering the territory of Latvia. The cases of disturbed coordinates were found among computed results in six selected periods: the week of St. Patrick's Day storm in March 2015, June and September 2015; and January, October and December 2016. The events of computed coordinate disturbances were found. These station coordinate disturbances were identified to be mainly the result of the influence of ionospheric scintillations. The statistics of the disturbance occurrences was analysed in relevance with geomagnetic storms registered by international services. Events of both disturbances and station domes of affected GNSS reference stations were listed and a comparison with a list of geomagnetic storms was performed. Graphs of occurrences of coordinate disturbances at the GNSS continuously operating reference stations were created (see Fig. 1). The subset of most affected GNSS reference stations was discovered.

It was concluded that the five-minute resolution GNSS observation coordinate results computed in kinematic mode for the ground based continuously operating GNSS reference stations represent a reasonable contribution for recognition of space weather anomalies.

Fig. 1. *Coordinate disturbances for GNSS station LIMB during St. Patrick's Day geomagnetic storm on March 17, 2015*

Short Historical Compendium on RF ICP Power Sources Circuitry

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Radio **F**requency **I**nductively **C**oupled **P**lasma (RF ICP) is the process for igniting the electrodeless reference spectra source (lamp) for spectrometry, as well as for many other hi-tech industrial or technological needs. The RF ICP plasma discharge is known as a unique source of high intensity atomic resonance spectra radiation with close to ideal spectral line profiles useful for various resonance absorption and resonance fluorescence measurements, e.g. [1].

Wish-list for power source is 50–200 W; 27–41–80–100 MHz; 2–10 Amp in coil; 1–4 kV on coil at ignition moment. Sad reality is that the ideal circuit is still in the search.

Tube circuits

The oldest circuitry was elaborated at LU-ASI between 1960–70 by our valued colleague J. Silins [2]. He based his work on Royer topology, using two vacuum tubes ГУ50 or alternatively one double tube ГУ19 or 29. Even after half a century, some of these devices are still in the use, revealing the high durability of the design. Circuit with ГУ50 produces power 2 × 40 W; frequency 72 MHz, is based on inner (parasitic) capacitances, thus avoiding the tank capacitor reactance problem; ignition voltage 1.2 kV; and current in coil 0.25*Q (Amperes), where Q > 100. The most irritating disadvantage is the need of a large and heavy DC voltage source. Special advantage – any abnormalities in the load gives you at least 20 seconds to react appropriately as the tube's anode becomes red-hot. Another advantage is the ease of impedance matching when finding the optimum anode voltage for tubes. Tubes checked were ГУ19, ГУ32, ГИ30, 6С33С, and ГУ50(RU)=EL/FL152(DE)=LS50(DE)=FU50(CH)=6L6(US).

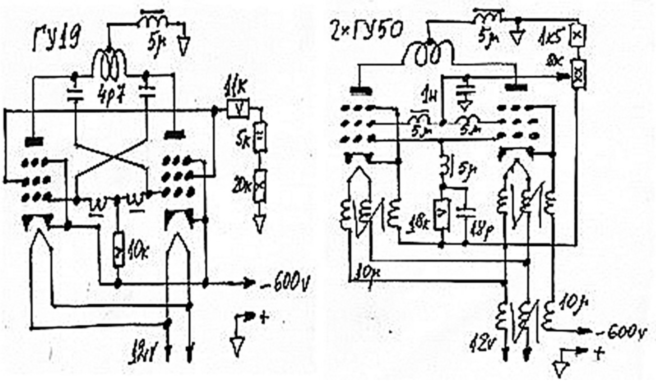

Fig. 1. *Tube circuits*

Royer circuits

The first attempts to redraw this circuit in the field effect transistor terms took a place already in the middle of 1980. Even today, little improvement has been made to the components required to build this circuit. Normally the Royer circuit exploits the gates connected to the work coil at opposite ends. The gate will burn out during normal use of expected voltage if delay between gate and source phases occurs. If the voltage divider is put in gate, transistor has insufficient amplification to start oscillating. The induction knob-heater circuit (Marko) is highly stable; however inoperable over a few MHz. Speed demands on feedback diodes are at least one or two orders higher than work frequency. Thus, the 100 pico-sec 4 kilovolt at 5 A (or at least 600 V if the output transformer is used with serial resonance branch) diodes are still just a dream but not a reality. Available diodes are 400 V@4 ns.

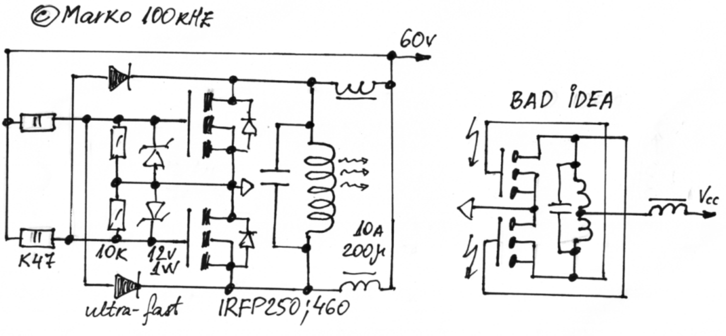

Fig. 2. *Royer circuits*

US Patents 6329757 and 2009/0129131

Both patent circuits give a pleasurable illusion of brilliant performance, especially since we discovered that from the abundance of coils, the majority are in fact mutual adjustable gaps between the normal wires in the second patent. However, the Spice simulations show that both circuit authors are not joking when demanding microcomputer regulated gate biasing. As our intention was to be ruled by the KISS principle of circuitry ('keep it stupidly simple'), both designs were implemented computerless on basis of DE275 and show a rapidly melted gate 'exitus lethalis', caused by gate-source phase shift.

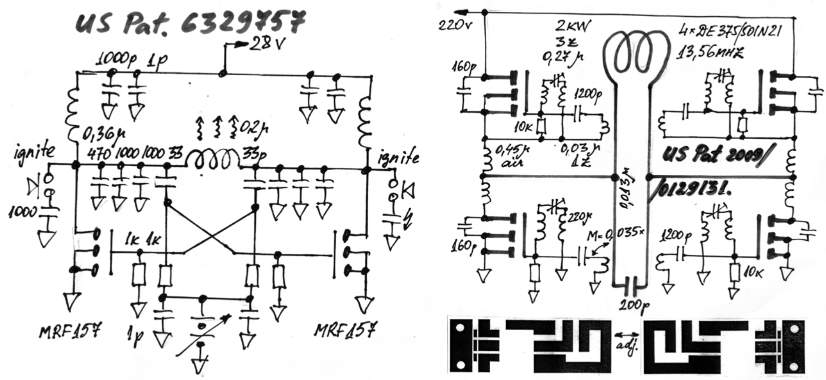

Fig. 3. *US Patents*

Serial resonance systems

- We have efforts to utilize the serial resonance oscillator circuits with push-pull transistors, which have the same problem with gates as a Royer circuit.
- The well-known Pierce crystal circuit, which works well in conduction with piezo quartz in serial resonance, has the aim to minimize the reactive power on quartz. As we have the aim to maximize the reactive power, this system is not suited well for ICP needs
- There exists a Poliakov circuit for even the most inactive crystal actuation; however, experiments show it possesses a weakness to oscillate with the real LC tank.

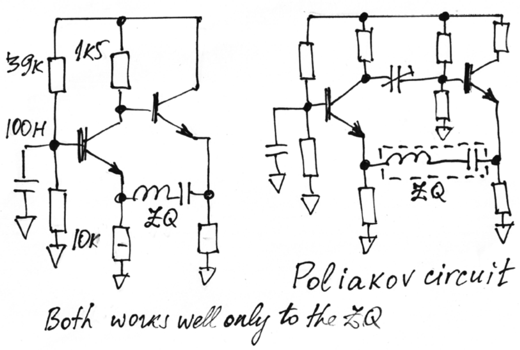

Fig. 4. *Serial resonance systems*

Clapp circuit

The revolution began again at Sankt Petersburg (Leningrad), about 1987, concerning a circuit with first Soviet vertical structure mosfet КП901. It utilized the Clapp tank for serial resonance against the ground wire, thus multiplying voltage on coil V(gate max)*Q, where Q > 100. This transistor may withstand the 30 V at the gate, thus 3 kV on coil was close to ideal, 80–100 MHz was fine, but 20 W on fanned radiator was shy of the intended result. Air-dielectric trimmer cap at such power is used, however smaller sorts are tended to boil up. For pure spectroscopy needs still this circuit are in active use, yet not rarely transistor become damaged and must be re-soldered. Many attempts were made to implement this circuit on more stable mosfets, but these attempts were unsuccessful: IRF510 withstands the frequency, but lacks the differential trans-conductance; thus, even using the Spice model, it cannot begin to oscillate. Infineon/IXYS DE150; DE275; DE375 series may work up to 20–30 MHz; however, the gates often burn out and must be re-soldered. This is both too time consuming/annoying and too costly (40–80 USD per piece). ARF449 and MRF157 are even more susceptible to spikes in voltage. Using DE we got a hands warm of exploding capacitors, just kiloVAR of reactive energy demands a special kind of cap, which is both larger and more expensive. The hopeful solution was seen by dividing the tank caps into multiple parallel branches of 10 pF, 2 kV, SMD capacitors in series of 2 or 3. By dissipating the energy, example, on 120 such SMDs, it stays much hot but persists under the fan at 2–3 Amp. Later this solution was rejected.

Back to Clapp again

Last modification of Clapp was made in 2017 by re-connection of the coil from gnd to the Vcc wire. In this version, the parasitic capacitance Cgs makes the positive background loop, thus minimizing the details count in the circuit. The gate bias must be fed via small choke; otherwise bias resistors are rapidly smoked. The Vcc is determined by Vgs max, which in the case of IXFH42N60 is 30 V, yet praxis shows that 20–25 V is the realistic limit, save gate from explode.

The gate burnout is still the weakness of the circuit at all transitional load conditions; however, this effect may be hardly diminished by using small (ca 0.1 Ω) resistor in the source wire. The result we received was 39 MHz as the max (better the 27 to avoid overheating) at 20–24 V and 3–7 A using the 150 W radiator with fan. If to boost the cooling, may permit current up to 10–20 A. This circuit surprized us by blowing-up all 100 cooled SMD capacitors at once, thus we chose to dissipate the reactive power instead on 6 × 8 cm 2-sided PCB piece of 2 mm thick (= 100 pF). The 3 mm of cut-around copper zone at perimeter avoid against arcing. Other PCB tested of 5 × 5.5 cm of 1.5 mm was overheated. Without cooling the measured T of larger PCB-capacitor was 200 °C at 3 Amp, but the simplest radiator by natural convection suppressed to 95 °C. As the IR imager shown no higher T around the wire stickers, we conclude the main cause of warmth is tgδ of our FR4 dielectric (tg = 0.035/China), not a skin-effect. Thus we plan to test a PTFE (teflon) core 2-sided boards Rogers© RT/d5880 (tg = 0.0004, rolled copper), RT/d6035HTC (tg = 0.0013, altered thermal conductivity), RT/TC350 (tg = 0.0015), where polished non-porous copper is the advantage too. To increase the copper thickness over 35 µm is senseless, as Foucault skin-effect layer is just 6 µm at 100 MHz, making current density at cap 10...50 A/mm^2. At least until 200–1000 W PCB solution seems be good enough, in contrast to nicest Vishay spec-caps within the cost margin of 6000 EUR/pc. Besides, the good topology of the mount is essential to all RF circuits; therefore, all our efforts failed to elaborate the PCB for the oscillator.

It is not worth it to do so again. Only the air-hang montage alone is worth it, just observe the topology in a draw. Safety warning: never touch the switched-on coil to cap connection point. It makes a severe and deep RF skin-burn, taking multiple weeks to heal.

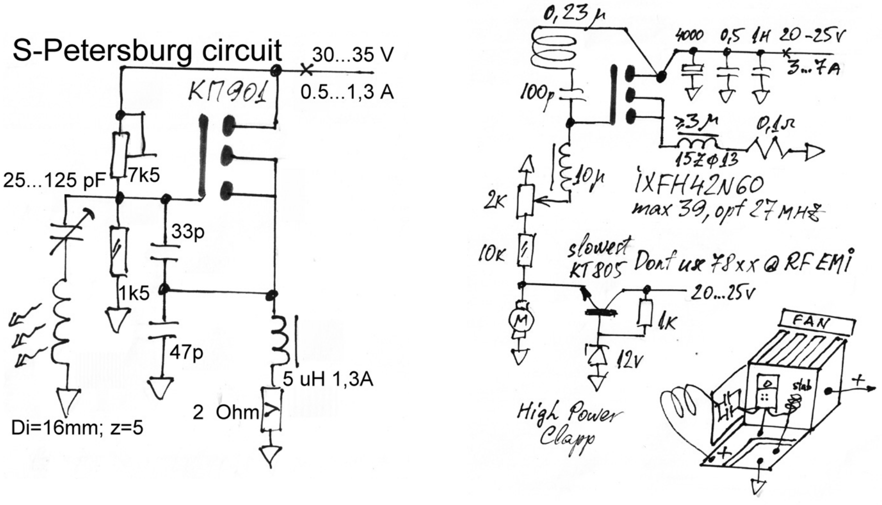

Fig. 5. *Modified Clapp circuit*

“LU Effective Cooperation Project” Innovative Boron Ion Source Design for Next Generation Ion Implanting Devices

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Industry has a specific **wish list for a miniature next generation implanter design**, shooting substances like Boron (A = 10.81), Phosphorus (30.97), Arsenic (74.92). The most difficult substance is sure boron, due to its high condensation temperature of 4200 °C. Therefore, this Project is concentrated on boron source design. Implant thickness demands 1E+13...1E+16 atoms/cm^2 or flux = 1E+15...1E+18 pcs/sec. This means that the concentration in the source plasma chamber ought to be greater by at least a magnitude of two. A purity of < 1E–20 is required, in other words, 1 atom per layer is fine, 10 atoms – tolerated, 100 atoms – unacceptable. This means the purification must be provided [1] by separate processing. Implant equability <10% means target (size max 95 mm) spinning. Beam energy is adjustable from 10–100 keV. This means different acceleration methods are available. Source – ‘long playing’ >150 hr, and the equipment is easy to operate and service.

Classical technology for boron source [2, 3] uses corrosive and extremely toxic boron trifluoride gas (BF_3), in contact with metallic boron at 1100–1800 °C to provide reduction to BF. Then BF is plasma chopped to form B^+ ions. This is a process we rejected. For design of innovative table-size mobile ion implantation apparatus, **our first aims were**:

1. To excite the boron plasma from metallic form boron, or at least powder-form boron oxides, to avoid poisoning and massive gas bottles (success).
2. To prove the boron ion density (success).
3. To compress and extract the ion beam using the most appropriate method. It was expected that this method would use the linear 6-phase coil (railgun) system (Phase-shifted Plasma Turbine) suggested at CrossFireFusion webpage (discovered that el-stat method works better).

It was known that practically alone plasma excitation method working well on boron is hollow cathode. Thus, we began with a 25-mm quartz pipe (see in picture below) in which there is a pure nickel cathode as well as a subsequent vacuum, inert gas (argon), and high voltage feeder subsystems. We expected that the first hit of any excited atom to pipe walls will freeze to the wall, which must inevitably be colder than 4200 K. Later we find that this effect creates a problem only in thin pipes.

For this reason, we had to plan to squeeze the plasma region into a magnetic rope and intensify the plasma ionisation degree by superpositioning the RF-ICP ionisation coil over the region between hollow cathode [4, 5, 6] and magnetic plasma rope. Further experiments showed that this was unnecessary.

First under our attention came Brazilian physicist from **crossfirefusion.com** (***CF Fusion Inc.***) Douglas M. Ferreira Palte had the idea of a linear accelerator using phase-shifted 6-phase coils (picture at left from his website). Indeed, exists a lot of publications about magnetic accelerator advances over electrostatic accelerator (see references below), yet most attractive feature of such coils is ultimately that they allow simultaneously compression the plasma rope and extraction the ions. After correspondence with this author we received a clue that no one has ever made any trajectory modelling for this proposed coil type [7, 8, 9, 10, 11, 12, 13, 14].

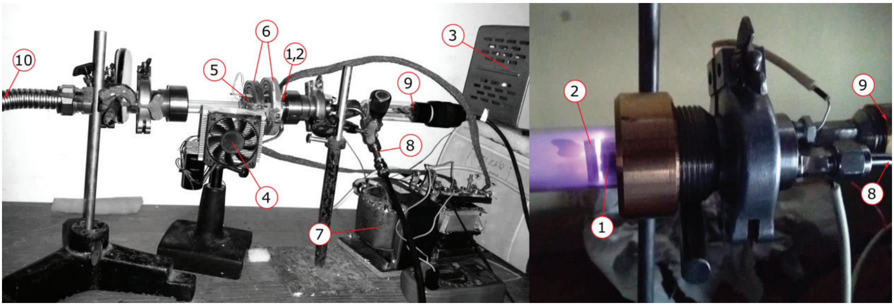

Fig. 1. *Our boron ion source: 1 – hollow cathode electrode; 2 – anode; 3 – high voltage source; 4 – ICP oscillator; 5 – ICP inductor; 6 – Helmholtz coils; 7 – 100 A DC current source; 8 – argon pipe; 9 – vacuum sensor; 10 – vacuum pump inlet*

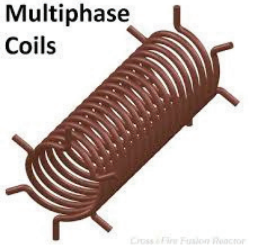

Fig. 2. *Proposed multiphase coils*

Thus, we built the appropriate **computer model**. There exists a lot of computer software for modelling E or H fields. However, even if the software is capable of solving both fields simultaneously, it must also be able to handle changing time-shifted fields. In view of these requirements, our hopes to use SimIon, Maxwell, Lisa-v8, Ansys, etc. diminished. Consequently, we used WolframMathematica-v10 to solve the full-set of Maxwell equations for the given geometry.

During the modelling process, we believe that we obtained a high level of accuracy; therefore, we trust that our results are dependable. In the result, we got particle trajectory in the field for the multiphase coil, which may be cautiously labelled as 'very sophisticated'. By this it is implied that this field is not comparable to any known geometric form such as a straight line or a spiral. For our needs the trajectory for the multiphase coil is completely invalid. After a year, we checked the CrossFireFusion site only to discover that most of the pictures and sentences about phase shifted coils had been removed. Thus we guessed the author himself realised the inconsistency of this coil geometry to be half of classical linear motor rail geometry, where coils stands one after another. It seems obvious that the basic reason for failure of the multiphase coil is that the H field diminishes too gradually, so the flying particle is influenced by several turns at once thereby producing contradicting fields simultaneously.

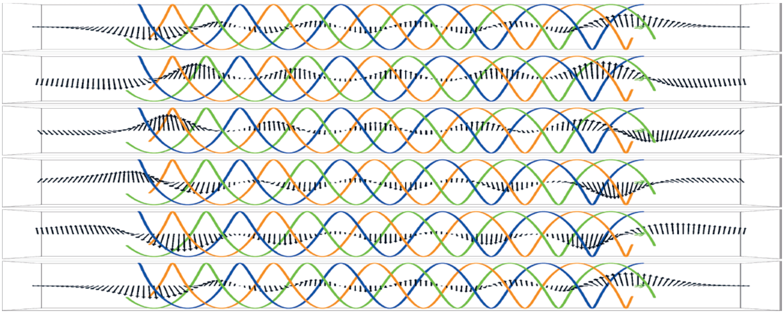

Fig. 3. *Force vectors field distribution v.s. current phases in 3-phase proposed coil, modelled for our size (Graphs differ with current time: upper at t = 0, below t = 0.2 of period τ; then 0.4 τ; 0.6 τ; and last 0.8 τ)*

At the visualisation from the computer simulation of linear multiphase accelerator of CrossFireFusion suggested geometry the small arrows represent the field forces at each time moment that act on a charged particle. The thruster is capable to act at least in part correctly, if the particle is laid into the field collinear to axis and step of winding is heavily large. However, this is not the case we are exploiting.

Thus, we provided our **experimental part** with simple Helmholtz DC bi-coil magnetic structure with 400 A*turns and 15 mm between the coils to create a magnetic squeezer that will compress the magnetic rope. In the quartz pipe of inner diameter 20 mm. and length 200 mm. we created a 0.01 Torr vacuum and a laminar flow of argon gas. The Nickel cathode diameter was 14 mm, and it was electrically insulated on the outside by a short length of quartz pipe. The inner volume of the nickel cathode was filled with boron powder, mixed in water and dried well. For our raw boron resource, we ultimately chose to use boric acid of medical purity. This decision was made as soon as we realized that 1 gram of metallic boron of poor technical purity costs ca 30 EUR and that the buyer must issue a document certifying that the material will never be used in a nuclear bomb. For excitation, we used three different high voltage DC sources (1–3 kV) with current stabilisation of 1 mA, 25 mA, 100 mA. The ion concentration was measured using arbitrary units to compare with other known ion sources of different producers, using pocket the spectrometer Ocean Optics USB4000-XR1. For multiple theoretical reasons, spectral line brightness is not very reliable measurement of ion count, but for a similar excitation system and similar current it may serve quite well indicator of ion density.

The first spectrogram above shows our results (arrow marker shows boron resonance line), the second spectrogram is typical for Perkin-Elmer reference boron spectra source, just similar for Russian ЛСП-1 source. The line is short here because both pictures are made with a narrow aperture to keep the sensitivity identical. This demonstrates that the intensity of light produced was quite strong. The partial answer on such riddle is that occasionally we found out, that plasma intensity at the **hollow anode discharge** is far brighter than at the hollow cathode. Just + and minus wires must be interchanged and voila. There exists a small number of publications regarding this effect, thus we are not first to observe this phenomenon.

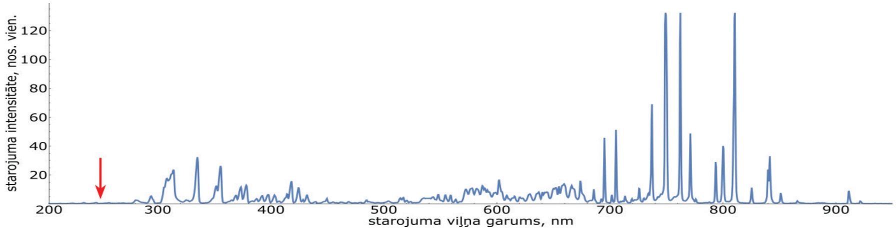

Fig. 4. *Spectrogram of our ion source*

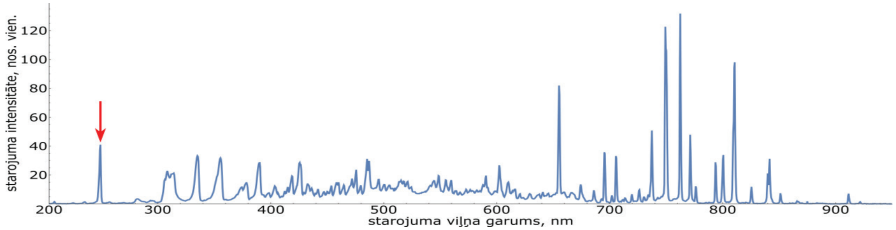

Fig. 5. *Spectrogram of standard boron ion source by the same aperture*

Future Work – must design optimal ion extracting, cleaning, and accelerating systems, which we will utilize to experiment with a conical electrostatic extractor and a MS-QMS mass filter. Most likely we will use a linear magnetic railgun as our particle accelerator.

The basic reason why we had no problems about **particle condensation on walls** may be demonstrated on basis of graph, provided by our computer model. The vertical axis is the ion beam radius. The horizontal axis is the distance from the ion source. Helmholtz coils A and B (each with a current of 100 A) steer the boron particle with initial speed of 1 km/s at an angle of 80° against the axial target. C is the focusing coil with 300 A*turn. Line 2 represents the case in which C is fed by a 2 MHz pulsed RF source. Thus, installing the aperture in the focal plane, even the velocity filter may be easily realized, a benefit later exploited by the QMS mass filter. It is worth emphasising that our success with a lack of boron condensation on walls seems due to the larger diameter quartz pipe in light of our initial experiments in which we employed a quartz pipe of smaller diameter and struggled with the problem of boron condensation.

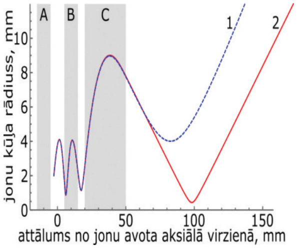

Fig. 6. *The ion beam radius v.s. distance from source modelled*

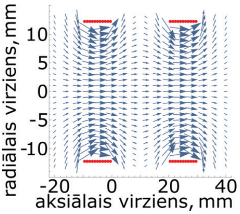

Fig. 7. *Helmholtz configuration coils (400 A·turn) impact – the magnetic bottle*

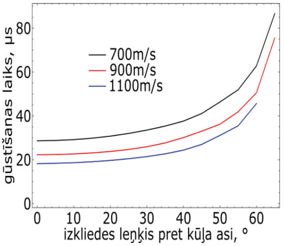

Fig. 8. *Computer simulation of B+ ion capture time. All particles with initial angle less than 65° toward target are captured and kept between both coils. All ions moving along the axis are free laid to run out*

Model is made for a solenoidal ion lens, focusing our B+ beam. Diameter 24 mm, length 10 mm, 5 turns/mm.

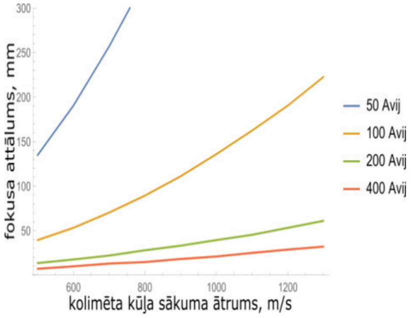

Fig. 9. *Focal plane distance (from those the coil end nearest to the ion source) versus particle speed and H*

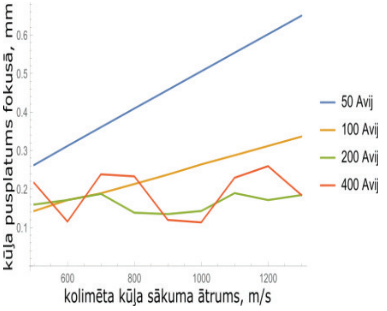

Fig. 10. *Beam width radius versus beam initial velocity and H*

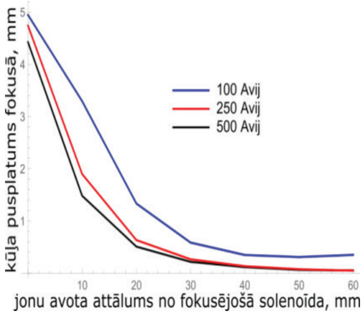

Fig. 11. *Beam width radius, versus distance to focusing coil and H at a particle velocity of 1 km/s, which is the average rms speed in this case*

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"LU Effective Cooperation Project" between Latvia University and Factory KEPP – High Power Electron Beam Gun Supply Design (100 kW; 30 kV; 4 A)

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Power supply was constructed on chassis of decommissioned 45×45×90 cm laser power supply on the wheels. The middle wall divides it into a HV (high voltage) (30 kV) and a low voltage (600 V) compartments.

Fig. 1. *Power supply frontal view*

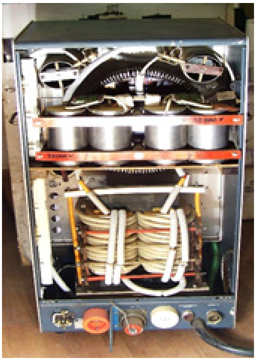

Fig. 2. *Power supply rear view*

Fig. 3. *Operator panel*

SMPS (switched mode power supply) generally begins with EMI filter: differential before synphase section. However, for a while this job is laid off for later Filter had been designed but not build. Entrance coil on alsipher toro: 50HH with inner diameter = 35 mm and external diameter = 55 mm, together 15 cm long stake with 4 turns of 5 mm thick 3 parallel wires for each phase were wound around the alsipher toro. Capacitors stay at 0.01 µF, and the common point hangs free. Second section is 3 separate iron core transformers 4×8 cm core; a window 1.5×5 cm; 6 turns per core; and attached capacitors of 0.047 µF with gnd to a common point.

SMPS begins with 25 mm^2 (5 A/mm^2) input cable, ending with 160 A magnetic fuse/switcher within time group 10 msec. That means that in ordinary conditions it is stable enough, but in case of a short-circuit because of the melting fuses which to protect the SMPS supervising laptop and all inner low-current parts feeding.

From the main switcher, all three phases go to the main rectifier – classical 6-pole 3-phase circuit. As it is loaded by main capacitor battery (8×650 µF), the sudden PON (power-on) will fail to pass with network zeroes, thus the over-current is imminent. There are several classical solutions. One such solution is to place a varistor before the capacitors, but it is impossible over the few amperes. Larger systems utilize the serial resistors of few Ω, shortened by massive relay or magnetic starter. However, for 120 Amp case, the cost is simply shocking. Therefore, our choice fell on a pure electronic switcher, using the thyristors instead of the diodes at rectifier which may appear illogical; nonetheless, thyristors are cheaper than diodes. As the 120 Amp diode cost ca 100 EUR, our choice was MCMA140P1200TA for 38 EUR/pc (seen at right; at left igbt's; all mounted on a cool water-filled platelet; most of PCB's are attached to this cooler).

Fig. 4. *EMI filter coils*

Fig. 5. *Main switcher*

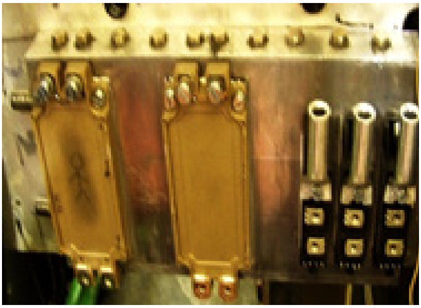

Fig. 6. *Cooler with igbt and thyristors*

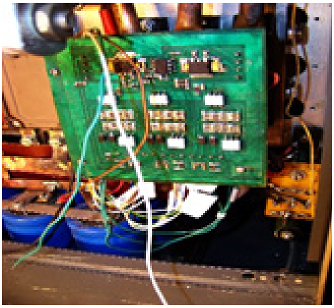

Fig. 7. *Rectifier control PCB mounted over rectifier*

Diodes may switch ON only when the capacitors are mostly charged-up, and simultaneously be zero in subsequent phase. These logics are provided by voltage sensors on the resistive divider, Zener diode, reciprocal-stabilizer TL431 and optron HCPL7720 basis. Signals are summed by a transistor half-bridge, loaded by 6 triac output type optrons MOC3083 with voltage zero control, to soften a PON current shock, which provides an ignition current for high power thyristors. Tests show that the system starts at 325–330 V on caps, and as a result, we adjusted it to 420–430 V. As the given voltage in 220/380 V 3-phase systems is p–p 538 V and at fall-downs is 465 V. Thus, the ignition is persistent, and there is no need to repeat it every half-period. As a safety measure, ignition requires the operator to push the panel button RUN; release of the STOP button; and cooling water circuit signals 'water flow good' and 'water cold enough'. This rectifier may also be interrupted by signals of 'one phase lost', 'gnd lost', and 'igbt too hot'.

A fresh idea we discovered here is that of a very small (1 A) rectifier on 1N4007 that via 1 kΩ charges up the main capacitor battery in approximately half a minute. When the main rectifier is ON, there is no need to disconnect this servo-rectifier, as the resistor provides no-current obstacles on the small diodes. As far we have read, such a solution is an innovation.

The rectifier is mounted on a water-cooled radiator beside the main igbt's. Realising the cost of multiple kilograms of pure copper (20 × 30 cm by 1-inch), we only bought a 5 mm sheet and attempted to solder the plumber copper-pipes to the sheet. This resulted in a fiasco, because 0.5 mm walled pipes and 5 mm plate makes too much of a difference in thickness, resulting in non-melted and burned-through zones. Thus, we redesigned the cooler to be a 1-inch thick aluminium platelet with drilled water channels, in ends screwed by conical threads. For 10 mm thread it was hermetic even under 12 kg/cm² tension, only 3 of 18 were leaking but re-packing stopped the leakage. But the manifold (3/8-inch) has no conical choice, thus even after 5-times re-packing they leaked and leaked. The ultimate solution we got from 'Locktite' metal to metal glue that hardens under pressure. We suggest that hydraulic testing is mandatory to ensure no leakage with high power and high voltage components. Our test was successful in this regard. A propeller type water counter with a Hall sensor was added to the water inlet to give warning if water stops.

Main capacitor battery was put together on a 350 V electrolyte basis. The capacitors were connected two-in-series with 4 branches in parallel. It is extremely important to use a non-inductive mounting; thus, we used the plane cut-out strips of copper, connected by hard-solder. Both wires were separated by 0.5 mm textolite, thereby making a bifilar sandwich. The total mount inductance was measured to be 0.05 µH, which is rather good but not brilliant. Capacitor middle points were dissipated on the block perimeter, thus current comes from both sides, while the hot-wire is a bifilar cross-branch from the main-line. There exist several different alternatives for connection of the battery terminals. The first is known as four-angle crosses for both poles. A better option is the six-sided-star net. The best option is monolete biphillary sheets with holes for through-going feet. All these arrangements demanded far more accurate mechanical realisation than we were ready to pay and receive in return only a small impact on inductance. Capacitors were shunted by appropriate resistors to equalize the voltages for a small current consumption case. At the igbt entrance this battery is shunted by a smaller fast capacitor battery to avoid the high frequency spikes. Oscilloscope shows spikes less than 30 V on DC power was for ca 20 nsec. We would wish to improve this, but as it is less than ~5% of nominal 535 V, this ripple together with spikes are acceptable.

The norm for our electron gun is periodic, short-circuits in the power supply many times per minute (30 000 V and 4 A !!). Such draconic obstacles cannot be allowed to burn-down nor blow-up the apparatus. Empirically it is known that the 6 mH coil, shunted with 1 kW capable 200 Ohm resistor, ought to be in the series with load; in order to give the security circuits time to stop everything. The coil was wound around an open-end 75 mm PVC pipe with 3 × 1 × 8-inch ferrite filling. We had to divide the coil into two equal halves to fit it into the case. From experience, we suspect that with time, perhaps several years, the coil will likely begin arcing. An epoxide bath would be the best solution to such a problem. However, at the moment we have seen no signs of sparks. The kilowatt resistor was absurdly expensive, thus we produced it ourselves by soldering the 1 W SMD 350 V resistors in matrix of 200 pcs in series and 3 such series in parallel (3 planks on coil in the picture, below the corner of HV rectifier). With a thermo-camera, it was determined that at the point of it shortening out, the temperature may rise-up to 70-90 °C, what is fully acceptable.

Those coils are getting energy from HV capacitor battery, for which we used 10 kV, 1 µF capacitors, connected in series of 4. Shunting resistors were applied to them. Battery voltage is controlled by HV divider, consisting of a special 36 kV 20 MΩ resistor. In the divider's output, the 5 V signal informs a ZVT controller to increase or decrease the duty factor. We were afraid those capacitors may be too slow, but as we chose extraordinary low frequency of SMPS (just to be as far as possible from the 'sin') at 15 kHz, the capacitors' inductive component was not disturbed. Capacitors to gnd are wired via 0.3 Ω current sensor resistors, used for analogue current scale, which we want to be sure to keep under small voltage.

Fig. 8. *Dempfer coils with 2 kW composite resistor*

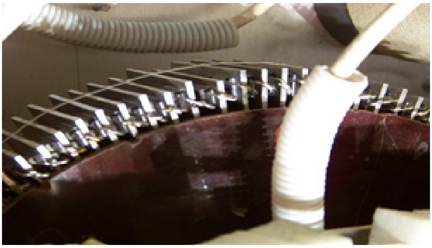

Fig. 9. *A part of HV rectifier with cooler platelets*

These capacitors are fed by 36 kV 5 A Graetz HV rectifier bridge. We found that as soon as the 'magical' 100 pcs in one bought is overstepped, the diode price diminishes multiple, referring to STTH51FP, thus 120 pcs cost under 100 EUR. This impressive count had to be mounted on insulated coolers under two fans of at least 6 × 8 cm (one fan on either side). Therefore, we machined 6 mm thick 33 cm diameter getinax disk with hole in the centre for fan mount. We found that best instrument to machine is hand ower-mill on a divider plank. The saw-path it gives is highly accurate, rapid and nice. On one side of the washer, we milled a 3 mm deep groove per diode. For this job, we used the lout-roll type of saw-machine stand. The lout hinge was fixed the required depth of 3 mm. Both roll-rods were used as grind-leaders, and instead of a saw-circle we used a rough abrasive circle. Our getinax washer was fixed on the centre-drill like a bearing. The accuracy of our machining was within about 1 mm which could be better, but it is good enough for the outer perimeter. In contrast however, in the centrum near the fan this was unacceptable. As a result, we fixed the inaccuracy on the non-grooved side of the other washer. In this side, we drilled 120 holes, threaded them (4 mm), and threaded through the holes cut-offs of plastic rod. Consequently, accuracy fell into +/– 0.3 mm and short-risk was eliminated. Each plate can be easily removed individually for repair if needed, and all wiring is soldered at the outer perimeter. Fans blow one from each side of our 'pancake'. Testing the job at 4 Amp, the thermovisor showed 9 diodes out of 120 which were 20 °C hotter than others. These diodes were extracted, washed, smeared anew and defect disappeared. Of these same diodes, 7 had thermal paste inaccuracy signs and did not screw in well. Two others simply did not function properly. The next test showed 70 °C +/– 1 °C which is fine. We suggest the use of the thermovisor for this final test to be a 'must-have.'

Main transformer at the chosen low frequency demanded a rather large cross section of 25–40 cm^2 with winding length of 30 cm, thus ready E cores was dead search. We chose to epoxy-glue our core from multiple I cores. Such are produced in Russia (8 EUR), USA (15 USD) and India (2–3 USD). The only unfavourable aspect about India was the 3 month (!) waiting time. The sizes obtained were 2 × 2 × 4-inch with surprisingly good magnetic qualities – $\mu = 2300$; $B_{max} = 0.39$ T; $f_{max} = 2$ MHz. Mechanically the core is very weak (brittle) and demands a great deal of care. The size allows very different sizing and form-factor gluing.

We glued 51 × 51 mm core with/on full width 22 cm, inner window 17 cm and height 23 cm. Glass fibre textolite envelope for windings was put on each side. For insulation on the sides we used a white type of hard flooring PVC linoleum, which is known to be capable of insulating up to 40 kV per layer. On lathe we wind 3 layers of 0.9 mm cotton double-insulated wire 200 turns per layer. Generally, the vacuum-imbue of epoxides ought to be provided; however, we were not sure if we would have to change the turn count. In the end, we laid this decision off until later. Technology with PE bag and vacuum-pump is well described elsewhere, so we will say little about this technology here. The risk is that the frequent micro-arcing may cause the carbon channels after a number of years to suddenly burn-out. Epoxides lower this risk about 10-fold. Secondary winding was produced from 13 mm 7-lode litzendrath. Instead of copper, we used aluminium, and for contacts crimped the standard cable pole shoes. To avoid the electrochemical rusting, we applied/used AISI-306 stainless washers. For initial testing of transformer, we switched reciprocally HV winding (secondary side) to 220 V network via adjustable laboratory autotransformer and constructed the graph i(o) = f(Uin). This is possible because we used in 50 Hz instead of a higher frequency. At 50 V current we had 6 mA; at 100 V was 12 mA; at 150 V was 22 mA; and at 200 V the graph sky-rocketed to a current of 36 mA. Calculating back from the secondary side to primary side, we found our losses were under 1% at SMPS frequency. That is not bad indicator.

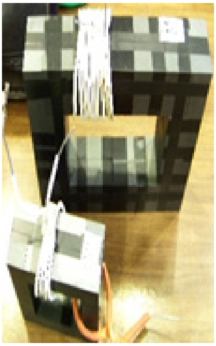

Fig. 10. *Dempfer coils with 2 kW composite resistor*

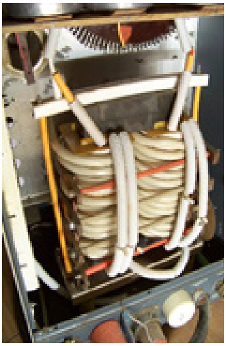

Fig. 11. *A part of HV rectifier with cooler platelets*

Fig. 12. *A part of HV rectifier with cooler platelets*

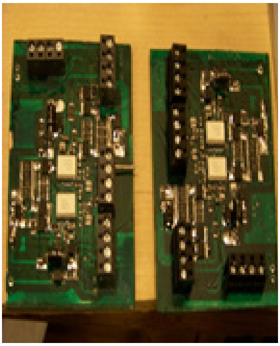

Fig. 13. *A part of HV rectifier with cooler platelets*

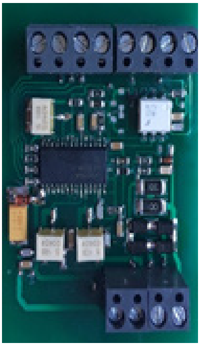

Fig. 14. *A part of HV rectifier with cooler platelets*

ZVT regime demands a surplus choke in series with primary of trafo, adjusted in resonance. We produced a coil form Indian 'Cosmo ferrites' (same as was used for the main transformer), 2×6 turns of 13 mm wire. Core central column 5×5×10 cm and outer width 22 or inner 16 cm. Between the two c-shaped cores on either side there is an air gap of 0,5 mm.

For power electronic keys, we used igbt modules 2MBI300U4N-120-50 which is a rather old FUJI design, and consequently, very cheap. As their parameters provide us with a large safety margin, we risked 70 EUR/pc against IXYS for 160 EUR/pc. Four such keys are commutating the 400 A and 600 V 'low voltage' at the full bridge circuit. Those igbt's are mounted on a water-cooled radiator, described above. Straight on each igbt is soldered a gate driver PCB, as seen in a picture.

The best quality driver solution is the specialized Fuji unit for 180 EUR/pc. However, since we require 4 pcs the price was not felt to worth it. As even the specialized driver chip costs about 50 EUR/pc, we found an even cheaper option without loss of quality with a chip for the hot half and a separate chip for the cold half. Initially, we thought about TC4422/TC4421 (one upper, other lower), because for less than 1 EUR they allow the 9 A gate current. However, the producer's consulting engineers suggested that none of them possessed the crucial security functionalities that we require. As a result, we bought a more modern ACPL336G, with branched high fidelity multiple safety functionality; thus, our igbt is secured against all dangerous regimes. Its only fault is very small, a 2.5 A output current, but this we fixed by a half-bridge booster cascade on the basis of complementary PHTP60415NY and PHTP60415PY transistors. The result was 30 A gate qualification at the peak. All PCB was produced by Positiv-20 resist micro photolithography at our lab plus green photosensitive lacquer. The only thermally suspicious component we discovered was an anti-oscillatory SMD resistor in series with the gate (+55 °C, thermo-camera is great indeed). However even this is not dangerously high.

The multiple small voltages' and small currents' power supplies for all the PCB's must all be galvanically insulated (4 pcs 20 V × 2.5 A, 4 pcs 5 V × 2.5 A, 4 pcs 5 V × 0.5 A). These power supplies were based on a boring classical transformer and stabilizer LM338J basis.

ZVT controller provides the correct phasing and duty factor control. We used the UC3875 on a separate PCB, because in the near future we intend to substitute it by ARM microcomputer chip, steered by external laptop.

Microprocessor: is sure it is needed by e-gun process physics and customer demands. But for the moment our construction life-capacity is demonstrated just by two manual knobs (current and voltage), thus we are confident to soon begin the second stage of this project – computerisation of our self-made power supply.

Principal full electric diagram, nominals and topology, unfortunately considered confidential. However, we invite all interested parties to contact us, taking in account that the second copy will come out much faster and cheaper than the first. Mass production is not the purpose any scientific institution, however, some hi-tech services can obtain any commercial partner according to our University competition rules, or through other means.

Bio-Sensing Antioxidant-Specific Biomarkers by Microwave Dielectric Whispering-Gallery-Mode Resonator

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Bio-sensing enzymatic and non-enzymatic antioxidants associated with the ROS (reactive oxygen species) and RNS (reactive nitrogen species) production under stress conditions in living cells is very relevant in the light of the growing interest in multi-functional biosensors and biomarkers. Therefore, their functional characterization in terms of analytical sensitivity, specificity and validity/utility is very important for biological studies [1]. Among the approaches proposed for cellular bio-sensing, the use of waveguide dielectric resonators is one of the most promising techniques for non-invasive detection of biomolecules *in situ* [2]. The whispering gallery mode (WGM) resonators have been shown to have super high sensitivity for bio-sensing due to the resonant light-matter interaction between the waveguide mode and the analyte, which can be enhanced in proportion to the resonator's Q-factor. Using a microfluidic WGM resonator in the microwave frequency band allows accurate measurement of a complex permittivity of biomolecules at nanoscale [3].

In our work, we applied the microwave WGM technique to study bio-sensory properties of specific antioxidant biomarkers related to the ROS and RNS mediated in cells under stress. For experiments, we used the high-Q sapphire dielectric micro-resonator, covered by a plastic layer with a microfluidic channel, and we tested several low molecular weight non-enzymatic antioxidants (ascorbate, glutathione) and antioxidant enzymes (superoxide dismutase, catalase) as samples. By systematic measurements, a set of characteristic responses of test substances at different concentrations and temperatures in the physiologically relevant aqueous solutions was obtained and analysed. Experiments showed very good sensitivity and selectivity in detecting biomolecules at different resonance frequencies at the ng/ml level with high accuracy. As well, the cells remain uninjured both during the measurement, and after the procedure. The obtained results indicate the potential of the WGM resonator technique for non-invasive microwave sensing of antioxidant-specific biomarkers, as well as the prospect of new reliable biosensors for express-diagnosis of oxidative stress in living cells. Research is in progress.

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Optical Fibre Melting Temperature Determination from Planck’s Law

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In our experiment, we melted the tip of the optical fibre with a gas-flame torch to make small glass ball and were needed to measure temperature during this process.

During melting a smooth-surface droplet-like ball is formed due to the surface tension effect. We intend to use such balls as whispering-gallery-mode (WGM) micro-resonators for optical biosensor applications [1]. They guide light by the total internal reflection, and increase the effective interaction length of the evanescent wave with the adsorbed biomolecules on the surface from a liquid sample.

The temperature at the melting zone can be estimated from the colour of the glow using Planck’s formula for the black body radiation [2]:

$$U(\lambda,T) = \frac{8\pi hc}{\lambda^5}\,\frac{1}{e^{\frac{hc}{\lambda kT}}-1}$$

The same fibre that is being melted is used to guide the light to a miniature grating spectrometer (Ocean Optics JAZ USB). This method has the potential industrial application [3] to monitor temperature during fibre bundle production in Z-Light [4].

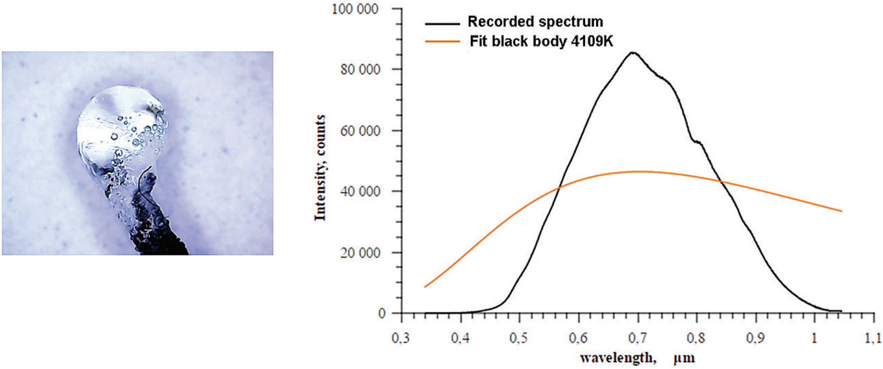

***Fig. 1.** Left: Microscope photo of a 1 mm diameter ball formed by melting of a fibre tip*
Right: recorded emission spectrum during melting and fit using Planck’s formula

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Thin Hydroxyapatite Coatings Structure and Phase Composition Manipulation by Variation of RF Magnetron Sputtering Parameters

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In the modern approach to regenerative medicine, calcium phosphate coatings are used to enhance implant stability and osseointegration. From the variety of calcium phosphate coatings such as tricalcium phosphate, tetracalcium phosphate and others, hydroxyapatite (HAp) [1, 2] is the most widely used material. The main features of the coatings are bio-resorption and dissolution rate which are influenced by the coatings surface morphology, structure, phase composition and crystallinity state. It is known that radio frequency magnetron sputtering allows a highly controllable process for the deposition by variation in the sputtering parameters.

In our work, the influence of the different parameters of the sputtering process, such as working gas mixture and substrate bias voltage regarding HAp coatings structure and crystallinity state were studied. In the TEM image (see Fig. 1), a cross-section of the coating deposited from the HAp target, Ar working gas in the vacuum chamber at the pressure of 0.1 Pa, sputtering power of 250 W and sample to target distance of 80 mm have the structure and phase composition closed to the HAp parameters. Raman spectroscopy provided detailed information about the chemical structure, phase and molecular interactions in the studied material. Also, this technique is sensitive to the degree of crystallinity in a sample. According to the Raman spectroscopy data, with 10% of O_2 addition to the Ar working gas or the application of –50 V substrate bias voltage leads to the amorphisation of the coating. It is possible to increase the concentration of the phosphate groups and the level of crystallinity of the coatings by applying +50 V substrate bias voltage. This is due to the attraction of negatively charged PO_4^{3-} groups and the partial crystallinity of the coating. The possible mechanism by which the change in working atmosphere and the application of a sample bias voltage cause an elemental composition and crystalline structure change was also discussed.

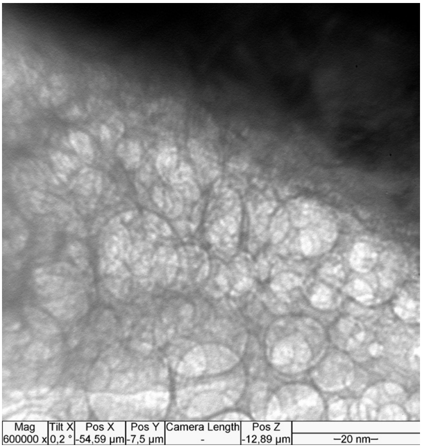

Fig. 1. TEM cross-section of HAp coating on Ti substrate

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Innovative Techniques of Crystal Growth to Avoid Pollution

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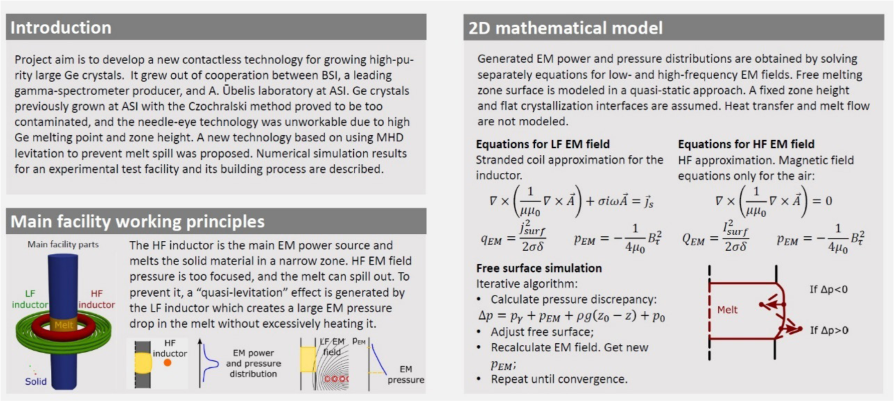
Based on the data of a previous joint project of University of Latvia and Baltic Scientific Instruments Ltd. in 2016–2017, where a theoretical possibility to grow crystals from quazi-levitating melted zone was calculated and tin crystals were grown (270 °C; 400 W; Ø10 mm), there is well founded interest to develop innovative crystal-growing technique for higher temperatures, power and size enlargement. This was impossible to achieve with the equipment available at the time.

Scientific literature indicates that zone melting and pedestal technology is widely used to grow high purity large size silicon monocrystals. However, these technologies cannot be easily used for growing germanium crystals due to differences in specific weight, thermal conductivity, melting temperatures, viscosity and surface tension which limit the use of needle-eye technology [1, 2, 3]. While the technology is limited, there is increasing demand for the highest purity, large-sized germanium crystals that are widely used in gamma spectrometers, photovoltaic technologies and in other instruments.

Up to this date large sized germanium monocrystals of highest purity are grown using Chohralsks' method. The template before growing the crystal is purified several times using the zone method.



Introduction

Project aim is to develop a new contactless technology for growing high-purity large Ge crystals. It grew out of cooperation between BSI, a leading gamma-spectrometer producer, and A. Ūbelis laboratory at ASI. Ge crystals previously grown at ASI with the Czochralski method proved to be too contaminated, and the needle-eye technology was unworkable due to high Ge melting point and zone height. A new technology based on using MHD levitation to prevent melt spill was proposed. Numerical simulation results for an experimental test facility and its building process are described.

Main facility working principles

The HF inductor is the main EM power source and melts the solid material in a narrow zone. HF EM field pressure is too focused, and the melt can spill out. To prevent it, a “quasi-levitation” effect is generated by the LF inductor which creates a large EM pressure drop in the melt without excessively heating it.

2D mathematical model

Generated EM power and pressure distributions are obtained by solving separately equations for low- and high-frequency EM fields. Free melting zone surface is modeled in a quasi-static approach. A fixed zone height and flat crystallization interfaces are assumed. Heat transfer and melt flow are not modeled.

Equations for LF EM field

Stranded coil approximation for the inductor.

$$\nabla \times \left(\frac{1}{\mu\mu_0} \nabla \times \vec{A} \right) + \sigma i \omega \vec{A} = \vec{j}_s$$

$$q_{EM} = \frac{j_{surf}^2}{2\sigma\delta} \qquad p_{EM} = -\frac{1}{4\mu_0} B_\tau^2$$

Equations for HF EM field

HF approximation. Magnetic field equations only for the air:

$$\nabla \times \left(\frac{1}{\mu\mu_0} \nabla \times \vec{A} \right) = 0$$

$$Q_{EM} = \frac{I_{surf}^2}{2\sigma\delta} \qquad p_{EM} = -\frac{1}{4\mu_0} B_\tau^2$$

Free surface simulation

Iterative algorithm:

- Calculate pressure discrepancy:
  $\Delta p = p_\gamma + p_{EM} + \rho g (z_0 - z) + p_0$
- Adjust free surface;
- Recalculate EM field. Get new p_{EM};
- Repeat until convergence.

***Fig. 1.** Theoretical background*

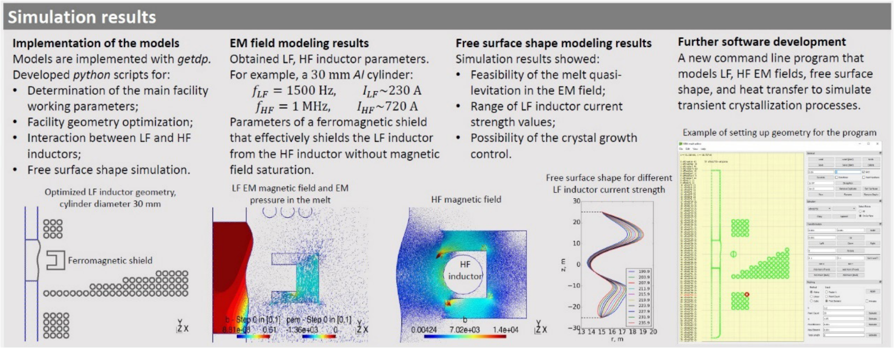
The objective of this project in long term is to create an apparatus which could grow monocrystals from a large levitating melted zone (3–10 cm) by combining Chohralski’s method, melted zone and pedestal methods. This would be an innovative and unique approach because the zone for growth of large crystals would not be in direct contact with the apparatus.

The perspective use of MHD levitation in metallurgy (Aluminium) has been discussed, both theoretically and experimentally in various scientific publications of LU FMF scientists since 2015 [4, 5, 6].

The aim of this project is to innovate the next step in growing technology of high purity Germanium crystals. This is a collaboration project and knowledge of various Latvian scientists is being applied to find optimal conditions and, acquire targeted manipulation of MHD levitation by changing configuration, power and frequency of generation inductor configuration to improve the geometry of growing crystal and melted zone.

The pedestal techniques are limited by problems maintaining the melting zone equilibrium. The innovation is proposed to ensure technological purity by MHD support of the melted zone the zonal purification being combined with crystal growth in a single unit. The necessary studies include:

1. Adjustment of a MHD levitation model to calculate the hydrodynamic stability of the melted material. So far a solution for small power and small sized crystals has been developed. Assessment of hydrodynamic stability of the melt – interrelations between the power of MHD inductors, frequency, ambient temperature and the temperature of the melt;
2. Assessment of the capacity of MHD control of large crystal diameter of a prototype device for temperatures below 300 °C;
3. Assessment of the capacity of MHD of a prototype device for 1000 °C.



Simulation results

Implementation of the models

Models are implemented with *getdp*.
Developed *python* scripts for:

- Determination of the main facility working parameters;
- Facility geometry optimization;
- Interaction between LF and HF inductors;
- Free surface shape simulation.

EM field modeling results

Obtained LF, HF inductor parameters.
For example, a 30 mm *Al* cylinder:

$$f_{LF} = 1500\ \mathrm{Hz}, \qquad I_{LF} \sim 230\ \mathrm{A}$$
$$f_{HF} = 1\ \mathrm{MHz}, \qquad I_{HF} \sim 720\ \mathrm{A}$$

Parameters of a ferromagnetic shield that effectively shields the LF inductor from the HF inductor without magnetic field saturation.

Free surface shape modeling results

Simulation results showed:

- Feasibility of the melt quasi-levitation in the EM field;
- Range of LF inductor current strength values;
- Possibility of the crystal growth control.

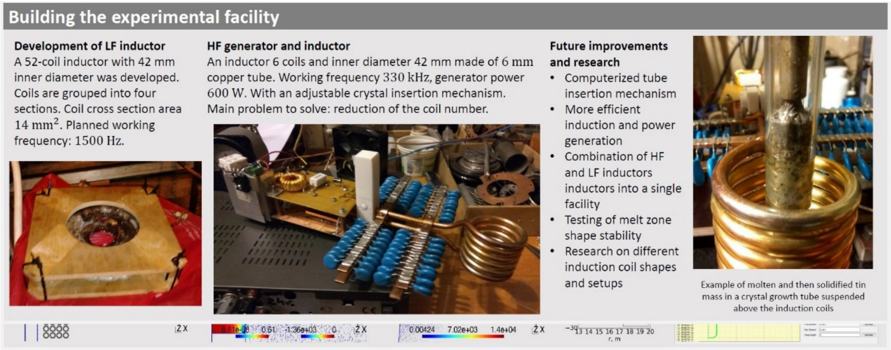
Further software development

A new command line program that models LF, HF EM fields, free surface shape, and heat transfer to simulate transient crystallization processes.

Fig. 2. *Simulation results*

The sequence of experiments to verify the MHD model and constructing the prototype:

1. MHD modelling (ongoing)
2. Design and assembly of the experimental set-up
3. Collection of experimental data
4. Summarization of experimental results and verification of the MHD model
5. Construction of the 1000 °C equipment for crystal growth
6. Growing crystals and collecting data
7. Analysis and appraisal of the results, conclusions.



Building the experimental facility

Development of LF inductor
A 52-coil inductor with 42 mm inner diameter was developed. Coils are grouped into four sections. Coil cross section area 14 mm^2. Planned working frequency: 1500 Hz.

HF generator and inductor
An inductor 6 coils and inner diameter 42 mm made of 6 mm copper tube. Working frequency 330 kHz, generator power 600 W. With an adjustable crystal insertion mechanism. Main problem to solve: reduction of the coil number.

Future improvements and research

- Computerized tube insertion mechanism
- More efficient induction and power generation
- Combination of HF and LF inductors into a single facility
- Testing of melt zone shape stability
- Research on different induction coil shapes and setups

Example of molten and then solidified tin mass in a crystal growth tube suspended above the induction coils

__Fig. 3.__ Building the experimental facility

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Prospects of Hybrid Organic-Inorganic Photovoltaic Solar Cells

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Today organic-inorganic hybrid (OIH) semiconductor materials are a creative alternative for applications in electronics and photonics, particularly, for photovoltaic (PV) solar cells [1]. The approach is based on the next innovative solutions: (1) use of low-cost bio- or synthetic organic compounds for creating OIH suitable for broad-band sunlight harvesting and PV energy conversion; (2) use of process of molecular self-organization and assembly for OIH growing at room temperature; (3) use of technology of thin film chemical deposition from a colloidal solution; and (4) use of smart technique of differential analysis of functional characteristics for optimization of OIH performance [2, 3].

According to our study of various samples of low-molecular-weight OIH cells fabricated on patterned Si substrates, including its structural, optical and electrical characterisation, such PV cells have the following features: (i) PV efficiency of energy conversation is up to 9% depending on the chemical composition and surface/interface morphology; (ii) performance of the Si-based OIH of thiamine diphosphate hydrochloride ($C_{12}H_{20}Cl_2N_4O_7P_2S$ cocarboxylase or Vitamin B1) for a thin layer of 30 nm and a self-organized net-like surface was found to be the best; (iii) intense optical absorption followed by photoluminescence in the range 400–900 nm, whose spectral distribution and peak have vibrionic origins; and (iv) there is a number of characteristic bands associated to functional groups containing amines $NH_x (x = 0, 1, 2)$, carboxamides *CON*, cyanides *CN*, hydrocarbons $CH_x (x = 1, 2, 3)$, hydroxyl *OH*, carbonyl *CO*, etc. Despite the limited understanding of the complex mechanism of charge-carrier transfer in such OIH, the classic model of electron-hole pair generation, charge separation, and recombination proved to be suitable to describe current-voltage characteristics, when the short circuit current *I*sc is a linear function of energy of irradiation, and the open circuit voltage *V*oc has a logarithmic dependence of energy followed by saturation. We found that even small changes in the OIH design can lead to essential differences in optical and electrical properties, however a proper technological manipulation can help to optimize the OIH performance to the desired results. Research is in progress.

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Collaborative Modification and Development of ICP RF Power Generator and Adaptation of Special Sources for Usage in ROFLEX-2 Instrument for Measurements of Iodine and Bromine in Atmosphere

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Iodine is released to the atmosphere mainly in the form of I_2 [1, 2] and alkyl iodides such as CH_3I and CH_2I_2 [3] by coastal and oceanic biological sources *(e.g. phytoplankton and 25 macroalgae)*. In the troposphere, I atoms are released by photolysis of I_2 and iodocarbons.

The measurement of atmospheric I_2 was first reported in [2] at Mace Head *(Ireland)*, who detected up to 95 pptv at night and 25 pptv during the day using active long path-differential optical absorption spectroscopy *(LP-DOAS)*.

A new instrument *(ROFLEX)* for in situ detection of atmospheric iodine atoms and molecules based on atomic and molecular resonance and off-resonance ultraviolet fluorescence excited by lamp emission has been demonstrated in laboratory and field measurements in 2011 [4]. The instrument has been optimised in laboratory experiments to reach detection limits of 1.2 pptv for I atoms and 13 pptv for I2, for S/N = 1 and 10 min of integration time. The ROFLEX system has been deployed in a field campaign in northern Spain, representing the first concurrent observation of ambient mixing ratios of iodine atoms and molecules in the 1-350 pptv range.

The new challenge for the ROFLEX instrument is the measurements of "tropical rings of atomic halogens" *(firstly iodine and eventually bromine)* predicted in modelling research [5] in 2016. The model results suggest that if experimentally confirmed, the extent and intensity of the halogen rings would directly respond to changes in oceanic halocarbon emissions, their atmospheric transport, and photochemistry. Therefore, new pilot project of collaboration is launched between research teams in Riga and in Madrid to contribute in production of a new version ROFLEX-2 with a completely new construction and increased sensitivity to meet the NASA's Armstrong Flight Research Center requirements for equipment packages on Global Hawk unmanned aircraft platform with the objective of measuring I or Br *(or both)* over the tropical Pacific *(Guam)* to confirm the existence of *"Halogen Rings"*.

The Collaboration Project somehow is going to be pilot initiative to the ERC Consolidator grant, *CLIMAHAL ("Climate dimension of natural halogens in the Earth system: Past, present, future")* awarded to prof. Alfonso Saiz Lopez. The *CLIMAHAL* project will use a multidisciplinary approach including spectroscopic and kinetic methods, as well as theoretical modelling to determine, for the first time, the effect of natural halogen molecules on the climate of our planet in past, present and future scenarios.

NASA's remotely piloted "Global Hawk" aircraft NASA's Goddard Space Flight Center (flight duration 30 hours, altitude up to 18 000 km)

Fig. 1. *Collaboration project for remotely piloted ROFLEX-2 device*

The model results suggest that if experimentally confirmed, the extent and intensity of the halogen rings would directly respond to changes in oceanic halocarbon emissions, their atmospheric transport, and photochemistry. Therefore, new collaboration project was launched between research teams in Riga and in Madrid to produce ROFLEX-2 version with a completely new construction to meet the NASA's Armstrong Flight Research Center requirements for equipment packages on Global Hawk unmanned aircraft platform with the objective of measuring I or Br (or both) over the tropical Pacific (Guam) to confirm the existence of *"Halogen Rings"*.

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The FP7-MC-IRSES Project "Development of Nanotechnology Based Biosensors for Agriculture – *BIOSENSORS-AGRICULT*"

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The application and the implementation of the Project No.: 318520, BIOSENSORS-AGRICULT (01.09.2012–31.08.2016) was precisely in line with the objectives of the FP7-REGPOT-2011-1, No. 285912, FOTONIKA-LV project contributing to effective collaboration, and sharing of knowledge between East European *(Belarus and Ukraine)* and West European countries (*Sweden and France*). The University of Latvia, Coordinator of the Project, represented the following consortium: CNRS, Montpellier, (*France, European Institute of Membranes);* University of Linköping, Sweden; Odessa National I. I. Mechnikov University, Ukraine; National University of Life and Environmental Sciences, Ukraine and Institute of Biophysics and Cell Engineering of National Academy of Sciences, Belarus.

The project resulted in outstanding research outcomes and effective training of early stage researchers, technicians and management staff: 20 publications in peer reviewed journals; 10 conference theses have been published; two international workshops, two summer schools and three conferences were organized; and more than 10 project proposals to the FP7 and H2020 calls were raised. Two PhD students applied for the Erasmus program between partner universities *(Ukraine-France and Latvia-France)*. Two bilateral projects Latvia-France and Ukraine-France were won in 2016.

Activities in the area of sample deposition and characterization resulted in the following:

- New photonic nanomaterials: ZnO ultrathin nanolayers (< 25 nm) and Al_2O_3/ZnO nanolaminates with layer thickness lower than 11 nm, deposited with ALD method on Si, glass and electrospinning fabricated organic nanofibers;
- New plasmonic Au/ZnO nanostructures deposited using PVD and ALD methods for Au and ZnO respectively;
- The deposited samples were characterized by SEM, EDX, Raman, FT-IR and XRD, optical and photoluminescence spectroscopy.

The following biosensors have been tested:

- Photoluminescence ZnO based biosensors were tested for use in glucose monitoring;
- CVD deposited ZnO nanostructures were tested as electrochemical biosensors for aflotoxine;
- Detection ZnO nanorods and TiO_2 nanoparticles were investigated for application in photoluminescence biosensors for Salmonella and Bovine leucosis detection;
- Novel optical fibre biosensor system has been developed and applied for detection of ethanol vapours and organic solvents with different refractive indexes;
- Novel plasmonic Au/ZnO nanostructures with advanced optical and structure properties for biosensor applications.

Within a project the following optical biosensors for the agriculture pathogens were developed:

- Salmonella;
- Bovine leukemia virus;
- Ochratoxin;
- Aflotoxin.

Bilateral LV-UA and LV-FR (*OSMOZE*) Projects as Long Lasting Collaboration between Project Partners of FP-7 Project BIOSENSORS-AGRICULT (Project No.: 318520)

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As result of fruitful cooperation, new bilateral projects were submitted and funded.

A collaborative project "Search of main effective algorithm of biosensor express control of biochemical parameters of the progression of cancer lesions and the effectiveness of its treatment", is funded within the Ukraine-Latvia research program. The partners are: the University of Latvia and National University of Kiev-Mogila Academy. Coordinators of project are Professor Mykola Starodub and Dr. Una Riekstina from Ukrainian and Latvian sides, respectively. The University of Latvia is represented by Faculty of Medicine (group of Dr. Una Riekstina) and Institute of Atomic Physics and Spectroscopy (Dr. Roman Viter).

The main objective of the project is finding an effective means to express biochemical diagnostics of tumour progression in a number of body tissues, assessing the effectiveness of cancer treatment and detailing the characterisation of approaches developed for practical use. The project runs from 2017 to 2019. Total budget of Latvian side is 20 000 EUR.

A collaborative project "ALD deposited ZnO/graphene nanostructures for optical sensors" is funded within the Latvia-France program OSMOZE. The partners are: the University of Latvia and the University of Montpellier. Coordinators of project are Dr. Mikhael Bechelany and Dr. Donats Erts from French and Latvian sides, respectively. University of Latvia is represented by the Institute of Chemical Physics (group of Dr. Donats Erts) and the Institute of Atomic Physics and Spectroscopy (Dr. Roman Viter).

The general aim of this project is to develop efficient nanotechnology solutions for novel, graphene based nanomaterials with advanced structural and optical properties. New physical properties, resulted from graphene monolayer/metal oxide nanolayer contact will be obtained. The application of the novel materials in optical biosensors (photoluminescence and optical reflectance) will be studied.

The project runs from 2016 to 2017. Total budget of Latvian side is 10 000 EUR.

Rīgas Fotonikas Centra darbība un nākotnes plāni

Vidvuds Beldavs

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Biedrība “Rīgas Fotonikas Centrs” (RFC) dibināta 2015. gada 2. oktobrī, lai turpinātu Latvijas fotonikas klastera veicināšanas darbu, kas tika iesākts FP7-REGPOT-2011-1, Nr. 285912, FOTONIKA-LV projekta laikā. Tās mērķi:

- veicināt fotonikas, kvantu zinātņu, kosmosa zinātņu un saistīto tehnoloģiju attīstību (turpmāk tekstā F-JOMAS);
- darboties kā F-JOMU klastera koordinatoram, kurā ietilpst zinātniskie institūti, uzņēmumi, universitātes un citas izglītības iestādes, kā arī valsts aģentūras, kas ir saistītas ar F-JOMĀM;
- konsultēt uzņēmumus un pētniecības laboratorijas F-JOMU attīstībai;
- nodarboties ar zinātniski popularizējošu darbību saistībā ar F-JOMĀM.

Savu mērķu sasniegšanai RFC īsteno šādus uzdevumus:

- organizē dažādus zinātniskus un sabiedriskus pasākumus F-JOMAS attīstībai;
- pārstāv un atbalsta F-JOMAS pētniecības institūtu, laboratoriju un uzņēmumu intereses augstskolu, zinātnisko institūciju, valsts un starptautiskā līmenī;
- reklamē F-JOMAS kā nozīmīgas tautsaimniecībai;
- veicina inovatīvo darbību F-JOMĀS;
- koordinē pētnieku un uzņēmumu sadarbību F-JOMU attīstībai;
- piesaka un realizē projektus F-JOMAS attīstībai.

RFC ir iesniedzis un plāno projektu pieteikumus projektu konkursiem 2015.–2017. gadā:

- *INTERREG Baltic Sea Region – seed money grant to plan large scale project PHOTONICS BALTICUM;*
    - *“INTERREG Baltic Sea Region”* ir Eiropas Komisijas (EK) programma, kas ir veidota efektīvākas sadarbības veicināšanai starp Baltijas jūras reģiona valstīm (sk. https://www.interreg-baltic.eu/home.html). Šo aktivitāšu atbalstam 2014.–2020. gadā EK plāno € 270 milj. Programmas prioritātes ir inovācija, dabas resursi un transports. RFC koordinētais projekta pieteikums ir inovācijas prioritātē, lai veicinātu sadarbību starp fotonikas klasteriem Latvijā, Lietuvā, Igaunijā, Polijā, Dānijā, Zviedrijā un Somijā;
    - *“INTERREG Central Baltic”* – ir Eiropas Komisijas Centrālā Baltijas jūras reģiona pārrobežu sadarbības programma noteiktām teritorijām Zviedrijā, Somijā, Igaunijā un Latvijā (sk. http://centralbaltic.eu). RFC plāno veidot projektu sadarbības veicināšanai starp pētniecības centriem un mazajiem uzņēmējiem sadarbības paplašināšanai ar Āfrikas universitātēm un pētniecības centriem, centrējot to uz vienotu zinātnisko instrumentu un izglītības programmu kompleksu, kas veicinātu zinātnes un pētnieciskā personāla attīstību Āfrikas Savienības dalībvalstīs. Kā galvenais sadarbības partneris plānota Āfrikas Savienības Komisija.
- *INTERRECT Central Baltic – BALTECHAFRICA – marketing of R&D capacity and research instruments produced in Sweden, Finland, Estonia, Latvia and Lithuania to Africa;*
- *Horizon 2020 Researchers’ Night*.

RFC plāno iesniegt projektu pieteikumus:

- *INTERREG Baltic Sea Region* programmai;
- LIAA klastera atbalsta programmai.

RFC turpinās palīdzēt Mazajiem un vidējiem uzņēmumiem (MVU) sagatavot pieteikumus *Horizon 2020 SME Instrument* projektu konkursiem.

RFC rīko kolokvijus, seminārus un konferences, lai veicinātu klastera attīstību.

Avoti

[1] www.rigaphotonicscentre.org
[2] https://www.facebook.com/fotonikalv/

Unique, Immune to Electromagnetic Interference Multi-Channel Ultrahigh Temperature Thermometer *(PLANC's-TERMO)* for up to 2400 °C

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A joint team of researchers from excellent RTD institutes in Belarus, Association FOTONIKA-LV at the University of Latvia and research-driven SME Keramserviss Ltd is going to overtake the specific market of high and ultrahigh temperature measurements with disruptive innovation – a unique Multi-Channel Ultrahigh Temperature Thermometer *(MC-UTT – PLANC's-TERMO*) immune to electromagnetic interference for the range 600 °C–2400 °C and applicable under extreme conditions where existing traditional devices (such as thermocouples and thermistors) have short resource in high temperature environments or are unable to function. The 4-channel prototype *(4C-UTT)* is already made and calibrated up to 1800 °C *(TRL>6, expected costs in series production – 5000€)*. The company is active in heating technologies since 1999. Turnover in 2015 was 0.664 M€, 2016 – 0.685 M€.

Advances in high-temperature measurements are specifically in demand: for energy efficient inductor or plasma heating technologies; processing in metallurgy and nanopowder metallurgy; machinery; space engine industry; biomass conversion; research laboratories dealing with the development of plasma technologies; advances in research of hard-melting metals [1, 2]; and of nanopowders metallurgy via ICP plasma synthesis [3]. The market may start from about 0.5 M€ with the pilot series in the Baltic countries and Belarus and will rise to 25 M€ and more worldwide in 3-5 years.

Instruments based on thermocouples, thermistors, etc., have a low immunity to electromagnetic interference and short lifetime at high temperature. The proposed MC-UTT has unique functional properties, advanced data processing capacities and substantially larger resource. Therefore, in the case of production in large series *(accordingly lowered costs)* will compete with classical thermocouples or optical pyrometers. Multichannelling allows recording of temperature profiles. Data processing computer allows easy integration with industrial data control systems. The device collects thermal radiation from the hot end of a thermo-probe, transfers it to spectrophotometer by optical fibre and calculates the temperature from the Planck's black body spectrum of the thermo-probe. A lifetime of 1000–5000 hours of the ceramic probe defines the lifetime of the MC-UTT. Feasibility study trial tests on the equipment for biomass gasification by microwave heating are planned.

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Upgraded MAXDOAS-RIGA Instrument for Validation of Sensors of the Atmospheric Spectra on Earth Satellite Platforms and Independent Tests of Air Quality in Riga

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A joint team of researchers from the Association FOTONIKA-LV at the University of Latvia and research-driven SME HEE Photonics Labs Ltd is upgrading the MAXDOAS-RIGA instrument for validation of atmospheric spectra sensors on Earth satellites platforms and independent tests of air quality in Riga.

The first version of the Multi Axis Differential Optical Absorption Spectroscopy (MAXDOAS) instrument was built to create the MAXDOAS satellite validation station far in the East of Europe for the GOME (*GOME – The Global Ozone Monitoring Experiment*) and SCIAMACHY (*SCIAMACHY – Scanning Imaging Absorption SpectroMeter for Atmospheric ChartographY*) instruments located on satellite platforms (*accordingly ERS-2 and ENVISAT*).

The telescopic system for MAXDOAS was installed on an observation platform for field work on the roof of the building of the Institute of Atomic Physics and Spectroscopy at Šķūņu street 4 (*mounted on long unused chimney*) and spectrometer with hardware components in the room a floor below. Since 2007 the MAXDOAS instrument was technically and morally outdated and needed upgrading according to the current state-of-the-art in technologies and data processing.

The joint collaboration project of the team of the University and HEE Photonic Labs Ltd faced the following objectives:

- Assessment of the existing MAXDOAS instrument technical capacity and evaluation including the observation platform technical condition and operation capabilities.
- Upgrade the MAXDOAS instrument to data quality level to satisfy the BREDOM (*Bremian DOAS Network for Atmospheric Measurements*) [1] net requirements.

The MAXDOAS instruments include a grating spectrometer (*Princeton Instruments-SPECTRA PRO 3500, (200–1400) nm, optimised 300–600 nm, $\Delta\lambda = 0.5$ nm*); tied-in Unit for MAXDOAS telescope for atmosphere spectral measurements in SUN light (*daytime*) and instrument light path spectral calibration from local spectral light source at night-time) equipped with temperature stabilized CCD camera (PIXIS 400B) and a separate narrow view angle telescope unit connected to the main instrument via a quartz fibre bundle of 400 fibres (*Light Guide Optics International, Ltd, Livani, Latvia; spectral range transparent until 220 nm*). Optimisation of spectral coverage and resolution is foreseen. The end of quartz bundle is split into two ends on the spectrometric side. Therefore, there is a choice to use one or two spectrometers: one for the UV and the other for the visible part of the spectrum. The Spectrometers room is temperature stabilized to avoid wavelength drifts.

The telescope unit has zenith-sky and horizon viewing modes for stratospheric and tropospheric measurements. The viewing direction is selected via a motorized mirror. The input light beam horizon window collects scattered light and light beam inclination is changed step by step by (*from 3°, and further 5°, 10°, 20°, 30°, to finally 90°*) cyclically passing every angular position within changeable integration time. Integration time in each inclination position is evaluated and depends on external (*lighting*) conditions. The cycle is passed periodically during the daytime. Integration time also is changed seasonally to keep an optimal signal level within the spectrometer dynamic range. At night time, the spectrometer calibration is executed in the same light path from tungsten and spectral lamps build in the telescope mainframe light sources.

To prevent direct sunlight entering the telescope, an input the additional light screen is mounted on the zenith window and the telescope mainframe is placed with horizontal window facing directly north.

For the stratospheric observations (*main interest column amounts of* O_3*,* NO_2*, BrO and OClO*), usually the zenith viewing direction is used, but if the species of interest is known to be negligible in the troposphere, any viewing direction available in the instrument can be used. The sensitivity of the instrument is largest at twilight as a result of the long path of scattered light path in the stratosphere. The vertical sensitivity is a function of elevation angle of the sun. Therefore, the combination of all measurements can be used to retrieve vertical profiles of absorber concentrations. If data is taken not only for different elevation angles, but also at various azimuth angles, information on the aerosol phase function and thus aerosol composition can also be obtained.

For satellite validation, the tropospheric column is often the quantity of interest. For tropospheric observations (*Main interest* NO_2*, HCHO, IO,* SO_2*, CO,* CO_2 *and* H_2O*. For calibration purposes known profiles of* O_2 *and* O_4 *will be used*), the MAXDOAS instruments use the horizon viewing measurement directions. The light path through the upper atmosphere does not depend on viewing direction, while in the lowest atmospheric layers, the light path increases as the viewing direction approaches the horizon. This can be determined either by integrating the retrieved profile or – more quickly – by using an observations in series of elevation angle viewing directions, where the last scattering point is almost always above the layer with high concentrations. If data is taken not only for different elevation angles, but also at various azimuth angles, information on the aerosol phase function and thus aerosol composition can also be obtained.

The MAXDOAS-RIGA instrument will be positioned in the centre of Riga. For more substantial monitoring, a similar instrument could provide valuable data by being placed in the Baldone Astrophysical observatory (*in forests about 40 km South East from Riga*) and in one or two EMEP stations in Latvia where only background or transboundary pollution affects would result. The "Rucava" EMEP station is located on the coast of the Baltic Sea south from Liepaja. The "ZOSENI" EMEP station is located about 100 km East of Riga far away from large industry sites (*agglomerates: Moscow 900 km, St. Petersburg 600 km and Minsk 500 km*).

References

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Annex 1:
External Contributions*

Abstracts accepted by European Planetary Science Congress EPSC2017,
September 17–22, 2017

Journal of Space Economics – Theoretical and Practical Considerations*

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The emerging field of space economics appears to include multiple subdisciplines that draw on analogous disciplines in the terrestrial realm – economics of space development (developmental economics), space resource economics (resource economics), economics of human/autonomous-robotics systems (information economics), lunar economics, Martian economics, multi-planetary economics (macro-macroeconomics?), and more. The range of economics issues to address is considerable. But thus, far there is no academic publication devoted to the study of the myriad issues that can arise in space economics or to the theoretical base for research in the field.

This paper will address theoretical and practical considerations for the emerging field of space economics and propose an editorial policy for a journal of space economics to provide a forum for the discussion of space economics issues. It is anticipated that initially the Journal of Space Economics will operate from two different nodes one offering a European perspective (University of Latvia) and the other a U.S. perspective (University of Wisconsin at Milwaukee).

The first edition of the Journal of Space Economics will focus on issues likely to arise during the course of the International Lunar Decade 2020–2030:

- Economics of a domain constrained by the Outer Space Treaty and the prohibition of claims of national ownership implicitly of real property rights;
- Money in the space domain;
- Economic choice in an environment of human and autonomous robotic agents;
- Economics of the space commons;
- Review of the Moon Treaty from the perspective of economics.

If economics has value on Earth economics to provide guidance in the management of the economies of the Earth, then economics should have value in managing the emerging space economy. If there is a self-sustaining space economy, then it is a subject of economic analysis.

Internationally recognized economists in key sub-disciplines will be invited to serve on the editorial board of the Journal of Space Economics. The first edition is targeted for release prior to the UNISPACE+50 Conference 20–21 June, 2018.

The Resurrection of Malthus: Space as the Final Escape from the Law of Diminishing Returns*

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Abstract

If there is a self-sustaining space economy, which is the goal of the International Lunar Decade, then it is a subject of economic analysis. Economics is a field with many sub-fields. We make the case for space economics as a field defined by the physical and temporal attributes of the space domain (distant, long duration, boundless) coupled with the virtual absence of human agents and very limited laws and conventions governing actions of economic agents. The Outer Space Treaty proscribes sovereign ownership of cosmic bodies and defines them as a commons – the common heritage of mankind.

The immediate challenge of space economics then is to conceptually demonstrate how a space economy could emerge and work where markets do not exist and few human agents may be involved, in fact where human agents may transact with either human agents or robotic agents or robotic agents may transact with other robotic agents.

Background

In 1798, Thomas Malthus predicted humans had approached a precipice and were set to drop over its edge. Population growth was set to intersect with the limits of nature (law of diminishing returns). Yet, precisely at the point of his prediction, a set of contingent variables were in play that launched humans in the opposite direction (toward unprecedented expansion and for many, prosperity). Today, we find ourselves at the Malthusian moment again. Will we find answers to the law of diminishing returns? Humans will either escape the gravitational pull of nature's limits and challenges to innovation, or they will fail the test of thriving into the future. Space provides both the means by which we can overcome our new Malthusian moment. The challenges will be how to find the political will to do so and the related problem of how to pay for it.

The two chief challenges facing us going forward, are the end of cheap nature and the productivity crisis. Ultimately, both can be solved by accelerating our return to space. The political will must be found for doing so, but so must ways of financing it.

Innovation is hampered by the materials needed for creating productivity and quality of life enhancing technologies. Many of these materials require rare earth metals that could block the development and spread of new technologies. Asteroids and other astral bodies contain minerals that could solve material constraints imposed by nature. Moreover, the vast technological challenges to accessing the wealth of space would require innovations that later could be commercialized, thereby advancing both productivity and quality of life.

The question is how to pay for it? Governments, as previously stated, the past four decades cut taxes, thus making less money available for research. Moreover, even as tax rates were lowered, offshore finance grew, thus further eroding public revenues. At first, tax cuts were funded by more public borrowing. But, as bond holders grew uncomfortable with this arrangement, governments eventually reduced spending. At the same time, supply-side policies were eroding wages under the banner of 'flexibility.' Thus, the puzzle was presented of how to sustain economic demand in an environment where both wages and public spending were under assault? The answer provided in the 1990s was expansion of private debt. This too inflated up to the point where it was no longer sustainable and saw its crescendo in the 2008 financial crisis. Thereafter, policymakers decided upon austerity: the twin contractions of both public and private debt. The effort worked imperfectly, ironically preventing total economic disaster, but well enough to slow growth. This economic environment can't provide the vast resources needed to fund science sustaining basic research at our universities, let alone the comparatively smaller resources needed for their application to building space hardware.

There are four possible means by which the return to space could be achieved:

1. Independent investors. We see some of this today, but it's mostly limited to a few billionaires as vanity projects and/or as expression of some genuine vision. While helpful, the sums required to accelerate the return to space far exceed the capacity of this group to alone fund both it and the basic research required to advance it.
2. New financial instruments. The challenge is how to make investment in space more profitable than, say, real estate, or financial markets flooded with quantitative easing produced cash. Such instruments would have to provide the means by which long-term investments in space, where the returns would take more than a generation to materialize. Of course, long-range investments are already funded, but one must convince markets that the returns would come and in quantities needed to justify investor returns now.
3. Modern Monetary Theory. If money can be created in the trillions of dollars and euros to fund global efforts to stabilize financial markets without generating inflation, then the same could be done to finance science and space. Given the limits of taxation in today's environment, it may be that governments simply begin funding infrastructure by creating credit on computer keyboards. Automatic triggers could be put in place to reign in this spending upon inflation hitting set targets.
4. Combinations of the above. Government guarantees coupled with outright grants parallel to public private partnerships as with COTS (Commercial Orbital Transportation Services).

Conclusions

We are again at a Malthusian turning point. But the world is awash in capital seeking higher returns. Higher returns can be made possible through significant expansion in research and space development involving a combination of new financial instruments, monetary policy and billionaire entrepreneurs leveraging public resources to drive down costs and risks of activities in space while continuing to expand the range of opportunities for public and private investment.

Space economics is the study of commercial activities in space in an environment where all resources are defined by the Outer Space Treaty as an international commons to be utilized for the benefit of all mankind. This raises major challenges for a field that has largely. evolved studying economic activity under varying degrees of private ownership and capitalism.

Annex 2

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