Guest editorial: Optics and image processing in Russia

Modern trends in the field of development of laser optical devices, units and systems, are indicative of the constantly increasing role of the problems of data processing and control. One glowing example of this statement is computer-synthesized diffractive optical elements (DOEs). The process of DOE generation bears no resemblance to the technology of conventional optics but is, to the maximum extent, formalized and brought close to applied mathematics in its use of calculational algorithms, and to control theory in the ways machining, photo-plotters and e-beam machines are used.

Another example, showing that methods of data processing and control find their way into optics, is digital image processing, which makes it possible to develop a non-traditional approach to solving problems that are classical in optics: the enhancement of resolution, contrast, brightness, the reduction of geometrical distortion and the improvement of image processing all enrich optical systems being used as elements in artificial intelligence, thus allowing a variety of measurements, as well as the detection and recognition of objects on an image, to be performed.

The papers included in this special issue of *Optics & Laser Technology* deal with the calculation and fabrication of diffractive optical elements and with optical image processing.

The papers devoted to the problem of DOE development place the main emphasis on focusators of laser radiation. Focusators are computer-synthesized DOEs capable of focusing laser radiation into a predetermined spatial area with a required intensity distribution. In principle, focusators allow one to control the spatial structure of the energy distribution in the focal plane. Focusators are of chief practical importance in the laser treatment and working of metals: that is, hardening by heat treatment, welding and cutting. The creation of focusators is a rather complicated and labour-intensive process involving mathematical calculation, design, fabrication techniques, testing and analysis of performance. The first three papers of the issue are just devoted to the consideration of this process.

The work by L. L. Doskolovich, N. L. Kasanskiy and V. A. Soifer deals with the detailed studies of focusators focusing into a straight line segment, with the phase function calculated using a variety of methods. Based on an analysis of the diffractive characteristics of the focusators, the authors draw conclusions about the high efficiency of the iterative calculational techniques that employ, as an initial approximation, the exact geometric-optical solution.

A technology of fabrication of the focusators for the far-infrared-range, with a wavelength of 1.06 μm, is discussed in the paper by M. A. Golub, O. E. Rybakov, G. V. Usplenjev, A. V. Volkov and S. G. Volotovsky. It is proposed that a reflecting focusator should be fabricated on the basis of widely used standard microelectronics equipment in combination with a unit for electrolithically growing the microrelief and applying the thermostable coating.

The work by L. L. Doskolovich, N. L. Kasanskiy, S. I. Kharitonov and A. Ye. Tsaregorodtzev reports the estimation of the focusator diffractive efficiency with consideration for technological errors in the microrelief formation. With reference to the DOE with radially symmetrical phase functions, the authors have derived convenient calculated formulae for estimating the reduction of the diffractive efficiency due to a piecewise linear approximation of the zoned phase microrelief. It has been shown that if the number of zones is large enough, the influence of technological errors on the energy efficiency is only a few per cent.

The next three papers are devoted to the generation of DOEs that are not focusators. The work by M. A. Golub and V. S. Pavelyev reports the development of a new method for iteratively calculating phase kinoforms elaborating the well-known Kirch–Jones and Gerchberg–Saxton algorithms. Using this method, the authors were able to synthesize phase holograms capable of providing the high quality of the reconstructed binary objects in combination with fairly high diffractive efficiency. Such phase holograms appear to show promise for optical instrumentation.

The paper by V. V. Kotlyar and S. V. Philippov is devoted to the development of an iterative algorithm for calculating phase optical elements forming pre-given wavefronts. The authors have shown a high efficiency of the algorithm when applied to the generation of aspheric wavefronts characterized by small curvature (for a phase detour of no more than $2\pi k$, $k = 1, 2, 3$). The DOEs synthesized are of indubitable interest for the problem of control of aspheric optical surfaces.

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In the work by V. V. Kotlyar, S. N. Khonina, and V. A. Soifer, an iterative technique is proposed for calculating radially-symmetrical phase optical elements permitting an increase in the diameter of the Airy disc. The possibility of realizing the elements using a small number of phase gradations turns out to be critical in terms of the fabrication technology. The idea may successively work for laser printers and photoplotters.

Note that as an important feature of the last two papers we can obtain the proof of the convergence of the proposed iterative algorithms.

The closing series of three papers deals with image processing. It opens with a theoretical work by N. I. Glumov, E. I. Kolomiyetz and V. V. Sergeyev that develops a technology of computer-aided detection of objects in the image in sliding window mode. The idea is elaborated by calculating the object features in the window using parallel-recursive filters. A method of the automated localization of objects on the image is developed and learning algorithms used in decision making are discussed. An example aimed at illustrating the developed methods of detection is discussed.

The following two works are concerned with the applied problems of image processing and are of great practical interest. In the paper by V. V. Kotlyar, P. G. Seraphimovich and O. K. Zalyalov it is proposed that, for the enhancement of spatial resolution in reconstructing the phase of the object field from the noisy interferogram, a Gerchberg–Papoulis method should be used.

In the paper by S. E. Volkova, N. Yu. Ilyasova, A. V. Ustinov and A. G. Khramov an optical–digital system for the analysis of images of blood preparations is reported. The system is simple, universal, space-saving (has the overall dimensions of a microscope) and provides a speed of about 1 minute.

Note that all the papers incorporated in the special issue have been performed in the Image Processing Systems Institute of the Russian Academy of Sciences.

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