Diffractive optical elements for the terahertz region

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ABSTRACT

Diffractive optical elements (silicon binary Fresnel lenses and silicon beam-splitters) for the terahertz spectral range have been designed and characterized using high-power terahertz radiation of the Novosibirsk free electron laser. Effect of an antireflecting coating at the silicon elements was studied.

1. INTRODUCTION AND BACKGROUND

DIFFRACTIVE optical elements (DOEs) are most beneficial for beam manipulation at THz frequencies. This statement is especially valid in a case of high-power terahertz beams, which damage conventional plastic lenses such as polypropylene or TPX ones. Such applications like holography, interferometry and polarimetry require dividing a beam into two beams of equal intensity. Other 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, often with a low *f* number.

In this paper we report characteristics of three types of diffractive optical elements: silicon binary Fresnel lenses (BFLs) and silicon beam-splitters (BSs). The elements were produced by TYDEX, IPSI RAS and SSAU.

2. EXPERIMENTS AND RESULTS

The experiments have been carried out using radiation of the terahertz Novosibirsk free electron laser (NovoFEL). The laser generated monochromatic radiation as a continuous stream of 100-ps pulses with a repetition rate of 5.6 MHz. The laser beam at the station had the Gaussian shape with a waist of 9 mm, which means that practically 100% of beam energy passed through a circle of 30-mm in diameter. Average power of radiation in the experiments was 50 – 100 W. All experiments have been carried out at λ=141 μm. The radiation having passed through the element under study was recorded with a microbolometer 320x240 2D array (MBA) with physical size of 16.32x12x24 mm moving with a motorized translation stage along the optical axis.

Binary Fresnel lenses. BFL was a two-level diffractive lens with a diameter of 30 mm (f = 120 mm, λ=130 μm). Fresnel zones have been etched on a high-resistivity silicon one-mm thick plate. We observed two focuses at a distance of 121 and 42 mm with excellent agreement with theory. The diffraction efficiencies were 17% for the main focus and 2.4% for the secondary focus. For the BFL with antireflecting coating they were 40% and 3.6%, respectively.

Beamsplitters. A beamsplitter of 30-mm in diameter with rectangular grating etched on silicon plate and a TPX lens with focal length of 50 mm were placed across the laser beam. Image in the focal plane was recorded with the MBA. Distance between zero order and first order focal points enabled to measure diffraction angle of the grating which appeared to be 15^0.

It is worth pointing out that FWHM of the focal spots for 140 μm were 0.76 mm for the BFL and 0.23 mm for FL.

Fig. 1. Binary Frensel lens and beamsplitter

Fig. 2. Experimental setup

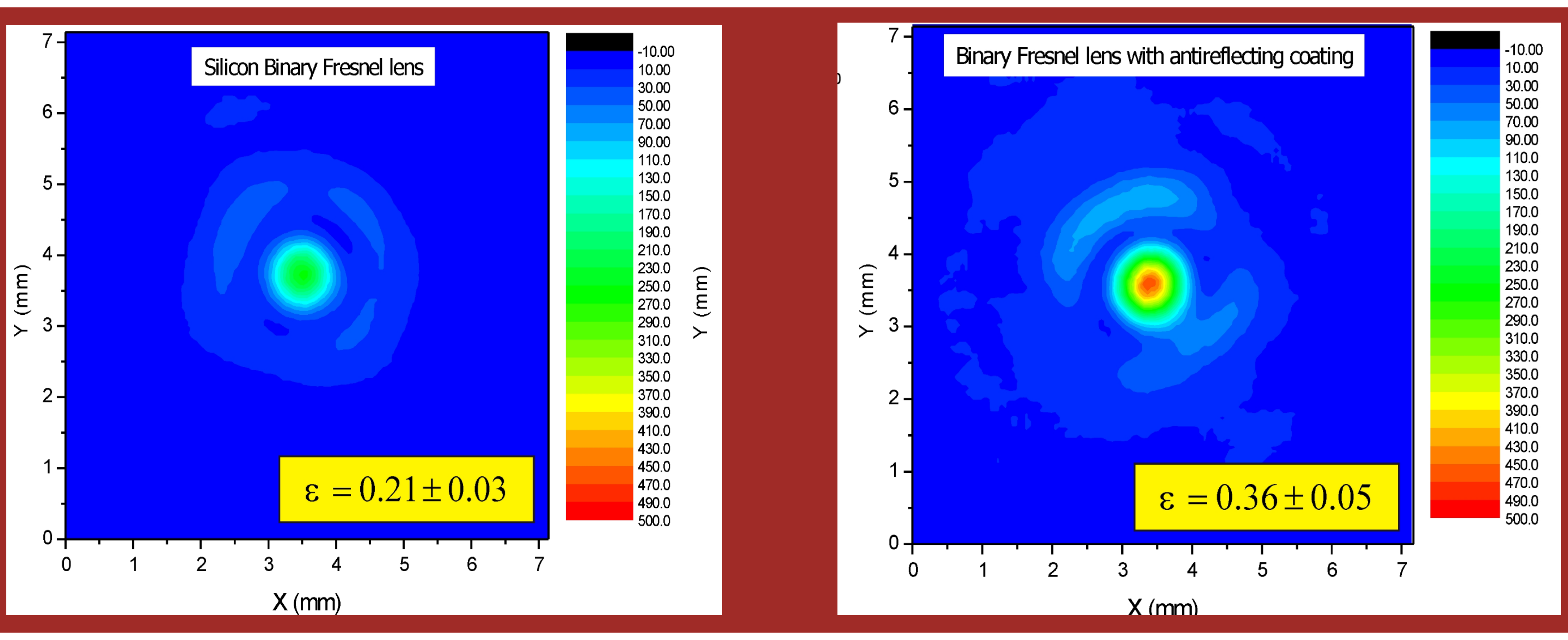
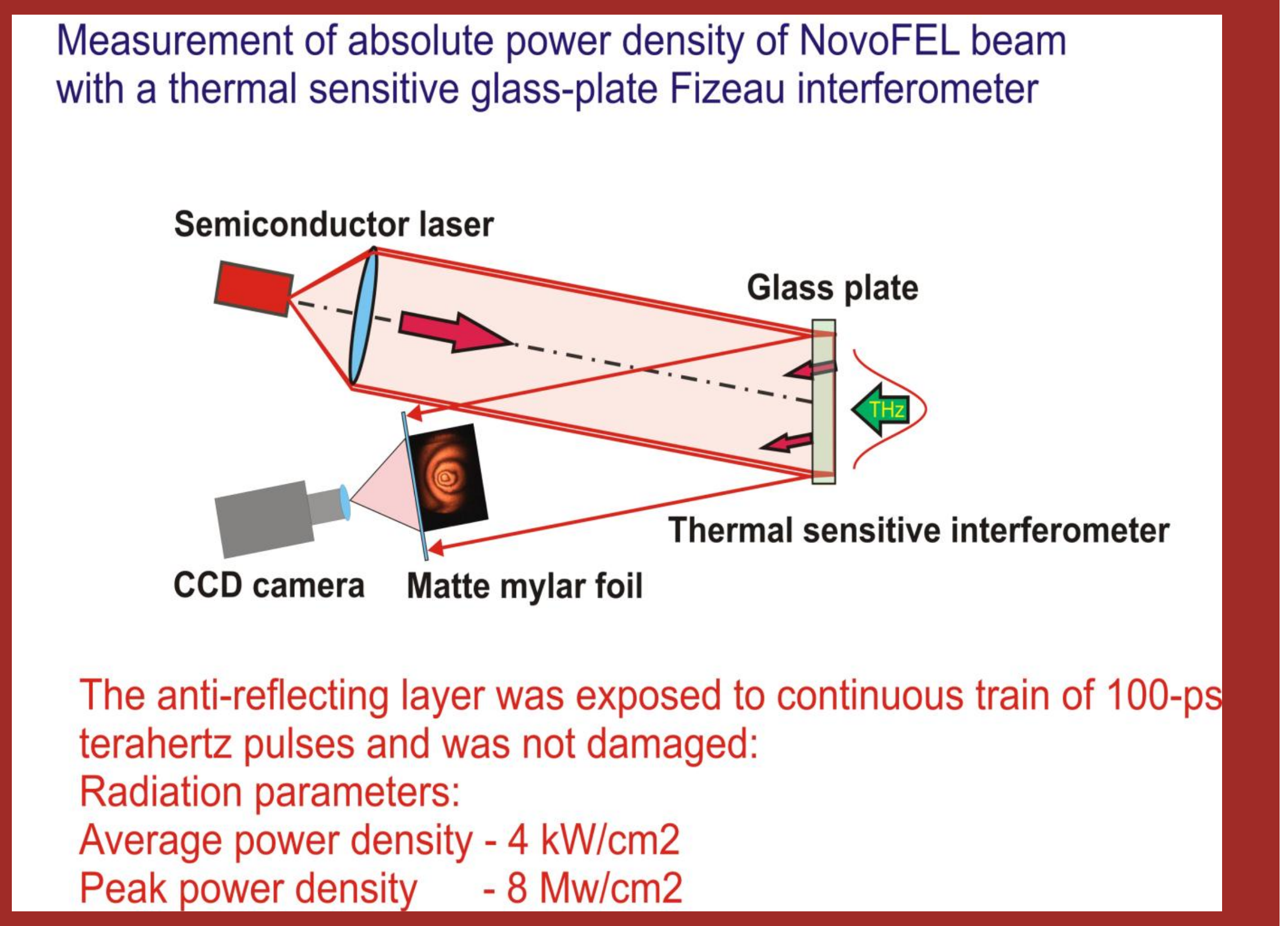


Fig. 3. Measured intensity distributions


Measurement of absolute power density of NovoFEL beam with a thermal sensitive glass-plate Fizeau interferometer

The anti-reflecting layer was exposed to continuous train of 100-ps terahertz pulses and was not damaged:
Radiation parameters:
Average power density - 4 kW/cm2
Peak power density - 8 Mw/cm2

Fig. 4. Investigation of radiation resistance of anti-reflecting layer

CONCLUSION

The experiments have demonstrated feasibility of application of different kinds of DOE for manipulation of low- and high-power terahertz radiation.