LATVIJAS UNIVERSITĀTE
ANNO 1919

FOTONIKA-LV
LATVIJAS UNIVERISTĀTES NACIONĀLĀ ZINĀTNES PLATFORMA

The 3rd International Conference FOTONIKA-LV

“Achievements and Future Prospects”

Four 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, 24–25 April 2019

Riga, 2019

The 3rd International Conference FOTONIKA-LV "Achievements and Future Prospects". "Unlocking and Boosting Research Potential for Photonics in Latvia – Towards Effective Integration in the European Research Area". University of Latvia, Riga, 24–25 April 2019.

Editors
Dina Bērziņa, Arnolds Ūbelis, Vidvuds Beldavs

ISBN 978-9934-18-457-4

Contents

Preface

The 3rd International FOTONIKA-LV conference ***"Achievements and Future Prospects"*** held in Riga (24-25 April 2019) – is a biannual conference summarising following 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" (2012–2015). The Association of research institutes FOTONIKA-LV was formed on April 24, 2010. In early spring nine years ago, directors of three institutes signed an agreement unique in the history of Latvian science to create a framework where research communities with differing specialisations joined forces to undertake larger cross-disciplinary research projects under the umbrella of photonics – the driving technology of the 21st Century. FOTONIKA-LV received special notice 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*". Further, National Science Platform FOTONIKA-LV in quantum sciences, space sciences and related technologies was established by the decree of the University of Latvia No. 1/215 on June 18, 2018.

This book of the 3rd FOTONIKA-LV conference is a collection of abstracts and articles highlighting research accomplishments and plans for future research activities and projects that will serve as a calling card for NSP FOTONIKA-LV at the University of Latvia until the next FOTONIKA-LV conference in 2021.

The laboratories and observatories from the institutes forming **NSP FOTONIKA-LV** have been contributing to RTD in Latvia since the early 1960s, including:

- Quantum optics, laser spectroscopy, VUV, UV and visible light spectroscopy;
- Atomic, molecular and optical physics, molecular beam and ion beam physics; ICP plasma devices;
- Atmosphere physics and photochemistry; development of atmospheric remote sensing devices;
- Observational astronomy and astrophysics of galactic carbon stars, research on late evolution stars (MS, S type);
- Observation, and monitoring of small objects (*asteroids*) 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*[2]);
- Advancement of satellite laser ranging (*SLR*) instruments, including software and hardware components;

[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

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

- Terrestrial geodesy and geodynamics measurements with the world class laser telescope LS-105 with which Latvian astronomers have served for decades as a node of the International Laser Ranging Service (*ILRS code name RIGL-1884, Riga*);
- Optical fibres technologies, in particular UV fibre optics;
- Vacuum-sputtering, quartz, glass and vacuum technologies.

June 2019

Dr. Arnolds Ūbelis
Scientific Secretary of the University of Latvia National Science Platform FOTONIKA-LV

Roots in History, and the Key Persons Contributing to the Emergence of the Currently Called Quantum Physics and Astronomy at the University of Latvia

The imposing yellow brick structure facing the Riga canal was home for Riga Polytechnicum since 1862; then, in 1919 was reorganised as University of Latvia for newly established Republic of Latvia whose independence had been declared on November 18, 1918. The emerging University drew on the remarkable heritage of the Polytechnicum that included Wilhelm Ostwald (*02.09.1953–04.04.1932*), the Nobel Prize winner in chemistry in 1909, who was a full professor during 1881–1887. Another notable figure is Friedrich Zander (*23.08.1887–28.03.1933*), who made significant advances in rocketry and pioneering work in space research, who graduated from the Polytechnicum in 1914, before the First World War and moved to Moscow in 1915.

Testimony to the quality of the physics studies at the newly established national university was the Danish government's scholarship granted to Alfons Apinis in 1936 for a year's studies at the Institute of Theoretical Physics of the University of Copenhagen then led by Nobel Prize winner N. Bohr, which provided an opportunity to work together with the outstanding physicists V. F. Weisskopf, O. R. Frisch and C. F. von Weizsäcker.

The Second World War interrupted the research development at the University of Latvia. At the end of the war (*autumn 1944*) the Faculty of Physics and Mathematics of the University faced an acute deficiency of human resources since much of the academic staff was lost in the front, or was in the exile, or subject to the repression of the ruling Stalinist regime. The restoration work in the University's laboratory building at 4 Kronvalda Boulevard was started by Alfons Apinis, Jāzeps Čudars, Ilmārs Everss, Roberts Ķipurs, Alma Jansone and Ludvigs Jansons, with notable support from auxiliary staff, such as Ernests Pūce, who had remained in the Latvian homeland. They were joined by the newly-appointed physicists of Latvian origin from Russia – Pauls Ēks, Ernests Papēdis, Jāzeps Eiduss, and Marta Loja, who were *a priori* supposed to be loyal to the new regime. The remaining staff applied tremendous work to bring the premises and the equipment in sufficient order so that in January 1945, the study work could be resumed in the Department of Theoretical Physics *(Deputy Head A. Apinis)* and the Department of Experimental Physics *(Deputy Head L. Jansons)*. Since February 1946 Valerians Šmēlings started working as an assistant at the Faculty of Physics and Mathematics, before studied at the Faculty of Physics and Mathematics at the Göttingen University (*1923–1927*) graduating with a PhD in physics in 1927. He had an opportunity to listen to lectures by famous physicists such as: M. Born, J. Franck, B. Gudden, W. Heisenberg, H. A. Lorentz, O. Oldenberg, L. Pohl, and G. Tammann. In the post-war years, with the support of colleagues, he had the opportunity to become the founder of the space technologies branch of the ground segment at the university.

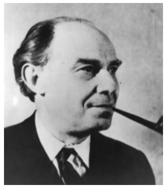
In January 1945, studies were started by the students who had previously studied but had not finished the studies *(A. Okmanis, E. Ozoliņa, E. Krauliņa, etc.)*, as well as those that had graduated during the German war time occupation. The Soviet government did not recognise their diplomas. In the autumn of 1945, 25 secondary school graduates were enrolled, including V. Fricbergs, P. Prokofjevs, L. Pelēķis, A. Valters, who later challenged leadership in physics research in Latvia. Also, the secondary school graduates that were admitted to the studies of physics in 1946, graduated in 1951. Among them were Ojārs Šmits and Egons Zablovskis (*born: 02.03.1926*).

Alfons Apinis
1911–1994

Jāzeps Čudars
16.06.1910–
19.12.1990

Alma Jansone
06.08.1908–
08.08.1987

Ludvigs Jansons
29.10.1909–
12.05.1958



Jāzeps Eiduss
3.07.1916–
20.04.2004

Already the mentioned above V. Fricbergs (*26.06.1926–06.08.1982*) and E. Krauliņa, together with the younger Ilmārs Vītols (*14.10.1931–19.08.2000*), became heads of the newly established Laboratories of the Segnetoelectrics and Piezoelectrics Physics, Spectroscopy Problems, and Semiconductor Physics in the 1960s. These three laboratories became the foundation of the present advanced Institute of Solid State Physics and Institute of Atomic Physics and Spectroscopy of the University of Latvia.

The continuation, and next step of the work of Alfons Apinis, as well as Ludvigs and Alma Jansons, and several other colleagues, in the area of optics and spectroscopy (*speaking in modern language – quantum optics and technology*) was the dissertation by Elza Krauliņa that was worked out under the leadership of Professor Sergey Frisch and defended at the Leningrad State University in 1954 on the second-kind collision problems in the fluorescence of the metal vapour mixtures (*sensitised fluorescence*). She continued the research in her department. At the same time Jāzeps Eiduss started collaboration with the chemists of the University and the Academy of Sciences in the spectral analysis of synthesised new organic compounds. Meanwhile Ēriks Andrejevs-Andersons began to focus on theoretical calculations of the atomic structures at the Department of Theoretical Physics, and a worldwide known group of atomic and nuclear physics was formed later at the University's newly established Computing Centre (*11.11.1959*) where the first computing machines BESM-2, built by the USSR, were deployed. One of this group, Visvaldis Zīlītis, is still active in theoretical nuclear physics *(https://www.researchgate.net/profile/Visvaldis_Zltis)*.

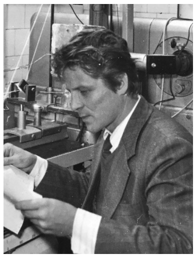
The first attempts to create a Spectroscopy Research Laboratory at the initiative of E. Krauliņa and L. Jansons took place already in 1954, when financial support was promised from S. Mandelstam (*22.02.1910–26.11.1990*), the Chairman of the Spectroscopy Commission of the USSR Academy of Sciences, who was a representative of the famous Mandelstam physicist family in Russia. Unluckily, the decision was postponed and only 13 years later on April 20, 1967, thanks to the great efforts of E. Krauliņa, J. Eiduss and O. Šmits, the Laboratory of Spectroscopy Problems was founded at the University by the decision of the USSR State Committee for Science and Technology. After joining a group of theoreticians in atomic physics from the Institute of Physics of the Latvian Academy of Sciences, in 1992 it was transformed into the Institute of Atomic Physics and Spectroscopy. Māris Jansons, Alma's and Ludvig's son, in 1968 became the first Doctor of Sciences of this laboratory, and five years later he was awarded a one-month scholarship for a trip to the University of Kaiserslautern in 1973, where he met Klaas Bergmann, who was a little younger than Māris. This was a very productive trip and a valuable meeting that resulted in friendship and cooperation that lasts until today. Klaas Bergman is now Doctor Honoris causa of the University of Latvia, and his donation of the ultrasonic molecular beam equipment to the University of Latvia laid a foundation for the University's Laser Centre (*establ.: 10.06.2005*), which now employs world-renowned scientists, Ruvīns Ferbers, Māris Tamanis and Mārcis Auziņš grown up under leadership of Ojārs Šmits.

Restoration of the physics studies during the post-war years, as well as the development and achievements in the field of the quantum sciences were possible only thanks to the unselfish and altruistic work of those mentioned and many other scientists of the University and Latvia under a repressive regime where loyalty to the regime was stressfully tested. This caused nuisance in the scientific work and study process to all colleagues. This is a separate story, but in this short article it is worth mentioning, as an illustration, the mistrustful and repressive attitude towards Alfons Apinis, about his studies with Niels Bohr and Valerians Šmēlings in connection with the Göttingen University diploma. An even more severe blow came over Jāzeps Eiduss, who had stopped his studies in England in 1941 and voluntarily arrived in Moscow in December to join the Red Army and fight against Hitler's army. He got into the Latvian Riflemen Division, and for four years he walked the front roads from Moscow's outskirts to the liberation of Riga in the autumn of 1944. And then he was appointed for the renovation works of the faculty. He did this work as a Latvian patriot without concealing his undoubted belief in the ideals of communism. Instead of gratitude, he was arrested in 1953, sentenced for espionage in favour of the United Kingdom, and dug coal in Northern Urals as a convict at the KGB camps until 1957.


Elza Krauliņa
4.08.1920–7.01.2002


Ēriks Andrējevs-Andersons
9.10.1928–3.06.1997


Ojārs Šmits
24.04.1930–14.03.1993


Māris Jansons
2.08.1936–18.09.1997


Sergey Frisch
7.06.1898–19.11.1977


Klaas Bergman
Born: 12.06.1942


Sune Svanberg
Born: 1.01.1943


Dag Hastorp
Born: 6.03.1960

The quality and amount of the scientific work of the newly established laboratory grew under the coherent management of Elza Krauliņa and Māris Jansons. New international scientific contacts emerged, and, as its recognition, there was decision to arrange *the 6th International Conference on Atomic Physics* in Riga in 1978 [1], which was well attended despite the unexpected aggravation in the course of the *"cold war"* of that time and the eventual boycott of the conference. Shortly before the conference on May 15, 1978, Yuri Orlov *(born 13.08.1924)* the nuclear physicist and a human rights activist, was sentenced to seven years in a labour camp and five years' internal exile for his collaboration with the Moscow Helsinki Group.

"The Iron Curtain" collapsed in 1990, twelve years after the mentioned conference. This gave a possibility for the Latvian science community to freely cooperate with their colleagues in Europe and the world, and this book provides a concise insight. Science has no national borders. It needs transnational cooperation. A necessary prerequisite for the success of the current National Science Platform FOTONIKA-LV at the University of Latvia was cooperation with many scientists from other countries; and among them of particular role was the aforementioned St Petersburg's science aristocracy student Sergey Frisch and Klaas Bergmann from Germany. Also, hard-to-overestimate assistance which was rendered after 1990 by the Swedish scientists Sune Svanberg from Lund and Dag Hanstorp from Gothenburg.

Astronomy, Astrophysics and space research are much older than research in quantum sciences and have held strong historical presence in Latvia forming an overall valuable experience and background in the field at present for the University. The Astronomy Tower on the roof of the University of Latvia main building was established in 1869 after the agreement of Prof. Anton Schell (*1835–1909*) with the architect of the building Gustav Hilbig (*1822–1887*). A. Schell was a lecturer in Geodesy and Spherical Astronomy during 1864–1873 in Riga Polytechnicum and afterwards was a professor in Technische Hochschule in Wien till 1905. Already mentioned Friedrich Zander born to a Baltic German family in Riga was an engineering student of Riga Polytechnicum (*1908–1914*). The University building has symbolic significance. In 1908, Zanders made notes on the problems of interplanetary travel in which he addressed issues such as life support and became the first to suggest growing plants in greenhouses aboard a spacecraft. In 1911, he published plans for a spacecraft building using combustible alloys of aluminium in its structure that would take off like a conventional aircraft and then burn its wings for fuel as it reaches the upper atmosphere and no longer needs them. He carried out trajectory calculations for a flight to Mars and "forward to Mars" became his famous motto.

References

[1] 6th International Conference on Atomic Physics (ICAP), Proceedings. Editors: R. Damburg., E. Kraulina, R. Peterkop. Riga, August 17–22, 1978. Zinatne Riga. Plenum Press New York-London, 666 pages.

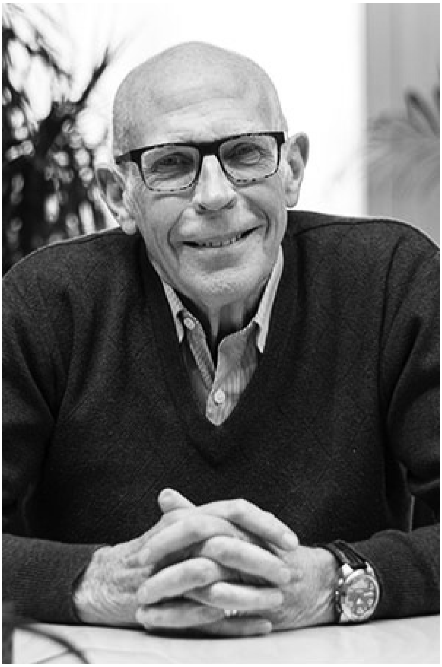
June 2019

Dr. Jānis Jansons
Doctor Honoris causa of the Latvian Academy of Sciences

Dr. Arnolds Ūbelis
Scientific Secretary of the National Science Platform FOTONIKA-LV, University of Latvia

Dr. Ilgmārs Eglītis
Director of Baldone Astrophysical Observatory of the Institute of Astronomy, University of Latvia

Sune Svanberg
Doctor Honoris causa of the University of Latvia



We start with a short introduction into the Curriculum Vitae of Sune Svanberg. He received his BSc in 1966 at the University of Gothenburg and obtained his PhD, defending a thesis on atomic resonance spectroscopy in 1972. After a post-doc year at Columbia University in the City of New York, and initial work on atomic laser spectroscopy, he continued working on laser-based spectroscopy at Chalmers University of Technology up till 1980. In this year he became a professor and head of the Atomic Physics Division at Lund Institute of Technology (Technical Faculty at Lund University) and held this position up till 2008. In Lund a vigorous program of laser spectroscopy, including basic atomic physics and applications to energy, environmental and medical research has been pursued. Basic research includes studies of radiative properties of atoms and ions as well as super-intense laser/matter interactions (high harmonics generation, X-ray laser pumping and broadband X-ray generation). Applications include laser radar sounding of pollutants in the atmosphere and hydrosphere, laser diagnostics of combustion processes, and laser-based detection and treatment of cancer and cardio-vascular disease. He has taken the initiative to create three centres for interdisciplinary work: the Combustion Centre, the Environmental Monitoring Centre and the Medical Laser Centre. He also proposed and helped to establish a High-Power Laser Facility including a multi-terawatt 10 Hz laser. In 1995 he was appointed director of the newly established Lund Laser Centre, which also gained the status of a European Large-Scale Facility. He remained its director till 2010 and continued as Senior Professor at the Centre. Since 2011 he is a part-time distinguished professor at the South China Normal University, Guangzhou. He has trained a large number of PhD students from home and abroad through the years. He is a member of the Royal Academy of Sciences, and the Royal Academy of Engineering Sciences. He was awarded the title Doctor Honoris causa by the Medical Faculty of Lund University, by the University of Latvia, by the Science Faculty of Université de Liège, and by the Universidad Nacional de Engineria, Lima. He is a Foreign Member of the Lithuanian Academy of Sciences and the Académie Royale de Belgique, an Associate Fellow of the Third World Academy of Sciences (TWAS), an Honorary Professor at the Zhejiang University, Jilin University and at HIT-Harbin, China, and a Fellow of the American Physical Society, the Optical Society of America, the European Optical Society, the Electromagnetic Academy, and the International Society for Optics and Photonics

(SPIE). He has been a member of the Board of Directors of the Optical Society of America and is the recipient of the first EPS Quantum Electronics Prize (1996) and of the first Azko Nobel Science Award (1999). In 2004 he was awarded the SKAPA Innovation Prize, in 2005 the W. E. Lamb Medal, in 2006 the Celsius Gold Medal (Uppsala), in 2009 the Memorial Gold Medal (Lund) and the V.K. Zworykin Award of the International Federation of Medical and Biological Engineering, in 2010 the Adelskold Medal of the Royal Academy of Sciences and the Large Gold Medal from the Royal Academy of Engineering Sciences, Stockholm, and in 2012 the Gold Medal of His Majesty the King of Sweden. He has been distinguished as an "Einstein Professor" of the Chinese Academy of Sciences since 2006 and received China´s highest distinction for non-Chinese, the China Friendship Award in 2013, and became Honorary Citizen of Guangzhou, China, in 2015. He serves on numerous international conference-, evaluation- and advisory committees. During the years 1987–1993 he was a member of the TetraPak Scientific Council and during the period 1993–2000 a member of the Scientific Council of the Volvo Research Foundation. He has supervised a large number of graduate students for their PhD in Physics. He is the co-author of more than 670 scientific papers and over 40 patents and patent applications. In the years 1983 and 1985, was visiting professor at The Department of Physics, Stanford University (Prof. A. L. Schawlow). He was elected to the Nobel Committee for Physics: as Adjoined Member in 1997, as Regular Member in 1998–2006, and as Chairman in 2004, 2005. Finishing with this, we switch to collaboration between the Institute of Atomic Physics and Spectroscopy of the University of Latvia and the Lund Laser Centre.

Collaboration started in 1991, when I was as post-doctoral fellow at Chalmers University of Technology in Professor's Ingvar Lindgren group, where Sune Svanberg during his PhD studies investigated properties of Se and Te atoms. I was interested to establish contact with Sune but at that time he was professor in Lund. But, since there were good contacts between the groups in Lund and Gothenburg, my visit to Lund was arranged, and just before midsummer of 1991 I arrived in Lund with two products from our institute in my back pack: 1) Selenium High Frequency Electrodeless Discharge Lamp, and 2) Collection of works from our institute printed in Russian: "Радиационные и столкновительные характеристики атомов и молекул. Теллур." Рига. Sune Svanberg seemed a little surprised!

The first thing I learned during my 2-weeks stay in Lund was how effective experimentation, results processing, and article writing could be performed. Funding for this collaboration was absent. As a result the professor gave me lodging at his home. During the day we prepared and ran experiments together with students at the institute. A Selenium cell for the experiments was made. The professor himself heated the selenium with a flame burner and distilled it into the cell. The experiment was successfully performed. In the evenings we had dinner together with his wife Katarina and daughters Emilie and Kristina. After dinner, until midnight, we worked on the manuscript for our first paper. I returned back to Riga in 1991 and our first common publication was submitted and accepted: J. Phys. II France 2 (1992) 773-779. Less than 8 months from idea till published results! Our joint work resulted in in total 11 joint papers. It should be borne in mind that our first interactions were happening at a time when there was no normal telephone contact between the Baltic Countries and the West. Access to the Internet and e-mail was only through the telephone and the UL Computing Center and Moscow.

Another opportunity was to see how interdisciplinary research between physics and medicine develops. In late 1980's it was uncommon. I assume that family ties were crucial in this case, but the result was excellent. Katarina Svanberg was a doctor in Lund University

Hospital. The medical laser research group was established between the Atomic Physics Division, and the Lund Medical Faculty, and an intense and very fruitful activity developed.

I continued my collaboration until November 1999, when in a late dark evening I went into Sune's office and said: "Sune, I am sorry I have to interrupt our project. I received the job offer from Mycronic near Stockholm, and I have to start from 1st of December." Sune knew what Mycronic is, since few of his former PhDs worked there. His only question was: "Is it a permanent position?"

Professor Svanberg had a major impact on key researchers of the Institute of Atomic Physics and Spectroscopy, resulting in 12 additional joint papers:

- In the late 1990s professor Jānis Spīgulis from our Institute applied the model for cross-disciplinary collaboration at Lund between physics and medicine to establish the medical physics group in the Institute of Atomic Physics and Spectroscopy including close collaboration with doctors from hospitals in Riga as well as at Riga Stradiņš University. Dr. Spīgulis continued close collaboration with Katarina Svanberg until 2013.
- Jānis Alnis made several visits to Lund during 1998–2003. He worked with diode laser spectroscopy and applications, at the time a blooming field. Jānis started as a master's degree student progressing to a PhD. His success at Lund helped him to apply and to be accepted for a postdoctoral fellowship of 8 years at Max-Planck Institute of Quantum Optics in Munich. His research continued in high resolution spectroscopy and diode laser applications under the supervision of Nobel Prize winner Theodor Haench. Now Jānis Alnis is back at the University of Latvia as head of the Quantum Optics laboratory and has been elected Full Member of Latvian Academy of Sciences.
- Dr. Jānis Kļaviņš and master's degree student Aigars Ekers visited Lund in the mid-1990s several times to continue their investigations of processes involving alkali metal vapours. Later, Aigars successfully pursued his career as a Marie Curie Fellow at the University of Kaiserslautern supervised by Professor Klaas Bergmann, as science officer at European Science Foundation in Strasburoug, and now serves as Assistant Dean for the Division of Computer, Electrical and Mathematical Sciences and Engineering at King Abdullah University of Science and Technology in Saudi Arabia.

Sune Svanberg's shaping impact on researchers of the Institute of Atomic Physics and Spectroscopy is part of the justification why he has been honoured as Doctor Honoris causa of University of Latvia.

An important final point: Sune Svanberg has been invited to serve as Chairman of the Advisory Board for the Quantum-LV ERA Chair project to be implemented by National Science Platform FOTONIKA-LV of the University of Latvia.

July 2019

Dr. Habil. Phys. Uldis Bērziņš
Senior researcher, Institute of Atomic Physics and Spectroscopy, University of Latvia

Agenda

The 3rd International conference FOTONIKA-LV "Achievements and Future Prospects"

Riga, 24–25 April 2019

APRIL 24 Institute of Atomic Physics and Spectroscopy, *Šķūņu 4*

10.00–10.30	**Welcome words from invited honoured guests**
10.30–12.00	**1st plenary: Quantum Sciences and Technologies** ***Chair: Dr. Aigars Atvars***
	Key note lectures:
10.30–10.50	**Dr. Arnolds Ūbelis**, Summary of efforts during the last two years since April 24, 2017
10.50–11.10	**Dr. Jānis Alnis**, Overview of achievements in quantum sciences
11.10–11.30	**Dr. Arnolds Ūbelis**, Application of visible, UV and VUV spectroscopy in research on basic properties of atoms excited in inductively coupled RF plasma or in combination with hollow cathode discharge
11.30–11.50	**Dr. Ulises Miranda Ordóñez**, Theoretical modelling of exotic dimers
11.50–12.00	**Discussion**
12.30–14.30	**2nd plenary: Space sciences, Geodynamics and related Technologies** ***Chair: Dr. Ilgmārs Eglītis***
	Key note lectures:
12.30–12.50	**Dr. Ilgmārs Eglītis**, Overview of achievements of Astrophysics and Planetary Sciences
12.50–13.10	PhD cand **Kalvis Salmiņš, Dr. Jorge del Pino**, Advances in Geodynamics research
13.10–13.30	**Dr. Māris Ābele, Dr. Elīna Rutkovska**, Advancing SLR Technologies
13.30–13.50	PhD cand **Lauris Goldbergs, Dr. Jānis Kaminskis, Dr. Jānis Zvirgzds**, Advances in space geodesy and Geoinformatics
13.50–14.00	**Discussion**
15.00–17.00	**Poster Sessions** ***Chair: Dr. Aigars Atvars***

A. Quantum sciences and technologies

B. Astrophysics, Space sciences and Technologies

C. Applied and Industry research

APRIL 25 Institute of Atomic Physics and Spectroscopy, *Šķūņu 4*

11.00–13.00	**3rd plenary: Applied and industry related research** ***Chairs: Dr. Arnolds Ūbelis, MSc Vidvuds Beldavs***
11.00–11.20	**Dr. Hab. Uldis Bērziņš**, NSP FOTONIKA-LV & Thorlabs Inc. (USA) collaboration project
11.20–11.40	**Dr. Arnolds Ūbelis**, Disruptive innovation and H2020 SME Instrument call capacities in Latvia
11.40–12.00	**Dr. Aigars Atvars, Dr. Arnolds Ūbelis**, NSP FOTONIKA-LV services for "high-tech" SMEs in Latvia in the domain of photonics
12.00–12.20	PhD cand **Kalvis Salmiņš, Dr. Jorge del Pino**, Contributions to ESS mission
12.20–12.40	**MSc Vidvuds Beldavs**, Towards sustainable presence on the Moon
12.40–13.00	**Dr. Vadym Naumov, Dr. Petro Smertenko**, Towards Cost-Efficient Photovoltaic Solar Cell Technology on the Base of Self-Organised Organic-on-Silicon Hybrid Nanostructures
13.30–14.00	**Open lecture session from invited guests** ***Chair: Dr. Arnolds Ūbelis***
	Dr. Vadym Naumov, Dr. Petro Smertenko, Ukraine research Community – highlights of integration in the European Research Area
14.00–15.00	**University Industry interplay – Round table panel** ***Chair: MSc Vidvuds Beldavs***
	Panellists: **Arnolds Ūbelis, Petro Smertenko, Vladimir Gostilo, Anatoly Kravcov, Uldis Bērziņš, Jānis Alnis, Aigars Atvars**

Poster Sessions

A. Quantum sciences and technologies

H2020 – Financed Projects and Ideas for new Project Proposals

A. Atvars
The project "ERA Chair in Quantum Optics and Photonics 2019–2023". Nr. 857624-QUANTUM-LV. Proposal for H2020-WIDESPREAD-2018-04 call; to be refinanced by ERDF

A. Ūbelis
The Project proposal "CALLENGE of IONS - Research and Theoretical Modelling of Exotic Atoms, Ions and Clusters to Contribute to Knowledge Base in Atomic and Molecular Physics and Astro-biology". To be re-submitted for H2020-MSCA-RISE-2019 call (July 2019)

V. Kochelap, V. Naumov, V. Korotaev, J. Alnis, A. Ūbelis
The project proposal "ANT THz - Future THz Technologies based on advanced Plasmonic semiconductor nanostructures". To be re-submitted for FETOPEN-01-2018-2019-2020: FET-Open Challenging Current Thinking call (September 2019)

Financed ERDF Projects and Ideas for new Project Proposals

J. Alnis
ERDF projekts Nr. 1.1.1.1/16/A/259 "Jaunu čukstošās galerijas modu mikrorezonatoru izstrāde optisko frekvenču standartu un biosensoru pielietojumiem, un to raksturošana ar femtosekunžu optisko frekvenču ķemmi". 01.03.2017.–29.02.2020.

J. Alnis
ERDF projekts Nr. 1.1.1.1/18/A/155 "Uz čukstošās galerijas modas mikrorezonatora bāzes veidota optisko frekvenču ķemmes ģeneratora izstrāde un tā pielietojumi telekomunikācijās". 16.05.2019.–15.05.2022.

U. Miranda, U. Bērziņš, J. Blahins, J. Kļaviņš, A. Apsītis
ERDF 1.1.1.1. (Praktiskas ievirzes pētījumi) projekta pieteikums 2019. gada projektu konkursam

V. Silamiķelis, U. Veispāls, A. Apsītis
ERDF 1.1.1.1. (Praktiskas ievirzes pētījumi) projekta pieteikums 2019. gada projektu konkursam

U. Miranda
ERDF PostDoc project proposal for 2019 call

Javed Ibhal
ERDF PostDoc project proposal for 2019 call

Financed Latvian Council of Science Projects and Ideas for new Project Proposals

A. Atvars
LZP projekts Nr. LZP-2018/1-0510 "Optiski čukstošās galerijas modu mikrorezonatoru sensori". 31.08.2018.–31.08.2021.

A. Ciniņš, K. Mičulis, A. Švarcs
Development of novel methods for coherent control of spectrally unresolved atomic hyperfine levels. Proposal to the Latvian Council of Science project call 2019

A. Ūbelis, U. Bērziņš, U. Gross, A. Apsītis
Application of visible, UV and VUV spectroscopy in research on basic properties of atoms excited in inductively coupled RF plasma or in combination with hollow cathode discharge. Proposal to the Latvian Council of Science project call 2019

A. Quantum sciences and technologies

U. Miranda, U. Bērziņš, J. Kļaviņš, J. Blahins, A. Apsītis
Theoretical and Experimental Studies of Electron Affinities for Molecules of Astrophysical Importance. Proposal to the Latvian Council of Science project call 2019

Curiosity Driven Research and Other Area related Research Activities

A. Ūbelis, A. A. Ūbele
Towards advanced MAX DOAS Satellite validation station in Riga and on ferries in the Baltic Sea

A. Ūbelis, A. *S. Lopes (Spain), A. Apsītis*
Progress towards application of methods of atomic and molecular spectroscopy in direct measurements of concentrations of atomic and molecular iodine and bromine in Earth atmosphere

B. Astrophysics, Space Sciences and Technologies

H2020 – Financed Projects and Ideas for new Project Proposals

I. Eglitis, A. Ūbelis, J. del Pino
ERA Chair in Space Sciences and Ground Segment Space Technologies at the University of Latvia. Project proposal SPACE-LV to H2020-WIDESPREAD-2019-4 call

A. Ūbelis, J. del Pino
Twinning project Boosting excellence in SLR Technologies and capacity to contribute to Space Situational Awareness. Project proposal to H2020 WIDESPREAD-2019-03 call

A. Ūbelis, J. del Pino
The project proposal SLR GLOBAL NET "Meeting future challenges of space surveillance and tracking – towards increased capabilities and novel applications of satellite laser ranging systems, technology and networks". To be re-submitted for H2020-MSCA-RISE-2019 call

ERASMUS and INTERREG Projects

I. Eglītis
ERASMUS+ project "Online Observatory"

J. del Pino
INTERREG project "Training the next generation entrepreneurs with hands-on methods in space STEM"

Financed Latvian Council of Science Projects and Ideas for new Project Proposals

I. Eglītis
LCS project Nr. LZP-2018/1-0401 "Complex investigations of the small bodies in the Solar system" (2018–2011)

J. del Pino, K. Salmiņš, M. Ābele, E. Sharma
"Advances in Earth Fundamental Geodynamics, Satellite Laser Ranging and Lidar Sciences & Technology and Breakthrough in Active Remote Sensing of Nocturnal Atmosphere". Proposal to the Latvian Council of Science project call 2019

Curiosity Driven Research and Other Area related Research Activities

Solomon Belay
Research and Observation at the Entoto Astrophysical Observatory at Ethiopia Space Sciences and Technology Institute

C. Applied and Industry research

K. Salmiņš
"Supply of Data Filtering Software and Detector Subsystem, in the frame of ESA LRS". European Space Agency subcontract project (2019–2020)

A. Ūbelis, M. Ābele, E. Sharma, J. Vjaters
Contract agreement between ESSTI in Addis Ababa and NSP FOTONIKA-LV at the University of Latvia about joint implementation of bilateral project "Development of the overall concept of Fundamental Geodynamic Observatory – a core site in Ethiopia for the International Terrestrial Reference Frame (ITRF) and the design and research on key elements of the next generation satellite laser ranging instrumentation" (2019–2021)

U. Bērziņš, J. Valdmanis (Thorlabs Inc., USA), J. Alnis, A. Ūbelis, A. Apsītis, V. Silamiķelis, A. Kapralovs, A. Ciniņš, A. Švarcs
"Absorption cell to stabilise emission frequencies of blue and violet diode laser with accuracy up to 11 decimal numbers". Effective Collaboration Project between NSP FOTONIKA-LV at the University of Latvia and Thorlabs, Inc. (USA) (2018–2019)

J. Blahins, A. Apsītis, V. Silamiķelis, A. Ūbelis
"The Table-Size Ion-Implanting Device Prototype (Tlr6) Design For Boron Dopants". Effective Collaboration Project between NSP FOTONIKA-LV at the University of Latvia and Baltic Scientific Instruments, Ltd.

J. Blahins, A. Bžiškjans, A. Kravcov
"The development of mechanisms for stabilisation of electron gun beam for silicon rod melting". Effective Collaboration Project between NSP FOTONIKA-LV at the University of Latvia and KEEP EU, Ltd.

A. Ūbelis, A. Apsītis, A. Kapralovs
"Application of intensive, monochromatic, UV & VUV atomic resonance spectra lines sources (RF ICP plasma) in gemstones (diamonds) quality tests and source identification". Effective Collaboration Project between NSP FOTONIKA-LV at the University of Latvia and 'Latvijas proves birojs', SIA

J. Blahins, V. Silamiķelis, A. Apsītis
Small size, cost effective clean room of NSP FOTONIKA-LV

A. Bžiškjans
Intelligent hardware and software for upgrade of sophisticated high resolution prism spectrometer SPM-2 (Carl Zeiss Jena) applicable in near VUV, far UV, UV, Visible and Near Infrared Spectroscopy to measure signals with low intensity

Plenary Reports

Summary of efforts during the two years since the last FOTONIKA-LV conference April 24, 2017

Arnolds Ūbelis

National Science Platform FOTONIKA-LV, University of Latvia

E-mail: arnolds@latnet.lv

The FP7 project No. 285912, FOTONIKA-LV, together with four others from Latvia received funding in highly competitive FP7-REGPOT calls for years 2007–2013 [1].

Latvia "per capita" was among the most successful nations in this competition where among 1,885 project proposals only 149 were financed. Average success rate 7.9%.

Unfortunately, the national landscape for research activities during the 2017–2018 was still quite unfavourable due to acute, inadequately addressed problems of national RTD & Innovation policy identified by the TECHNOPOLIS assessment already in 2014 [2]. As a result, the FOTONIKA-LV research community faced multiple problems. An indicator of the challenge facing FOTONIKA-LV is that institutional funding comprised less *10–15% of expenditures with the balance secured from competitive grants committing staff to complete project work leaving little opportunity for exploratory research and innovative initiatives particularly new project initiatives with industry and RTD institutions worldwide*. See the following statements of the TECHNOPOLIS report below:

- ***Latvia face disastrous problems with institutional funding for research****, page 22 in the report "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.*

Implementation of the FP7-REGPOT-2011-1, No 285912, FOTONIKA-LV project which ended in July 2015 endowed the FOTONIKA-LV research community with significant research capital:

- 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 EUR 20 million);
- strong team of excellent repatriated and recruited scientists bringing access to their research networks;
- impressive list of partnerships and collaborations in different countries worldwide via funded FP7 and H2020 projects as well as via various high-quality consortium project proposals as well as new and strengthened ties to research-based industry;
- formation of the Riga Photonics Centre association to advance photonics research and innovation in Latvia comprised of institutes, SMEs, and interested individuals, which continues outreach work initiated during the FOTONIKA-LV REGPOT project.

Building on this endowment, but with inadequate institutional funding the project task force now developing the NSP FOTONIKA-LV platform invested considerable uncompensated effort to develop new projects by writing a large number of project proposals that were submitted to various H2020 calls as well as nationally competitive calls with funding from EU Structural funds. Our researchers also competed in calls of the Latvian Council of Science as well as University of Latvia co-funded collaborative projects with partners in Latvia as well as in Ukraine, Italy, Spain, Ethiopia and the USA Additionally, multiple proposals have been submitted to ESA as well as to Baltic Sea Region Interreg programme. The visibility of FOTONIKA-LV research groups, laboratories and observatories acquired during the implementation of FP7-REGPOT project enabled FOTONIKA-LV associated researchers to take the role of project coordinator. Horizon 2020 calls are highly competitive, but highly limited resources available for proposal development have no doubt affected the success rate despite the large number of proposals that have been submitted. However, for many projects there are resubmission possibilities opening opportunities to benefit from the learning experience of proposal development to submit improved proposals in the future.

During the years 2017–2019 the efforts of various teams from the FOTONIKA-LV community resulted in the following:

- Two book chapters and 22 articles published in peer reviewed journals and about 20 reports in large scale international conferences;
- Intensive efforts were made to contribute to the implementation of Horizon 2020 programme via applications to various calls:
  - two project proposals to the call H2020-MSCA-RISE-2017 were retained for financing and are under the implementation till 2021;
  - two more MSCA-RISE project proposals dedicated to quantum sciences and space sciences accordingly have been submitted;
  - ERA Chair project proposal QUANTUM-LV-857624 (2019–2023) was scored considerably above the quality threshold (11.5 from 15), but was not retained for financing from H2020 budget due to budgetary restrictions, but is refinanced from EU Structural funds budget in Latvia;
- 17 project proposals to the H2020 calls during the years 2017–2019, 15 project proposals were submitted taking role of the Coordinator (*H2020-Widespread-2-2017, Twinning: "PHOTONICS BALTICUM-810966"; H2020-Widespread-2-2018, Twinning: SPACE BALTICUM-857342"; H2020-Widespread-3-2017&18, ERA Chair: "SPACE LV – 811043 & 857610"; H2020-Widespread-3-2018,ERA Chair: "FOTONIKA SOAR – 811025"; H2020-MSCA-RISE-2017&2018: CHALLENGE of IONS-778066 & 823959; H2020-MSCA-RISE-2017&2018: SLR GLOBAL NET -778374 & 823930; H2020-MSCA-IF-2017: InHype-66402; H2020-COMPET-2017: LasComnX-776417; H2020-COMPET-2017: INFO-STREAM-7756163; H2020-FETOPEN-2016-2017: THz-ANT-767196; H2020-MSCA-NIGHT-2018: Light4Future-819108; H2020-SPACE-2018-2020: LUNAR BASALT FIBRE-821958; H2020-SC5-2028-2019-2020:SENSING CRUST – 821097; H2020-SwafS-2018-2020: NL-ELL-824616*). **The proposals received high overall scoring but failed to be retained for financing from the H2020 budget due to very high competition**. Many of them incorporate perspective ideas to be fine-tuned and resubmitted to relevant calls of H2020 or the next EU Framework programme HORIZON EUROPE;
- The task force of NSP FOTONIKA-LV during the 2017–2019 supported submission of about 30 project proposals on disruptive innovation to the H2020 SMEs instrument call from which two Phase 1 projects were retained for financing and 10 received scoring above 12 from 15. That is excellent outcome keeping in mind that average success rate to the programme is about 5%. Most of them are worth for fine-tuning and resubmission;

- Besides H2020 projects the following projects are under implementation during 2017–2019:
  - COST programme – 1 financed Project;
  - INTERREG BSC regional programme – 1 financed project from 2 applications;
  - LV – UA bilateral cooperation programme – 1 financed project;
  - European Space Agency projects – 1 financed project;
  - ISLR (NASA) technical workshop – 1 financed Project;
  - Industry University effective collaboration – financed projects with Thorlabs Inc., USA; 7 financed projects with SMEs in Latvia;
  - University partnership project with Ethiopia Space Science and Technology centre;
  - University partnership project with ROSCASOLANO, CSIS, Spain, Madrid;
  - ERDF National Structural Funds projects – 2 financed from 4 submitted and highly scored project proposals pending for the resubmission to next calls;
  - Latvian Council of Science grants – 1 financed project from 5 submitted and highly scored project proposals pending for the resubmission to next calls.

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

Finally, active relations **with a "club" of research driven SMEs** should be mentioned, which includes bilateral collaboration projects, H2020 project proposal development via joint participation in H2020 project consortiums going for H2020 Industry Leadership and particularly Space related calls. This cooperation with the photonics industry in Latvia opens possibilities for collaboration with photonics clusters elsewhere in Europe.

Following the practice started in 2012 by the mentioned FP7-REGPOT-2011-1, No 285912, FOTONIKA-LV project, we continue recruiting foreign researchers and ensuring internship opportunities for students. Dr. Ulises Miranda Ordóñez, talented young researcher from Mexico University was recruited in 2018 for duration of six years. PhD cand. Max Lozach from France now cooperates with our research team to perform experimental efforts to finalise his PhD Thesis. Internship training was ensured for three BSc students coming from Brigham Young University in USA in summer of 2017 and 2018. MSc student in space sciences Roberts Kancans (Latvian diaspora in USA) from the University Southern California received research training in the SLR technologies in Astrophysical Observatory during the summer 2018. Thibaud Mourlon from *Universite Jean Monnet – Saint-Etienne*, Lion, France has internship training for 6 months till September 2019. Visit of another MSc student for three months starting from September 2019 is envisaged.

References

[1] Report on key players in convergence regions, FP7- REGPOT-(2007-2013)-1 Contribution to ERA. Grant holders, high ranked proposers & partners. 2013. A survey of unlocked capacity of outstanding research centres in convergence regions. By Dr. Arnolds Ūbelis, Co-editors: Greg Macdonald, Regina Ūbele. Tech.editors: Inga Šīrante, Alma Anna Ūbele, REGPOT proj. report #203926, 458 p.

[2] Latvia. Innovation System Review and Research Assessment Exercise: Final Report, TECHNOPOLIS, April 20, 2014.

Research on basic properties of atoms excited in inductively coupled RF plasma or in combination with hollow cathode discharge

Arnolds Ūbelis

National Science Platform FOTONIKA-LV, University of Latvia

E-mail: arnolds@latnet.lv

Inductively coupled RF plasma *(ICP, but frequently named as high frequency electrodeless discharge)* is a well-known ideal source of intensive atomic resonance spectra of various elements not perturbed by ion spectra [1]**.** Researchers coming from the former Laboratory of Spectroscopy Problems at the university of Latvia and currently linked to NSP FOTONIKA-LV collected for decades valuable experience in designing [2], manufacturing and application of resonance atomic spectra sources for analytical purposes and research on spectroscopy and basic properties of atoms, e.g. [3], atomic spectra [4] as well as in photochemistry and in research using flash photolysis methods [5–7]. Collected experience in ICP technologies allows to the team to make new efforts in response to emerging demand.

Up to now tellurium is an atom which atomic properties were most persistently studied by our team using ICP plasma source [8, 9]. Particularly, our results were recently found useful for astrophysics research performed by multi-university team led from Massachusetts Institute of Technology in USA and using Hubble Space Telescope [10, 11]. Current and pending positioning of telescopes on satellite platforms *(like James Webb telescope*) [12, 13] revitalised interest for the research data on basic properties of atoms from astrophysicists. Uldis Berzins, a team member of our group is a research contributor, and co-author of several articles related to dedicated research efforts in response to astrophysics needs [14–16].

In summary should be mentioned, that the team of mentioned laboratory boosted by the demand for analytical spectra sources in various projects since 1970 collected remarkable experience in the design and development of ICP powered atomic spectra sources for the following atoms: Na, Rb, Cs, Cu, Zn, Cd, Hg, Tl, Sn, Pb, Sb, Bi, S, Se, and Te from various subgroups of Mendeleev chart *(mostly only case by case short information is available about mentioned atomic spectra sources in laboratory notes, project reports or in the proceedings of the University of Latvia in Latvian or in Russian)*.

The **hollow cathode glow discharge** is a modification of the conventional glow discharge with a positive column. The closed cathode configuration is a prerequisite for enhanced plasma ionisation resulting in more efficient excitation of the atoms. The hollow cathode glow discharge exhibits a specific electron energy distribution function which includes a small group of high energy electrons, apart from the much larger group of thermalised electrons. The hollow cathode discharge also exhibits a low electric field in the negative glow region, low pressure and low gas temperature. The hollow cathode discharge is an excellent spectral source emitting narrow bright lines of a large number of elements with very good stability, reproducibility, and ensuring sensitivity *(line profiles)* in detection. Currently *(2017)* the best survey of publications concerning hollow cathode physics and authors own research efforts in the field is available in the Doctoral Thesis work performed in 2017 [17]. Need to be mentioned that the hollow cathode discharge in comparison with ICP plasma discharge produces atomic as well as ionic spectra of elements and experimentally reachable intensity of resonance atomic spectral lines usually is up to 5–10 lower than in the case of ICP plasma sources.

The methodology of combination of hollow cathode discharge and ICP plasma were for the first time mentioned in the article and comprehensively described in the article published in the proceedings of the University of Massachusetts in 1990 [19].

As a result of quite modest resources allocated in Latvia for fundamental research during the last decade the project team was engaged *(busy)* with other partly fundamental, but mostly applied research topics, particularly with the implementation of EU framework programme FP6 and FP7 projects. As a result, during the project life, the following experimental skills, methods and technologies were developed which form the instrumental and methodological foundations for the experiments foreseen for the implementation of the current project activities:

a) Development of specifically designed RF power sources – generators of inductively coupled plasma based on modified Clapp oscillator circuit, able to function at adjustable power supply from 20–100 W and operational at several fixed frequencies in the range of 27–50 MHz. Particularly, such devices were used to perform experiments of modification of biomaterials at high temperatures in the specific environment. *For reaching maximum effectivity* a special form of inductive element and custom-made high-power resonance tank capacitor was made from material of very low tg $\partial \sim 0.0015$.
b) A unique approach was used for the purposes of the applied research project: to generate boron ions in a hollow cathode to be extracted from the hollow cathode by Ar flow to the area of inductively coupled plasma and then formed and accelerated in a highly energised ion beam for the implantation. As a result, lessons were learned about details of application.
c) Capacity was developed to perform spectroscopic measurements in a wide range from visible to vacuum ultraviolet regions.
d) The capacity of the mechanical workshop, the laboratory of quartz and glass technologies and relevant quartz glass high vacuum technologies were developed allowing the production, pumping and filling of sophisticated devices, tubes and cells having complex geometry from glass and quartz.

Overall estimates show need for new or improved data on basic properties *(transition probabilities and branching ratios)* of various atoms, particularly with astrophysics interest and emerging new needs in analytical spectroscopy concerning atmosphere research. Besides that, experimentally complicated investigation of spectroscopic properties of atoms in UV and VUV regions still need more intensive research efforts.

The research team is making pilot research efforts to be prepared and resubmit a previously highly scored project proposal to the call of Latvian Science Council in August 2019 to compete for fundamental research grants to make a significant contribution to progress in fundamental atomic physics with research on basic properties of atoms using novel approaches. Research is foreseen on the following list of atoms: halogen atoms – Iodine and Bromine; Sulphur; Arsenic; Antimony; Bismuth; atoms of hardly volatile elements like: B, Al, Ga, In, Tl, C, Si, Ge, and others.

Currently, more comprehensive information about basic atomic properties can be found in the Handbook of Basic Atomic Spectroscopic Data by Sansonettia and Martin [20] from the *National Institute of Standards and Technology, Gaithersburg, Maryland* and in the data base of the Institute [21] which was described by W. L. Wiese in his presentation [22]. Mentioned sources envisage that most wavelengths and energy levels were measured experimentally in a middle of the last century. Currently, basing on the development of various experimental assets, the precision of data for many atoms can be substantially improved in response to renewed demand in several research domains for basic properties of atoms including astrophysics and theoretical atomic physics.

References

[1] Kazantsev, S. A., *et al.* (2010). Practical Spectroscopy of High-Frequency Discharges *(Physics of Atoms and Molecules)*, Plenum Press, New York and London, 340 p.

[2] Khuzmieva, B., *et al.* Soviet patent, *date 04/15/1991:* http://www.lib.umich.edu/articles/details/fetch-epo_espacenet_su1642537a12

[3] Spietz, P., *et al.* (2001). Estimation of the Emission Temperature of an Electrodeless Discharge Lamp and Determination of the Oscillator Strength for the I($^2P_{3/2}$) 183.038 nm Resonance Transition. Spectrochimica Acta, Part B, V 56, p. 2456.

[4] Ubelis, A., *et al.* (1981). The Spectra of High Frequency Electrodeless Lamps in the Vacuum UV Region. Zhrn.Prikl.Spectr. 35(2), p. 216 (in Russian).

[5] Gross, U., *et al.* (2000). Iodine and mercury resonance lamps for kinetics experiments and their spectra in the far ultraviolet, J. Phys. D: Appl. Phys., 33, p. 1588.

[6] Spietz, P., *et al.* (1998). Study of iodine oxides and iodine chemistry using flash photolysis and time resolved absorption spectroscopy. Ann. Geophys. Supp. II, **16**C, p. 722.

[7] Gross, U. (2002). The Flash Photolysis Method in the Iodine-Ozone Mixture, Photochemical Research. Summary of the PhD Thesis, University of Latvia.

[8] Ubelis, A., Berzinsh, U. (1991). 5s 5p 6s-5s 5p Transition Probabilities of Te I. Physica Scripta. 43(2), p. 162.

[9] Ubelis, A., Berzinsh, U. (2006). Transition Probability Measurements of Te I Spectral Lines by Methods of Emission and Absorption of Radiation. Physica Scripta, 28(2), p. 171.

[10] http://annesastronomynews.com/tellurium-detected-for-the-first-time-in-ancient-stars/

[11] Roederer, Ian U., *et al.* (2012). Detection of the Second R-Process Peak Element Tellurium in Metal-Poor Stars. The Astrophysical J.Letters, 747(1), p. 5.

[12] https://www.jwst.nasa.gov/resources/JWST_SSR_JPG.pdf.

[13] https://www.nasa.gov/sites/.../atoms/.../webb_irb_report_and_response....

[14] Bengtsson, J., *et al.* (1992). Determination of Radiative Lifetimes in Neutral Arsenic Using Time Resolved Laser Spectroscopy in the VUV Region. Astron. & Astrophýs. V. 263, p. 440.

[15] Berzinsh, U., Svanberg, S., Biemont, E. (1997). Radiative Lifetimes for the 4p Excited States of Phosphorous and the Osciliator Strengths of Solar Lines, Astron. & Astrphys. V. 326, p. 412.

[16] Li, Z. S., *et al.* (2001). The FERRUM project: radiative lifetimes of the 3d5(6S)4s4p(3P)y6Po states of Fe II measured with time-resolved vacuum ultra-violet laser spectroscopy, J.Phys. B: At. Mol. Opt. Phys. V34, p. 1.

[17] Kkaratodorov, S. I. (2017). Combined plasma source for emission spectroscopy: laser-induced plasma in hollow cathode discharge. Institute of Solid State Physics, Bulgarian Acad. of Sci. 132 p. PhD Thesis.

[18] Masamba, W. R., *et al.* (1988). Atomic and Ionic Fluorescence in an Inductively Coupled Plasma Using Hollow Cathode Lamps Pulsed at High Currents as Excitation Sources, Appl. Spectrosc. V. 42, p. 872.

[19] Greenfield, S., *et al.* (1990). A Comparison of Boosted-Discharge Hollow Cathode Lamps and an Inductively Coupled Plasma (ICP) as Excitation Sources in ICP Atomic Fluorescence Spectrometry. Chemistry Department Faculty Publication Series, https://scholarworks.umass.edu/chem_faculty_pubs

[20] Sansonettia, J. L., Martin, W.C. (2005). Handbook of Basic Atomic Spectroscopic Data J. Phys. Chem. Ref. Data, Vol. 34, No. 4, DOI: 10.1063/1.1800011.

[21] https://physics.nist.gov/PhysRefData/Handbook/periodictable.htm

[22] Wiese W. L. Activities 2009-2011 at the Atomic Spectroscopy Data Center at the National Institute of Standards and Technology. https://www-amdis.iaea.org/DCN/Presentations/2011/Wiese.pdf.

Theoretical modelling of exotic dimers

Ulises Miranda Ordóñez
Institute of Atomic Physics and Spectroscopy, University of Latvia
E-mail: ulises.ordonez@lu.lv

Clusters are defined [1] as agglomerates of a limited number of atoms or molecules. Such systems can be of different composition; in the case of atomic clusters these can be homonuclear or heternuclear. It is clear that in both cases the composition is one factor that determines their properties and how and where they can be applied. However, not only the technological [2] or practical applications [3] of these systems are interesting and important. From the scientific point of view the study of clusters is still a fertile field in which we can enlarge the knowledge and understanding of nature, more specifically, the formation of matter. It is also important to understand the very nature of clusters and the origins of the properties they exhibit. When we refer to atomic clusters, it is clear that they can be of any element of the periodic table, as it follows from the definition given above. Of special interest to us are the metallic clusters with many applications [2, 3–6]; more specifically, diatomic clusters of transition-metals (Fig. 1). The latter are complex systems and there are several aspects and systems that need to be inspected both theoretically and experimentally.

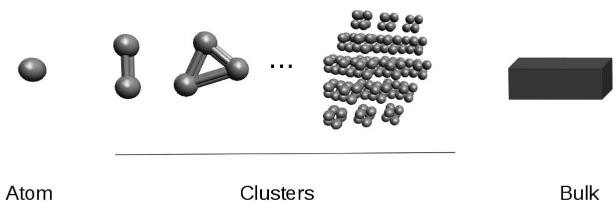


***Figure 1**. Representation of metal clusters with respect to a single atom and the solid state*

Small transition metals have been studied [1, 4–9] for many years; however, the interest in such systems has faded. From the experimental point of view, it can be a challenge to produce and detect them in the laboratory and to collect data. From the theoretical point of view, they represent another methodological challenge for several reasons. As can be seen in Fig. 1, dimers are the smallest clusters, and, in the case of transition metals, they have a marked multiconfigurational nature. This means, that there is more than one electron configuration that substantially contributes to the wave function and a proper description of the bond dissociation is not possible using single-reference methods, such Hartree-Fock, Moller-Plesset perturbation theory or coupled cluster [10]. Nowadays, this problem can be solved by means of sophisticated methods such as the multiconfigurational self-consistent-field or the complete-active self-consistent-field [10]. Other complication in small transition clusters, especially in dimers, is the large amount of quasi-degenerate molecular states, which make these simple systems very demanding in terms of computational resources. Scandium dimer is a good example of these problems. According to the Wigner and Witmer rules [11] for building electronic states there are 80 singlet and triplet states arising from the interaction of 2 atoms in the ground state; however, the ground state is a quintet that arises from the interaction of an atom in the ground state and an atom in a excited, quartet atomic term [12–14]. As a result of these details, the computation of the full potential energy curve of only the ground state of scandium dimer takes about 6 months running a job in 4 processors in parallel.

Experimental studies on larger clusters gained notoriety with advances in nanotechnology. Currently, the synthesis and application of nanoparticles has become common. These nanoparticles are large clusters [15]. It is clear that research attention will remain focused on nanosized clusters due to all the application they have in technology and science. Nevertheless, the research on the smallest clusters remains a big and open area for scientific work. As technology is moving beyond the nano range [16–18] it may be expected that small clusters will become much more relevant in the near future.

References

[1] Koutecký, J. & Fantucci, P. (1986). Theoretical aspects of metal atom clusters. *Chemical Reviews*, 86, p. 539.

[2] Service, R. F. (1996). Small clusters hit the big time. *Science*, 271, p. 920.

[3] http://www.clusterlab.jp/2012/researchIchihashi_e.html

[4] Muetterties, E. L., *et al*. (1979). Clusters and surfaces. *Chemical Reviews*, 79, p. 91.

[5] Alonso, J. A. (2000). Electronic and atomic structure, and magnetism of transition-metal clusters. *Chemical Reviews*, 100, p. 637.

[6] Roucoux, A., Schulz, J., Patin, H. (2002). Reduced transition-metal colloids: A novel family of reusable catalysts? *Chemical Reviews*, 102, p. 3757.

[7] Morse, M. D. (1986). Clusters of transition metal atoms. *Chemical Reviews*, 86, p. 1049.

[8] Tatewaki, H. & Tomonari, M. (1992). The electronic structure of small transition metal clusters. *Canadian Journal of Chemistry*, 70, p. 642.

[9] Lombardi, J. R. & Davis, B. (2002). Periodic properties of force constants of small transition-metal and lanthanide clusters. *Chemical Reviews*, 102, p. 2431.

[10] Piela, L. Ideas of quantum chemistry. Elsevier, Amsterdam, 2007.

[11] Wigner, E., Witmer, E. (1928). On the structure of the spectra of two-atomic molecules according to quantum mechanics. *Zeitschrift für Physik*, 51, p. 859. Translation by H. Hettema, Quantum Chemistry: Classic Scientific Papers. (World Scientific, Singapore, 2000), p. 287.

[12] Kalemos, A. Kaplan, I. G. & Mavridis, A. (2010). The Sc2 revisited. *Journal of Chemical Physics*, 132, 024309.

[13] Kaplan, I. G., Miranda, U. (2014). Multi-reference ab initio calculations of 3d transition-metal dimers: Sc2. *Russian Journal of Physical Chemistry A-Theory of Atomic molecular Processes*, 88, p. 1861.

[14] Miranda, U. (2019). Long-range interactions and role of static and dynamic correlation energy in scandium dimer. *Molecular Physics*, 117, p. 404.

[15] https://www.oulu.fi/nanomo/clusters

[16] https://www.industrial-lasers.com/micromachining/article/16485073/nano-to-pico-to-femto-pulse-widths-for-optimal-laser-micromachining-outcomes

[17] https://www.polypico.com/applications-info/

[18] Alpaslan, E., Webster, T. J. (2014). Nanotechnology and picotechnology to increase tissue growth: a summary of in vivo studies. *International Journal of Nanomedicine*, 9, p. 7.

Overview of achievements of Astrophysics and Planetary Sciences in Baldone

Ilgmārs Eglītis

Institute of Astronomy, University of Latvia

E-mail: Ilgmars.Eglitis@lu.lv

The Astrophysical Observatory (*code 069*) of the Institute of Astronomy, University of Latvia in Baldone, Riekstukalns began its activities in 1958, by separating the Astronomy sector from the Institute of Physics of the Latvian Academy of Sciences (LAS) as an independent structure. A year later, the first building of the Laboratory of Astrophysics was built in the territory of the next observatory, 5 km from Baldone town near Riekstu Hill, the so-called "White House". The founder and first director of the Observatory, Jānis Ikaunieks (1912–1969), planned to develop two directions of research: to create a large base interferometer in radio astronomy and in red optics, and investigations of stars in the last evolutionary stage. In 1959, an agreement was signed with Carl Zeiss of East Germany on the construction of a Schmidt telescope to ensure the performance of optical observations.

In 1967 the name of the Laboratory of Astrophysics was changed by decision of LAS to Latvian SSR AS Radioastrophysical Observatory with an objective – creation of a 2 km ridge for a multi-antenna variable base radio interferometer. This project was not realised due to premature death of Jānis Ikaunieks; the development of the area of radio interferometry, the placement of 30 m rotating radio antennas on Roņu Island, Engure and Salacgrīva was stopped also. These plans were developed twelve years earlier than in England, where a radio-like interferometer of similar size recorded radio signals from distant galaxies for the first time resulting in a Nobel Prize (1974). Thanks to the efforts of Arturs Balklavs (1933–2005), the next long-term director of the Observatory, the direction of radio astronomy studies remained, and 10 m radio antenna was bought in 1972 to study solar activity at ranges 755, 610 and 326 MHz.

The development of optical astronomy is in line with Jānis Ikauniek's idea. At the beginning of January 1965, the 1.2 m large field of view (19 m^2 field of view) Schmidt system telescope with an input aperture of 0.8 m was added to the Observatory's infrastructure. It is the twelfth largest Schmidt telescope in the world still to date.

Investigations of carbon stars: B, V, R, I photometry, low resolution spectroscopy

More than 5% carbon stars in Milky Way Galaxy were discovered in Baldone Observatory. Main photometric characteristics of these stars were obtained. New type of variability of late stars – DY Per with irregular dimming by 2–5 magnitudes was selected. "General Catalogue of Galactic Carbon Stars" was prepared in 2001 and the catalogue data now are continuously updated. On the basis of the Schmidt telescope low resolution objective prism spectrum analysis, a method for estimating the absolute size, surface temperature, distance and evolution stage of carbon stars has been developed (Fig. 1). This method uses the latest achievements of carbon star research in the Great Magellan Cloud and estimates of the magnitude of interstellar absorption. The results of the method are currently being tested using Gaia's space telescope measurements. The distribution of the carbon star is believed to be related to the structure of the Milky Way galaxy arms. The hypothesis that the Galaxy has another, more distant arm than the "outer arm" is being checked. The loss of matter from the C stars forms carbon-rich shells – space areas with a high concentration of a vital chemical element.

Monitoring of small bodies of Solar system

CCD observations of the asteroids with Baldone Schmidt telescope began in 2008. In the Minor Planet Circulars and the Minor Planet Electronic Circulars were published 5434 astrometric positions of 1488 asteroids to now. Among them, 77 asteroids were newly discovered at Baldone Observatory. Eleven asteroids were named. The accurate orbits of asteroids were calculated with OpenOrb 4.2 and for two interesting asteroids (428694) 2008 OS9 from the Apollo group and the Centaur (330836) Orius (2009 HW77), the evolution of orbital elements was calculated. The results of the project will provide an opportunity to predict the probability of collision of dangerous asteroids and small bodies of the Solar System with the Earth, as well as to analyse the chemical composition of the observed small bodies of the solar system, thus obtaining information about useful minerals on the cosmic bodies.

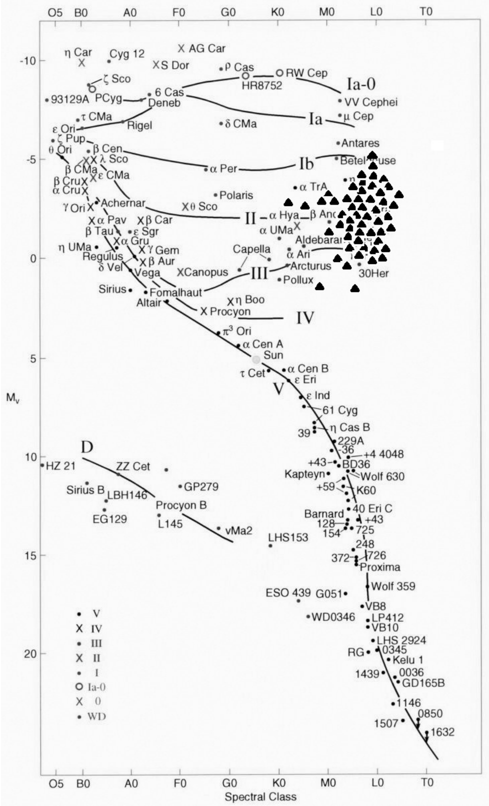


Figure 1. *By blue dots labelled displacement of C stars on H-R diagram*

Digitisation of Baldone Schmidt telescope wide field 22000 direct astroplate archive

Digital processing of photographic plates of star fields allows determining the coordinates and stellar magnitudes with high accuracy, 0.5" and 0.1 mag respectively, for all registered objects on these plates. The images were processed using advanced complex of LINUX / MIDAS / ROMAPHOT programmes. Modern approach to processing of early photographic observations with new technologies is an effective instrument for rediscovery of asteroids, correction of their orbits, investigation of variable stars of different type and obtaining proper motion of stars. Approbations of this software complex are the catalogues of stars coordinates and their U-magnitudes. In addition, the project ensures the preservation of a unique national database with international access.

Upgrading the Baldone Schmidt telescope

Upgrade of Baldone Schmidt telescope mechanics and optical system using "fly eye" technologies allows looking forwards to participate in projects of investigation of carbon stars, blazars, and studies of Solar system small bodies. Two 1 square-degree of view CCD cameras were installed in the main focus of the Baldone Schmidt telescope.

Advances in Geodynamical Research

Kalvis Salmiņš, Jorge del Pino
Institute of Astronomy, University of Latvia
E-mail: Kalvis.Salmins@lu.lv

The SLR station 1884 Riga reported several interesting results during the year 2018 and early 2019. In this presentation we summarise the most noteworthy results:

- Participation on the GREAT experiment, confirming Einstein's Relativity Theory;
- The Galileo navigation satellites 201 and 202 are in a non-circular orbit caused by a launch failure.

As a consequence of the variable gravity field, the time and frequency signals are modulated following Einstein's General Relativity theory. The value of this modulation can be measured if the Galileo orbit is independently determined from the radio navigation data.

All the Galileo satellites having a set of laser retroreflectors on board and the International Laser Ranging Service were asked to participate into the GREAT experiment with dedicated SLR Tracking sessions from the 1st to the 7th of each month during one year in order to supply the independent orbital data. Riga was able to observe Galileo 201 during April 2017. The experimental data confirmed the Relativity Theory with improved reliability [1, 2].

Observing Rotating Space Debris

There is a subgroup of space debris, consisting of intact satellites which suddenly stopped working and cannot be deorbited using the on-board resources. In general, these satellites are rotating in a complicated way. Many of them have laser retro reflectors on board. By laser tracking, supplemented in some cases by photometry, all the rotational parameters can be determined supporting the future operation of "capture and deorbit" satellites which are under research design at this moment.

Riga contributed to the observational campaign for the Topex-Poseidon satellite [3] and was one of the top observing sites during 2018 (Tab.1).

First Worldwide observation of the cubesat SNET-4

The SNET cubesat constellation is a group of 4 cubesats (24 × 24 × 24 cm) from Berlin Technical University and was launched on February 1, 2018, with the purpose of investigating and demonstration the inter-satellite communication technology within a distributed autonomously operating nanosatellite network. Because of this the exact interorbital distance between the SNET satellites is needed, and due to the weight, size and power limitation, the use autonomous orbital determination equipment as GNSS receivers on board is impossible.

The option used was to install very small (1 cm diameter) laser retroreflectors on the SNET satellites. The challenge of the small reflector size and the initial orbital parameters contributed to Riga being on April 12, 2018 the first SLR station in the world to get laser returns from any of the SNET satellites. Riga closed the year 2018 with a total of 46 observations for the 4 SNET satellites in orbit.

Participation on International and National Projects

During 2018 Riga participated on the development of a new state-of-the-art SLR system for ESA to be installed at "Pico del Teide" in Tenerife Spain. A full description of the project is provided in reference [4].

In a project financed by University of Latvia Foundation under the Mikrotīkls company donation in support of university research, a team from the Institute of Electronics and Computer Science and the Institute of Astronomy, University of Latvia have built the TS/ATIC to improve the precision and resolution of the time interval measurements at the SLR Station 1884 Riga. A full description of the project is provided in reference [5].

Table 1. *Rotating Space Debris SLR world observations for 2018*

Station	Total	Topex	Oicets	Adeos	% World
Borowiec	138	75	34	29	26.85%
Riga	120	77	29	14	23.35%
Graz	95	68		27	18.48%
Changchun	77	72	5		14.98%
Matera	47	47			9.14%
Herstmonceux	30	30			5.84%
Zimmerwald	6	6			1.17%
Potsdam	1	1			0.19%

References

[1] Delva, P. N., *et al.* (2018). Gravitational Redshift Test Using Eccentric Galileo Satellites *Physical Review Letters 121, 231101.*

[2] Herrmann, S., *et al.* (2018). Test of the Gravitational Redshift with Galileo Satellites in an Eccentric Orbit *Physical Review Letters 121, 231102.*

[3] Kucharski, D., *et al.* (2017). Photon Pressure Force on Space Debris TOPEX/Poseidon Measured by Satellite Laser Ranging, *Earth and Space Science, 4, 661.*

[4] Kloth, A., *et al.* (2018). Towards Turnkey SLR Systems: New ESA Laser Ranging Station (ELRS). *21st International Workshop on Laser Ranging, Canberra, November 5–9, 2018.*

[5] Bespal'ko, V., Salmins, K., Buraks, I. (2018). Modernization of Event Timer RTS 2006. 21st *International Workshop on Laser Ranging, Canberra, November 5–9, 2018*.

Absorption Cells for Stabilisation of Blue and Violet Diode Laser Frequency with 11 Decimal Digit Precision

Uldis Bērziņš[1], Jānis Valdmanis[2], Arnolds Ūbelis[3], Jānis Alnis[1], Artūrs Ciniņš[3], Aleksandrs Švarcs[3], Aigars Apsītis[3], Viesturs Silamiķelis[3]

[1] *Institute of Atomic Physics and Spectroscopy, University of Latvia*
[2] *Thorlabs Inc., United States of America*
[3] *National Science Platform FOTONIKA-LV, University of Latvia*
E-mail: Uldis.Berzins@lu.lv

Further progress in smart and sophisticated application of violet and blue diode lasers (facing rapid quantitative and quality growth) is strongly limited via insufficient emission wavelength stabilisation. Ultraprecision optical frequency standards are required, e.g. for optical clocks, but also as a powerful tool for optical fibre communications, quantum information technologies, metrology, astrophysics and proofs of fundamental physical laws. We are aiming to design, to produce and to deliver absorption cells filled with ^{130}Te isotope molecules, which have absorption spectra in the range of 390–500 nm, with central positions of absorption lines known with 11 decimal digits precision. Later it can be improved to 14 decimal digits.

Molecular electronic spectra usually cover a broad range of wavelengths, making them an ideal choice for optical laser frequency standards which do not necessarily demand accuracy, but they have to be stable. The most widely used molecules are iodine and tellurium, both are homo-nuclear and hence not IR active. Some absorption lines of iodine molecule have been recommended as frequency standards with 11 digits precision already since 1984 [1] and later supplemented [2]. Since iodine vapour is easy to create in a cell at room temperature, and different diode lasers in near infrared and red spectral region are cheap and easily available, high precision spectroscopy of iodine molecules is popular for training physics students [3].

For accurate detection of central absorption wavelengths, the laser-saturated absorption spectroscopy method is used. In the early 1970s Schawlow and Hänsch (both Nobel Prize winners now) [4] developed a practical way to use nonlinear interactions of laser light with atoms to produce spectra without Doppler broadening. Their technique, what we use now, grew out of fundamental work on nonlinear optics done by them and other physicists, e.g., Bloembergen, Lamb, and Javan [5, 6]. In this technique, two counter-propagating, overlapping laser beams of exactly the same frequency interact with atoms in a vapour. When the laser frequency is different from the resonant frequency f_0, one beam interacts with a set of atoms with some velocity vz and the other beam interacts with an entirely different set of atoms, those with velocity – vz. However, when the frequency is tuned, the two beams interact with the same group of atoms, those with velocity component parallel to the beams is approximately 0.

We work on iodine and tellurium molecules that are well known and used as frequency standards since 1980s [7, 8]. The electronic spectrum of iodine shows strong absorption band starting at around 500 nm for the transition between its X and B electronic states which are the lowest two electronic states of the system [1, 2]. Therefore, iodine lines are suitable to frequency lock lasers in the longer wavelength range. The tellurium spectrum has been observed starting from ultra violet (UV) wavelength of about 350 nm onward. The main advantage of this molecule is its large spin-orbit coupling and the presence of a large number of isotopes. This combination allows a wide spectral range to be accessible in a single molecular species [9]. Tellurium spectrum has been studied extensively in many contexts. The most extensive work has been done by J. Cariou and P. Luc, *Atlas du spectre d'Absorption de la Molecule de Tellure*, CNRS, Paris, 1980 [8]. Subsequent work has already been done to extend this atlas on both sides of the spectrum available in the atlas [10–12], and with 10 decimal digit precision around 450 nm [13].

As a first step in our project the iodine and tellurium cells were manufactured in our glassblower workshop. The cell bodies were made from quartz and attached to the vacuum system. Inside surface of cells was cleaned by RF discharge in argon. After that tellurium and iodine were placed inside the cells and vacuum was pumped down to 10^{-7} torr pressure. At that pressure cells were sealed off. Sealed off cells are presented in Fig 1.

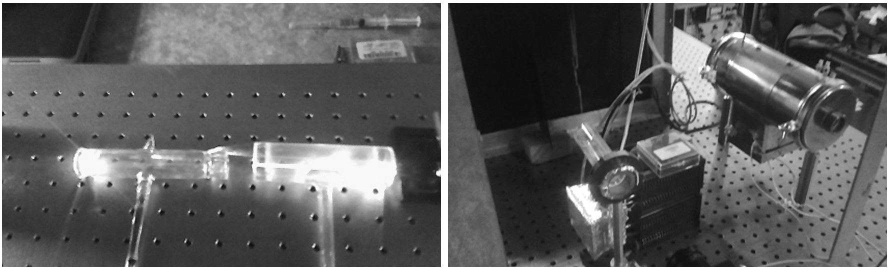


Figure 1. *a) fluorescence from tellurium and iodine cells* *b) iodine cell assembled with appendix in cooling unit and tellurium cell in oven*

Fig. 1a presents two cells, one filled with tellurium (left) and second with iodine (right). They are about 20 cm long and about 2.5 cm in diameter with appendix about 15 cm long and 1 cm in diameter. A 532 nm laser beam is sent through cells. We see yellow fluorescence from the iodine cell and no fluorescence from the tellurium cell. There's insufficient vapour pressure of Te_2 molecules at room temperatures. In Fig. 1b on left side we see iodine cell assembled with appendix in cooling unit and tellurium cell in oven.

Finally, the Te_2 line position will be overlapped with frequency marks from femtosecond pulse laser optical frequency comb. The measurement precision will be adjusted to an accuracy of 11 decimal digits by comparison with signal with Rb radiofrequency Atomic Clock.

In the Laboratory of Quantum Optics we have access to Frequency Comb and Ti Sapphire laser with frequency doubling unit and coupling with Rb atomic Clock and to GPS signal from frequency standard from Braunschweig frequency standard (14 decimal digits accuracy).

References

[1] Hudson, R. P. (1984). Documents Concerning the New Definition of the Metre*, Metrologia 19, p. 163.

[2] Quinn, T. J. (1992). Mise en Pratique of the Definition of the Metre, Metrologia 30, p. 523.

[3] Chen, L. (2005). High Precission Spectroscopy of Molecular Iodine: From Optical Frequency Standards to Global Descriptions of Hyperfine Interactions and Associated Electronic Structure, Thesis University of Colorado.

[4] Hänsch, T. W., Levenson, M. D., Schawlow, A. L. (1971). Complete Hyperfine Structure of a Molecular Iodine Line, Phys. Rew. Lett. 26, p. 946.

[5] Schawlow, A. L. (1982). Spectroscopy in a new light (1981 Nobel lecture), Rev. Mod. Phys. 54, p. 697.
[6] Bloembergen, N. (1982). Nonlinear optics and Spectroscopy (1981 Nobel lecture) Rev. Mod. Phys. 54, p. 685.
[7] Gerstenkorn, S., *et al*. (1978). Atlas du Spectre dAbsorption de la molecule de Iode, Part I – Part IV, Laboratoire AimeCotton, CNRS II", Orsay, France.
[8] Cariou, J., Luc, P. (1980). Atlas du Spectre dAbsorption de la molecule de Tellure, Laboratoire AimeCotton, CNRS II, Orsay, France.
[9] Vergès, J., *et al*. (1982). The Laser Induced Fluorescence Spectrum of Te_2 Studied by Fourier Transform Spectrometry, Phys. Scr. 25, 2.
[10] Gillaspy, J. D., Sansonetti, C. J. (1991). Absolute wavelength determinations in molecular tellurium: new reference lines for precision laser spectroscopy, J. Opt. Soc. Am. B8, p. 2414.
[11] Russell J. De Young (1994). Visible spectrum optical absorption in Te_2 vapor", Appl. Phys. Lett. 64, p. 2631.
[12] McIntyre, D. H., *et al*. (1990). Interferometric frequency measurement of $130Te_2$ reference transitions at 486 nm, Phys. Rev. A41, p. 4632.
[13] Dutta, T., Muktherjee, M. (2019). High Resolution Spectroscopy on Te_2: new lines for reference. Spectrochim Acta A Mol Biomol Spectrosc. 208, p. 109.

Disruptive innovation and H2020 SME Instrument call capacities in Latvia

Arnolds Ūbelis

National Science Platform FOTONIKA-LV, University of Latvia
E-mail: arnolds@latnet.lv

The H2020 SME instrument (*https://ec.europa.eu/programmes/horizon2020/en/h2020-section/sme-instrument*) supports high-potential small and medium-sized innovative enterprises willing to commercialise new products that could drive economic growth and shape new markets or disrupt existing ones in Europe and worldwide through close-to-market activities, aiming at breakthrough innovation with a market-creating potential. SMEs in Latvia have been modest performers in this Europe-wide competition. At the end of 2018 nearly 36,000 1st phase project proposals (*of EUR 50,000 for feasibility studies*) were submitted to four calls annually starting from 2014. Only about 3,000 were funded resulting in success rate 8.48%. Competition for 2nd phase projects (*EUR 0.5–2.5 million to bring a TLR 6 level prototype to commercialisation stage*) is much stronger. By end of 2018 close to 21,000 project proposals were submitted, but only 975 projects were financed (*success rate 4.7%*). The best performers have come from the largest countries. Surprisingly Spain and Italy are overcoming UK, Germany and France.

Latvia is not among the best performers having success rate well below the average (*3.7% and 2.5% accordingly*), but deeper insight provides some promising information indicating Latvia's "high-tech" potential with a significant share of proposals receiving excellent ratings from international evaluation experts engaged by the European Commission. EC has recommended that such highly rated projects could be supported by EU structural funds accessible to countries like Latvia. This could enable innovation activities to proceed to the benefit of the country without any bureaucratic procedures based only on the evaluation outcomes ensured by independent experts.

In total, at the end of 2018 about 350 1st phase project proposals were submitted by more than 170 Latvian SMEs. From these 13 project proposals were retained for funding, 11 SMEs received scoring above 13 for their proposal and have been awarded with EU "Seal of Excellence" signed by two EU Commissioners. 25 SMEs received more than 12 points for performance of their projects. 121 2nd phase project proposals were submitted by 43 SMEs to the relevant H2020 calls. Only 3 were financed, but 14 SMEs received scoring above 13 and have been awarded with "Seal of Excellence" to support financing prospects from national funds.

Latvia is ranked among the last ones on EU Innovation scoreboard. Results of Latvian innovative companies for H2020 SMEs instrument competition clearly indicate the first strong steps towards solution. Only EUR 30 million financing from EU structural funds would be needed to finance the projects of about 15 highly innovative companies in Latvia to allow them to transform disruptive innovation prototypes into commercial products with global market potential. 12 point or better scoring means, those authors of the projects convincingly demonstrated to the high-level experts the capabilities of the company to scale up market reach and production to ensure annual turnover of EUR 20 million or more in coming 5 years after the project. Given that Latvia choses to fund such excellent projects the volume of "high-tech" exports from Latvia could increase by at least EUR 300 million coupled with associated high quality, knowledge intensive jobs and greater opportunities for researchers.

International Lunar Decade and sustainable development for Earth

Vidvuds Beldavs

National Science Platform FOTONIKA-LV, University of Latvia

E-mail: Vidvuds.Beldavs@lu.lv

The International Lunar Decade (ILD) is a framework for international cooperation in lunar exploration and development from 2021–2030 to establish the technical, economic and political feasibility of industrial development of the Moon as a source of resources for economic expansion of humankind into the Solar System. Resources in outer space are practically boundless compared to present human needs and to the finite resources of the Earth with its delicately balanced biosphere that is now under great stress from industrial civilisation. Sustainable Development Goals (SDG) have been adopted by the UN to address the challenge of population growth coupled with rising needs of people in the finite environment of the Earth [1]. The UN Committee on the Peaceful Uses of Outer Space (COPUOS) is formulating a plan for Space Agenda 2030 to address the contribution of uses of outer space to address the SDG with the theme "Space as the driver of sustainable development". COPOUS will submit its plan for approval by the UN General Assembly at its 2020 session to guide UN space activities in the 2021–2030 period [2].

The ILD Working Group formed in November 2014 has sought to interest COPUOS and other major international organisations to sponsor ILD. COPUOS will listen to ideas from NGOs and scientific organisations but only accepts proposals from member states of COPUOS. This paper is an argument to include ILD within the UN's Space Agenda 2030 based on the logic that lunar development contributes to sustainable development on Earth and that development of the capacity to use the resources of the Moon can unlock the potential to use resources elsewhere in the Solar System to enable sustainable development of civilisation for centuries to come while safeguarding the Earth's biosphere. The capacity to sustainably use the resources of the Solar System enables human settlement beyond the Earth. Rather than a win-lose future with threats of conflict over the limited resources of the Earth, space settlement creates an open future with widening prospects for people from all countries, irrespective of their present economic or scientific development.

The ILD is intended to facilitate international cooperation in lunar exploration, scientific research, technology development, and joint financing to enable rules-based competition among countries and firms to create the foundations for an open future for humankind through lunar development.

Challenges of lunar development

Thus far only the U.S. has had the financial and technical capacity to land astronauts on the Moon and return them to the Earth. The last mission to the Moon was in December 1972. Much has been learned about the Moon in the intervening decades through the Lunar Reconnaissance Orbiter (LRO), probes like Smart One, and rovers by the Soviet Union, Japan, India and China. Many missions are planned in the coming decade including a manned landing by the U.S. in 2024.

The Moon has similar composition to much of the Earth and the finding that the Moon was split off the Earth in a collision with a sister planet called Thea is widely accepted. That the Moon is composed of materials common on Earth raises the question – why go there?

At present no business case exists for the use of lunar resources. Identical materials can be recovered on Earth at much lower cost without going to the Moon. The one known material on the Moon potentially valuable on Earth is helium-3 (3He), an isotope of helium with only one neutron that theoretically may have advantages in fusion energy. 3He is more abundant on the Moon than on Earth as a result of lunar regolith being impacted by cosmic rays and solar wind over billions of years. However, over 150 tonnes of regolith must be processed to obtain one gram of 3He. India, China and Russia have shown interest in lunar 3He, but prospects for use prior to 2040 are slim. New uses for lunar materials need to be demonstrated in outer space, starting with orbits near the Earth. However, even if the use of lunar material is in outer space, value must be created for governments or investors on Earth.

Since the material that makes up the Moon is similar to materials on Earth technical feasibility can be established allowing for differences that include the fractional gravity of the Moon that is 1/6 that of Earth and that the Moon's surface is open to the vacuum of space subject to solar and cosmic radiation without the protection of the Earth's magnetosphere and atmosphere. Economic feasibility presents the additional challenges of demonstrating that markets can be created for lunar resources and the products that can be produced from them will find customers willing to pay for them. At present there is a hope that water can be recovered from polar regions of the Moon to generate returns that can justify the investment. The presence of water has been detected and guesses have been made about the possible size of water deposits, but there is insufficient data about the water deposits to estimate recovery costs with a degree of confidence. Additional uncertainties about launch costs and demand for lunar water indicate that the business case cannot be closed despite an excellent analysis involving a large team of recognised expert [3].

Strategic basket of materials to diversify risk multiply paths to success

To establish economic feasibility of sustainable lunar development the ILD calls for considering a *strategic basket of lunar materials* to diversify risk of failure and create multiple paths for success. This is similar to other investments where a diverse portfolio lowers overall risk and increases prospects for success. Candidates for the *strategic basket of lunar materials* would have uses that demonstrate high confidence of long-term economic returns. The strategic basket will be resources that are abundant on the Moon and recoverable with well-understood processes for which plausible markets can be identified. Working groups of experts can identify the materials in the *strategic basket* setting forth proposed recovery processes, identified uses, and estimates of requirements to develop the processes and markets and value chains that need to be created.

The recent discovery of a large mass anomaly at the South Pole Aitken Basin [4] suggests that a large metallic asteroid comparable in size to the asteroid Psyche 16 may exist below the surface of the Moon. Psyche 16 may have a value exceeding the size of the Earth's economy [5]. Psyche 16 lies between the orbit of Mars and Jupiter and effectively inaccessible for decades. If such mineral wealth is present on the Moon it could provide resources for sustainable development on the Earth as well as in outer space. There may be other such opportunities on the Moon that intensive exploration and research over a decade involving resources from all countries may develop opening an open future for sustainable development for centuries to come.

Recovery of lunar resources has to be potentially profitable at levels of risk that satisfy investor requirements within a defined time horizon. No lunar operation is expected to generate profits by 2030. However, the investments required will be very large and public support for lunar development will have to be weighed against other priorities facing the U.S. and other spacefaring countries. We assume that profitable recovery of a *strategic basket of lunar resources* needs to be demonstrable before 2040 to assure that public subsidies for lunar development will not be needed indefinitely. The earlier that profitability for some operations on the Moon can be demonstrated the stronger will be the case for continued government support of the investments required.

The ILD framework is being designed to demonstrated technical and economic feasibility of indefinitely sustainable industrial activities on the Moon by the end of ILD decade in 2030. Working groups of experts need to be established to define the key elements of the ILD process and the framework for international cooperation within which this process will be conducted as well as the public outreach at national levels and globally to maintain necessary public support over the decade of the ILD.

To achieve this result commitment to ILD by the major spacefaring countries as well as international cooperation called for by ILD. Given that feasibility of has been demonstrated, then a sound business case can be made for long term investments in lunar and cislunar commercial activity including mining and manufacturing, assembly operations in LEO for satellites and spacecraft, tourism, logistics, space-based solar power, and more.

The ILD framework is intended to enable leading countries in space to advance more rapidly while creating opportunities for smaller and less developed countries to participate and to develop capabilities to derive benefits from the Earth-Moon economy that will emerge as use is made of lunar resources to enable sustainable presence on the Moon.

Lunar development is will require large investment for decades to come. That is why it is imperative to develop ways to reduce costs and risks through international cooperation in shared infrastructure, programmes operation, and strategic coordination. Concurrently, the ILD framework needs to allow and even encourage productive competition between teams, companies and states to drive innovation, reduce costs, and speed up development.

ILD is inspired by the International Geophysical Year (IGY – 1957-8)

IGY [6] engaged tens of thousands of scientists from 67 countries to study the Earth as a total physical system. The first satellites were launched by the USSR and the U.S. as party of IGY marking the dawn of the space age. ILD can mark not only the dawn of the Solar System Age it can also enable sustainable development on Earth by lessening use of Earth's resources and opening the opportunity for human settlements beyond the Earth.

The U.S. is planning a manned landing at the South Pole by 2024. China has also made a strategic commitment to sustainable operations on the Moon. India, the EU, Japan, Brazil, Korea and even small states like Israel and the Arab Emirates are targeting the Moon. The cost to reach Earth orbit and the Moon is on a downward trend that would be accelerated by a decade long global programmes for lunar exploration and development. As costs decline, the range of opportunities for both research and private investment will expand. However, barriers to sustained operations on the Moon remain that cooperation through the ILD framework could overcome:

- There is no international agreement on exploitation of lunar resources and of governance of operations on the Moon. The Hague Space Resources Governance Working Group work may help to form necessary international agreements, but negotiations need to take place between states within internationally recognised forums like UN COPUOS.

- There is no agreed to vision for long-term industrial development of the Moon and the emergence of an Earth – Moon economy does not exist. This constrains long term investments. Such a vision can be developed through a series of international conferences.
- Low frequency of launch and use is the largest factor in high costs. Frequency of launch must be increased to drive down costs.
- Costs to reach and operate on the Moon remain very large discouraging planning of projects that could rapidly become feasible given greater use.
- Infrastructure does not exist that could reduce costs and risks for all participants and drive up rates of use.

The ILD Working Group has proposed ILD to COSPAR and other international organisations. Key is sponsorship by the UN and acceptance by UN COPUOS and inclusion in the Space Agenda 2030 that will be approved by the General Assembly in 2020. The next step is to convince at least one member state of UN COPUOS to propose inclusion of ILD as part of Space Agenda 2030.

A more complete version of this article is available at https://www.researchgate.net/publication/334285391_International_Lunar_Decade_and_sustainable_development_for_Earth.

References

[1] https://www.un.org/sustainabledevelopment/sustainable-development-goals/
[2] http://www.unoosa.org/oosa/en/outreach/events/2018/spacetrust.html
[3] "Commercial Lunar Propellant Architecture", https://www.philipmetzger.com/wp-content/uploads/2018/11/Commercial-Lunar-Propellant-Architecture.pdf
[4] https://www.baylor.edu/mediacommunications/news.php?action=story&story=210457
[5] https://www.forbes.com/sites/bridaineparnell/2017/05/26/nasa-psyche-mission-fast-tracked
[6] Fae L. Korsmo "The Genesis of the International Geophysical Year", https://physicstoday.scitation.org/doi/full/10.1063/1.2761801.

Towards Cost-Efficient Photovoltaic Solar Cell Technology on the Base of Self-Organised Organic-on-Silicon Hybrid Nanostructures

Petro Smertenko[1, 2], Vadym Naumov[1, 2], Nina Roshchina[1], Arnolds Ūbelis[3], Grzegorz Wisz[4]

[1] *Institute of Semiconductor Physics, National Academy of Sciences of Ukraine, Kyiv, Ukraine*
[2] *Institute of Fundamental Problems for High Technology, Kyiv, Ukraine*
[3] *National Science Platform FOTONIKA-LV, University of Latvia*
[4] *University of Rzeszow, Rzeszow, Poland*
E-mail: petrosmertenko@gmail.com

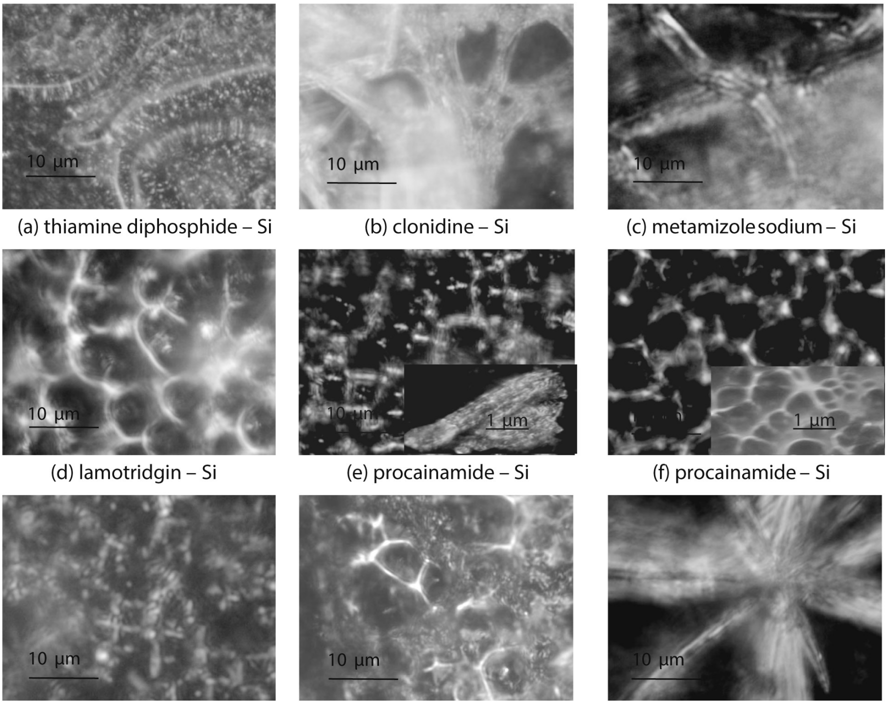
Photovoltaic (PV) solar cells have become a mainstream technology in creating renewable energy sources for sustainable development and progress on the Earth and in space for the future. At that, the development of today's PV technologies is grounded mainly on silicon-based PV materials and structures [1]. However, despite all the advances in silicon PV technologies, overall progress in PV applications is still limited due to the problem of high cost and complexity of fabrication of silicon PV cells. Therefore, hybrid silicon-organic PV materials and hetero-structures using carbon-containing organic compounds are considered to be a good alternative for creating new, cost-efficient PV cells of the next generation [2].

PV silicon-organic hybrids (SiOH) are very promising since they combine the best of both worlds: high-level processing of integrated silicon nanoelectronics and ultra-thin lightweight, and flexible characteristics of organic optoelectronics. Such an approach can merge many essential features for optimal solution to complex issues in PV development. Our innovative approach is based on: (1) use of inexpensive and nontoxic bio- or synthetic organics for creating hybrids suitable for broad-band sunlight harvesting and PV energy conversion; (2) use of natural processes of molecular self-organisation and self-assembly for hybrids growing on patterned Si substrates; (3) use of simple technology of thin-film deposition from a colloidal solution at room temperature conditions; and (4) use of smart technique of differential analysis of functional characteristics for optimisation of hybrid PV cell performance [3].

The current challenges for novel PV technology are: (i) designing an optimal architecture of low-cost, thin-film SiOH PV structures, and (ii) developing a cheap and reliable process of fabrication of SiOH PV cells applicable for mass production. The proposed organic PV materials do not need additional doping, and their manufacture can be carried out by a simple room temperature deposition process. Knowledge about the mechanisms of self-organisation of organic layers on patterned silicon substrates, control of surface/interface morphology, regimes for injection and transfer of charge carriers, acceleration of carrier mobility due to synergistic effects like a soliton conductivity, and other know-how provides a solid base for creating SiOH PV cells with improved functionality due to optimal architecture enabling, enhanced efficiency with low power consumption during operation, and low cost of manufacture with a small amount of materials.

For the study, we have chosen low-molecular-weight organic compounds belonging to the family of heterocyclic amines (HCA). They include both the simplest aromatic ring of benzene consisting of six carbon atoms, and five- and six-membered rings containing heteroatoms, such as pyrrole, thiazole, pyridine, etc. Among them are well-known aromatic drugs and vitamins, such as thiamine diphosphate hydrochloride (vitamin B1), cyanocobalamin (vitamin B12), clonidine hydrochloride, procainamide hydrochloride, and others used to form organic-inorganic hybrids on patterned silicon substrates [4, 5]. These HCA compounds contain in the aromatic rings not only carbon, hydrogen, oxygen, and nitrogen but also phosphorus, sulphur, chlorine, and iodine atoms as well as functional groups containing amines NHx (x = 0,1,2), carboxamides CON, hydrocarbons CHx (x = 1,2,3), hydroxyl OH, carbonyl CO, etc.

As a result of our study, the possibility of the interface engineering and modification, sensitisation and functionalisation of the surface of crystalline silicon cells by HCA organics using room-temperature chemical bath precipitation has been successfully demonstrated. The typical morphology of various HCA films (thickness 10–100 nm) formed on patterned n-Si substrates is shown in Fig. 1. It varies between self-organised pyramid-like, net-like and bunch-like forms depending on the parameters and regimes of technological processing.



(a) thiamine diphosphide – Si (b) clonidine – Si (c) metamizole sodium – Si

(d) lamotridgin – Si (e) procainamide – Si (f) procainamide – Si

(g) pentacene – Si (h) clonidine – Si (i) sulfacil sodium – Si

***Figure 1**. Optical microscopy images of surface morphology of self-organised organic-on-silicon hybrids: (a) thiamine diphosphide; (b), (h) clonidine; (c) metamizole sodium; (d) lamotridgin; (e), (f) procainamide; (g) pentacene; (i) sulfacil sodium. Insets in (e) and (f) shows fragments of filament and fractal nanostructure*

Thus, the fabrication of PV solar cells on the base of organic-on-silicon hybrids using self-organised 2D-layered heterocyclic amines deposited on patterned silicon substrates in a bath with a water solution at room temperature has to be a relatively simple and controlled process. In the short- and medium-term perspective, this is expected to become the base for creating an innovative low-cost 2D-printing PV cell technology for photovoltaics of the next generation. Research continues progress.

References

[1] Polman, A., *et al*. (2016). Photovoltaic materials: Present efficiencies and future challenges, *Science*, **352**(6283): 307.

[2] Da, Y., *et al*. (2018). Photon management effects of hybrid nanostructures / microstructures for organic-silicon heterojunction solar cells, *Int. J. Energy Res.*, **42**(15): 4875.

[3] Smertenko, P., *et al.* (2017). Prospect of photovoltaic organic-inorganic hybrid solar cells, The 2nd FOTONIKA-LV Conference "Achievements and Future Prospects", 23-25 April 2017, Riga, Latvia, Book of Abstracts, Ed. D. Berzina, Univ. Latvia, 88.

[4] Gorbach, T. Ya., Smertenko, P. S., Venger, E. F. (2014). Investigation of photovoltaic and optical properties of self-organized organic-inorganic hybrids using aromatic drugs and patterned silicon. *Ukr. J. Phys.,* **59**(6): 601.

[5] Smertenko, P. S., *et al.* (2018). Vitamin B12-functionalized patterned Si surface for solar energy conversion. *Semiconductor Physics, Quantum Electronics and Optoelectronics*, **21**(2): 206.

Selected Abstracts from Poster Sessions and Other Contributions

ERA Chair in Quantum Optics and Photonics.

Project proposal to H2020-WIDESPREAD-2019-4 call

Aigars Atvars

National Science Platform FOTONIKA-LV, University of Latvia

E-mail: Aigars.Atvars@lu.lv

Horizon 2020 has a dedicated work programme “Spreading Excellence and Widening participation” [1] to support low-performing Member States and Associated Countries of European Union to increase their excellence in research and innovation by networking with high-performing research institutions and SMEs, recruitment of high-quality human capital and an update of a research infrastructure. This support is expected to complement initiatives funded with European Structural and Investment Funds (ESIF), and the implementation of Smart Specialisation Strategy of the region (Latvia is one region).

Horizon 2020 call “ERA Chairs” (WIDESPREAD-04-2019) aims to attract high-quality human capital – the ERA Chair holder and his/her team – to the applicant institution and perform structural changes of the Institution to achieve its excellence on a sustainable basis. Expected impact of the call:

- institutional changes within the ERA Chair host institution allowing for its full participation in the European Research Area (ERA);
- increased attractiveness of the institution for internationally excellent and mobile researchers;
- increased research excellence of the institution in the specific fields pursued by the ERA Chair holder with results demonstrated quantitatively and qualitatively through indicators such as expected future publications in peer reviewed journals, collaboration agreements with businesses, intellectual property (patents), new innovative products or services;
- improved capability to compete successfully for internationally competitive research funding.

University of Latvia (LU) prepared the proposal for the “ERA Chair” call – titled “ERA Chair in Quantum Optics and Photonics”, No. 857624, acronym Quantum-LV with the aim to boost the performance of LU in the field of quantum optics, photonics, atomic and molecular physics. Currently LU has 13 labs and more than 50 active researchers in this field whose contribution to ERA has not been fully realised. The project anticipates recruiting an excellent researcher / manager – the ERA Chair holder – and his/her team, who will produce high quality research papers, proposals and patents, and who will inspire and empower the community of LU researchers in quantum optics field to highest performance.

Quantum-LV project’s proposal was evaluated above the threshold (11.5) yet failed to be funded by Horizon 2020. In 2017 the Cabinet of Ministers of Latvia determined that such highly ranked ERA Chair project could be funded through European Regional Development Funds (ERDF) in Latvia that created the opportunity to finance the Quantum-LV project under the activity 1.1.1.5 [2]. Therefore, a proposal No. 1.1.1.5/19/A/003 “The Development of Quantum Optics and Photonics in University of Latvia” was submitted. The realisation period for the project is 01.05.2019–30.11.2023 and it will include all activities of the Quantum-LV proposal and reach impacts anticipated by the Horizon 2020 ERA Chair’s call.

In July/August/September 2019 an open competition for the ERA Chair holder’s position in LU will be announced on EURAXESS portal for EU and non-EU candidates to apply in a global search. ERA Chair candidates should be "Established Researchers (R3)" or "Leading Researchers (R4)" with significant research and managerial experience. Candidates will be evaluated by the Selection Committee consisting of project's leaders, representatives of LU and international Advisory Board. The leader of the Advisory Board is Prof. Sune Svanberg, Doctor Honoris causa at the Lund University, at the University of Latvia, at the Université de Liège, at the Universidad Nacional de Engineria, Lima.

Specific outcomes of the Quantum-LV project are: 24 scientific publications; 2 patent applications; 6 project proposals (Horizon 2020 / Horizon Europe, ERDF and Latvian Council of Science projects); organisation of 2 international conferences; development of a course in quantum optics; development of a "Strategy for the Development of Quantum Optics and Photonics at the University of Latvia" including a "Strategy for human resources".

The ERA Chair holder will relocate to Latvia and will start to work in LU not later than in January 2020. An early task will be to define qualifications for 4 to 6 members of the ERA Chair team and candidate positions announced in the EURAXESS portal. The team will support the ERA Chair to achieve the expected results of the project including preparation of project proposals and research papers. It is expected that the excellence and reputation of the ERA Chair will attract top quality candidates with high potential for research performance.

The project supports visits to conferences, exhibitions and meetings as well as visits to external partners and incoming visits of external experts. Two international conferences in quantum optics related fields will be organised thus raising visibility of LU in the field and furthering participation in related research networks. Conferences will be combined with meetings of the Advisory Board where Quantum-LV project leaders will report on the progress of the project and will listen to the feedback.

The Quantum-LV project will be implemented within the framework of the Department of Science of LU by the National Science Platform (NSP) FOTONIKA-LV, which includes two field related labs from the Institute of Atomic Physics and Spectroscopy (LU ASI). The project aims to foster collaboration with industry in Latvia as well as in other countries as well as with other research institutions that work in the field of quantum optics. Close cooperation is anticipated with the Riga Photonics Centre, an NGO formed to advance photonics related research as well as manufacturing and other commercial activity involving photonics in Latvia.

(a) (b)

***Figure 1**. (a) "Science Building" of University of Latvia (Jelgavas 3), (b) Building of the National Science Platform FOTONIKA-LV of University of Latvia (Šķūņu 4)*

The ERA Chair holder will have to decide on the workplace address for him/her and his/her team. Two possibilities are available – "Science building" in the new campus of LU, Jelgavas 3 (Fig. 1a), and the former building of LU ASI, Šķūņu 4 (Fig. 1b), which is the central building hosting NSP FOTONIKA-LV as well as the Riga Photonics Centre. The combination of them offers both a location at Riga's centre and superb space for development.

Quantum-LV project was developed to further advanced photonics in Latvia beyond what was realised through the implementation of FP7-REGPOT-CT-2011-1 project No. 285912 (2012–2015), coordinator – A. Ūbelis by the FOTONIKA-LV association consisting of LU ASI and Institute of Astronomy (IA). Recently NSP FOTONIKA-LV was founded as an open research platform of the University of Latvia to advance transdisciplinary research in photonics as a successor of the Association FOTONIKA-LV. At present the platform's research focus is quantum optics and no longer includes parts of the former association's institute members not oriented towards the research focus of the platform. NSP FOTONIKA-LV initiated Quantum-LV project development and will be responsible for implementation within the framework of the Research Department.

References

[1] Horizon 2020 Work Programme 2018–2020. 15. Spreading Excellence and Widening Participation.

[2] "Regulations Regarding the Implementation of the First, Second, and Third Project Application Selection Round for the Activity 1.1.1.5 "Support for International Cooperation Projects in Research and Innovation" of the Specific Objective 1.1.1 "To Increase the Research and Innovative Capacity of Scientific Institutions of Latvia and the Ability to Attract External Financing, Investing in Human Resources and Infrastructure" of the Operational Programme "Growth and Employment"", Cabinet Regulation No. 315, Adopted 6 June 2017, Latvia.

CHALLENGE of IONS – Research and Theoretical Modelling of Exotic Atoms, Ions and Clusters to Contribute to the Knowledge Base in Atomic and Molecular Physics and Astro-biology.

Project proposal to H2020-MSCA-RISE-call

Arnolds Ūbelis[1], Jānis Blahins[1], Aigars Apsītis[1], Uldis Bērziņš[2], Ulises Miranda Ordóñez[2]

[1] *National Science Platform FOTONIKA-LV, University of Latvia*
[2] *Institute of Atomic Physics and Spectroscopy, University of Latvia*
E-mail: arnolds@latnet.lv

The *CHALLENGE of IONS* consortium has been formed to conduct research with negative ion beams to address timely problems in atomic ionic physics, materials science, and astrobiology. The consortium includes partners with complementary experience in Sweden *(Department of Physics, University of Gothenburg),* Latvia *(Laboratory of Atomic Physics, Atmosphere Physics and Photochemistry of the Institute of Atomic Physics and Spectroscopy participating in NSP FOTONIKA-LV at the University of Latvia),* and Ukraine *(Institute for Scintillation Materials, National Academy of Sciences of Ukraine).* Additionally, there are two partners outside the EU – Belarus *(A. V. Luikov Heat and Mass Transfer Institute, National Academy of Science of Belarus)* and Russia *(Optics Department, Faculty of Physics, Saint Petersburg State University)*. Collaboration between the University of Latvia and the University of Gothenburg was established about 25 years ago and between the University of Latvia and Saint Petersburg State University more than 50 years ago.

The conceptually new mobile ion beam apparatus *GRIBA* that is complementary with the stationary laboratory instrument *GUNILLA* built and upgraded jointly by research teams in Gothenburg and Riga enables new research topics to be addressed. Interest in **negative molecular ions** was recently boosted in **astrophysics** in the symposium held Gothenburg [1]. Unexpectedly, a branched carbon chain alkyl molecule, iso-propyl cyanide (i-C_3-H_7-CN) has been detected in interstellar space with relative abundance of 40% [2] and, seems participate in forming branched structures similar to amino-acids. Reaction rates and electron affinity measurements in ion beam experiments may contribute data to enable modelling of formation of complex organic molecules in interstellar space.

The joint research and exchange programme involving research centres and industry with complementary skills will ensure the creation of a "critical mass" of human potential to perform leading edge research with top level research interest as well as contributing to the development of industrial technologies with commercial potential while fostering diversity of career development options of the researchers and technicians involved. Industry partner, Baltic Scientific Instruments, Ltd (BSI), is one of three worldwide producers of short-wave radiation detection equipment for the nuclear energy industry as well as for applications in space, medicine, mining and security. BSI's stature in its field is demonstrated by recent orders from the International Atomic Energy Agency and from Japanese institutions at the Fukushima accident site in Japan.

Negative ion beam technologies are also a topic of interest in **materials research** with the potential for ion implantation to produce unique sensor materials for commercial applications [3, 4]. The team in Riga is already involved in pilot applied research activities to develop a small sized device for boron implantation in germanium [5].

References

[1] Negative Ions and Molecules in Astrophysics. Symposium 22-24 August 2011, Gothenburg, Sweden. *www.gu.se/digitalAssets/1331/1331762_astrophysics-symposium-2.pdf*

[2] Belloche, R.T., *et al*. (2014). Detection of a branched alkyl molecule in the interstellar medium: Iso-propyl cyanide. Science, 345, p. 1584.

[3] Junzo Ishikawa. (1994). Applications of negative-ion beams. Surface and Coatings Technology. 65(1–3), p. 64.

[4] Junzo Ishikawa, Hiroshi Tsuji Yasuhito Gotoh, (2009). Surface modification by negative-ion implantation. Surface and Coatings Technology. 203(17–18**),** p. 235.

[5] The table-size ion-implanting device prototype (TLR 6) design for boron dopants. Pilot-scale cooperation project between BSI Ltd and NSP FOTONIKA-LV at the University of Latvia.

Towards Future THz Technologies based on Wide Bandgap Quantum Heterostructures for Integrated Nanoelectronics and Optoelectronics.

Project proposal to H2020 FET-OPEN-01-2018-2020 call "Challenging Current Thinking"

Vyacheslav Kochelap[1, 2], Vyacheslav Korotyeyev[1, 2], Vadym Naumov[1, 2], Petro Smertenko[1, 2], Jānis Alnis[3], Arnolds Ūbelis[4]

[1] *Institute of Semiconductor Physics, National Academy of Sciences of Ukraine, Kyiv, Ukraine*
[2] *Institute of Fundamental Problems for High Technology, Kyiv, Ukraine*
[3] *Quantum Optics laboratory, Institute of Atomic Physics and Spectroscopy, University of Latvia*
[4] *National Science Platform FOTONIKA-LV, University of Latvia*
E-mail: kochelap @gmail.com

Low-energy terahertz (THz) electromagnetic radiation (sub-millimetre band 30 µm < λ < 1 mm) is non-ionising like microwaves and penetrates through many dielectric materials such as plastics, ceramics, wood, paper, and leather but is absorbed by metals, chemicals and water molecules. Therefore, non-destructive THz remote sensing and monitoring are of great scientific and public interest both for fundamentals: astronomy, biochemistry, nanophysics, materials spectroscopy and for applications in: wireless telecommunications, biomedical diagnostics, environmental control, security inspection and other. Currently existing THz generators (synchrotrons, gyrations, back-ward-wave oscillators, free-electron lasers, optically pumped frequency mixing lasers, etc.), and THz detectors (micro-bolometers, pyroelectric radiometers, optoacoustic cells, etc.) do not meet real needs in terms of compactness, efficiency, selectivity, frequency tuning, trouble-free operation, and require substantial improvements. Today's challenge is to accelerate the development of a scientific and technological basis for radically new, compact and cost-efficient electronic devices capable of generating THz rays and detecting THz waves, which will be used as the core elements in future integrated THz nanoelectronics and optoelectronics [1].

The authors of this report are considering the development of a collaborative project proposal to the H2020 FET-OPEN-01-2018-2019-2020 call "Challenging Current Thinking". The eventual consortium formed jointly with partners from Fraunhofer Institute for Laser Technology/ RWTH Aachen University, *Forschungszentrum Jülich GmBH*, *CNRS Institut d'Electronique et des Systèmes in Montpellier*, FORTH Institute of Electronic Structure and Laser in Heraklion and Center for Physical Sciences and Technology in Vilnius, will be led by Prof. V.A. Kochelap, a well-known physicist with an internationally recognised reputation *(Google Scholar Citations* 1829*, H-index* 20*)*. His recent book on the topic was published in April 2019 [2].

The project aim is to develop innovative all-solid-state electrically-driven THz devices based on wide bandgap quantum heterostructures, including group III-nitrides, which have high electronic mobility that leads to their widespread use in light-emitting diodes and provides an excellent alternative for their use in resonant-tunnelling diodes and field-effect transistors. Given the fact that today's microelectronics based on traditional silicon have already exhausted their potential, gallium-nitride 1D/2D quantum well heterostructures seem to be very perspective for a new generation of high-frequency electronic devices (oscillators, modulators, detectors) for microwave nanoelectronics and optoelectronics covering sub-THz and far-IR spectral ranges.

The project work-plan foresees step-by-step theoretical and experimental proof-of-principle studies beyond "state-of-the-art" technology: (1) high-field and high-frequency fluctuation phenomena related to fast inter-valley transitions of hot electrons in wide-bandgap quantum heterostructures; (2) dynamic mobility and negative differential conductivity effects under quick transient processes at short-pulse electric loads; (3) fast transit-time electron resonance effects in short-base nanostructures of planar and vertical configuration; (4) tuneable THz oscillations under the quasi-ballistic streaming transport of electrons in quantum wells; (5) resonance amplification of synchronised THz oscillations using available diagnostics and simulation of low-dimensional diode/transistor structures in different high-field and high-frequency conditions. The first results are very promising. Research is in progress.

References

[1] Shur, M. (2019). Wide band gap semiconductor technology: State-of-the-art. Solid State Electron. 155, 65-75. DOI:10.1016/j.sse.2019.03.020.

[2] Mitin, V.A., *et al.* (2019). Introduction to Optical and Optoelectronic Properties of Nanostructures, Cambridge University Press, 424 pages. ISBN 9781108428149.

Development of a microfluidic prototype with an optical microresonator in liquid sample for biosensing applications.

Project funded by the European Regional Development Fund call 2017

Inga Brice, Roman Viter, Kārlis Grundšteins, Jānis Alnis

Quantum Optics laboratory, Institute of Atomic Physics and Spectroscopy, University of Latvia

E-mail: Janis.Alnis@lu.lv

So called optical whispering gallery mode (WGM) microresonators do not need mirror coating as they confine light inside due to the effect of total internal reflection. However, a small fraction of light around 5% travels outside of the resonator in an evanescent wave at distances about 1/10 λ from the surface. This evanescent part of the light can be used for sensing of refractive index changes of the surrounding media. Increase of the refractive index of the surrounding media elongates the effective optical path length of a roundtrip and shifts resonances to longer optical wavelengths.

We made a system for glucose refractive index sensing in water. Glucose monitoring is important for diabetic diagnostics. We dip coat 0.5 mm diameter SiO_2 microsphere melted from a telecom fibre with glucose oxydase enzyme to increase the sensitivity to glucose.

A microfluidic system was constructed using three syringe pumps controlled by stepper motors. Two pumps allowed mixing a defined concentration of glucose in water. The third pump was used to drain the sample. A tuneable ECDL laser at 780 nm was continuously scanned around the 2 GHz spectral region. The resonances in water are typically 1 GHz wide and the optical Q factor is limited to 106 range due to water absorption. Shifts in MHz range were observed.

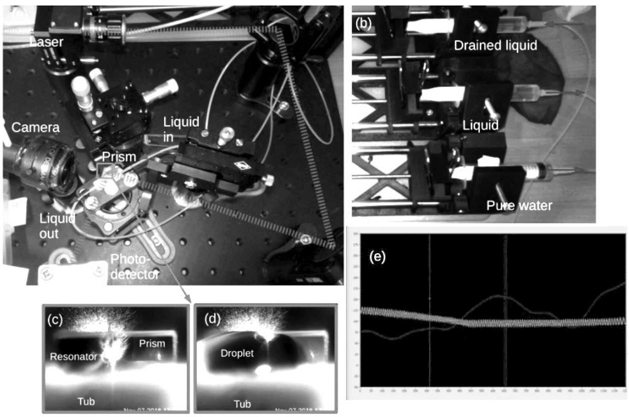


***Figure 1**. a) setup, b) syringe pumps, c) SiO_2 microresonator outside the liquid, d) resonator inside a liquid drop, e) resonances from a microresonator inside a liquid (blue) with 50 MHz calibration fringes (yellow)*

This research was financed by ERDF project Nr.1.1.1.1/16/A/259: "Development of novel WGM microresonators for optical frequency standards and biosensors, and their characterisation with a femtosecond optical frequency comb".

Development of optical frequency comb generator based on a whispering gallery mode microresonator and its applications in telecommunications.

Project funded by the European Regional Development Fund call 2018

Dina Bērziņa, Jānis Alnis

Quantum Optics laboratory, Institute of Atomic Physics and Spectroscopy, University of Latvia

E-mail: Janis.Alnis@lu.lv

The project proposal (1.1.1.1/18/A/155) has been developed in response to the European Regional Development Fund's (ERDF) measure in Latvia 1.1.1.1 "Support for applied research" specific objective 1.1.1 "Improve research and innovation capacity and the ability of Latvian research institutions to attract external funding, by investing in human capital and infrastructure". The project was ranked second and is being implemented since May 2019 [1].

The objective of the project is to obtain new knowledge on whispering gallery mode resonator-based optical frequency combs (WCOMBs) and to develop, construct and test a comb generator prototype for telecommunication applications. The project duration is 36 months: 16.05.2019–15.05.2022. The project's total costs are EUR 648,000, from which the ERDF share is 57.8% of the total budget, state budget contribution is 34.7%.

Main activities (work packages) of the project are:

A1. Development, modelling, testing and optimisation of WCOMB;

A2. The development, construction and testing of portable WCOMB for application in fibre optical communication systems;

A3. The adjustment and validation of the portable WCOMB prototype in commercial fibre optical communication system;

A4. Dissemination of project results.

All activities are implemented in collaboration among all 3 partners of the project: University of Latvia (lead partner, project coordinator – Jānis Alnis), Riga Technical University and AFFOC Solutions, Ltd. The budget is distributed among the partners: University of Latvia (40%), Riga Technical University (20%), AFFOC Solutions, Ltd. (40%).

Main results planned in the project:

- 5 scientific publications cited in SCOPUS: 2 of them will be in journals with citation rate above 50% of the average;
- 3 technology rights – know-how;
- 1 technology right – patent application;
- 1 license agreement on one or more technology rights;
- 3 prototypes.

References

[1] https://www.lu.lv/zinatne/programmas-un-projekti/es-strukturfondi/eraf-sam-1111-praktiskas-ievirzes-petijumi-2karta/uz-cukstosas-galerijas-modas-mikrorezonatora-bazes-veidota-optisko-frekvencu-kemmes-generatora-izstrade-un-ta-pielietojumi-telekomunikacijas/

Pilot project development and testing a new type of small 100 keV Boron ion implantation device.

Project proposal to the European Regional Development Fund call 2018

Jānis Blahins[1], Aigars Apsītis[1], Uldis Bērziņš[2], Ulises Miranda Ordóñez[2], Jānis Kļaviņš[1]

[1] *National Science Platform FOTONIKA-LV, University of Latvia*
[2] *Institute of Atomic Physics and Spectroscopy, University of Latvia*
E-mail: janis_59@inbox.lv

The project proposal (1.1.1.1/18/A/163) has been developed in response to the European Regional Development Fund's (ERDF) measure in Latvia 1.1.1.1 "Support for applied research" specific objective 1.1.1 "Improve research and innovation capacity and the ability of Latvian research institutions to attract external funding, by investing in human capital and infrastructure". The project proposal with scoring 16.5 was ranked 60 among 133 project proposals which were above quality threshold and could be financed in case of availability of funding. Less than 30 from this list were financed. Total number of submitted proposals was 186.

Ion implantation is a well-known (*see http://www.casetechnology.com/links.html*) fundamental material engineering process, in which ion beams of selected elements are accelerated by a very strong electric field and driven into a specific location and depth in the crystalline target thereby changing its basic physical, chemical and electrical properties.

In order to achieve the project objective (*develop a next generation laboratory prototype ion implantation device*) based on the novel ideas and "know-how" of the project team, the proposal anticipated research and elaboration on the following procedures and technologies:

1) boron ion production in a hollow cathode from solid state and guiding the ion beam;
2) linear accelerator;
3) use of the altered transparency QMS filter to clean the ion beam;
4) ion beam focusing & defocusing, and guidance systems;
5) implantation systems mechanical development.

Total costs EUR 646,614. Planned duration – 30 months.

The justification of the project aim is the need to solve the following acute problem linked to research driven "high-tech" SMEs active in the domain both in Latvia and EU: the production of sensors and other electronics components requires semiconductors with precisely doped areas. These n or p type dopants ions can be implanted with precise depth and location using particle beam cannon. SMEs producing semiconductor devices cannot afford financially to use on the worldwide market available ion implantation equipment, which up to now is very expensive and large by size. SMEs generally outsource ion implantation processing. Shipping components to European suppliers under vacuum often results in loss of vacuum and unacceptably high scrap rates. A better solution would be for the SME to implant ions to avoid shipping. The project intends to make this possible by developing small-sized, relatively inexpensive ion implant devices suitable for SMEs – the size of a table as opposed to large equipment that occupies a manufacturing hall.

Several Latvian globally competitive and science oriented, small and medium-sized enterprises would benefit from presently unavailable, cost effective, ion implantation equipment in manufacturing new products.

The project team utilises accumulated experience and results from the implementation of the EU Seventh's Framework programme project FP7-REGPOT, FOTONIKA-LV 2011-1, No 285912 (2012–2015) "Unlocking and Boosting Research Potential for Photonics in Latvia – Towards an Integration in the European Research Area" with ion beam technologies, including, collaboration with colleagues at the Gothenburg University in the creation of the world's first portable ion beam equipment GRIBA which has now been transferred to Riga.

The project team will use opportunity to resubmit the project to the next ERDF call in Latvia and besides that will make persistent efforts to ensure step by step progress using available minor financing from various sources case by case.

Development of innovative technology to ensure highest purity in crystal growth using MHD levitation.

Project proposal to the European Regional Development Fund call 2018

Viesturs Silamiķelis, Āris Veispāls, Aigars Apsītis

National Science Platform FOTONIKA-LV, University of Latvia
E-mail: Silamikelis@gmail.com

The project proposal (1.1.1.1/18/A/186) has been developed in response to the European Regional Development Fund's (ERDF) measure in Latvia 1.1.1.1 "Support for applied research" specific objective 1.1.1 "Improve research and innovation capacity and the ability of Latvian research institutions to attract external funding, by investing in human capital and infrastructure". The project proposal with scoring 16.85 was ranked 43 among 133 project proposals which were above quality threshold and could be financed in case of funding availability. Less than 30 from this list were financed. Total number of submitted proposals was 186.

The project of fundamentally industrial research complex *(FOS 1.3; 2.5*) is set to solve a trans-disciplinary problem. The studies are aimed at design and construction of unique more efficient equipment for growing crystals (*germanium in particular*) of high purity. The papers on unique computer-modelling and experimental results on aluminium MHD levitation co-authored by Latvian and German scientists and published in 2015 unlock potentials for technological innovation and progress in growing crystals [1]. The project is a timely proposal for application of the innovative opportunities in growing crystals by a multi-disciplinary team of physicists, electronic engineers, chemists and material scientists of the University of Latvia.

The unique laboratory device, custom made prototype, designed and constructed in the course of project implementation, will combine multiple zonal purification, Chokhralski and melted zone (pedestal) techniques to grow high-purity crystals avoiding contacts with parts of the construction in the zone of crystal growth from a large melted zone by application of magneto-hydrodynamic levitation. Compared with the equipment used in general practice advantages of the novel device consists of three interrelated substantial improvements providing raw material of the highest purity (zonal purification in the equipment used to grow the crystal), absence of contacts between the melted zone and casing, computer control of the process ensuring reproduction and precision of the management.

The project proposal was a three-year single partner non-commercial project of EUR 642,036 total costs with support of EUR 545,730.59 from ERDF with scheduled start in March 2019.

The project team will use opportunity to resubmit the project to the next ERDF call in Latvia and besides that will make persistent efforts in step-by-step incremental progress using available minor financing from various sources as such become available.

References

[1] Spitans, S., Baake, E., Jakovics, A. (2015), New technology for electromagnetic levitation melting of metals. Applied mechanics and materials. V698, p. 237.

Optical whispering gallery mode microresonator sensors.
Project funded by Latvian Council of Science call 2018

Aigars Atvars, Inga Brice, Kārlis Grundšteins, Roberts Berķis, Kristiāns Draguns, Jānis Alnis

Quantum Optics laboratory, Institute of Atomic Physics and Spectroscopy, University of Latvia
E-mail: Aigars.Atvars@lu.lv

Whispering gallery mode resonators (WGMR) are optically transparent curved structures, e.g., silica balls that confine light due to total internal reflection. When integer number of wavelengths is equal to the perimeter of light path in the structure, a resonance condition is formed. The simplest model describing the resonance condition in spherical or ring resonators is:

$$2\pi rn = \lambda N,$$

where r – radius of the resonator, n – refraction index of resonator, N – number, λ – resonance wavelength. This model can be improved by assuming that r is the radius of light path in the resonator which is smaller than radius of the resonator for about the fraction of the wavelength.

For obtaining the resonance condition experimentally, light has to be introduced in the resonator. This is done using prism or tapered fibre. This allows the evanescent wave to travel outside the prism or tapered fibre and then to enter the resonator. Incident laser light is scanned, transmitted light is registered on the photodiode. Several resonance peaks are seen during one laser scan [1].

Resonance peaks can change their wavelengths if radius or refraction index of the resonator changes. This appears when temperature changes as radius changes due to thermal expansion and refraction index is changed due to thermo-optical effect:

$$r = r_0\,(1 + \alpha(T - T_0))$$
$$n = n_0\,(1 + \beta(T - T_0)),$$

where T – temperature of the resonator, T_0 – temperature of the resonator at normal conditions, when refraction index n_0 in tables are set, typically, $T_0 = 20^oC$, α – thermal expansion coefficient, β – thermo-optical coefficient. For fused silica $\alpha = 0.55*10^{-6}$ 1/K and $\beta = 12.8*10^{-6}$ 1/K, thus showing that for resonance frequency shifts thermo-optical effect gives the major contribution.

Experiments were performed using ball resonators melted from Corning SMF28 Optical Telecommunication Fibre. The radius of the resonator was about 0.3 mm, wavelength of incident light was scanned around 780 nm. Experimentally observed resonance shifts due to temperature change gave value $\Delta\nu = -1585.6$ MHz/K. This gives experimental values of $\alpha + \beta = 4.12*10^{-6}$ 1/K. This sum of coefficients is about 3 times smaller than that of fused silica. This difference is explained by the fact that SMF28 is not a pure fused silica [2].

WGM resonators can be used also as humidity sensors [3] and wavelength sensors.

This research is supported by the Latvian Science Council Project No. lzp-2018/1-0510 “Optical whispering gallery mode microresonator sensors”.

References

[1] Brice, I., *et al*. (2017). Development of optical WGM resonators for biosensors, Proceeding of SPIE, Vo. 10592, 105920B.
[2] Brice, I., *et al*. Temperature scanning the whispering gallery mode resonator resonances, Frontiers in Physics. submitted, 2019.
[3] Labrador-Páez, L., *et al*. (2017). Liquid whispering-gallery-mode resonator as a humidity sensor. Optics Express, 25(2), 1165.

Development of novel methods for coherent control of spectrally unresolved atomic hyperfine levels.

Project proposal to Latvian Council of Science project 2019

Artūrs Ciniņš[1], Aleksandrs Švarcs[1], Kaspars Mičulis[1], Nikolai Bezuglov[2]

[1] *National Science Platform FOTONIKA-LV, University of Latvia*
[2] *St. Petersburg State University, Russia*
E-mail: arturs.cinins@lu.lv

In the project proposal to the 2018 Latvian Council of Science second project call the project team offered to use their knowledge and skills, and advanced experimental infrastructure, developed within previous national and EU framework programme projects for basic research and transfer of knowledge, to study the changes in energy level structure and its properties emerging from interaction with coherent laser radiation, and to find new ways for manipulation and control of these phenomena with coherent radiation fields.

The ability to selectively address quantum states, which may be spectrally unresolved, is of particular interest in the areas of Rydberg physics and quantum information processing and storage. Hyperfine components of a stable atomic ground level can be used to implement quantum information storage, while properties of Rydberg states enable implementation of single and multi-qubit operations. The ability to selectively address hyperfine components of a Rydberg state can be beneficial in fine tuning of properties of Rydberg ensembles. Furthermore, multiple independent excitation schemes can be implemented in the same medium utilising different hyperfine components of atomic energy levels, even when the hyperfine components are spectrally unresolved. This peculiar feature can be used to implement multiple qubits in the same sample of ultra-cold medium, thus reducing complexity of multi-qubit quantum computers. Coherent control over the independent excitation schemes would allow production of mutually independent polaritons, with tuneable polariton-polariton interaction strength.

The main technical objectives of the proposed research are (*i*) to study properties of laser-dressed quantum state systems with hyperfine structure, developing an in-depth understanding about formation of dark, bright and recently theoretically predicted chameleon states [1], and (*ii*) to develop novel techniques for coherent control of spectrally unresolved hyperfine structure components. The objectives will be achieved by combining theoretical and experimental work, backed by numerical simulations of the relevant physical phenomena.

The physical and mathematical models will be developed in synergy between theoretical research and numerical simulations. The numerical simulations will use a framework for composition and numerical solution of the master equation, developed within previous research projects, while theoretical work will use a variety of methods for analysis of properties of quantum systems.

The experimental part of the research will be conducted in a supersonic beam of sodium atoms and Na_2 dimer molecules, which crosses a set of laser beams perpendicular to the flow of atoms/molecules. Collimation of the supersonic beam ensures Doppler broadening of molecular lines below 30 MHz. Furthermore, counter-propagating laser beams can be used to perform sub-Doppler spectroscopic measurements. In addition to interaction with laser beams, stationary or low frequency electric and magnetic fields can be applied to the beam as well. The experimental data points are obtained by recording the amount of fluorescence radiation from the molecular beam. In experiments with atomic sodium, radiation from a cw Coherent CR-699-21 dye laser is used to excite the D_1 or D_2 transition, while excitation from the chosen $3P_J$ level is achieved using either an infrared radiation from cw Coherent MBR-110 titanium-sapphire laser, or its second harmonic obtained from Coherent MBD-200 frequency doubling unit. Both lasers are pumped using a frequency-doubled Nd:YAG laser Coherent Verdi G18. A few other cw and pulsed laser sources will be available on demand.

The project proposal received score equal to the pre-defined quality threshold 10 out of 15, and, due to shortage of funding failed to be among the 41 projects listed for financing. Only 13% from the total number of 306 proposals were financed. 41 proposals are only 18% of the 234 project proposals reaching the quality threshold of 10.

While the research was not funded by this call, efforts of the team members have ensured continuous progress of research in this field, and a theoretical basis for selective addressing of spectrally unresolved energy levels will be submitted for publication within this year. The project proposal will be updated and resubmitted to next Latvian Council of Science call for proposals with deadline August 19, 2019.

References

[1] Kirova T., *et al*. (2017). Phys. Rev. A 96, 043421, https://doi.org/10.1103/PhysRevA.96.043421.

Application of visible, UV and VUV spectroscopy in research on basic properties of atoms excited in inductively coupled RF plasma or in combination with hollow cathode discharge.

Project proposal to Latvian Council of Science call 2019

Arnolds Ūbelis[1], Uldis Gross[1, 2], Uldis Bērziņš[3], Aigars Apsītis[1]

[1] *National Science Platform FOTONIKA-LV, University of Latvia*
[2] *Latvia University of Life Sciences and Technologies*
[3] *Institute of Atomic Physics and Spectroscopy, University of Latvia*
E-mail: arnolds@latnet.lv

In the project proposal to the 2018 second call of Latvian Council of Science, the project team aimed to study basic atomic properties of: halogen atoms (I and Br); S, As, Sb, Bi atoms; and atoms with low vapour pressure such as B, Al, Ga, In, Tl, C, Si, Ge, and others. The proposed project draws on the accumulated knowledge and skills and developed experimental infrastructure from four earlier EU framework programme projects for basic research. Studies of iodine and bromine are needed for use in in the ROFLEX instrument designed for studies of abundance of iodine and bromine in the troposphere and stratosphere above the Pacific Ocean that would use Global Hawk – a high-altitude, long-endurance, remotely piloted NASA aircraft. Coordination of research activities with Prof. Alfonso Saíz-Lopez, holder of prestigious EU ERC grant *(Department of Atmospheric Chemistry at CSIC, Spain*) has been foreseen [1]. This project aims to quantify the so far unrecognised natural halogen-climate feedbacks and the impact of these feedbacks on global atmospheric oxidising capacity (AOC) and radiative forcing (RF) across pre-industrial, present and future climates. Currently the project team of NSP FOTONIKA-LV is the only one worldwide with appropriate experience and skills able to design the source of intense I and Br resonance lines with line profile free from reabsorption.

The other mentioned atoms are interesting because they lack measurements performed by Inductively Coupled Plasma light sources in UV and VUV spectral regions. The project implementation will provide new knowledge in the domain of fundamental atomic physics and spectroscopy, in response to renewed demand from theoretical atomic physics and astrophysics (e.g. for data processing of telescopes positioned on satellite platforms – Hubble telescope and others). The project proposal offers attractive research topics for BSc, MSc and PhD students.

The project proposal received a score of 11 from 15 where the threshold was 10. Due to insufficient funding for the call the project was not financed. Only 41 or 13% from the total of 306 proposals were financed. 41 proposals are only 18% of the 234 project proposals reaching the quality threshold of 10.

The project proposal is be updated and resubmitted to the Latvian Council of Science call for proposals with deadline August 19, 2019.

References

[1] Saíz-Lopez, A. CLIMAHAL – Climate dimension of natural halogens in the Earth system: Past, present, future. ERC Consolidators grant ID: 726349 (2017–2022).

Development of ZnO/porphyrin nanocomposites for optical nanosensors for detection of volatile organic compounds.

Project proposal to Latvian Council of Science call 2019

Ulises Miranda Ordóñez

Institute of Atomic Physics and Spectroscopy, University of Latvia
E-mail: ulises.ordonez@lu.lv

Early detection can be crucial in their successful treatment and having the appropriate tools to get the diagnostics is highly relevant. Breath analysis can help to determine some illnesses; for example, it may contain volatile organic compounds (VOCs) such as benzene, phenol and other aliphatic organic acids, which are related to lung cancer and liver diseases [1, 2]. However, human breath can contain hundreds of substances and the detection of molecules of a specific gas clearly represents a difficult task. Therefore, it is necessary to count with a sensing device capable of receiving such a large mixture of gases and selecting those which are of most clinical interest. This means, that the sensing material in such device must have a high sensitivity and selectivity towards a target group of gases. The present project proposes the development of a sensing material based on nanocomposites of zinc oxide (ZnO) and porphyrins, which will have enhanced sensing properties [3]. In order to obtain these materials, nanostructures of ZnO will be synthesised and characterised by XRD, FTIR and Raman spectroscopy, coated with porphyrins and their sensing capabilities tested and analysed for a set of gases. Theoretical analysis of structure, electronic, optical properties of nanocomposite, interaction ZnO-porphyrin and ZnO-porphyrin-target molecule will be performed using the density functional theory (DFT), time-dependent DFT, perturbation theory and computational modelling. Modern software such as Quantum Espresso [4] and CP2K [5] and graphical viewers such as Burai [6], VMD [7] and Vesta [8] will be used.

References

[1] Brekelmans, M. P., *et al*. (2016). Smelling the diagnosis: The electronic nose as diagnostic tool in inflammatory arthritis. A case-reference study. PLOS ONE, 11, 0151715.
[2] Dragonieri, S., *et al.* (2007). An electronic nose in the discrimination of patients with asthma and controls, Journal of Allegy and Clinical Immunology, 120, 856–862.
[3] Di Natale, C., *et al.* (2003). Lung cancer identification by the analysis of breath by means of an array of non-selective gas sensor. Biosensors and Bioelectronics, 18, 1209–1218.
[4] https://www.quantum-espresso.org/
[5] https://www.cp2k.org/
[6] https://burai.readthedocs.io/en/latest/
[7] http://www.ks.uiuc.edu/Research/vmd/
[8] http://www.jp-minerals.org/vesta/en/.

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

Alma Anna Ūbele, Arnolds Ūbelis

National Science Platform FOTONIKA-LV, University of Latvia
E-mail: arnolds@latnet.lv

Differential optical absorption spectroscopy (DOAS) is used to measure concentrations of trace gases. The MAX(Multi-axial)-DOAS uses sunlight as its passive light source rather than its own light source [1]. Further progress is underway for sustaining application of MAXDOAS-RIGA instrument. The instrument will be installed on an observation platform for field work on the roof of the building at Šķūņu str. 4 positioned in the centre of Riga (the main building of the NSP FOTONIKA-LV) and the spectrometer with hardware components in the room a floor below. To ensure more substantial validity of monitoring data sets similar instrument is foreseen to be located in the Baldone Astrophysical Observatory (*in forest 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 Liepāja. 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*). The dream project is allocation of MAXDOAS-RIGA instrument on ferry ships crossing Baltic Sea from Riga to Stockholm.

The MAXDOAS instruments includes 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 stabilised 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., Līvani, Latvia; spectral range transparent up to 220 nm). 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 telescope unit has zenith-sky and horizon viewing modes for stratospheric and tropospheric measurements. The viewing direction is selected via a motorised 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 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.

Towards application of atomic and molecular spectroscopy methods in direct measurements of atomic and molecular I and Br concentrations in Earth's atmosphere

Arnolds Ūbelis[1], Aigars Apsītis[1], Alfonso Saíz-Lopez[2]

[1] *National Science Platform FOTONIKA-LV, University of Latvia*
[2] *Instituto de Química Física "Rocasolano", CSIC, Madrid, Spain*
E-mail: arnolds@latnet.lv

The measurement of atmospheric I_2 was firstly reported in [1] at Mace Head (*Ireland*), which 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 trials in 2011 [2]. The instrument has been optimised in laboratory experiments to reach detection limits of 1.2 pptv for I atoms and 13 pptv for I_2, for S/N = 1 and 10 min of integration time.

The new challenge for the ROFLEX instrument is online measurements of "tropical rings of atomic halogens" (*firstly iodine and eventually bromine*) predicted in modelling research [3] in 2016. Collaboration between research teams in Riga and Madrid aims at production of a new version ROFLEX-2 with a completely new construction and increased sensitivity to meet the NASA's Armstrong Flight Research Centre requirements for equipment packages on the Global Hawk unmanned aircraft platform [4] with the objective of measuring I or Br (*or both*) over the tropical Pacific (*Guam*) to confirm the existence of "*Halogen Rings*".

The backbone of the instrument is an intensive source of two atomic iodine resonance spectra lines 183.038 nm and 206.163 nm. The instrument is based on a combination of inductively coupled plasma excitation (ICP) of iodine atoms in resonance cell with appendix, temperature is stabilised by Peltier cooler allowing controlling iodine vapour pressure in the cell and thus selecting the spectral profiles of lines applicable for atomic absorption or resonance fluorescence of molecular iodine. Ultrasil quartz is used for iodine spectra sources. Resonance spectrum of bromine is allocated further in VUV region and a sophisticated technology has been developed by combining MgF windows and quartz cell able for sufficiently larger lifetime under influence of ICP plasma.

The collaboration of both teams has synergy with the implementation of ERC grant coordinated Alfonso Saíz-Lopez [5].

References

[1] Saíz-Lopez, A., Plane John, M.C. (2004). Novel iodine chemistry in the marine boundary layer. Geophys. Res. Lett., 31, L04112, doi:10.1029/2003GL019215.
[2] Gómez Martın, C., *et al.* (2011). In situ detection of atomic and molecular iodine using Resonance and Off-Resonance Fluorescence by Lamp Excitation: ROFLEX. Atmos. Meas. Tech., 4, p. 29.
[3] Saíz-Lopez, A., Fernandez, R. (2016). On the formation of tropical rings of atomic halogens: Causes and implications, Geophys. Res. Lett., 43, 2928–2935, doi:10.1002/2015GL067.
[4] https://www.nasa.gov/centers/armstrong/aircraft/GlobalHawk/index.html
[5] Saíz-Lopez, A. CLIMAHAL – Climate dimension of natural halogens in the Earth system: Past, present, future. ERC Consolidators grant ID: 726349 (2017–2022).

ERA Chair in Space Sciences and Ground Segment Space Technologies at the NSP FOTONIKA-LV, University of Latvia.

Project proposal to H2020-WIDESPREAD-2019-4 call

Ilgmārs Eglītis, Jorge del Pino, Arnolds Ūbelis

National Science Platform FOTONIKA-LV, University of Latvia

E-mail: Ilgmars.Eglitis@lu.lv

The newly established National Science Platform FOTONIKA-LV at the University of Latvia *(NSP FOTONIKA-LV)* in quantum sciences, space sciences and related technologies has prepared two ERA Chair project proposals to the H2020-WIDESPREAD-2019-4 call: *QUANTUM-LV* and *SPACE-LV*. The proposals target key research interests of the platform to gain a timely *"fresh wind in the sails"* through ERA-Chair grants for *NSP FOTONIKA-LV* to implement its national and *ERA* mission. Both projects are in line with the EU strategies. The first one relates to the EU Quantum Technology Flagship *(https://qt.eu/)* and the second one is in compliance with EU Space Strategy [1].

The SPACE-LV project proposal – *ERA Chair in Space Sciences and Ground Segment Space Technologies at the University of Latvia* received scores about quality threshold for the criteria *"excellence"* and *"impact"* but had a modest score for "*implementation*". Keeping in mind the encouraging evaluation, the project will be improved and resubmitted to H2020 call WIDESPREAD-04-2020.

The project is aimed at attracting to the Institute of Astronomy, University of Latvia (constituent of NSP FOTONIKA-LV) an outstanding researcher and research manager – ERA Chair – with a proven record of effective leadership challenging national leadership in the field and having the ability to be a strong contributor in solving current and emerging tasks in the European Research Area or at a global level. The SPACE-LV project proposal key objectives are:

- to make more effective resource allocation decisions, supervision and leadership of team members and institute personnel through utilisation of the unique astronomical research infrastructure in Latvia and drawing on the research capacities of the whole *NSP FOTONIKA-LV in complementary disciplines;*
- to attract bright students and researchers from around the world and specifically from Africa and other developing countries by launching a Baltic Sea regional PhD curriculum in space sciences and technologies drawing on expertise from the region;
- to make efforts for securing funding from the next framework programme (Horizon Europe), *European Space agency* and other sources to enable research, innovation and commercial application;
- to develop strategic intelligence and research management capabilities including proposal development and project management through a *task force of NSP FOTONIKA-LV* to enable the *ERA Chair* to realise the potential of the position effectively;
- to empower the *ERA Chair* to serve as the spokesperson in Latvia and for Latvia on issues related to astronomy, space sciences and ground segment space technologies promoting further necessary structural changes on national and Pan Baltic level.

References

[1] Space strategy for Europe. Brussels, 26.10.2016 COM(2016) 705 final.

Meeting future challenges of space surveillance and tracking - towards increased capabilities and novel applications of satellite laser ranging systems, technology and networks.

Project proposal to H2020-MSCA-RISE-2019 call

Jorge del Pino, Arnolds Ūbelis

National Science Platform FOTONIKA-LV, University of Latvia
E-mail: Arnolds@latnet.lv

The project proposal *SLR GLOBAL NET* was submitted to the H2020-MSCA-RISE-2019 call. ***The challenging overall objective*** of the *SLR GLOBAL NET* project proposal is contribution to the technology breakthrough needed to respond to avalanching space debris problems – today's principal threats to satellites and to safety on Earth. According with the overall objective the following advancements, novel approaches, and innovations are foreseen:

- substantial contributions to strengthening the measurement and research capacity of operating SLR stations of the consortium via innovations and advancement of technique;
- efforts towards breakthrough in the development of future SLR technologies like bistatic and multistatic [1] laser ranging, addressing the challenge of tracking space debris and dormant satellites, as well as time transfer experiments and other sophisticated exercises;
- contribution to the revival of presently inactive stations in Cuba and Egypt, with beyond the "state of the art" concepts and technologies;
- and finally, contribution to the development of a new fundamental Geodynamic Observatory and SLR station in Ethiopia as a core site the International Terrestrial Reference Frame with advanced instrumentation prepared to meet future challenges.

Alongside with important contribution to space surveillance and tracking needs, Earth science as well will benefit from increased accuracy in distance measurements enabling more precise measurement of ocean levels and Earth's surface and subsurface movements, more sophisticated technologies and powerful data analysis, and finally from adoption of common standards and sharing of instrumentation and facilities inside the consortium. Many SLR stations from *SLR GLOBAL NET* are members of International Laser Ranging Service [2] and are linked with global ETRS89/WGS84 [3], gravimetric networks [4] and GGOS [5].

Coordinated sharing of knowledge and skills *(academia ↔ academia and academia ↔ industry)*, training and joint research activities complementary with precisely scheduled, four-year career development programmes are foreseen and planned for 12 participating teams in the EU/AC (*Riga, Potsdam, Helsinki, Graz, Warsaw, Kyiv*) and internationally: Havana *(Cuba)*; Cairo-Helwan *(Egypt)*, and Addis Ababa *(Ethiopia)*. SMEs are from Riga, Potsdam, Kyiv and Graz.

Intensification of existing scientific partnerships are aimed at sustained synergy via enhancing excellence in research of the whole consortium via cross-discipline and cross-generation exchange benefiting from more than a half a century of expertise in SLR instrumentation design, software and data processing in Riga and later in Potsdam, Warsaw, Graz and in Kyiv. The impressive experience and capacity invested in the consortium *SLR GLOBAL NET* project forms a basis for the success:

- Coordinator of the project – the National Science platform FOTONIKA-LV (*photonics framing quantum sciences, space sciences and related technologies)* is being formed by the multidisciplinary FOTONIKA-LV association of research institutes founded on April 24, 2011 at the University of Latvia. Up to now, the largest success of the association has been the EUR 3.8 million FP7 research potential project (2012–2015) that contributed substantially to the development of human potential and research infrastructure of research groups, laboratories and observatories of the Centre including the "RIGL-1884" SLR station at the Fundamental Geodynamic Observatory in Riga.
- EU/AC partners have demonstrated excellence at the international level: Potsdam SLR and Metsahovi SLR are built according to the latest technical standards. The German GFZ operates one of the most advanced SLR stations in Europe and operates several satellites which use the SLR technique for orbit determination *(GFZ-1. CHAMP, GRACE-A/B in cooperation with DLR and NASA)*. The Gratz SLR station is the most precise SLR station of ILRS network. Ukraine has the largest national SLR network of 4 stations of which three are operational and one is inactive. The Main Astronomical Observatory in Kyiv supervises the largest national (Ukraine) network of 4 SLR stations and has implemented contracts with ESA [7].
- The excellence of industry part of the *SLR Global Net* project is approved by EU Commission Seal of Excellence awarded to DIGOS (GMB) in 2016 as consortium member *(coordinated by HEEP Photonics Ltd from Latvia and STSG Oy from Finland)* for the H2020 SME instrument 2nd phase project proposal. Joint Stock Company KURS in Kyiv is a recognised leader in space geodesy technologies in Ukraine. EVENTEX in Riga is worldwide recognised producer of event-timers used in many SLR stations worldwide and used by European Space Agency institutions as well.

References

[1] Kirchner, G., *et al*. (2013). Multistatic Laser Ranging to Space Debris. https://cddis.nasa.gov/lw18/docs/papers/Session4/13-0213Kirchner.pdf, 6 pages.

[2] http://ilrs.gsfc.nasa.gov/network/site_procedures/station_upgrade_status.html (as of November 7, 2017).

[3] https://epsg.io/1149.

[4] https://www.fig.net/.../TS03G_peneva_gospodinov_et_al_7498_ppt.pd.

[5] http://www.ggosdays.com/en/about/ggos-infos/

[6] "FOTONIKA-LV – Unlocking and Boosting Research Potential for Photonics in Latvia – Towards Effective Integration in the European Research Area", grant agreement Nr. REGPOT-CT-2011-285912.

[7] Assessment of Space to Ground Optical Link by Space Diversity (2007–2009) No. 19861/06/NL/PA.

Progress of Latvian Council of Science project Nr. LZP-2018/1-0401 "Complex investigations of the small bodies in the Solar system" in 2018

Ilgmārs Eglītis

Institute of Astronomy, University of Latvia

E-mail: Ilgmars.Eglitis@lu.lv

Project implementation time is 3 years (31.08.2018–31.08.2021). The head of project is Dr. Phys. I. Eglitis leading researcher of the Institute of Astronomy of University of Latvia.

Scientific institutions involved in the project are:

1. University of Latvia, (Baldone Astrophysical Observatory of the Institute of Astronomy) – coordinator;
2. Ventspils University College (Ventspils International Radio Astronomy Centre) – participant.

The main objective of the project is to carry out research on the Solar System's small bodies (asteroids and comets) using modern optical and radio methods and data processing methods.

The following tasks are identified to achieve the objective:

- Observations of asteroids, comets, and Near Earth Objects (NEO) using the Baldone Schmidt Telescope;
- Photometric studies of asteroids and comets;
- Simultaneous comet observations in single antenna mode and VLBI (Very Long Baseline Interferometry) modes;
- Combined radio and optical data processing.

The results of the project will provide an opportunity to predict the probability of collision with the Earth of small asteroids and small bodies of the Solar System, as well as to evaluate the chemical composition of the observed small bodies, thus obtaining information on useful minerals on the cosmic bodies. In the future properties of asteroids: the rotation period, the peculiarities of surface (craters, fields of frozen gases, ice) may be useful information for exploitation of asteroid mineral resources. The results of the project will be used to plan use of asteroid water for fuel and life support for deep space missions. Research results are of interest to companies that are planning to extract useful minerals from asteroids in the future, such as Deep Space Industries, USA. "Cryogenic and Vacuum Systems" Ltd. is interested in innovative ideas in the construction of space equipment (receivers / transmitters), benefiting from experience gained during the project by improving the L-band (18 cm range) radio receiver.

Working in the project for less than eight months, with Baldone Schmidt telescope 1028 measurements for 826 faint asteroids (magnitude less than 19 in the red spectral range) were obtained. 9 new asteroids were discovered. 566 positions and photometric observations of NEO objects 2006 VB14 = Y5705 = 345705 and 1986 DA were obtained and discovered that the surface of the asteroid 2006 VB 14 has a deep crater and frozen gas fields on surface. Observations confirm the previously obtained rotation period P = 3.04 h for 2006 VB14.

The processing of Pluto's observation data has been performed using a methodology that repeatedly increases the accuracy of position measurements, which are important for refining the orbit.

The following comets: C/2016 R2 (PANSTARRS) 21 observations; P/2018 P3 (PANSTARRS) 21 observations; 38P/Stephan-Oterma (Fig. 1) 3 observations; C/2018 W2 (Africano) 3 observations were observed. Photometric measurements, including determination of brightness equinox in the comet tails were made.

Project research results were presented at five international meetings in Riga, Cardiff (UK) and Bamberg (Germany).

32 public lectures were conducted at the Baldone Observatory, dedicated to Solar system small body studies; and also, speeches on TV1 broadcast "Cognitive Impulse" series 12 on October 17, 2018 and in LR4 "One hundred success stories – Asteroids" on November 22, 2018 took place.

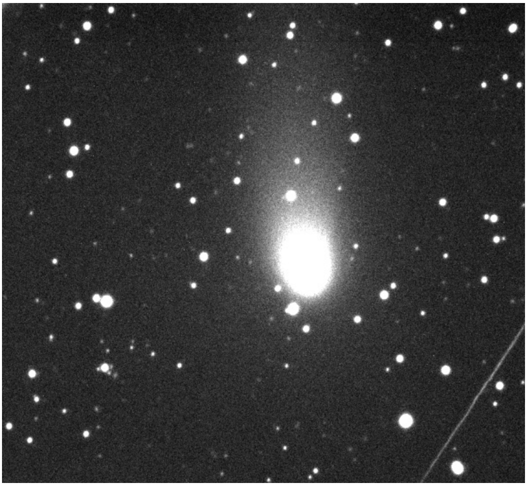


Figure 1. *Image of comet 38P/Stephan-Oterma obtained with Baldone Schmidt telescope*

During eight months the following publications were prepared and published:

1.–7. Eglitis, I.; Cernis, K. Minor Planet Observations [069 Baldone], Minor Planet Circular: Nr. 107827, 2, 2018; Nr. 108759, 1, 2018; Nr. 109640, 1, 2018, Nr. 109684, 1, 2018, Nr. 110175, 2, 2018, Nr. 110809, 2, 2018, 111864, 2, 2018

8. Eglītis, I. (2018). Asteroids Exploration with Baldone Schmidt Telescope, Odesa Astronomical Publications, 31, 204

9. Eglitis, I., *et al*. (2018). VizieR Online Data Catalog: Topocentric positions of Pluto (Eglitis+)

10. Graps, A. (2019). ASIME 2018 White Paper IN-SPACE UTILISATION OF ASTEROIDS: Asteroid Composition, arXiv:1904.11831

11. Eglitis, I., *et al.* (2019). COMET C/2018 W2 (Africano, Minor Planet Electronic Circular, 73

This research is funded by the Latvian Council of Science, project "Complex investigations of Solar System small bodies", No. lzp-2018/1-0401.

Advances in Earth Fundamental Geodynamics, Satellite Laser Ranging and Lidar Sciences & Technology and Breakthrough in Active Remote Sensing of Nocturnal Atmosphere.

Project proposal to Latvian Council of Science call 2018

Māris Ābele, Jānis Vjaters, Jorge del Pino, Kalvis Salmiņš, Arnolds Ūbelis

National Science Platform FOTONIKA-LV, University of Latvia
E-mail: Arnolds@latnet.lv

Satellite laser ranging *(SLR)* offers the most precise available measurements of the motion of satellites by monitoring and fixing their geocentric positions in a fixed coordinate system. SLR data collected for decades provides unique data sets for the solid Earth and its oceanic and atmospheric systems exploration. Such data is needed for monitoring the impact of climate change on sea level and polar ice thickness, detection of basin-scale ocean tides, the time varying high-resolution determination of global gravity and magnetic fields and the modelling of convection in the Earth's mantle [1].

SLR also plays an important role in calibration of other modern geodetic methods like GNSS or DORIS and permits carrying out research in fundamental physics on relativity theory by determining frame dragging effects [2].

In addition to the above mentioned, in the future SLR will be needed for ranging nanosat constellations [2]. SLR is also a key technology for the space-debris monitoring and will contribute to ranging of potentially dangerous asteroids as well as in lunar exploration.

The SLR data sets are integral to deliver basic global data services, e.g. by the International Terrestrial Reference Frame [3], the International Earth Rotation and Reference Systems Service [4], and other important international and national services.

In summary: advances in SLR sciences and technologies are multidisciplinary in their content impacting socially vital research with socially significant outreach.

In order to make further progress an increase of both the spatial and temporal resolution, is necessary to go beyond the current SLR sub-centimetre resolution *(10–7 mm)* done using high repetition rate lasers with pulses up to 10 pS with a very narrow wavelength. To reach the "true" mm resolution *(below 5 mm)* the use of femtosecond laser pulses should be explored. These pulses combine a very short pulse length with a very wide wavelength range therefore theoretical and experimental research is needed before femtosecond lasers can be used in regular SLR practice.

One of the problems is the "pulse length spreading" due to the refraction index dependency on wavelength. This spreading happens both in the SLR optics and during the propagation in air. This is one of the reasons that the distances measured up to now with femtosecond pulses are in the order of 100 m and we need to go up to 4–5 orders of magnitude in distance to reach the current operational SLR range.

On the other side, if the "pure" atmospheric pulse spreading during the SLR femtosecond observations can be measured and modelled, the optical path value for each SLR measurement can be evaluated. This will be one step beyond the current SLR atmospheric effects models *(as the Marini-Murray)* based on the local meteorological values at the SLR site. Other attempts to do this, using dual frequency pS lasers, have not been generalised.

This connects to parallel research done in Riga, concerning the use of white light sources for atmospheric sensing, both at relatively short distances (i.e. using drones) up to orbital distances. To the best of our knowledge, nobody has succeeded in **active** remote sensing of the atmospheric column ranging a **beam of white light** across a sky segment, covered by a selected satellite or an airborne vehicle, providing accurate planetary altitude-resolved day and **night data** and on-line spectral and spatial high-resolution data of the absorption of a broadband spectrum in an atmosphere column.

In order to challenge highlighted problems, the project proposal "Advances in Earth Fundamental Geodynamics, Satellite Laser Ranging and Lidar Sciences & Technology and Breakthrough in Active Remote Sensing of Nocturnal Atmosphere" was designed and submitted in response to the Latvian Council of Science call for proposals for fundamental research efforts in 2018. The project was based on the team possessing multidisciplinary in SLR sciences and technologies, femtosecond lasers and atmospheric sensing. Involvement of experienced experts from Ukraine and Finland was also foreseen.

The project proposal received high scoring 12 from 15, but, due to the insufficient funding for the call this highly rated project was not among the 41 projects listed for financing. Only 13% from the total number of 306 proposals were financed. 41 proposals are only 18% of the 234 project proposals reaching the quality threshold of 10.

The project proposal is updated and resubmitted to next Latvian Council of Science call for proposals in August, 2019.

References

[1] Degan, J. J. (2013). Impact of SLR Technology Innovation on Modern Science. 18th International Workshop on Laser Ranging. Fujiyshida, Japan, Nov. 11, 2013.

[2] Kirchner, G., *et al.* (2013). Laser Ranging to Nano Satellites in LEO Orbits: Plans, Issues, Simulations. 18th International Workshop on Laser Ranging. Fujiyshida, Japan, Nov. 11, 2013.

[3] International Terrestrial Reference Frame: http://itrf.ensg.ign.fr/

[4] International Earth Rotation and Reference Systems Service: https://www.iers.org.

Survey of solutions to the Fermi Paradox

Vidvuds Beldavs

National Science Platform FOTONIKA-LV, University of Latvia
E-mail: Vidvuds.Beldavs@lu.lv

The Fermi Paradox is one of the great scientific challenges of our time. Given the assumption that that the emergence of life and subsequent emergence of intelligence and technological civilisation are natural processes, then over billions of years among the many billions of planets intelligent life and technological civilisations would have emerged. Enrico Fermi's famous question "Where are they?" came up during his lunchtime discussion of UFOs in 1950 with Teller, York and Konopinski at Los Alamos. Even before the first spaceflights rough calculations of the size and age of the universe suggested that numerous advanced civilisations were likely to have emerged. Of note here is the famous Drake equation which remains relevant for estimating the number of intelligent civilisations in the galaxy. Yet after six decades none has been verifiably detected. That is the Fermi Paradox.

This paper is a survey of solutions offered to the Fermi Paradox primarily drawing on two recent books in the topic:

- Stephen Webb, *If the Universe Is Teeming with Aliens. WHERE IS EVERYBODY?: Seventy-Five Solutions to the Fermi Paradox and the Problem of Extraterrestrial Life* Second Edition, 2015
- Ćirković, Milan M. *The Great Silence: Science and Philosophy of Fermi's Paradox* Oxford University Press. 2018.

Milan Ćirković's *The Great Silence* uses the device of the Fermi Paradox to present the scientific and philosophical problem of the existence of human, and more generally any intelligent, life in the universe. Webb presented encapsulations of 75 solutions to the Fermi Paradox in his book. Cirkovič broadens the field and rates the solutions with the intent to identify productive lines of research in astrobiology to understand how intelligent life emerged and evolved.

Now in 2019 thousands of exoplanets have been discovered and organic molecules have been confirmed in many environments including interstellar space, and the emergence of astrobiology confirm the potential for life to have emerged and for evolution, including post-biological evolution to have taken place. Advances in computing and cognitive science in the astronomically brief span of human civilisation provide compelling arguments for the possible emergence of advanced technological civilisations during the billions of years during which evolution of life could have taken place. Evidence suggests that many earth-like planets could be much older than Earth providing time for many advanced civilisations to emerge. At 1% of light speed, which is assumed to be attainable by advanced civilisations, our galaxy could be crossed leaving artefacts or signals. Yet none have been discovered.

The Great Silence approaches resolution of the Fermi Paradox from the perspective of branches of science, philosophy, history, literature, and film. In this Ćirković is similar to Douglas Hofstadter whose Pulitzer Prize winning book on cognitive science *Gödel, Escher Bach* is cited. *The Great Silence* draws on a comparably vast range of literature targeting a similar widely read audience that enjoyed how a mind like Hofstadter shed light on the underlying patterns of human cognition by analysing the analogy of patterns in the mathematics and philosophy of Gödel, and the art and design of Escher with the fugal music of Bach.

Ćirković sets the stage in chapter 1, then reviews the relevant astrophysics, astrobiology and related science in chapter 2, followed by a review of the philosophical basis for analysis of the Fermi Paradox. The author distinguishes between WeakFP (absence of signs of extra-terrestrial civilisation in the Solar System and StrongFP, absence of evidence of extra-terrestrial civilisation in the galaxy and beyond. The first three chapters draw on a challenging array of sources and ideas unlikely to be familiar to many readers that are not already deep into the field of SETI studies. Ćirković has also equipped the book with nearly 100 pages of reference tools including end notes referenced to pages and chapters, followed by an excellent alphabetical bibliography and an index. I would suggest reading an e-book format like a Kindle edition to ease looking up the sources and definitions.

Rising to the challenge of understanding the scholarly first three chapters the reader is rewarded by deeper understanding of the taxonomy of possible solutions to the Fermi Paradox covered in thematic chapters four, five, six, and seven that are written in a lighter, sometimes humorous style that is a delight to read.

Chapter 4 covers Solipsist Solutions which subsume topics like Limits of realism, UFOs, Special Creation, Humanity in a zoo, humanity in a sim-city, directed panspermia (are we the aliens?), and a new cosmogony – essentially an SF story by Stanislav Lem in the form of a Nobel Prize lecture by the fictional scientist. Advanced civilisations under such a scenario could choose to simply avoid contact with humans (Zoo Hypothesis) or as in the Interdict Hypothesis advanced civilisations isolate planets with a biosphere capable of evolution and remain unknown. A Leaky-Interdict is like the random UFO sighting that cannot be explained away and may indicate contact with extraterrestrials. The Planetarium Hypothesis presents a cosmos that is an artefact of an advanced civilisation that can manipulate space and matter at a fundamental level yielding our astronomical observations and perceived reality, but the Directors remain hidden and beyond our comprehension. The Peer Hypothesis is an alternative view of the Planetarium concept with the twist that the Directors create multiple (peers) biospheres as experiments. Humans in the experiment may discover their peers but the Directors would remain hidden. An alternative view is that the advanced civilisation is effectively paranoid and encrypts its communications such that they are indistinguishable from noise (cosmic background radiation) and therefor would be undetectable. The Directed Panspermia Hypothesis presents the idea that we are the aliens or the results of the advanced civilisation seeding the Earth with primitive life during a window in time in the early Earth that may not have lasted more than 200 million years. Before or after that period seeding would probably have failed and been no longer detectable. Since life emerged on Earth 3.8 billion years ago, where are the Seeders now? The energy required for seeding would not differ much from the energy required for direct colonisation. Why would the Solar System not have been colonised?

Ćirković discusses Michael Mautner's view that humanity has an obligation to spread life throughout the galaxy and raises the objection that if panspermia is easy, then those planets that could sustain a biosphere would have been seeded and multiple SETI signals should now be detected. But there is silence. "We need not presume that the alternative to design is purely random origin. Quite to the contrary, processes which are 'neither chance nor design' are crucial for a modern understanding of abiogenesis, and we can hope they will help in understanding the origin of the genetic code." Stanislav Lem's New Cosmogony presents an alternative view to the Planetarium hypothesis that the universe known to humanity is an artefact created by a civilisation billions of years older than us. The laws of physics and other natural processes are the form of communication in a cosmic process involving alteration to those laws to create new stages of cosmological evolution and there would be no Fermi Paradox. Lem's New Cosmogony brings to mind Michael Cremo's *Human Devolution* that draws on the ancient Indian Veddas to claim that human like civilisations have risen on the Earth multiple times over hundreds of millions of years. This well-documented book points to archaeological anomalies in geological layers dated tens of millions of years ago.

Some interpretations of the observer effect in quantum physics imply, if there is no conscious observer, there is no reality resulting in a solipsist resolution of Fermi's Paradox – more advanced beings and civilisations don't expand across the galaxy following Kardashev pattern to a Stage III Civilisation drawing on the resources of a galaxy, but rather leave our space-time entirely, and thus would no longer be detectable. Cancer cells expand without limit. Capitalist economic expansion, which is limited primarily by the availability of resources, would follow a Kardashev pattern. But, why would a civilisation of very advanced beings follow such a pattern? Richard Prum's 2017 book *The Evolution of Beauty* addresses the emergence of beauty among birds and animals in nature. Selection appears to occur based on beauty rather than utility. Intelligent beings may pursue the quest for beauty rather than to creating a galaxy spanning civilisation. Prum draws on Darwin's theory of sexual selection as described in a recent New York Times article.

Ćirković builds his review of rare earth scenarios that reject Copernicanism in Chapter 5 on a discussion of *Terra Nostra*, a fantastical novel by Mexican author Carlos Fuentes published in 1975. The chapter keys off with a discussion of Copernicanism, the view that Earth is not central to the cosmos and humans are not unique which accepts that the Sun is a modest typical star on the edge of the galaxy filled with similar modest planets with billions of other similar galaxies. If Copernicanism rules life can emerge and evolve in natural processes that appear to be likely on numerous typical Earth-like planets and the great silence would remain paradoxical.

The Fermi Paradox would hold if the emergence of intelligent life on Earth is dependent on conditions unique to Earth such as a large moon, a large gaseous planet like Jupiter within a defined distance from Earth, as well as a local star with a specific range of solar radiation and related factors. Earth's evolutionary history led to the biosphere of the Earth changing the atmosphere and albedo of the planet such that further evolution became possible. If life did not evolve extremely rapidly during a limited time in the early Earth photosynthesis and the oxygen content of the atmosphere would not have had the large-scale effects that enabled evolution to be sustained. Ćirković draws on the work of Aditya Chopra & Charles Lineweaver whose paper addresses the multiple barriers to the emergence of intelligent life in the process of planetary development. What needs to be explained is why the possibility that only Earth harbours intelligent life could not be demonstrated.

Ćirković discusses evolution and the adaptation to local conditions at length raising questions about the evolutionary advantage of intelligence and consciousness. The advance of our technological civilisation has been marked by the development of tools and technologies that make doing tasks easier thereby placing a lower demand on the use of intelligence after the technology has been deployed. Toolmaking may disappear well before permanent artefacts that could survive tens of millions of years could be created. Fermi's Paradox would remain.

Agreement between ESSTI and NSP FOTONIKA-LV about joint implementation of bilateral project "Development of the overall concept of Astronomy Observatory – a core site in Ethiopia for the International Terrestrial Reference Frame and the design and research on key elements of next generation SLR technologies

Māris Ābele[1], Ilgmārs Eglītis[1], Jorge del Pino[1], Jānis Vjaters[1], Arnolds Ūbelis[1], Solomon Besay[2]

[1] *National Science Platform FOTONIKA-LV, University of Latvia*
[2] *Ethiopia Space Sciences Technology Institute*
E-mail: arnolds@latnet.lv

On October 26, 2014, the ILRS Governing Board announced that "Filling the remaining geographic gaps will require many more partnerships and lots more resources …" http://ilrs.gsfc.nasa.gov/docs/2014/ILRS_GBpresentations_20141026.pdf. ILRS stations range to a constellation of artificial satellites and Moon systems and transmit data on hourly basis to specified International Laser Ranging Service (ILRS) Operational centres. That is direct evidence of the urgent need for upgrade and denser global network of SLR stations of ILRS, as well as national networks of SLR stations and new Fundamental Geodynamic Observatories in developing countries worldwide having ambitions to benefit from the future global space economy.

The need to expand in numbers, and to improve the quality of the SLR tracking capability was intensely discussed by the ILRS workshop in Potsdam in October 2016, and again during the ILSR Technical workshop in Riga, Latvia in October 2017, where the workshop declaration noted the unfortunate absence of SLR stations in the Southern Hemisphere. The ISLR network practically has no coverage in Africa. Ethiopia's new observatory at Entoto is an exciting development for the SLR community. Close to 3 km above sea level the Entoto Observatory makes it very attractive place for establishing a fundamental geodynamic observatory and a key site for the International Terrestrial Reference Frame.

The aim of the project is to contribute towards expanding the coverage of SRL stations in the Southern Hemisphere via the following activities:

- development of the ITRF core site concept for the Entoto observatory of the Ethiopia Space Science and Technology Institute (ESSTI);
- research and design of key elements of the next generation satellite laser ranging instrumentation for future applications of SLR technologies, e.g.: space debris orbit determination, and observations of dangerous space objects;
- research training of Entoto team (*Development of PhD thesis work, learning by doing, participation in SLR observation sessions at the ILRS station RIGL 1884*).

The ESSTI was established on October 14, 2016 by Ethiopia's Council of Ministers. The main objectives of ESSTI is to enable the country to fully exploit multidimensional uses of space science and technologies. The approval of the ESSTI is one big step forward towards the development of Ethiopian space science activities that will give advantage for Ethiopia to be effective and extensive user of space science and technology for its sustainable development.

Entoto Observatory is a part of the Ethiopia Space Science and Technology Institute (http://www.eo.org.et/) Mount Entoto at altitude of ~3,100 m.

NSP FOTONIKA-LV & THORLAB Collaboration Project

Uldis Bērziņš

Institute of Atomic Physics and Spectroscopy, University of Latvia
E-mail: Uldis.Berzins@lu.lv

The project "Absorption Cells for Stabilisation of Blue and Violet Diode Laser Frequency with 11 Decimal Digit Precision" is a University of Latvia Effective Collaboration Project, meaning that it is financed from both partners: Thorlabs Inc. $ 45,000 and University of Latvia € 15,000.

Thorlabs Inc. financed the development of the project with a $ 5,000 donation to the University of Latvia Foundation at the end of 2018. In 2019 we have designed and manufactured prototype tellurium absorption cells together with a temperature stabilisation system. Work is performed in the Institute of Atomic Physics and Spectroscopy by Aigars Apsitis, Arturs Cinins, Aleksandrs Kapralovs, Viesturs Silamikelis, Aleksandrs Svarcs, and lead by Uldis Berzins. Janis Valdmanis of Thorlabs participates in project progress monitoring, advising, and supporting with donated Thorlabs products as needed.

After a successful first year we plan to continue this project for one more year. Second year project objectives are to demonstrate the stabilisation scheme of diode laser on tellurium vapour, and to design and manufacture the prototype to demonstrate successful operation. In the case of success, a spinoff company from the University of Latvia may be formed by the end of 2020 to manufacture the new product in Latvia.

The most widely used molecules for laser frequency standards are iodine and tellurium. Both are homo-nuclear and hence not IR active. Molecular electronic spectra usually cover a broad range of wavelengths, making them an ideal choice for optical laser frequency standards which does not necessarily require accuracy, but they must be stable. The electronic spectra of iodine show strong absorption band starting at around 500 nm for the transition between its X and B electronic states which are the lowest two electronic states of the system [1]. Therefore, iodine lines are suitable to frequency lock lasers in the longer wavelength range. The tellurium spectra have been observed starting from ultra violet (UV) wavelength of about 350 nm onward. The main advantage of this molecule is its large spin-orbit coupling and the presence of a large number of isotopes. This combination allows a wide spectral range to be accessible in a single molecular specie [2]. Subsequent work already has been done to extend this atlas on both sides of the spectrum [3] and with 10 decimal digit precision [4].

References

[1] George, S., Krishnamurthy, N. (1989). Absorption spectrum of iodine vapor – An experiment, American Journal of Physics 57, 850.

[2] Vergès, J., *et al.* (1982). The Laser Induced Fluorescence Spectrum of Te_2 Studied by Fourier Transform Spectrometry, Phys. Scr. 25, 2.

[3] Cariou, J., Luc, P. (1980). Atlas du Spectre dAbsorption de la molecule de Tellure, Laboratoire AimeCotton, CNRS II, Orsay, France.

[4] Dutta, T., Muktherjee, M. (2018). High Resolution Spectroscopy on Te_2: new lines for reference. arXiv:*1806.07658v1 [physsics.atom-ph] 8 pages*.

Towards Commercialisation of Energy Power Supply to Electron Beam Gun

Jānis Blahins[1], Arman Bzhishkian[1], Anatolij Kravtsov[2]

[1] *National Science Platform FOTONIKA-LV, University of Latvia*
[2] *KEEP EU, Ltd*
E-mail: janis_59@inbox.lv

The usage of electron beams is more thermally efficient than classical resistive ovens or induction heating technologies in the semiconductors' industry. In reference [1] the author presented a prototype, a 30 kV 4 A direct current adjustable SMPS, capable of withstanding frequent short-circuit pulses (up to 10 per minute), used to power an electron beam gun in the melting of silica metallurgy able to withstand frequent short-circuits occurring many times per minute. It's known that e-beam gives an important power economy over classical resistive oven or induction oven technologies for semiconductors manufacturing, yet inexpensive SMPS are not available in the market at this high power. The team of researchers composed of professionals from the University of Latvia and the enterprise KEEP EU, Ltd. are currently collaborating to build a commercial version of the described power source. The expected market value is between EUR 50,000 and EUR 200,000.

References

[1] Blahins, J., *et al*. (2017). Know-how and experience how to build a >100 kW power source for laboratory experiments in beam physics. Int. J. of Innovative and Applied Research. 5(9), p. 85.

Small size, cost effective cleanroom of NSP FOTONIKA-LV

Jānis Blahins, Viesturs Silamiķelis, Aigars Apsītis

National Science Platform FOTONIKA-LV, University of Latvia

E-mail: janis_59@inbox.lv

NSP FOTONIKA-LV developed a low-cost cleanroom which has been erected in the lower level of the FOTONIKA-LV at the 4 Šķūņu street facility in central Riga.

Construction of the cleanroom

The first layer of the cleanroom was the walls and ceiling using 0.2 mm thick LDPE film (TIP200) on which 0.5 mm thick polished AISI-306 plates were fixed by multiple anchors that were glued in holes using silicon resin. All gaps of plate sticking were glued as well. Thus, the room of 20 m^2 was hermetically sealed from outside air. The walls were constructed by applying a second layer of stainless steel, which was bent to form multiple vertical air channels with dimensions 35 x 120 mm. The entire wall serves to transport air from floor level towards ceiling mounted filters. Ceilings are typical hang-on ceilings supporting numerous HEPA filters, with 16 pieces of UF-15 class 61 x 122 sections. Across the full length of corners between walls and ceiling we installed AISI blowers with a total power of 10,000 m^3/h, thus forming an effective local recirculation system with ultrafine particulate cleaning. Input air was sucked in from the 6th floor level (over roof level) by a 4 kW ASI-304 metal centrifugal blower 4000 m^3/h, cleaning air initially via fabric filter and then via class-14 HEPA filter and then via UF-15 filter connected in series, such 4 sheets in parallel. So, in the cleanroom both flows are mixed over ceiling filter and forwarded to ground rather laminar at 0.5 m/s. Incoming air flow may be adjusted, but recirculation air may be only switched on or off. For the floor was used special formulation of Hagmann (Sweden) epoxy resin developed for heavy-duty floors, that employ a curing agent making circular chemical bonds. It is highly elastic and simultaneously prevents abrasion. For the door systems was used anodised passivated aluminium frames with glass. Seven doors sequenced in series were designed for human traffic in and out the cleanroom to obey the principle that any door may not divide more than 2 orders of magnitude of dust concentration.

Status of the cleanroom

At present (April 2019) the cleanroom is in an initial clean-up stage altering every day. As a result, we cannot precisely specify acquired dust counts to certify the cleanroom. The cleanroom has been constructed using materials and methods to easily reach ISO-5th class cleanness. With a time and patience, and steady improvements ISO-3rd class is possible. Recently visitors from Finland and Estonia cleanrooms inspected our facility construction and noted good design, right engineering ideas and suitable materials.

An unexpected side-effect was gained after electrically grounding the wall plates. The whole room forms a Faraday cage, where we may find as small as 1 pW/m^2 at 2.4 GHz electromagnetic influence and total of RF fields 1–3 μW/m^2. In contrast, a normal electromagnetically "very clean" place in average city suburb typically has 3–4 mW/m^2 of RF-EMI. However low frequency EMI is not so idyllic at 50 Hz, the substation transformer of the electric company gives the influence between 1–0.1 μT depending on place in the cleanroom. Understandably a Faraday cage is not able to block pure magnetics.

Use of the cleanroom

The cleanroom may be used for precision-mechanical assembly work in a clean environment (for products like CubeSats, HDD, experimental nano-devices, photonics micro-devices), for vacuum coating/sputtering technologies, and for low-noise electronics design calibration/testing. The cleanroom is equipped with a chemical box with plumbing for water and bidistillate. A multitude of indirect support technologies are installed nearby outside of the cleanroom including scanning electron microscope, ellipsometer thickness optical metering, angle measuring/setting with 3–5 angular seconds accuracy, wafer laser-inscriber, ingot cutter to wafers (Secotom), precision grinder, powerful adjustable lasers incl. UV, vacuum ovens (3-zone and 10-zone) and some induction heating systems (30 kW) that may be used for crystal growth. Thus, the full technological service centre to serve the needs of Latvia's photonics cluster is nearing readiness. The goal is to give anyone with a "bright idea" in photonics the possibility to try out that idea in metal & glass and test it at work giving the photonics sector in Latvia a boost to accelerate time from idea to innovative product.

Intelligent hardware and software for modernisation of universal high-resolution prism monochromator SPM-2 (*Carl Zeiss Jena*) applicable in near VUV, far UV, UV, visible and near infrared spectroscopy to measure light signals with low intensity

Arman Bzhishkian, Arnolds Ūbelis

National Science Platform FOTONIKA-LV, University of Latvia

E-mail: astrolit@gmail.com

Today's fast computer processors allow processing of large volumes of spectroscopic information creating opportunities to reuse and upgrade monochromators with sophisticated optical and mechanical systems that had been designed and used in the middle of the last century. Particularly specific interest is towards high resolution prism monochromators. We used this approach to computerise and automate the manual operation of the universal mirror monochromator SPM-2 equipped with changeable quartz, glass, NaCl and KBr crystal prisms. SPM-2 was produced by VEB Carl Zeiss Jena in the early 1960s (*in the former GDR*) and was widely used due to its advanced features [1]. The monochromator has an operational wavelength range from 190 µm in near VUV up to 40 µm in infrared spectral region and is equipped with an imaging mirror with a focal length of 400 mm, mechanically coupled entrance and exit slits, and coordinated prism setting and wavelength scale. Due to its broadband applicability from one side and high spectral resolution, SPM-2 is still attractive for a variety of spectroscopic measurements, but the manual operation mode is a serious disadvantage. Innovation with data processing system allowed us to perform high resolution measurements of atomic and molecular spectra in broad spectral region and, alongside ordinary measurements, to use cooled photomultipliers (PMT) in photon counting mode to measure very weak spectroscopic signals. We've saved a lot of resources by avoiding payment for very costly systems currently available on the market that don't have the advantage to perform the variety of measurements possible with a signal universal spectrometer.

The following steps were made to get computerised version of SPM-2 called SPM2+:

- The wavelengths knob of the monochromator is driven by a step motor controlled by a microprocessor, using data from a rotary encoder. This is necessary to avoid situations when motor steps are missed for any reason.
- PMT signal is converted into digital data with the help of ADC (*analogue digital converter*). These data are analysed by an ARM microprocessor and then sent to a PC using USB port. For correct PMT read-out, taking into account prism rotation, high sample rate ADC and high-speed microprocessor, must be used, to get digital data corresponding to $\Delta\lambda$ of the prism.
- Data visualisation is done by software, which is designed especially for the SPM2+ system. It represents a diagram with two axes. The horizontal axis is wavelength in angstroms or nanometres and the vertical axis is relative unit of PMT signal amplitude.
- It is well known that the ratio of the quartz refractive index/wavelength is not linear. To ensure comfortable visualisation of recorded spectra on the screen a specifically designed SPM2+ software algorithm automatically transforms data into linear scale.

References

[1] Schiek, O., Winter, E. (1965). Two New Mirror Monochromators, Applied Optics 4(2), p. 195.

Statistics on Participation to EU Horizon2020 SME Instrument Calls

Dina Bērziņa
Institute of Atomic Physics and Spectroscopy, University of Latvia
Dina.Berzina@lu.lv

Paper presents an overview on current results and statistics of country participation for the Horizon 2020 (H2020) SME Instrument proposals. All the results are from the European Commission Horizon Dashboard as of 29 April 2019 [1]. The Horizon Dashboard is public, interactive reporting platform that allows different views to filter the H2020 data. This brief review covers top-12 and Baltic countries for each of the analysed performance categories. The overall comparative country performance is compiled in Table 1.

Table 1. *Horizon 2020 top-12 and Baltic countries' participants*

	Top-12 & Baltic Countries	***success rate***			***participation***			
		H20		***SME***	***H20***		***SME***	
	1		2		3		4	
1	FO – Faroe Islands	24%	FO	22%	DE	13,110	ES	885
2	IE – Ireland	21%	IS	18%	UK	12,335	IT	667
3	IS – Iceland	21%	CH	16%	ES	11,220	UK	440
4	BE – Belgium	19%	AT	12%	FR	10,527	DE	322
5	AT – Austria	18%	DK	11%	IT	10,312	FR	280
6	CH – Switzerland	18%	IE	10%	NL	6,744	IL	218
7	FR – France	18%	NO	9%	BE	4,932	SE	207
8	LU – Luxembourg	17%	IL	9%	SE	3,274	NL	205
9	TN – Tunisia	17%	SE	9%	AT	3,044	DK	190
10	NL – Netherlands	17%	ES	9%	EL	3,010	FI	146
11	DE – Germany	17%	NL	8%	CH	2,970	CH	123
12	BA – Bosnia and Herzegovina	17%	UK	8%	DK	2,451	NO	117
	LV – Latvia – 24	14%	EE – 16	7%	EE – 26	495	EE – 21	57
	EE – Estonia – 25	14%	LT – 18	7%	LT – 29	362	LT – 24	27
	LT – Lithuania – 30	13%	LV – 32	3%	LV – 32	314	LV – 27	16
	Total H2020	**15%**		**7%**				

DK – Denmark, EL – Greece, ES – Spain, FI – Finland, IL – Israel, IT – Italy,
NO – Norway, SE – Sweden, UK – United Kingdom

As one can observe, the highest success rates (ratio of submitted/funded project proposals) are for smaller countries. From EU big-5 only France is in top-10 ranking as 7th. According to the number of participants, the big-5 is followed by the Netherlands, Belgium, Sweden, Austria and Greece (Tab. 1, column 3). From Baltic countries, the smallest – Estonia, is convincingly leading according to number of participations and retained EU funding: on average 1.5 times more participants and twice as much funding compared to Latvia/Lithuania). However, the country performance is different for H2020 SME Instrument type of action (Tab. 1, columns 2 and 4).

The SME Instrument supports top class innovators, entrepreneurs and small companies with funding opportunities and acceleration services. The main focus of the SME Instrument is on market-creating innovations that shape new markets and generate jobs, growth and higher standards of living. Currently (2018–2020) there are no topics set – any[1] innovative company can submit their bright ideas. However, the competition for this kind of proposals is much tougher, resulting only in 7% success (the overall for H2020 is 15%). Since the success rates for SME Instrument proposals are extremely low, EC has introduced the "Seal of Excellence" (SoE) – a quality label awarded to project proposals, which were evaluated to deserve funding (scored 13 or above) but did not receive it due to the budgetary constraints. Such proposals can be financed form national funds without additional re-evaluation of the proposal. It should be noted – there are two kinds of SME Instrument proposals: Feasibility study – Phase 1 and From concept to market – Phase 2; Phase 1 projects are entitled for a lump sum of EUR 50,000 and should last around 6 months, Phase 2 projects could include trials, prototyping, validation, demonstration and testing in real-world conditions, and market replication and concern a Technology Readiness Level (TRL) of 6 or above. Projects could ask for up to EUR 2.5 million and last for 12 to 24 months [2]. The success rates and SoE awarding frequency are different for both of them: for Phase 1 the success rate is 9% and SoE awarding rate is 10%; for Phase 2 success rate is 5% and SoE awarding rate is 34% [1] – Tab. 2 represents the average success and SoE rates for SME Instrument.

Table 2. *SME Instrument top-12 proposers and project participants (including Baltic countries)*

	Top-12 & Baltic Countries	***total number of SME instrument***					***average success rate***			
		pro-posals	***participa-tions***		***SoE***		***SME Instrument***		***SoE***	
	1		2		3		4		5	
1	IT – Italy	10 756	ES	885	ES	2 567	FO	22%	DK	31%
2	ES – Spain	10 536	IT	667	IT	2 041	IS	18%	IS	30%
3	UK – United Kingdom	5 542	UK	440	UK	1 314	CH	16%	IL	29%
4	DE – Germany	4 098	DE	322	DE	1 006	AT	12%	SE	29%
5	FR – France	3 781	FR	280	FR	947	DK	11%	AT	29%
6	NL – Netherlands	2 563	IL	218	IL	756	IE	10%	CH	29%
7	IL – Israel	2 560	SE	207	SE	727	NO	9%	FI	27%
8	SE – Sweden	2 453	NL	205	NL	626	IL	9%	NO	25%
9	FI – Finland	2 082	DK	190	FI	564	SE	9%	FR	24%
10	HU – Hungary	2 019	FI	146	DK	562	ES	9%	ES	23%
11	PL – Poland	2 000	CH	123	HU	355	NL	8%	NL	23%
12	DK – Denmark	1 746	NO	117	NO	334	UK	8%	DE	23%
	EE – Estonia – 23	821	EE – 21	57	EE – 20	175	EE – 16	7%	EE – 17	20%
	LV – Latvia – 26	539	LT – 24	27	LV – 25	81	LT – 18	7%	LT – 24	14%
	LT – Lithuania – 28	434	LV – 27	16	LT – 28	64	LV – 32	3%	LV – 25	14%
							Total	**7%**		**20%**

AT – Austria, CH – Switzerland, FO – Faroe Islands, IE – Ireland, IS – Iceland, NO – Norway

[1] All applicants need to be legally established in the EU-28 or in a country associated to Horizon 2020: http://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/hi/3cpart/h2020-hi-list-ac_en.pdf

Comparing country performance one can guess – in which countries there is an established mechanism (governmental policy) for supporting SMEs and which are lacking it…

Latvian entrepreneurs implement 13 Phase 1 and 3 Phase 2 projects [3].

a)

b)

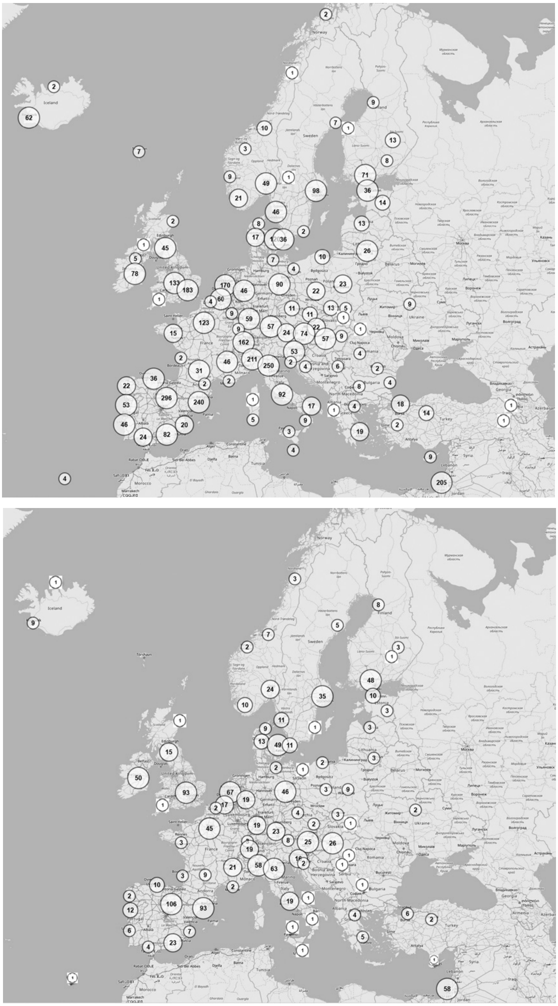


Figure 1. *SME Instrument data hub: a) Phase 1, b) Phase 2. Data from 22 July 2019*

References

[1] European Commission. Horizon Dashboard. https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-dashboard. Data from 29 April 2019.

[2] European Commission, Executive Agency for SMEs. EIC SME Instrument. https://ec.europa.eu/easme/en/eic-sme-instrument [cited 2019 May 22].

[3] EIC SME Instrument data hub: https://sme.easme-web.eu.

Concept-project: Three physics problems shoot by one electro-technical hit

Jānis Blahins, Viesturs Silamiķelis, Arman Bzhishkian

National Science Platform FOTONIKA-LV, University of Latvia

E-mail: janis_59@inbox.lv

The 1971 Intel-4004 computer core contained 23,000 transistors. Some 44 years later, the 6th generation Intel Core Skylake CPU has 1.3 billion. Computer components have been extremely miniaturised. If smallest dust particle be noted by eye is 50 microns, nowadays the patch sizes for IC technologists mostly use are 45 μm with accuracy of ±5, where p-n barrier layer size is 20 μm – actually smaller than a swine-flu virus diameter. From 2015/16 Intel is shifting to 3-fold thinner technology of 15 μm. Thus, the size is a physical reason why CPU power supply (PS) voltage for PC cores is extremely small ~1 V, but current is extremely high, typically desktop PC cores run at 100–150 A. Computer PS (ATX or altered) are not able to produce such amperage. Specialised step-down converters, such as two integrated circuits (IC) HiP6301+HiP6601 located near the CPU on the motherboard are used to convert 12 V to 1 V, proportionally rising amperage. Using switched modes power source (SMPS) technologies this is a rather simple task even if multiphase technique is the high-end state of the art of SMPS technologies. We see use of this specific technique in physics technologies in applications highly removed from PC circuits. The HiP6301+HiP6601 ICs have many newer successors. These modern IC are not as handy for our purposes as the older Hi6301+Hi6601 models.

Aims for use:

- A few turns of electrical coil on a core can be used to build a strong permanent electromagnet. For a boron ion source such is needed to provide the "magnetic rope" of plasma. In physics research equipment low voltage high amperage stabilised PS are commonly used to feed power to DC magnets. For a boron ion source, a DC-PS is needed that produces several hundred Amps at voltages as small as 1 V to 2 V. Such PS may thus unlock the new horizons for ion source technologies adapting it for hard-melting metal ions. Until now there are no PS available to buy as an "off the shelf" offering output at such high current and stabilised. For user a 100 A PS may be viewed as "small" and 1000 A as "good".
- Coils with a few turns that produce AC at acoustic range frequencies for three-phase rotating field electromagnet demand another type of specialised PS as well. Such a magnet may be applied for semiconductor (especially for small viscosity) materials rectification (zone purification) in the state of vacuum levitation or pseudo-levitation. Even if the need is for 1 or 2 or 4 phases, the circuitry may be uniform. Such a 3-phase PS for support of levitation magnetic systems may unlock new horizons for ultra-pure semiconductor rectification and/or ultra-pure crystal growing, because such a field can provide magnetic levitation in vacuum without-contact of the growing ingot with the crucible wall, enabling extremely high purity crystal growing. If such magnet may have a Gauss 0.5 mH inductance, then U = di/dt*L = 1/2/3.14*500.000 Hz*0.0005 H = 40 V at 0.5 MHz. Contrary, at 50 kHz the current demand I = N/u is resulting in 120 A for 5 kW estimated maximum power. Similarly, as noted above, there are no such flexible and adjustable PS available "off the shelf" in the market.

- Few turns RF coil for electromagnet applied for the same need can also be used to produce induction heating thermal energy. Generally, as frequency is elevated, the magnetic field causes swirling mechanical movement and produces greater thermal impact. Mechanical movement is detrimental when mass is suspended in empty space, thus the frequency must be as high as permissible to allow effective functioning of the system. Experimentally it is known that 1 MHz is too little, thus the next target is about 3 MHz. Levitation demands both PS units to work together simultaneously producing acoustic frequencies for suspending the ingot and RF frequencies for heating the ingot with precise adjustment of the balance between both power sources. Ease of adjustment of the power and frequency plays a crucial role in maintaining the stability required for proper functioning. Many generators are available in the market rated at 1 MHz, but at 3 MHz there are no devices in the 30 kW range. To develop a suitable device, we considered a relatively rare "vertical" half-bridge topology what was elaborated and patented in the 1980~ies by the international company Johnsson/Trumpf (now Rolands Moisejs Ltd) for induction heating systems that used high power MOSFETs, because they are relatively insensitive about clocking inaccuracies.

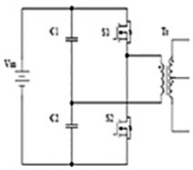


***Figure 1**. Custom (horizontal) half-bridge*

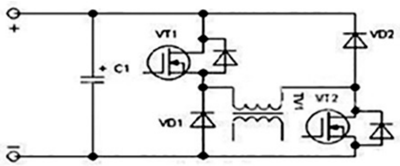


***Figure 2**. Skewed half-bridge (switch forward converter)*

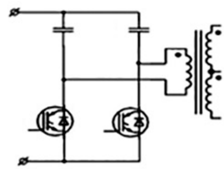


***Figure 3**. Vertical half-bridge*

The proposed solution for solve all three tasks at once:

All those three circuits may be synthesised on basis of ordinary computer-core PS circuitry, with minor modifications described below. The circuit topologies are used according the data-sheets of HiP6301 / HiP6601 and their application notes (AN).

- DC 1 V 240 A CC-CV-SMPS circuit contains four identical HiP6601 sections swung by HiP6301 in 4-phase shifts for chopping the power of the step-down converter. So, the output transistors are thermally independent because they are active serially one after another in shifts, thus may persist rather large overload with radiators as small as 50 cm^2. PWM loop for regulating may be taken from a linear voltage regulator like LM7805 or TL431 comparing it to circuit output voltage (or current), thus providing the regulation and stabilisation of output current by one knob. If 240 A is not enough, there are possible to use a stronger output MOSFETs, or apply a current booster, or parallelise output transistors. Taking into account that frequency here is far from the maximum permitted, allows consideration of the simplest of these solutions – use BSC050 but with 4 pieces parallel in each channel, one HiP6601 (what is gate driver) ought be able to steer all four MOSFETs as one unit (a gate resistor is needed for each separate, as always), may resulting in about 1000 A output, what is better than our best expectations. The radiator area required is comparable to one or two PC core ribs under PC fan, thus the unit could be rather miniature in size.
- 3-phase 50 kHz–500 kHz generator of 5 kW contains three HiP6601 sections driving straight toward both HiP data-sheets recommended output transistors (12 V, 58 A,

BSC050) or using an appropriate booster cascade after it for larger output voltage and amperage. Three phase output here means the sequential pulses one after another at three outputs of HiP6301 with positive voltage and then sequence repeats. The PWM of generator is adjustable by one knob and frequency with another knob, keeping the form-factor of the output signal ultra-symmetrical, which is very important to keep the magnetic field from being skewed. As the output works in on/off mode the sinus-like form-factor (if any is demanded) must be organised by means of proper resonant capacitors on the coils.

- 0.03–3 MHz 600 V 30 kW induction heating generator contains two HiP6601 sections to provide the low side driving of gates for 6 paralleled IXFH42N60 in each shoulder, where the adaptive regulation loop is organised between pin (7) of HiP6301 and the resonant output coil end, giving a one-knob adjustment for stabilised output power. As soon the pin (7) gets more than 1.1 V, the oscillations are stopped, whilst near below the PWM is regulated between 5%–70%. The circuit also stabilizes the output current for gates to 58 A, so saving BSC050 gate booster from being overloaded. Frequency is adjusted by one knob, or used for PLL circuit (CD4046) alternatively, for resonance lock-in. For choice of resonant tank capacitors at heater coil, assumed diameter 200 mm and z = 3 what makes 2–3 μH, what demands two 2200 pF of high kVAR-proof capacitors. Such capacitors made by Vishay or other competitor may cost several thousand dollars. We found another solution to use Rogers Corp. Teflon-based PCB material Duroid-5880(R) with 1.73 pF/cm^2, thus the need is for 35 x 35 cm sheet placed under fan, what may cost only about $350. At loss factor tan(δ) = 0.00035 the thermal flux out of capacitor sheets may be so high as 30 kW*quality factor 100*0.00035 =1 kW – thus the ordinary PC fan would be capable to cool it down with an ease.

Discussion

The combination HiP6301–HiP6601 gives unique possibilities for magnet PS design even though these ICs are not the last word in the PC Cores PS tech. Designing & testing of such project is important, because it may lead to many benefits in novel physical technologies development at ion physics and crystal grows technologies.

ANNEX
Author Index

Publisher: University of Latvia Press
Aspazijas bulvāris 5, Riga, LV-1050
www.apgads.lu.lv
apgads@lu.lv