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Recognition of objects radiating with broad spectrum in dispersive holographic correlator

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ABSTRACT

Results of experiments on the formation of correlation signals based on spatial and spectral characteristics of the objects in dispersive holographic correlator are presented. For the first time the most difficult recognition case of input radiation with broad spectrum was considered. Light emitting diodes were used in capacity of radiation sources. The obtained results on the correlation recognition of test objects showed a confident identification of each object. The degradation value of the output signal due to non-coincidence of characteristics of reference object and object to be recognized was 2.2 times at least.

0. Introduction

Currently the optical methods of information processing using calculation of correlation functions as final or intermediate output are most widespread. These methods are very effective and can be organically implemented by optical means. Optical correlators have found wide applications among the recognition devices. The spatial characteristics of the objects to be recognized are mainly used as information parameters in these devices. However, in the majority of correlators, object recognition can be successfully performed only with quasi-monochromatic input radiation [1–3]. The use of non-monochromatic radiation in these correlators leads to the necessity of introducing of additional elements into the optical scheme of a correlator due to the necessity of compensation of arising chromatic effects [4–7]. The possibility of objects optical recognition using direct radiation generated or scattered by objects [7–12] allows to increase the speed of processing and to reduce weight, size and cost of the recognition systems. However, most researchers take into account only spatial characteristics of objects. There is a range of practical problems in which the identification of an object can be performed not only by its shape but by the spectrum of its radiation as well.

To solve problems of object recognition by their spatial and spectral parameters in real time, dispersive correlators were developed [13]. In such devices the light correlation signals are formed by the radiation of the analyzed object through its interaction with the spatial filter-memory. In capacity of spatial filter-memory Fourier holograms can be used. The method of synthesis of such holograms is described in [14]. Dispersive correlators can be constructed using traditional "4f-scheme" [15], or the scheme utilizing single lens [16]. In these papers objects to be recognized have linear spectra.

The most difficult recognition case is when spectrum of input radiation is broad (non-linear spectrum). In this case, it is necessary to determine the most informative spectral ranges which will adequately characterize the recognizable spectrum. In the presented work, light emitting diodes, including RGB-LED, which have complex spectrum composition, were used as example in capacity of radiation sources.

1. The forming of correlation signals in dispersive correlators

One of the possible schemes for constructing dispersive correlators is the traditional "4f-scheme". This scheme uses a Fourier hologram as a spatial frequency filter. A generalized spatial pattern of the reference object is recorded in the hologram. It contains information about both the spatial structure of the object and spectrum of radiation propagating from the object. The last one is referred to as the reference spectrum. A generalized spatial pattern consists of several different-sized copies of the image of the reference object. The number of copies is determined by the quantity of components in the reference spectrum. The sizes of the object's image copies and its locations are inversely proportional to the wavelengths in the reference spectrum.

As shown in [15], the resulting correlation signal formed in the output plane of the dispersive correlator for non-monochromatic radiation is the total distribution of the correlation signals formed by each of the input radiation components. The values of each component of

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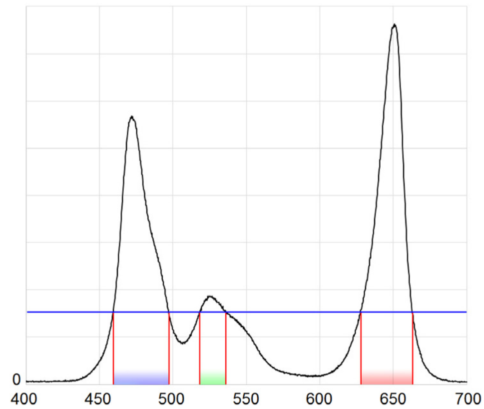

Fig. 1. Threshold-based selection of informative components of the spectrum (using the RGB-LED spectrum as example).

the correlation signal are determined by the degree of similarity of the spatial form of the input (to be recognized) and the reference object. The degree of spatial coincidence of the maxima of the spectral components of the correlation signal is determined by the degree of coincidence of the input spectrum of the radiation with the spectrum, information about which is recorded on the Fourier hologram. If one or several frequencies of the radiation spectrum coincide with the frequencies of the reference spectrum, correlation intensity distribution over spatial parameters without distortion of the scale will be observed at these frequencies with center of the distribution.

Therefore, for successful recognition of objects in a dispersive correlator, following conditions are necessary. First, localized correlation signals should be formed in the output plane only for those spectral components of the input radiation, information about which is recorded in the hologram. Secondly, the centers of these correlation signals should be located at a single point in the output plane. The fulfillment of these conditions is designed in advance at the creation of holographic filters, which can be recorded as interference pattern formed by the object and the reference light beams or synthesized with a computer.

The procedure of the synthesis of Fourier holograms for the dispersive correlator is described in [14]. It includes the following steps: the synthesis of a generalized spatial image containing information on both the spatial form of the reference object and its spectrum; calculation of the location of the generalized spatial image relative to the coordinates of the virtual source of the reference wave; generation of a random phase mask to reduce the dynamic range of synthesized holograms; calculation of propagation of the light field from the object to hologram plane; calculation of the transmission of the synthesized Fourier hologram; creation of a graphic file containing the synthesized hologram consistent with the parameters of the output device.

The main step in this procedure is the correct synthesis of a generalized image of the reference object, since this factor is crucial in obtaining of correlation signals between the reference object and objects to be recognized.

The most difficult case of object's recognition is when spectrum of the input radiation is wide and non-linear. In this case, it is necessary to determine the most informative spectral ranges. One of the simplest methods of determining the informative spectral ranges is demonstrated in Fig. 1. Highlighted ranges are selected as informative; in them the radiation intensity is greater than a given threshold value, which is usually chosen taking into account the nature of the spectrum. In this case, the generalized spatial image of the object consists of several different-scale copies of the image of the reference object. The number of copies, their positions and sizes are determined by these informational ranges in the reference radiation spectrum. Then these copies are placed in the object field. In this case it is assumed that the virtual reference point source is located in the center of the object field. The distance from the center of the object field to the smallest copy of the image of the reference object (corresponding to the largest wavelength in the reference spectrum) is determined by the condition that the zero diffraction order in the reconstruction plane of the hologram, which contains the image of the input object, should not overlap correlation signal structure [17].

According to the procedure described above, Fourier holograms were synthesized for its application in the scheme of dispersive correlator with a single lens. Software algorithm of synthesis of a generalized image of the reference object and its placement in the object field was implemented. The virtual source of the reference wave was placed in the center of the object field. The size of the object field is 1024×1024 pixels. The calculated hologram also has 1024×1024 pixels. The threshold binarization procedure was applied to the calculated amplitude Fourier holograms before their printing. To perform the printing of synthesized holograms on a physical medium (film), a laser phototypesetter was used with a maximum resolution of 2540 dots/in. (the minimum hologram pixel size equals to 10 μm).

2. The experimental results on recognition of objects radiating with broad spectrum

The setup of the dispersive correlator used in the experiments is shown in Fig. 2. It includes only one lens, located between the input (object) and frequency planes. The synthesized hologram is located in frequency plane. In such scheme, it becomes possible to correct the scale of the reference object in the recognition process if the geometric parameters of the setup are changed [18]. The object to be recognized (input object) 1 was a non-monochromatic light distribution in plane where a transparent film with a test object was placed (input plane) after illumination by a test source. As test sources three-channel RGB-LEDs, single-channel LEDs, and mercury lamp were used. The lens 2 is located in front of the holographic filter 3. The expressions which relate parameters of the holographic filter with the spatial and spectral characteristics of the reference object and the geometric parameters of used (one lens) correlator scheme are given in [14]. The neutral filter 4 was used to attenuate light in the zero diffraction order. The output signals were registered by the camera 5 and then processed on computer 6. Camera Canon EOS 400D was used in the experiments, the noise characteristics of this camera are given in [19]. The geometric parameters of the setup are: the focal length of the lens is 210 mm, the distance from the lens location to the input (object) plane is 320 mm, the distance from the hologram location to the output (camera) plane is

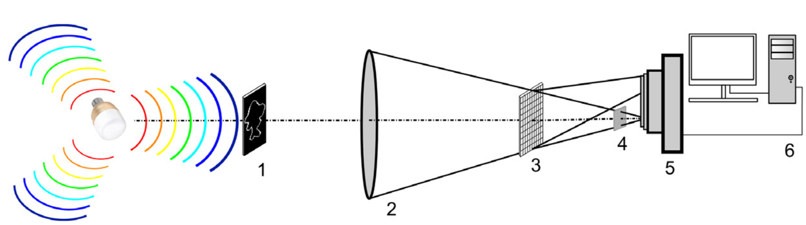

Fig. 2. The scheme of the experimental setup: 1 — test object for recognition (light distribution in the transparent film plane after illumination by a test source), 2 — lens, 3 — holographic filter, 4 — neutral filter, 5 — registering camera, 6 — computer.

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