

Terahertz optical elements for control of high-power laser irradiation

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Appearance of the sources of coherent and high power THz radiation [1] opened new horizons for investigations in this frequency range [2]. High attention is focused on silicon diffractive optical elements (DOE), which are used for the beam manipulation [3-7]. The lithographic etching of a silicon substrate has been used in [3-7] to fabricate binary relief of diffractive optical elements. Binary silicon element [4] coated with the antireflection coating remained intact upon exposure to an average radiation power density of 4 kW/cm²; the peak power in a 100 ps pulse was almost 8 MW/cm². Experimental estimates of the diffraction efficiency of the elements coated with the antireflection coating [4] are in good agreement with theoretical estimates.

Such applications like imaging, material ablation, generation of continuous optical discharge, and even more exotic for the terahertz range application, namely the field ionization of individual atoms, require focusing of THz radiation [3-5], often with an enhanced focal depth [3].

Non-diffractive Bessel beams with angular orbital momentum (vortex beams) with different topological charges were formed by use of binary phase spiral axicons [6]. Binary phase axicon (BPA) with spiral zone structure and with aperture diameter of 100 mm (Fig. 1a,b) has been realized in [7] by technology similar to described in [3-6].

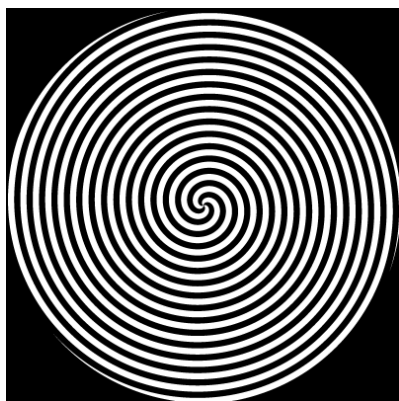


Fig. 1a. Calculated phase of binary diffractive optical element (black, 0; white, π)



Fig. 1b. Photo of realized element

The research has been performed at workstations of the free electron laser NOVOFEL (Budker Institute of Nuclear Physics of SB RAS, Novosibirsk). A high power radiation (in a routine regime, the average power is 50-150 W), a relatively narrow linewidth and the tunability of the radiation enable performing a wide variety of experiments. Vortex beam (Fig. 2) was formed from the NOVOFEL Gaussian beam (wavelength is of 129.5 μm) transformed by binary phase axicon (BPA) with spiral zone structures (Fig. 1) and with aperture diameter of 100 mm.

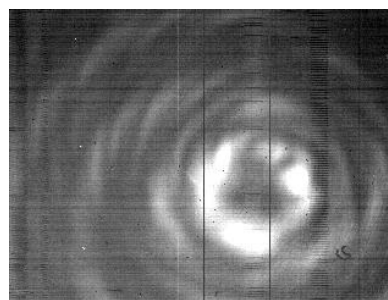


Fig. 2. Intensity distribution measured in the cross-section of beam formed by realized element (Fig. 1)

Vortex beams have great potential for use in free telecommunications and remote sensing [8].

However, lithographic etching has disadvantages in the case of multilevel elements, when an expensive and complicated procedure of alignment of photo-mask is required [8]. Binary (two-level) elements [3-7], in turn, have limited energy efficiency [8]. The laser ablation technology has been used in [9, 10] for fabrication of multilevel diffractive lens with high energy efficiency. However, diffractive optical elements are designed for working with monochromatic radiation of fixed wavelength [8] only. Fabrication of

terahertz reflective free-form elements for transformation of high-power beams of Free Electron Laser has been considered in [11]. Aluminium elements (spherical and cylindrical mirrors (Fig. 3), reflective axicons) were fabricated by technology of micromilling [11].

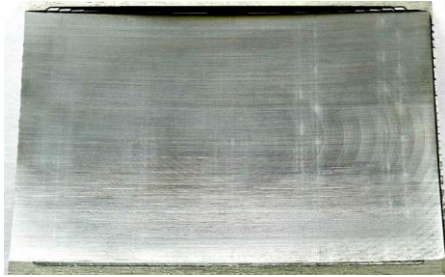


Fig. 3. Fabricated mirror

Realized optical elements were tested in the beam of NOVOFEL at the wavelength of 129.5 μm (Fig.4). The measured diffractive efficiency of the spherical mirror (>94%) is in good agreement with both numerical calculations and theoretical predictions.

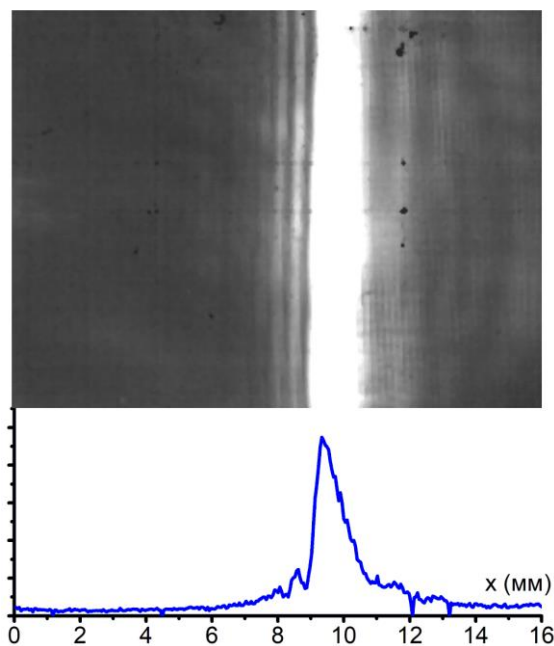


Fig. 4. Intensity distribution in the focal plane of cylindrical mirror

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