

MODERN NONLINEAR OPTICS

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Sixty years of nonlinear optics

S.G. Grechin, A.B. Savel'ev

Apparently, the concept of 'nonlinear optics' was first introduced by S.I. Vavilov when analysing the results of absorption saturation in uranium glasses obtained in 1926. In particular, he noted that "In an absorbing medium 'nonlinearity' should be observed not only in relation to absorption. The latter is related to dispersion, so the speed of light propagation in a medium, generally speaking, must also depend on the light power". One of the defining criteria for nonlinear optics, according to S.I. Vavilov, is the violation of the superposition principle. Sixteen years later, in 1942, E. Schrödinger, considering the problem of light scattering by electrons, also defined the processes as nonlinearly optical.

Nonlinear optics, as an independent branch of physics, dates back to the work by Franken et al. in 1961, when the generation of the second harmonic of ruby laser radiation was obtained at an extremely low efficiency ($\sim 10^{-12}$) in terms of the number of photons: only 10^6 second harmonic photons. But already in 1962, second harmonic generation was realised in the phase-matched regime with a conversion efficiency that was several orders of magnitude higher. Then, literally within a few years, it was possible to obtain effective generation of the third and fourth harmonics and of the sum frequency, to implement parametric amplification and generation, and to observe stimulated Raman scattering, two-photon absorption, and other nonlinear effects. The works of Pockels, Kerr, Faraday and others, performed back in the 19th century, turned out to be the basis for understanding the essence of the effects observed, and research on nonlinear optics itself became a logical continuation of work on radiophysics, nonlinear electrodynamics of the microwave range, optics, hydrodynamics and acoustics, the theory of oscillations, etc.

As with many other branches of physics, it is difficult to give an exact definition of nonlinear optics by specifying its boundaries. In 1965 one of the founders of nonlinear optics, R.V. Khokhlov, divided nonlinear wave processes into two groups: dispersive and nondispersive, in each of which these effects are possible in reactive and absorbing media. Such a definition does not raise the question that nonlinear optical processes are possible only under high-intensity irradiation, which is not infrequently done even today. R. Boyd adheres to the same approach in his 2020 monograph, with clarification for parametric and nonparametric processes in dispersive media. It is difficult to say to what extent the existing definitions correspond to the problems of nonlinear optics of tomorrow, but even now the rapid development of quantum nonlinear optics clearly indicates the importance of nonlinear optical processes occurring with single quanta, i.e., in the regime of extremely low intensities.

Research in the field of nonlinear optics is carried out by many teams of scientists around the world. An invaluable contribution to the formation and development of the theory of nonlinear wave processes was made by N. Blombergen, D.A. Kleinman, J.A. Armstrong, R. Byer, J. Ducuing, P.S. Pershan, and many others. In the USSR, the scientific school formed back in the late 1950s under the leadership of R.V. Khokhlov and S.A. Akhmanov largely determined the development of nonlinear optics in our country.

One of the key tasks of nonlinear optics is the frequency conversion of laser radiation, which significantly expands the functionality of lasers. This made it possible to ensure the efficient generation of radiation in a wide range of wavelengths: from soft X-rays (due to the generation of high harmonics) to millimetre and terahertz (due to optical rectification) radiation with pulse durations down to a few femtoseconds in the optical range, and an order of magnitude shorter attosecond pulses in the X-ray range and with a peak power of several PW. The fields of application of lasers with frequency conversion are very wide. These are spectroscopy, environmental monitoring, diagnostics, medicine, various types of material processing, information and telecommunication systems, including the problems of quantum optics and quantum computing, etc. Significant progress is being observed in the study of fast-flowing processes, within the framework of qualitatively new analysis capabilities, the search for "lost time". Nevertheless, there are still many unsolved fundamental problems in nonlinear optics, a significant part of which is associated with the development of laser and nonlinear optical technologies. These, in particular, include theoretical and experimental studies of problems at the junction with modern quantum electrodynamics: polarisation and nonlinearity of vacuum and its breakdown under the action of laser radiation of extreme intensity.

Works on nonlinear optics have always been among the most important and actual topics of the Quantum Electronics journal. The papers presented in this issue by no means reflect all the scientific areas of modern nonlinear optics, in which numerous scientific groups are actively working in Russia. We would like to express our deep gratitude to the authors of all papers who sent their work for publication. However, since the number of papers on this topic received by the journal exceeded the total volume of possible publications in one issue, some of the papers will be published in the next issue.

S.G. Grechin Prokhorov General Physics Institute of the Russian Academy of Sciences, ul. Vavilova, 38, 119991 Moscow, Russia; e-mail: s.g.grechin@mail.ru;
A.B. Savel'ev Faculty of Physics, Lomonosov Moscow State University, Leninskie Gory 1, stroenie 2, 119991 Moscow, Russia; Lebedev Physical Institute, Russian Academy of Sciences, Leninsky prosp. 53, 119991 Moscow, Russia;

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