# OPTICAL DATA PROCESSING USING THE PRIZ LIGHT MODULATOR

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ABSTRACT. We have built an optical processing system of direct insertion of images from an electron tube screen. The PRIZ light modulator is used as a photorefractive cell providing a real-time performance. The cell is also helpful to filter images in the spatial frequency domain. The fine modulator resolution shortens considerably the optical processing path, which is very appropriate for use aboard. Various holographic techniques are investigated using the PRIZ modulator as a phase-noise image filter.

INTRODUCTION. The advantages of optical processing are very much restricted by the problem of fast input and output of data, i.e. the problem of preparing 2-D images. Conventional photomaterials are hardly satisfactory for this purpose because of their inability to provide a real-time performance. In this application, photorefractive materials have greate potences. Nowadays various kinds of such materials, say liquid and semiconducting crystals, as well as thermoplastics [1], are used as light modulators in optical data processing systems. In this paper we consider a processing system including the PRIZ light modulator of the BOS crystal. Compared to the most PROM modulators, PRIZs have higher sensitivity and resolution. Besides they exhibit a considerably lower noise level than that of liquid crystals and do not need deep cooling, unlike phototituses. additionally, PRIZs make it possible to perform some special functions such as angular and dynamic filtering of an image.

1. PRIZ AS A CONTROLLABLE TRANSPARENCY. The main parameters of the PRIZ and the PROM modulators are represented in Table 1.

Table 1. Main parameters of modulators.

| | PROM | PRIZ |
|---|---|---|
| Sensitivity, as exposition per 1% of diffractional efficiency, $\mu J/cm^2$ | 10 | 2 |
| Spatial resolution, $mm^{-1}$ | 10 | 40 |
| Maximum diffractional efficiency, % | 0.1 | 1 |

We employed the PRIZ modulator with the objectives of carrying actual radioimages of the sea surface and photoimages of the sea bottom into an optical Fourier analyzer, and providing phase-noise holographic filters. It is common practice, that radar information is carried by photofilms requiring a lot of time to prepare image optical transparencies. To operate in real time we have built an experimental setup using the PRIZ as a photorefractive cell of optical memory to enter images directly from the radar tube screen into an optical analyzer. The experimental setup is schematically shown in Fig. 1. The input of sea surface images was modelled by a TV tube illuminating

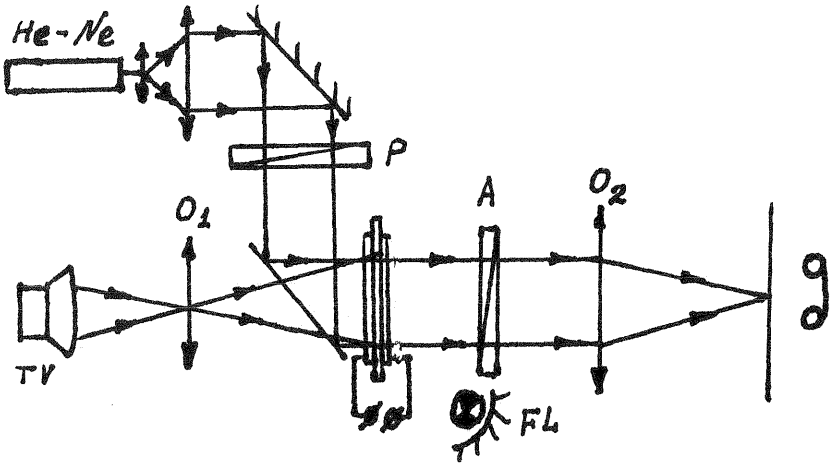


Fig. 1. Experimental setup.

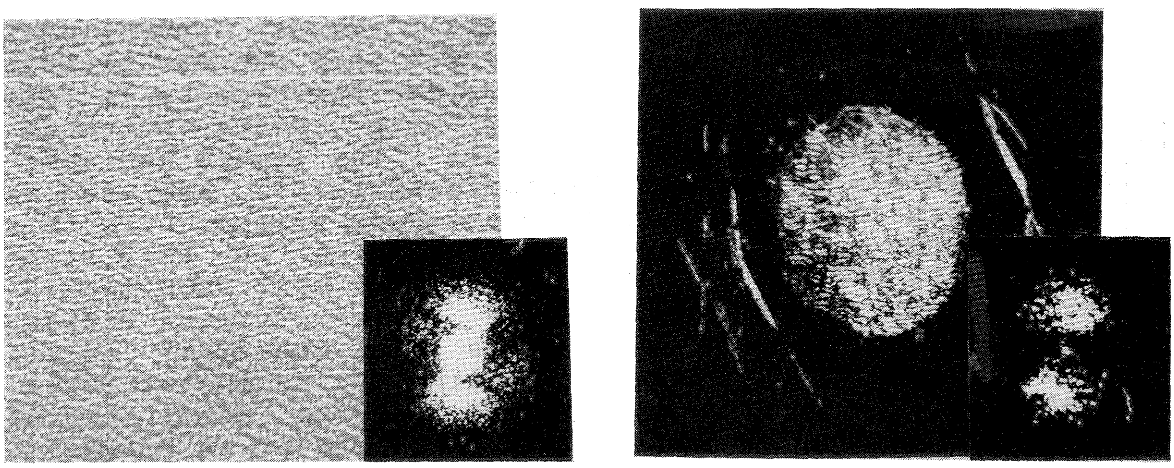

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Fig. 2. The sea radioimage (a) recorded by the PRIZ (b) and its spectra (c, d).

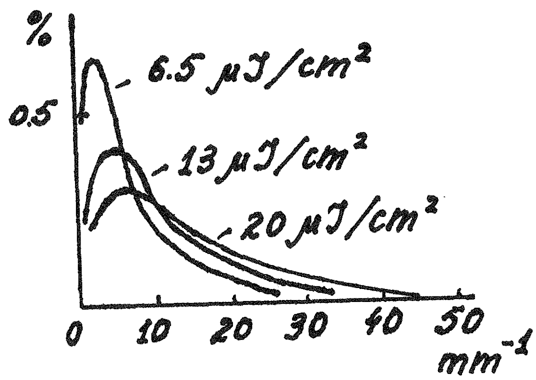



Fig. 3. PRIZ diffractional efficiency VS spatial frequency.

a superposed actual radioimage transparency. The setup was operated in the stages of data recording, data reading and modulator clearing. To attain a maximum sensitivity of the PRIZ was used a blue 6LK1A tube. To avoid modulator record destructions, the reading was effected by the red beam of a He-Ne laser of wavelength $\lambda$=632.8 nm. Thanks to the PRIZ position between crossed polarizers, P and A, only a modulated portion of the red beam could pass through them, while the intensity of the zeroth diffraction order was effectively suppressed. The model image was being exposed by the lens O1 onto the modulator during from several seconds to several minutes. After the exposition and reading the image was Fourier -transformed by using the lens O2 of a focal distace of 40 cm. The PRIZ memory time (around 2 minutes ) was determined by an exposition time voltage, applied to the modulator terminals , and reading beam intensity. For erasing an image out of the PRIZ, we used a flash lamp, FL. The raster of the reproducing tube was checked by a computer to imitate the motion of a radar carrier aircraft. The processed data were compared to these obtained with a conventional optical Fourier analyzer [2] of high resolution (around 3")using transparency immersion. Fig. 2a presents the sea radioimage of a 7.5 x 6.5 km area. Its central portion of around 3 km in diameter was recorder by the PRIZ, as shown in Fig. 2c. One can estimate the image quality by comparing the Fourier spectra of the PRIZ (Fig. 2d) and of a conventional analyzer (Fig. 2b). The main feature of the PRIZ spectrum is reduced intensity of the central bright spot and, hence, increased low-frequency resolution. The PRIZ diffraction efficiency, i.e. the ratio of intensities of the first and the zeroth diffraction orders versus spatial frequency is plotted in Fig. 3. Its rapid decrease at frequencies under 3 mm provides the same resolution a 40-cm focus lens as the conventional analyzer of a 4 m focal distance does.

2. PRIZ AS A PHASE-NOISE HOLOGRAPHIC FILTER. In processing a problem arises related to the phase noise produced by a transparency and by optical elements themselves. Let us consider briefly the idea of a holographic technique of phase-noise filtering. Using a reconstructing beam, which is directed against to the reference one and diffracted by a hologram conveying the information about the useful signal and phase noise, we form a wave of the phase conjugated to an object. This wave passing through the object, annihilates its phase noise modulation. The result is a plane wave of the amplitude proportional to the squared signal. Compared to the Vander Luht filters, our technique does not require a priori information about the signal or noise. The only restriction here is the purely phase nature of filtered noise.

We investigated filters of three types, namely, Fresnel, Fourier and image plane holograms(IPH) and compared their noise levels, diffractional efficiencies and interference stabilities. In experiment, Fig. 4, the He-Ne laser beam collimated by lenses L1, L2 forms a 2-D Fourier spectrum of an image, T, in the focal plane of the lens L. Beamsplitters, BS1, BS2, were used to create oppositely directed reference and reconstructing beams as well as an object beam. As a test object, we took the plane periodic pattern of the spectrum plotted in Fig. 5a. A phase plate, PP, was placed behind the object to introduce a phase noise destroying

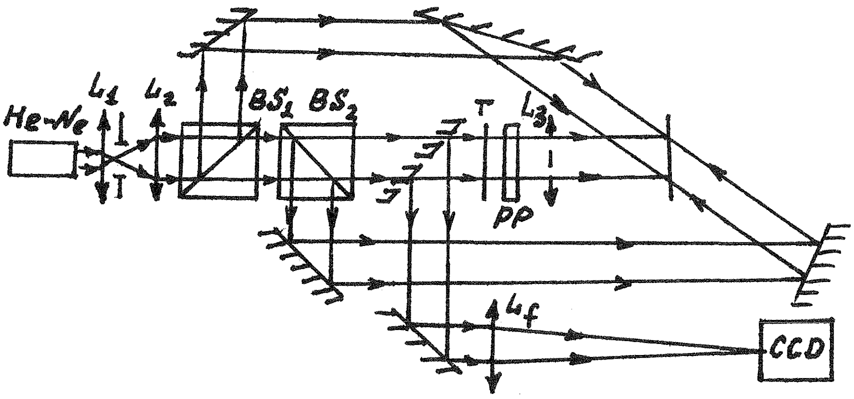
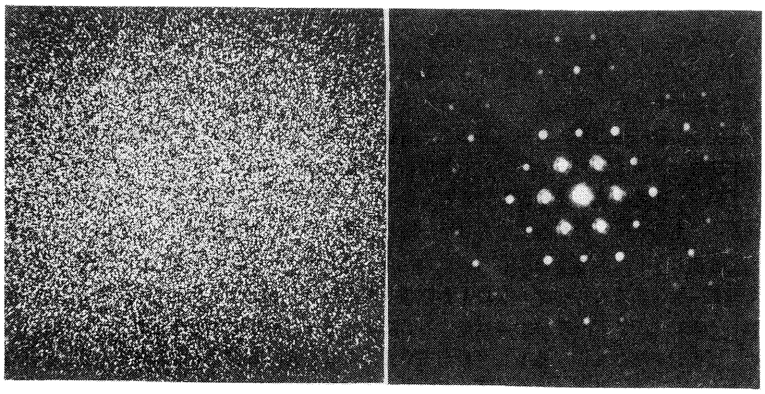
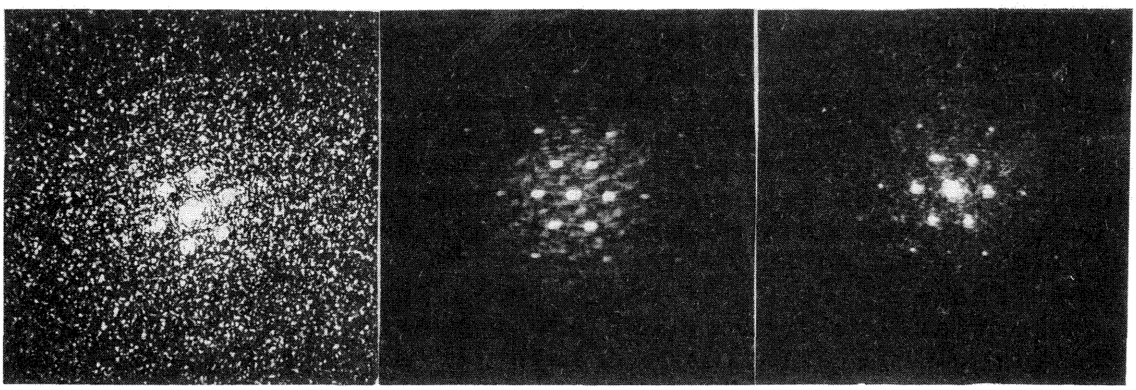



Fig. 4. Experimental setup for holographic filtering.



a b

Fig. 5. The test object spectra without (a) and with the phase-noise filtering.



a b c

Fig. 6. The results of the Fresnel hologram phase-noise filtering.

completely the object spectrum, as seen in Fig. 5b. Depending on the position of the lens L3, we realized holograms of various types. The filtered spectrum was registered by a CCD camera and subsequently processed by a computer. The results of the Fresnel hologram phase-noise filtering are presented in Fig. 6 for various ratios, $\alpha$ , of an object and reference intensities. At $\alpha = 1$, Fig. 6a, a high noise level occured due to: (i) the interference from different fragments of an image, (ii) false spectral maxima, and (iii) the speckles from diffuse scattering of the reconstructing beam. Changing from 1 to 0.25, we managed to decrease the intermodulation, as seen in Fig. 6b, while the speckles could be averaged by an appropriate scanning of the reconstructing beam (Fig. 6c). The rest of the noise was generated solely by aberrations of optics placed behind the filter.
The IPH phase-noise filtering is very similar to the Fresnel one, except for the higher diffractional efficiency ( 1.3 times more at $\alpha = 1$ ) and the lower intermodulation level obtainable in the former case. Under the Fourier holographic filtering reconstructed images suffer from some spectral distortions due to the nonlinear dependence of hologram density on exposition. This nonlinearity can be used in turn to filter a certain spectral range. Fig. 7 plots spectra of an overexposed (b), (c), and an underexposed (d) image, which is presented in Fig. 7a . Here we see relatively intensive low frequencies and weak high spatial frequencies. The Fourier as well as the Fresnel holograms are of a lower maximum diffractional efficiency ( 0.6 %) compared to the IPH filters ( 4.5 %). In practice a reconstructed image may undergo various linear and angular displacements related to the position of an original because of optical adjustments and hologram deformations. Our calculations and experiments have shown that the best stability against these distortions exhibited by IPH filters, and, precisely such filters have been selected to cut the phase noise off actual sea radioimages (Fig. 8a). Fig. 8b display the radioimage spectrum taken from a conventional optical Fourier analyzer of high resolution ( 370-cm focus ) with an immersion cell. The spectrum processed by our PRIZ analyzer ( 70-cm focus ) without any filtering is presented in Fig. 8c and the one with IPH phase-noise filtering given in Fig. 8d. As seen, the resulting filtered spectrum is of a fairly good quality for further processing, meanwhile preserving the main advantage of the PRIZ application, i.e. its potency of a real-time performance.
All the experiments described above were done with the holographic photo plates, whose development needed about 1 hour. To operate in real time we suggest to use the PRIZ modulator as a photorefractive cell of the optical memory producing holographic filters. Further experiments demonstrates a potency of the PRIZ modulator for phase conjugation. The Ar-laser was used to generate the object, reference and reconstructing beams. Its wavelength 489 nm yields 50% absorption of light energy by the modulator, that is satisfactory to form the hologram, but not to destroy it during a reconstruction.
Experimental set (Fig. 9a) is the Max-Zender interferometer with one of the mirrows substituted by a beamsplitter, which forms the object and reference beams and directs them on the modulator at a fixed angle. The mirrow is placed behind the modulator perpendicular in position to the reference beam and forms the reconstructing one. Phase plate plays the role of an object. The

wave phase-conjugated by the hologram to the object one is transformed into the plane wave passing the phase plate. Being focused by the lens L, the latter forms a small light spot in its focal plane (Fig. 9b). In the same plane the zeroth diffraction order disturbed by the phase plate forms a broad light spot of low intensity. Therefore, substituting the phase plate by an object transparency, the lens L can perform the phase filtered Fourier spectrum.

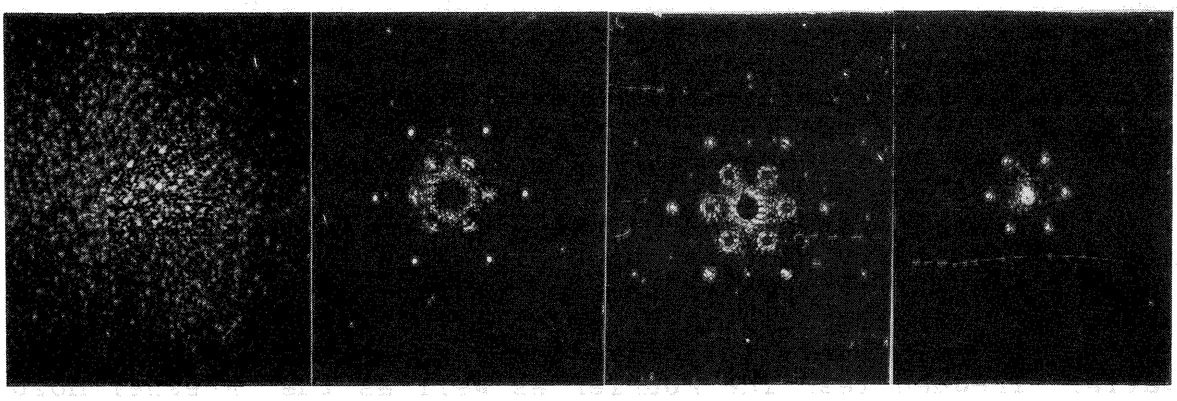


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Fig. 7. The results of Fourier hologram phase-noise and spatial filtering.

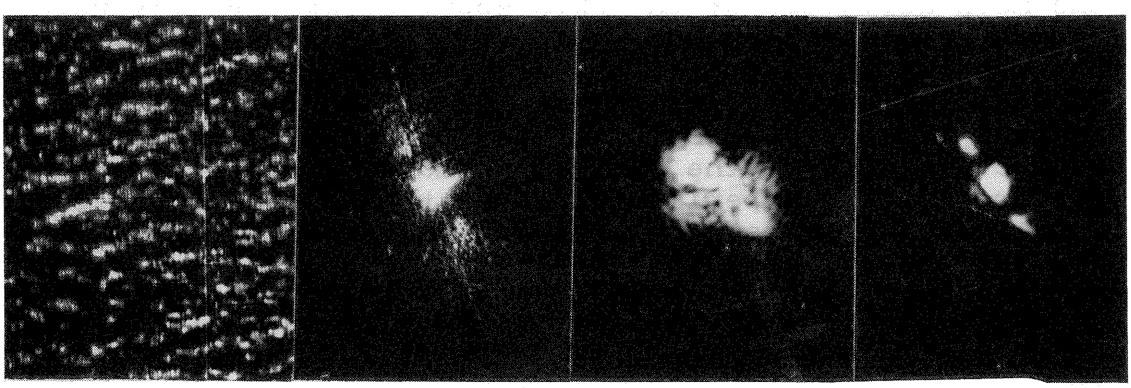

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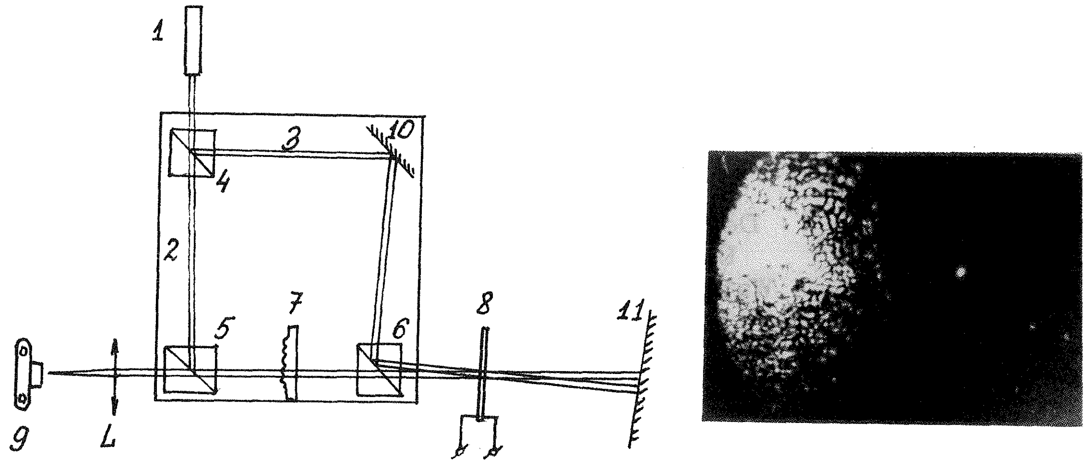
Fig. 8. The sea surface radioimage (a) and its spectra obtained with an immersion cell (b), without any filtering (c) and with IPH phase-noise filtering (d).




a b

Fig. 9. Phase conjugation by the PRIZ modulator;

(a): 1 - Ar laser;
2 - object beam;
3 - reference beam;
4, 5, 6 - beamsplitters;
7 - phase plate;
8 - PRIZ;
L - lens;
9 - camera;
10, 11 - mirriors.

(b): diffraction pattern (spectrum).

3. CONCLUSIONS. Our investigations have demonstrated the principal applicability of the PRIZ light modulator to optical sea radio and photo image processing in real time. Generally, incorporation of the PRIZ in optical data processing systems makes it possible to : (i) reduce the dimentions of an analyzer; (ii) increase the resolution in the low spatial frequency domain; (iii) insert information directly from an electron tube screen; (iv) carry out spatial and phase-noise filtering, involving, holographic techniques.

REFERENCES

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