NEWSLETTER

of the International Consortium “Development of High-Power Terahertz Science & Technology”

June 2017 № 6

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EDITORIAL: HOW TO CONTRIBUTE TO THE NEWSLETTER

Dear Reader,

We are inviting contributions to the following rubrics:

- Research highlights (annotations) presenting the projects pursued by the members of the Consortium.
- Short regular papers.
- Proposals for collaborative research work.
- News from the participating institutions.
- Information about conferences, symposia, workshops, seminars.
- Programs and frameworks for an exchange of visits and mobility of researchers. Job opportunities (especially for young researchers, e.g. postdoctoral positions, specializations, internships).
- Annotations of books, conference proceedings, software and internet resources. Additions to the list of the recent scientific publications and conference reports at the website of the Consortium (http://fir.u-fukui.ac.jp/Website_Consortium/publist.html).
- Information and announcements about awards and nominations.
- Short presentations of laboratories and research groups belonging to the participating institutions.

Please submit your contributions to the Newsletter as well as requests for information to:

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NEWS FROM THE MEMBERS OF THE CONSORTIUM

The 6th International Workshop on Far-Infrared Technologies 2017 (IW-FIRT 2017)

The 6th International Workshop on Far-Infrared Technologies 2017 (IW-FIRT 2017) and the 2nd International Symposium on Development of High-Power Terahertz Science and technology (DHP-TST 2017) organized by the Research Center for Development of Far-Infrared Region has been held successfully at the University of Fukui from 7th to 9th March, 2017.

Testing the European 1MW/170 GHz gyrotron at KIT-IHM

Excellent results for the European 1 MW gyrotron prototype were reported on 28 February 2017 (visit: http://fusionforenergy.europa.eu/mediacorner/newsview.aspx?content=1099). It has been developed in a collaboration between the manufacturer – the French company Thales Electron Devices (TED) and the European Gyrotron Consortium (EGYC) as a powerful source for Electron Cyclotron Resonance Heating (ECRH) of fusion plasma in ITER. During testing, the gyrotron (pictured below) repeatedly produced up to 0.8 MW of output power during periods of 180 seconds – the maximum time possible at the test facility at Karlsruhe Institute of Technology (KIT). These results have been assessed by an independent expert panel which concluded that for a first gyrotron prototype, they are impressive.

SHORT PAPER

Design for a Power Combiner in the range around 460 GHz

Walter Kasparek, IGVP Stuttgart, walter.kasparek@igvp.uni-stuttgart.de;

Possible application: DNP experiments with two combined frequencies

1. source: gyrotron with variable frequency f_1 = 459 GHz ….461 GHz
2. source: gyrotron with fixed frequency f_2 = 460.4 GHz

Input / Output waveguides: HE11, diameter 19.05 mm

Power combiner based on ring resonator

Principle:

The power combiner is based on a ring resonator consisting of 4 mirrors, two of them are focusing, two plane phase gratings provide the coupling to the input and output. For combining two sources of different frequency, one source (with resonant frequency f_2) is coupled through the resonator, and one source (with non-resonant frequency) is reflected from the resonator.

The transmission characteristics are defined by the grating efficiencies, the internal loss of the resonator, the round-trip length L in the resonator, and frequency f. If the grating efficiency for zeroth order and -1st order are denoted as R_0, R_{-1}, respectively, and the round-trip efficiency of the unloaded resonator as R_q, then the power transmission coefficients from the input to outputs 1 and 2, respectively, are given by

$$T_1(f) = R_0 \cdot \frac{1+R_q-2\sqrt{R_q}\cdot\cos(2\pi Lf/c)}{1+R_0^2R_q-2R_0\sqrt{R_q}\cdot\cos(2\pi Lf/c)} \qquad (1)$$

$$T_2(f) = \frac{R_1^2\sqrt{R_q}}{1+R_0^2R_q-2R_0\sqrt{R_q}\cdot\cos(2\pi Lf/c)} \qquad (2)$$

with $R_0 + R_{-1} = 1$.

Typical calculated transmission functions of the diplexer are shown in Fig. 1

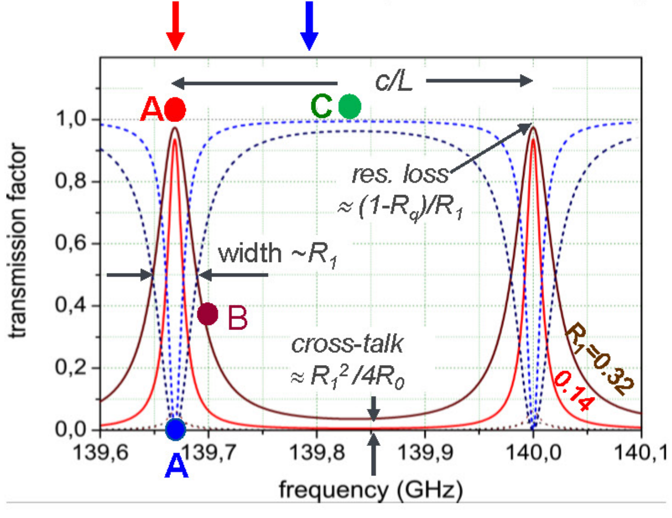

Fig. 1: *Transmission functions showing the dependence on main design parameters*

Mechanical design:

The cube design given in Fig. 1 is very stable and robust. The walls of the cube include the optical elements. The top plate carrying one of the resonator mirrors is spring loaded to allow tuning of the diplexer resonance to the frequency of gyrotron 2.

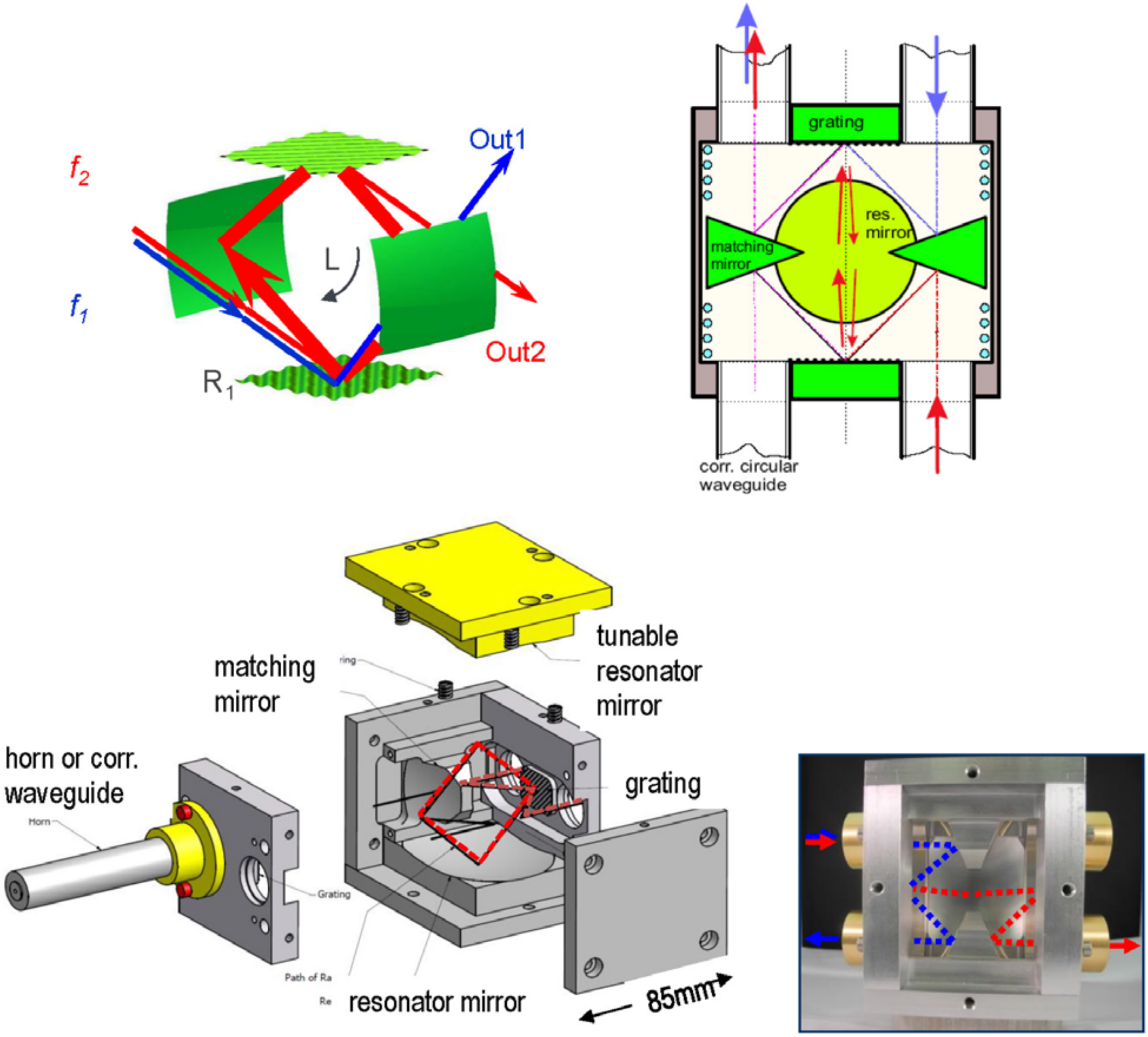

Fig. 2: *Mechanical design for ring resonator with resonator length L = 183 mm. Upper, left: Principle; note that power combining occurs with the beam path inversed compared to the figure.* ***Upper right: positon of the inputs and outputs for power combination****. Bottom, left: mechanical design. Bottom, right: Photograph with beam path.*

Example for transmission functions (depend on resonator length *L* and coupling grating R_1, influences insertion loss and useful bandwidth):

Ring resonator with resonator length of L = 183 mm (like drawing Fig. 2). Simplest solution, can be produced by reaching surfaces of an available resonator diplexer.

Insertion loss: typ 0.5 dB for gyrotron 1, and 1.5 dB for gyrotron 2

Frequency ranges: gyrotron 1: 458.9 ... 460.28 GHz, and 460.52 ... 461.8 GHz
gyrotron 2: 460. 4 GHz ± 10 MHz

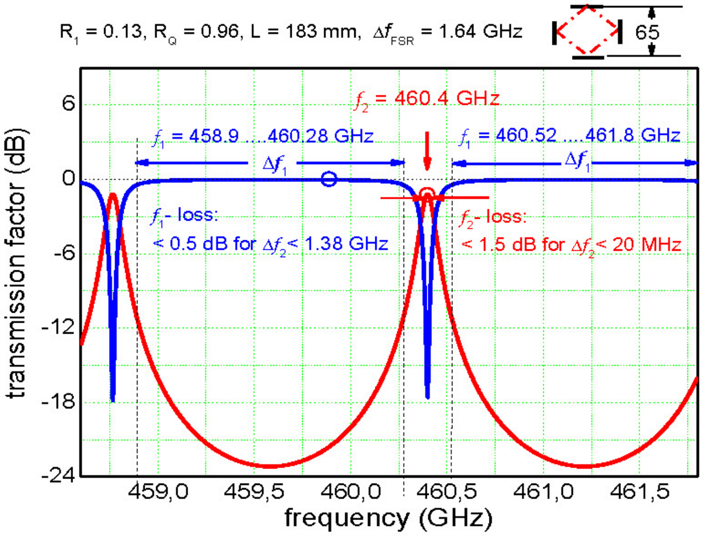

Fig. 3: Transmission function for ring resonator with L = 183 m, R_1 = 0.13

Ring resonator with resonator length of L = 367 mm (dimensions 2 x as large as in drawing Fig. 2; reduced loss, more complicated).

Insertion loss: typ. 0.5 dB for gyrotron 1, and 1.0 dB for gyrotron 2

Frequency ranges: gyrotron 1: 458.86 ... 459.49 GHz / 459.68 ... 460.31 / 460.49 ... 461.12 GHz
gyrotron 2: 460. 4 GHz ± 7 MHz

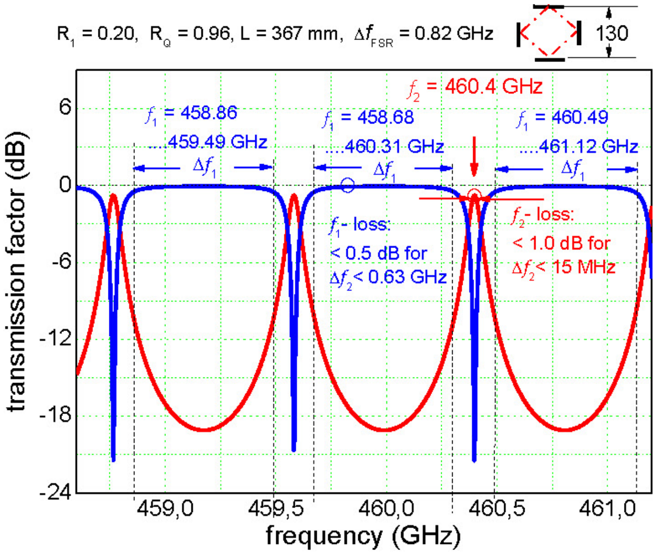

Fig. 4: Transmission function for ring resonator with L = 367 mm, R_1 = 0.20

Design of optical elements (data files and technical drawings are available from the author):

The three types of reflectors, matching mirror, resonator mirrors, and gratings are shown in Fig. 5 and 6.

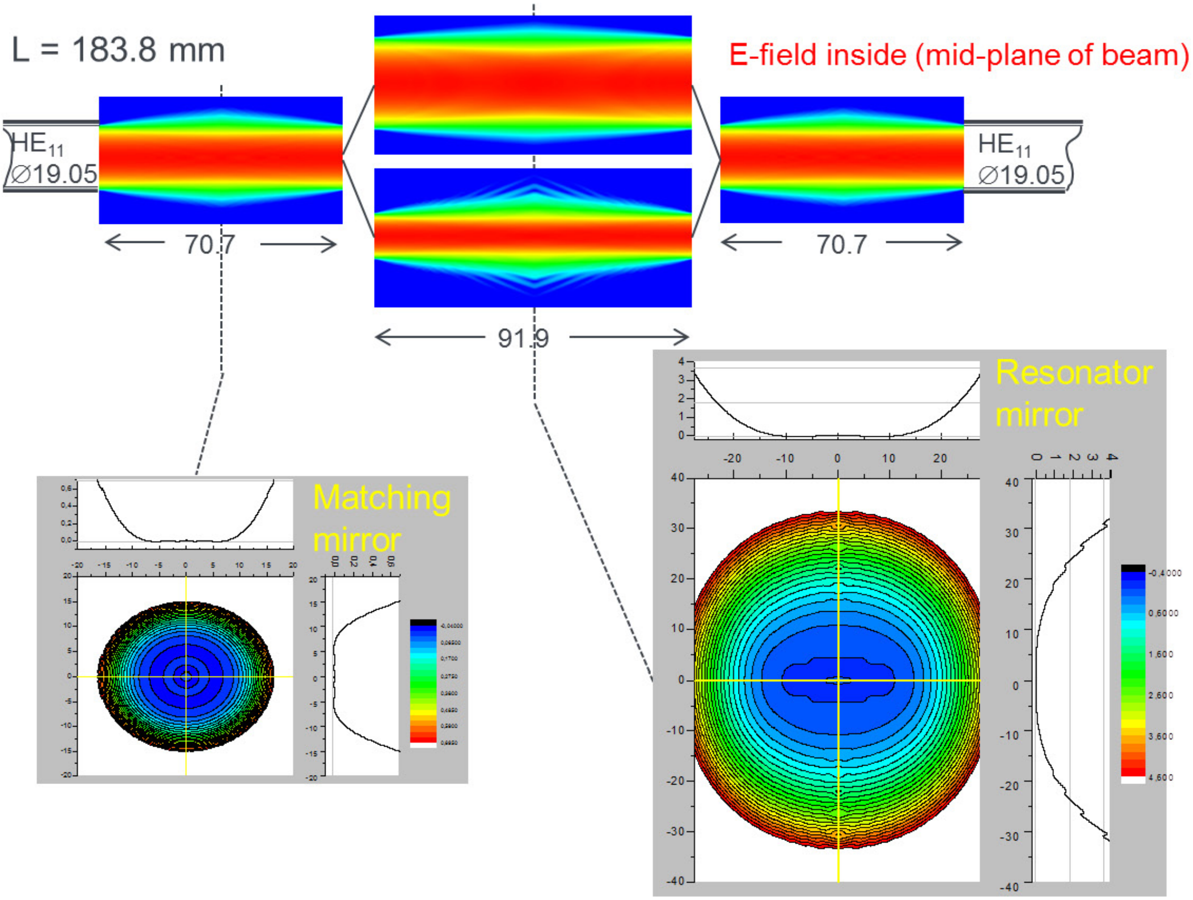

Fig. 5: Top: Beam path from the input waveguide aperture via matching mirror to grating 1 (left), beam path from grating 1 via the resonator mirror to grating 2 (middle), and beam path from grating 2 via the output matching mirror to the output waveguide (right), in E-plane and in H-plane. Bottom: Profiles of the matching mirror (left) and the resonator mirror (right).

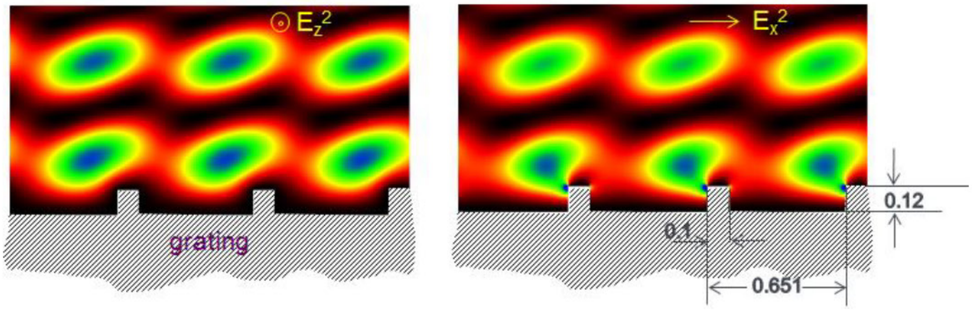

Fig. 6: Coupling grating with parameters for $R_1 = 0.25$

Table 1: parameters of coupling gratings for 460 GHz with various coupling factors, but identical coupling for TE and TM polarization.

Coupling grating efficiency R_1	Period p (mm)	depth t (mm)	Width of groove c (mm)	With of tooth b (mm)
0.13	**0.651**	**0.095**	**0.576**	**0.075**
0.2	0.651	0.110	0.561	0.090
0.25	0.651	0.120	0.551	0.100

Integration issues:

The reference plane for the end/start of the waveguide is the outer surface of the casing.

The neutral position of the tuning plate of the resonator is characterized by a slit of 1 mm between casing and plate.

The polarization for the diplexer is linear, and is inclined with respect to the casing as shown in Fig. 7.

Control of the temperature of the diplexer is probably needed to keep resonance condition. Note that the thermal tuning sensitivity is approx. 10 MHz/degree C.

The residual power which is not coupled to the combiner output shows up at the fourth (isolated) output; here an appropriate load needs to be installed.

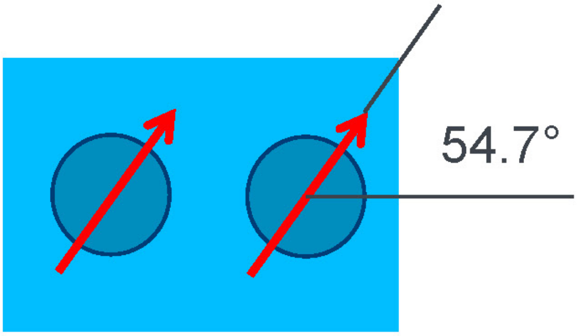

Fig. 7: Orientation of the input and output polarization (view onto the waveguide flange connections).

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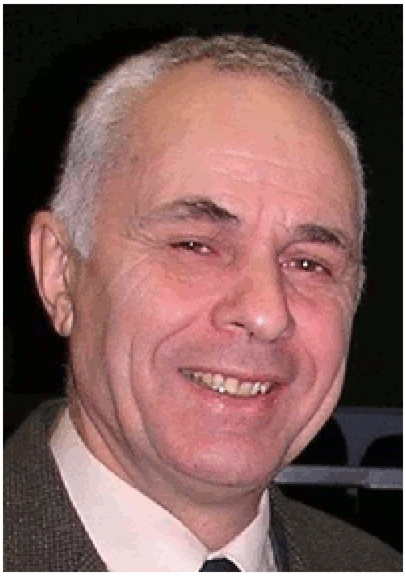
Z. Wu et al., IEEE Trans. Microwave Theory Techn. **63** (2015) 3537.

Michail Petelin (on his 80th birthday)



Professor Michael Ivanovich Petelin was born on 7 March 1937 in Nizhniy Novgorod. He graduated from the University of Nizhny Novgorod, Russia, in 1959. He has been employed since then by the Russian Ministry for Higher Education and the Russian Academy of Sciences, combining theoretical and experimental research activities with the training of new generations of researchers at the Institute of Applied Physics, Russian Academy of Science in Nizhny Novgorod and at the Nizhny Novgorod State University. He has held positions as a visiting professor at the University of California, Davis, Seoul University, Korea, Institute of Electronics, Chinese Academy of Sciences, Beijing, and the Research center for Development of Far-Infrared Region at the University of Fukui, Japan..

Prof. M. Petelin has worked since nearly the beginning of his career on the theory and design of components for high power coherent radiation sources using relativistic electron beams. From 1963 to 1973 he led a team of scientists and engineers that developed the gyrotron. During that period the peak power achieved in a gyrotron increased from a few watts to 1MW. Gyrotron oscillators are now commonly used for plasma heating and current drive in magnetic fusion systems. Gyro-amplifiers are used in long-range high-resolution radar systems. Starting in 1969, jointly with various Russian, American and European teams, Prof Petelin led research to develop gigawatt, nanosecond pulse microwave generators driven by high-current electron accelerators. In 1996 such a microwave generator was used in the UK-Russian research radar NAGIRA. From 1966 Prof. Petelin led the development of quasi-optical wave transmission and control components, including mode converters, polarizers, pulse compressors, and multiplexers for matching high power millimeter and microwave sources to various systems. Recently he helped develop the German-Italian-Russian quasi-optical duplexer FADIS, which is used for combining powers from two 140 GHz / ~1MW gyrotrons and for fast switching of the combined beam. These duplexers are designed to help control hot plasmas in fusion experiments.

In 1967 Prof. Petelin was the co-recipient of the State Prize of the USSR for the development of the gyrotron and in 2003, the State Prize of Russia for the development of pulsed High Power Microwave generators. In 1996 he was awarded the K. J. Button Prize for his contributions to research on millimeter waves. In 2011 Professor M. Petelin received the John R. Pierce Award for Excellence in Vacuum Electronics for “the invention of the gyrotron and for seminal contributions to the development of relativistic coherent radiation sources and quasi-optical components for high-power RF systems” (Visit: http://vacuumelectronics.org/ivec_award/michael_petelin.html).

ANNIVERSARY

Institute of Applied Physics of the Russian Academy of Sciences has marked its 40th anniversary

In May, 2017 the Institute of Applied Physics of the Russian Academy of Sciences has celebrated its 40th anniversary. For photos and videos of this event please visit: http://www.ipfran.ru/news/40/news_40.html.

ИПФ РАН Institute of Applied Physics of the Russian Academy of Sciences

The IAP RAS is a multipurpose institution combining basic and applied research in the field of plasma physics, high-power electronics, physics of the atmosphere, hydrophysics, and quantum electronics. The gyrotrons, i.e., high-power millimeter-wave oscillators, and respective results on interaction of high-power electromagnetic radiation with plasma and matter are widely used in controlled nuclear fusion facilities. In cooperation with the scientific and production enterprise GYCOM the IAP RAS has become one of the world leaders in developing gyrotrons for different purposes. Theoretical and experimental achievements in nonlinear and adaptive optics have been the basis for the construction of high-power laser systems at the IAP RAS, including a femtosecond laser complex of petawatt power. The pioneering research in the field of acoustics performed as early as in the 1960-1970s has led to the development of new highly sensitive methods of nondestructive testing and defectoscopy. Many years of experience in the field of precision optical measurements ensured the development and introduction into clinical practice of a generation of methods and instruments of optical biomedical diagnostics. Large-scale field studies and unique solutions in low-frequency ocean acoustics resulted in the creation and industrial application of advanced tools of hydroacoustic metrology and diagnostics of complex vibroactive systems, the implementation of coherent methods of high-resolution seismoacoustic diagnostics, etc. Many of the research lines actively developed at the IAP RAS are related to the inverse problems of remote diagnostics and tomography of different objects. Recently studies in the topical problems in physics of condensed media and quantum physics, attosecond physics, nanophotonics, modeling and construction of neuromorphic systems, the development of physical principles and technologies for the creation of nanostructural materials, study of catastrophic phenomena in the Earth’s natural shells (ocean and atmosphere), and the development of new-generation tools and techniques for diagnostics of natural environments and complex technical systems have successfully been started at the Institute. The Institute has a powerful experimental base and a large set of modern diagnostic tools for both laboratory and field experiments. The research activities are provided by more than 1100 employees, of which about 450 are research scientists, including 4 full members of RAS, 7 corresponding members of RAS, 90 doctors of science and 197 candidates of science.

Excerpt taken from the web site of IAP-RAS. Visit: http://www.ipfran.ru/english/info_e.html

LIST OF SELECTED RECENT PUBLICATIONS

Bibliography and links to selected recent publications on topics related to the research field of the International Consortium

This is a cumulative list of selected publications in a chronological order as collected from various bibliographical and alert services and published after February 2017, i.e. after issuing the previous Newsletter #5

A. Publications by authors from the institutions participating in the International Consortium

Ginzburg N.S., Denisov G.G., Vilkov M.N., Sergeev A.S., Zotova I.V., Samsonov S.V., Mishakin S.V., “Generation of trains of ultrashort microwave pulses by two coupled helical gyro-TWTs operating in regimes of amplification and nonlinear absorption,” Phys. Plasmas, 24 (2017) 023103. DOI:10.1063/1.4975084.
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C. Patents

Mirrors Transparent to Specific Regions of the Electromagnetic Spectrum
United States Patent Application 20170025992
Inventors: Atwater, Harry A. (South Pasadena, CA, US), Pellegrino, Sergio (Pasadena, CA, US), Hajimiri, Seyed Ali (La Canada, CA, US), Warmann, Emily C. (Riverside, CA, US)
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D. New books

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NEWS FROM THE NET (OUR BROADER HORIZONTS)

NEWS FROM IVEC

John R. Pierce Award for Excellence in Vacuum Electronics 2017 received by Yue-Ying Lau

“For seminal contributions to our understanding of the technical foundations of vacuum electronics, and for training generations of talented engineers and scientists in the field.”

Yue-Ying Lau made contributions to gyrotron traveling wave amplifier, fluid theory of gyrotron, multipactor discharge, relativistic klystron, accelerator and Z-pinch stability, quantum and higher-dimensional Child-Langmuir Law, low noise magnetron, Thomson X-ray sources, and electrical contact. He has eleven patents and over 230 refereed publications.

See more at: http://vacuumelectronics.org/ivec_award/yy_lau.html

Alexander Soane wins International Vacuum Electronics Conference best student paper award

”MIT graduate student Alexander Soane received the best student paper award at IEEE 18th International Vacuum Electronics Conference (IVEC), held in London from 24 to 26 April 2017. Soane works at MIT’s Plasma Science and Fusion Center (PSFC) on microwave sources, specifically on an amplifier for generating high-gain, high-power, and high-frequency millimeter wave radio frequency power. Using the PSFC’s gyrotron, he is trying to create a source for specific pulses of 140 GHz microwaves that will excite the electron spin system in a chemical sample in a nuclear magnetic resonance spectrometer. Soane says chemists can hope to see the signal from their spectrometer enhanced by a factor of more than 100, allowing them to acquire data faster, cutting costs, and speeding up research into protein structure.”

Visit the source at: http://news.mit.edu/2017/sasha-soane-wins-ivec-best-student-paper-award-0517
The abstract of the awarded conference report (A 140 GHZ GYRO-AMPLIFIER USING A DIELECTRIC-LOADED, SEVER-LESS CONFOCAL WAVEGUIDE by A.V. Soane, M.A. Shapiro, and R.J. Temkin) is available at: https://tinyurl.com/y9hkzv2u