Laser technologies in the formation of harmonic lenses microreliefs

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Abstract. Briefly describes the technology of forming high microreliefs in the context of the scientific path of a senior researcher at the Institute of Image Processing Systems of the Russian Academy of Sciences Candidate of Technical Sciences Oleg Yuryevich Moiseyev - a unique specialist in the technology of diffraction computer optics, recording optical micro- and nanorelief.

1. Introduction

With the advent of optical quantum generators, the technologists received a powerful tool to perform the unique technological processes of local energy deposition with the power levels sufficient for both thermal treatment and local deposition on photosensitive compositions. Typically, the radiation cross section of lasers is quite large in size, around several millimeters, but in a focused state it is possible to form the details smaller than a micrometer in size. Despite the fact that traditional optics can solve a wide range of tasks, it becomes obvious that in some cases refractive lenses begin to come short of diffractive optics.

The works of I.N. Sisakyan and V.A. Soifer et al. in the first half of the 1980s provided the main geometric-optical solutions of the focusing problem for different focal regions and created various focusing diffractive optical elements (DOE) [1-3]. A key problem in making the diffractive optical elements is to achieve high energy efficiency together with the required intensity distribution in the operating area. In particular, the lack of diffraction efficiency hinders the use of focusators in laser machining systems. It should be noted that almost all the works on theoretical evaluation of efficiency of optical elements are based on the assumption of a perfect or almost perfect accuracy of microrelief production. In reality, there certainly occur technological manufacturing errors both in terms of the dimensions of DOE zones and in the height of microstructures, which is especially characteristic of wide-aperture power focusators. The above works consider the theoretical issues of the construction of diffraction elements, but not the technological preparation of production. For example, the production of DOE using traditional materials and traditional methods does not allow to reach the potential of diffractive optics: it is impossible to achieve continuous or almost continuous reliefs needed for the construction of optical elements without the excessive costs. The development of production technologies of DOE with a continuous microrelief is inextricably associated with the name of the...
senior scientific researcher at the Institute of Image Processing Systems of the Russian Academy of Sciences, Candidate of Technical Sciences Oleg Y. Moiseev (January 6, 1959 - July 29, 2016) [4].

2. Continuous DOE production technologies

Starting from the beginning of his scientific career, O.Y. Moiseev had been dealing with the methods of DOE microrelief formation using photoresists and photopolymer compositions. It was quite easy to borrow the technologies of a binary microrelief formation from microelectronics, but the formation of multilevel microreliefs required the development of fundamentally new technological operations. O.Y. Moiseev developed a unique method for forming a diffraction microrelief based on layer-by-layer photoresist buildup [5-6]. This method allows to form a multilevel (up to 16 levels) microrelief for reflecting focusators designed to concentrate the emission of CO$_2$ lasers (wavelength of 10.6 $\mu$m) (Fig. 1) without the etching operations.

![Figure 1. Photo of a focusator [6].](image)

In 1996, O.Y. Moiseev used this method to make the focusators into a ring [7-8], which still function in the pedestal plant [9] at the Prokhorov General Physics Institute of the Russian Academy of Sciences and allow to grow unique crystalline fibers [10-11].

O.Y. Moiseev also studied the limitations of the method of dark growth of a microrelief in liquid photopolymerizable compositions [12]. The method of dark growth allowed to obtain “high” microreliefs of long-focus harmonic lenses. The methods developed by O.Y. Moiseev in his Candidate's dissertation allowed him to create and patent a number of optical devices and technological methods [13-22].

O.Y. Moiseev created several interesting works on the development, research and optimization of a semi-automatic plant for the formation of microreliefs at the ends of halide IR waveguides [23-31] (Fig. 2).

![Figure 2. 3D reconstruction of microrelief shape at the end of a halide IR waveguide [26].](image)

The opening of a laser recording station at the center of collective use of equipment of the Samara University and the Institute of Image Processing Systems of the Russian Academy of Sciences in 2004 became a new stage for O.Y. Moiseev in the development of technologies for the formation of...
multilevel microreliefs [32-35]. Due to the use of direct laser photomask recording technology O.Y. Moiseev succeeded in creating and studying many new diffractive elements [36-50] (Fig. 3).

Starting from 2008, O.Y. Moiseev had been developing a fundamentally new single-stage technology for the manufacturing of diffractive optical elements based on the oxidation of thin films of chromium, copper and molybdenum in a focused laser beam [51-62]. As a result, the methods appeared that allow to form a microrelief in one stage on the basis of making the structures of a given height from chromium oxide or molybdenum (Fig. 4).

Starting from 2015, O.Y. Moiseev had been developing the technology allowing to obtain high-quality microrelief of harmonic lenses of a visible range [63]. In terms of reproduction accuracy of “high” microrelief (braking the corners, verticality of walls, etc.), the results achieved by O.Y. Moiseev exceed significantly the results obtained previously by way of dark growth of liquid photopolymerizable compositions [12] or the results obtained on machines with computerized numerical control [64]. This opened up fundamentally new opportunities for the application of harmonic lenses in ultralight computer vision systems [65-66].

![Figure 3. The central part of the axicon with a period of 8 microns.](image-url)

![Figure 4. 3D reconstruction of microrelief surface (a) and profilogram of an axicon (b) manufactured by oxidation of a chromium film.](image-url)

![Figure 5. The shape of microturbine surface obtained with scanning electron microscope Supra [67].](image-url)

Despite the sudden death of O.Y. Moiseev, the scientific publications on the technologies developed by him are still being published. For example, the technology of manufacturing of
microturbines using the method of direct laser recording over a thick layer of photoresist (Fig. 5) was described in [67].

Thus, the technologies developed by O.Y. Moiseev have found application in micromechanics.

3. Conclusion
The long evolution of the methods of forming multilevel microreliefs, which had started at the end of the last century, led to the creation of sophisticated and practically important technologies for imaging systems and more. Laser techniques of high multilevel microreliefs production developed by O.Y. Moiseev confer the possibility to make a qualitative breakthrough in the development of the significant branches of science like technical vision systems, micromechanics, and fiber-optic communications in the nearest future.

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