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The research programme 'Extreme Light Fields and Their Applications' (2012–2014) of the Presidium of the Russian Academy of Sciences

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During the last decade due to rapid development of laser technologies new achievements have been made in extending energy, temporal, and frequency characteristics of laser radiation. Currently the peak power of laser pulses, achieved in several laboratories in the world, is 100 times higher than the total power of all sources supplying all kinds of energy on the Earth. When focusing such a pulse, the optical field is almost three orders of magnitude higher than that of a typical field inside an atom, and the measured duration of the shortest pulse is smaller than the electron orbital period in a hydrogen atom. Frequency stability in the available femtosecond optical clocks allows measurements of fundamental constants with higher precision, than using other methods. The research area, related to production and use of optical fields with currently record-breaking characteristics, has recently become referred to as 'physics of extreme light'.

The fundamental research programme 'Extreme Light Fields and Their Applications' of the Presidium of the Russian Academy of Sciences is aimed at fabrication and experimental use, in the RAS institutions, of various unique sources of coherent electromagnetic radiation with extreme (currently record-breaking in the world) characteristics, namely, the pulse duration smaller than 100 as, the intensity of the radiation greater than 10^{23} W cm^{-2}, the wavelength range smaller than 1 nm, the optical frequency stability better than 10^{-15}. Fabrication of sources with such parameters will in the nearest future allow conduction of fundamental research in essentially novel areas of science, including the investigation of vacuum properties in the presence of super-strong fields, laboratory modelling of the processes that occur in the interior of stars and planets, implementation of quantum control of intramolecular and intra-atomic processes, observation of temporal drift of fundamental constants. Compact laser accelerators of charged particles with the energies within 1 GeV, based on the focusing of petawatt optical pulses on targets, will open the possibility to perform high-energy physics experiments in academic laboratories. Together with fundamental research, the programme implies development of basic practical applications of extreme fields, such as compact ion sources for hadron therapy, X-ray sources for low-dose phase-contrast X-ray tomography, ultra-stable sources for newest navigation systems.

The Programme continues and develops the research, carried out in the course of executing the Programmes of the Presidium of the Russian Academy of Sciences 'Femtosecond optics and new optical materials' (2002–2008) and 'Extreme light fields and their applications' (2009–2011). During all these years the co-coordinators of the Programmes are Academician S.N. Bagayev and Academician A.V. Gaponov-Grekhov.

The results, achieved in the previous years, are acknowledged in the world, which is confirmed by the full-scale participation of our country (represented by RAS institutes) in the international projects on the development of unique laser facilities. These are the ELI (Extreme Light Infrastructure) and HiPER (High Power Laser Energy Research) projects. Moreover, the successful studies carried out at the Applied Physics Institute and other RAS institutes in the area of super-high power lasers became a basis for including the megaproject XCELS (eXawatt Centre of Extreme Light Studies), aimed at development of a sub-exawatt laser system, into the list of megaprojects ('Megascience') in Russian. At present, the proposal on implementation of this megaproject is submitted to the Government of the Russian Federation.

The Programme includes the following sections:

1) multi-petawatt and sub-exawatt lasers;

2) high-pulse-repetition-rate sub-petawatt lasers;

3) laser-plasma acceleration of charged particles up to ultra-relativistic energies;

4) physics and fundamentals of practical application of interaction between superstrong optical fields and matter;

5) ultrastable sources of optical radiation and high-precision femto-and attosecond metrology;

6) novel optical materials and devices for lasers with extreme parameters.

Nineteen RAS institutes participate in the Programme, namely, Institute of Applied Physics of RAS; A.M. Prokhorov General Physics Institute of RAS; P.N. Lebedev Physics Institute of RAS; Institute for Physics of Microstructure of RAS; Fibre Optics Research Centre of RAS; Institute for Spectroscopy of RAS; Institute of Crystallography of RAS; Fryazino Branch of the Institute of Radio Engineering and Electronics of RAS; Joint Institute for High Temperatures of RAS; Institute of Chemical Physics of RAS; Institute of Chemistry of High-Purity Substances of RAS; Institute of Microelectronics Technology and High Purity Materials of RAS; Institute of Laser Physics, Siberian Branch of RAS; Institute of High Current Electronics, Siberian Branch of RAS; Institute of Atmospheric Optics, Siberian Branch of RAS; Institute of Nuclear Physics, Siberian Branch of RAS; Institute of Geology and Mineralogy, Siberian Branch of RAS; Institute of Electrophysics, Ural Branch of RAS; Institute of Automation and Control Processes, Far Eastern Branch of RAS.

The results, obtained in the course of the Programme in 2012, are partially published in March and April issues of 'Kvantovaya Electronika' (Quantum Electronics).

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