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GENERAL EXPERIMENTAL TECHNIQUES

A Method for Obtaining Inverted Images

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Abstract—A method for obtaining a brightness-inverted image of opaque objects is described. The factor of conversion of images from negative into positive was up to 350% relative to the average intensity level of the incident beam, which is in agreement with numerical calculations.

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The reproduction (visualization) of images of transparent objects in the phase-contrast scheme with a photothermal Zernicke cell is considered in [1–4]. The photothermal Zernicke cell (filter) fulfills the same function as a classical Zernicke cell, i.e., it carries out a quarter-wave shift between waves diffracted on the object and transmitted waves. In this work, this method is used for obtaining brightness-inverted images of opaque objects.

The scheme of the setup for obtaining the inverted image of an opaque object or structure is shown in Fig. 1.

The opaque structures, located in the plane of object *3*, are illuminated by the Gaussian beam of single-mode linearly polarized He–Ne laser *1* with power $P \leq 6$ mW, wavelength $\lambda = 0.63$ μm, and diameter $D \approx$ 1 cm. The radiation power is regulated by rotating Glan prism *2* around its axis. The light power is measured by the Ophyr calorimeter.

The radiation transmitted through the object was focused by objective lens *4* into the cuvette filled with alcohol with an absorber added to it or into a colored (green) Plexiglas parallel-sided plate. It is more convenient to use the plate, although, in this case, the power of the illuminating laser needed for inversion should be about four-fold higher. A DCC1545M CCD camera was placed in image plane *6*.

The images of the opaque grid on the glass substrate are shown in Fig. 2 at the top, and the intensity cuts corresponding to these images and perpendicular to one of grid lines are shown at the bottom. The distance between the grid lines is 100 μm. The images are obtained for different milliwatt powers of the incident beam. The intensity cuts, given in Fig. 2, show that the conversion into the positive image up to 350% relative the intensity of the incident beam is attained (the maximal intensity value in the cut in Fig. 2c to the average intensity level). This is in agreement with the numerical calculations (Fig. 3), performed in accordance with [3]. The mode change time is determined by the temperature-settling time at the heating point of the photothermal filter by changing the beam power and is a fraction of a second.

The inversion operation (obtaining the positive from the negative and vice versa) is the standard operation performed during processing images (see, e.g.,

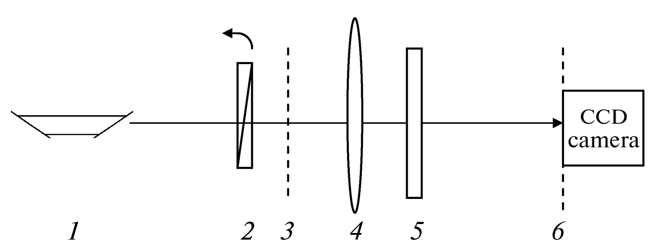

Fig. 1. Diagram of the setup: (*1*) He–Ne laser, (*2*) polarizer, (*3*) plane of the object position, (*4*) objective lens, (*5*) photothermal filter, and (*6*) image plane.

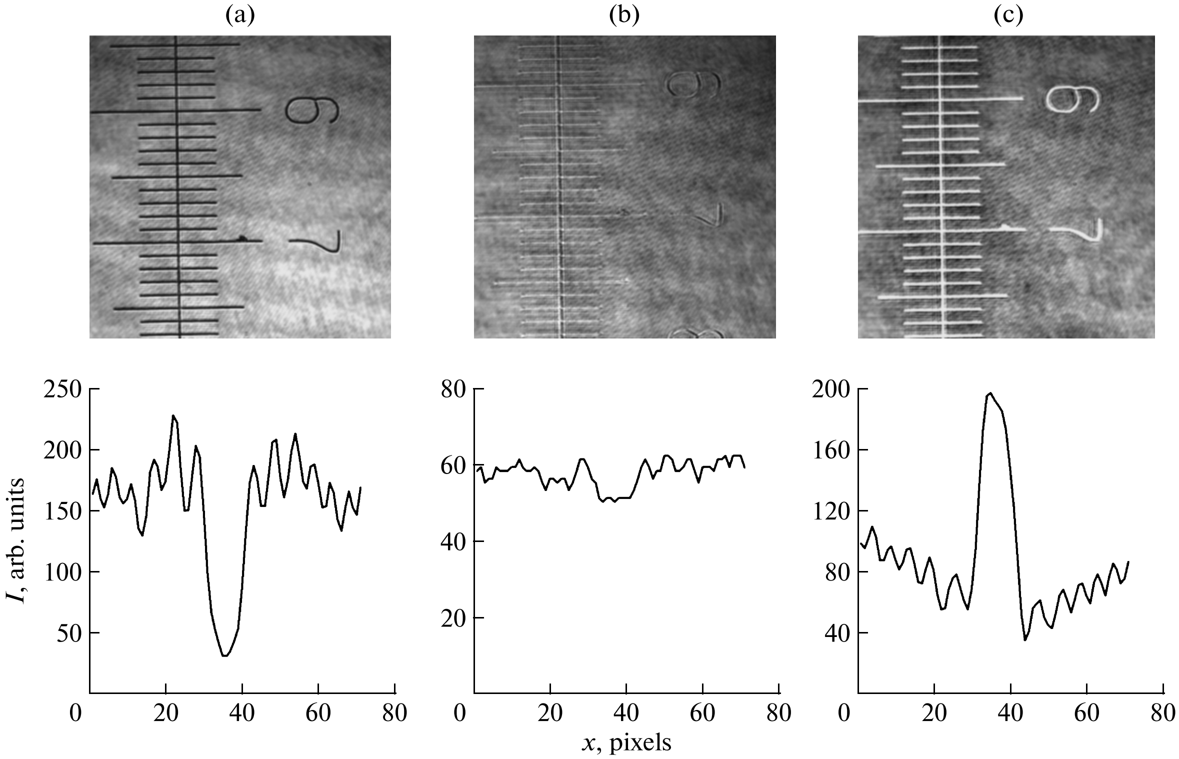

Fig. 2. Image of the opaque grid at different intensities of the incident beam (at the top) and the corresponding intensity cuts (at the bottom) (a) without photothermal filter, (b) with the power of the incident beam $P \approx 3$ mW, and (c) with $P \approx 6$ mW.

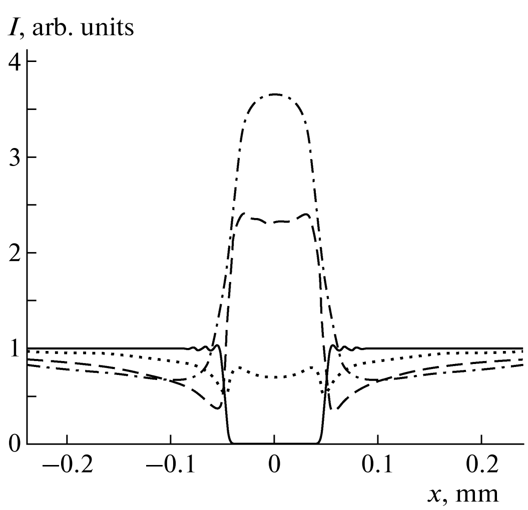

Fig. 3. Results of the numerical simulation of the image inverting process for the amplitude object with a 100-μm width. Different powers of the incident radiation and corresponding phase incursions in the Zernicke filter correspond to the curves of different types: the dashed line corresponds to the phase incursion at the beam maximum of 2.1π; the dotted curve, to 1.4π; the broken curve, to 0.7π; and the solid line, to 0. The following parameters were taken for the calculation: the size of the incident beam is 0.5 cm, the focal distance of the lens is 6 cm, and the radius of the photothermal cell is 2 cm.

[5]). The presented analog method is sufficiently simple, ensures a good quality of the image reproduction, and is easy to implement.

Note in conclusion that this phase-contrast scheme is the all-optical scheme with a nonlinear Zernicke filter in which the output image depends on the intensity of the incident light. When the intensity of the incident beam is changed, the image changes sign until it completely disappears, which is important for some applications in laser physics.

REFERENCES

1. Bubis, E.L., *Instrum. Exper. Techn.*, 2009, vol. 52, no. 1, p. 108.
2. Bubis, E.L., *Quant. Electr.*, 2011, vol. 41, no. 6, p. 568.
3. Bubis, E.L. and Matveev, A.Z., *Quant. Electr.*, 2012, vol. 42, no. 4, p. 361.
4. Bubis, E.L., Gusev, S.A., Kozhevatov, I.E., Martynov, V.O., Sanin, A.G., Stukachev, S.E., and Shishkov, A.V., *Instrum. Exper. Techn.*, 2012, vol. 55, no. 5, p. 594.
5. Gonzales, R.C., Woods, R.E., and Eddins, S.L., *Digital Image Processing Using MATLAB*, Upper Saddle River, New Jersey: Prentice-Hall, 2004.

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