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Classification of structures by thick holograms

The classification of linear point structures is investigated theoretically with the aid of associative behaviour of volume holograms.

1. Introduction

Investigations in the wide field of holographic associative memory have been made, for example, by GABOR [1], SAKAGUCHI, NISHIDA, NEMOTO [2], and KNIGHT [3]. The practical benefit of this work was the logical connection of information.

In this paper the classification of linear point structures is investigated theoretically. The linear point structures are represented by plane waves. The intention of our investigations is to answer the question of how and in what way it is possible to make a classification of determined information groups.

2. Theoretical considerations

From [4] we obtain the following equation

$$\frac{dS}{dz}+qS = -j\varkappa\frac{R}{a}\sum_{\nu=1}^{N}\exp\left(-j(\boldsymbol{K}_1-\boldsymbol{K}_\nu)\boldsymbol{r}\right). \quad (1)$$

Equation (1) describes the readout of information taking account of information recorded before. In (1) a, q, and $\varkappa$ are constants, where $\varkappa$ is the coupling constant. Equation (1) is derived from the theory of coupled waves. We suppose that the hologram thickness (z-direction) is small compared with the other hologram dimensions (see e.g. [5]). If we use one signal wave $(S(z))$ and many reference waves $(R(z))$ then instead of equation (1) we obtain

$$\frac{dS}{dz}+qS = -j\frac{\varkappa}{a}\left[R_1\sum_{\nu=1}^{N}\exp\left(-j(\boldsymbol{K}_1-\boldsymbol{K}_\nu)\boldsymbol{r}\right)+\right.$$

$$+R_2\sum_{\nu=1}^{N}\exp\left(-j(\boldsymbol{K}_2-\boldsymbol{K}_\nu)\boldsymbol{r}\right)+\ldots \quad (2)$$

$$\left.\ldots+R_N\sum_{\nu=1}^{N}\exp\left(-j(\boldsymbol{K}_N-\boldsymbol{K}_\nu)\boldsymbol{r}\right)\right],$$

where $\boldsymbol{K}_N$ is the grating vector of the recorded N^{th} information. Taking into account the boundary conditions for the transmission hologram and the existence of N reference parts, from equation (2) we get

$$S = -j\frac{\varkappa}{aN}\sum_{\nu=1}^{N}\left[\exp\left(-j(K_{1x}-K_{\nu x})x\right)\times\right.$$

$$\times\int_0^z\exp\left(-j(K_{1z}-K_{\nu z})z\right)dz+ \quad (3)$$

$$+\exp\left(-j(K_{2x}-K_{\nu x})x\right)\int_0^z\exp\left(-j(K_{2z}-K_{\nu z})z\right)dz+\ldots$$

$$\left.\ldots+\exp\left(-j(K_{Nx}-K_{\nu x})x\right)\int_0^z\exp\left(-j(K_{Nz}-K_{\nu z})z\right)dz\right].$$

Hence, considering the optimum scattered light we obtain

$$S = -j\frac{\varkappa}{aN}\left[(N-N')z-2j\left(\frac{1}{\Delta K_1}+\ldots\right.\right.$$

$$\left.\left...+\frac{1}{\Delta K_\nu}\right)\sum_{\nu=1}^{N}\frac{1}{\nu}\right]. \quad (4)$$

Here N is the number of reference parts used in the recording process, N' is the number of the reconstruction elements absent during the reconstruction process, and ΔK_N is described by

$$\Delta K_N = K_{Nz}-K_{\nu z},\ (\nu \neq N).$$

We assume, that one of the previously used reference structure is used during the reconstruction

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process. If we separate the signal part from the scattering light in equation (4) then for the signal intensity we obtain

$$I_s = \frac{\varkappa^2 (N-N')^2}{a^2 N^2} z^2, \tag{5}$$

and for the scattering intensity

$$I_R = \frac{4\varkappa^2 \left(\sum_{\nu=1}^{N} \frac{1}{\nu}\right)^2 \left(\frac{1}{\Delta K_1} + \ldots + \frac{1}{\Delta K_\nu}\right)^2}{a^2 N^2}. \tag{6}$$

From equations (5) and (6) we obtain the ratio between scattering intensity and signal intensity

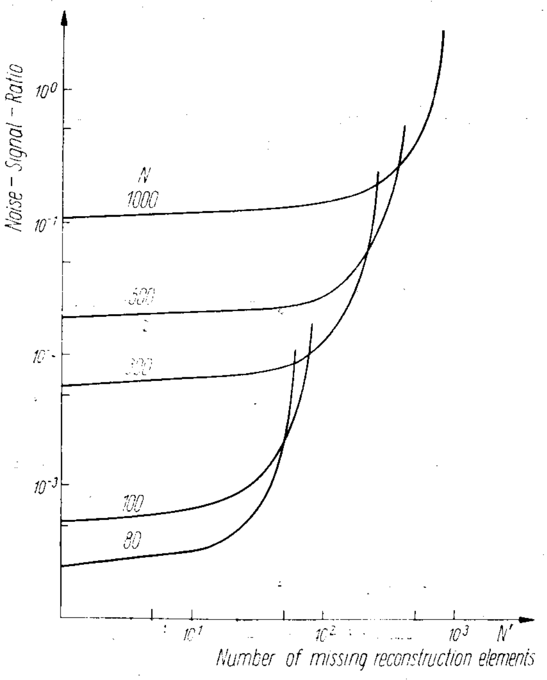
$$RS = \frac{4 \left(\sum_{\nu=1}^{N} \frac{1}{\nu}\right)^2 \left(\frac{1}{\Delta K_1} + \ldots + \frac{1}{\Delta K_\nu}\right)^2}{(N-N')^2 z^2}. \tag{7}$$

Equation (7) shows that the ratio RS is diminished with increasing hologram thickness z. In this way effect of thickness improves the quality of reconstruction.

3. Recording and reconstruction by angular coding

The interference pattern resulting from the superposition of plane wave S with a reference structure is recorded. After rotating the medium we make a second recording and so on. The number of rotation steps is equal to the maximum number of plane waves in the reference structure. As seen in equation (7), the ratio RS is minimum if the reconstruction structure is equal to one of the reference structures used previously.

The greater the differences between the two structures (reference and reconstruction) the more unfavourable is the ratio RS. This is shown in figure.



The ratio RS as function of N'

4. Discussion

After recording different linear point structures by angular coding and reconstructing with a previous reference structure we obtain a plane wave. Beside the correlation peak the observation of scattering light is also possible. When reconstructing with the correct reconstruction structure the scattering intensity is minimum. The ratio RS indicates whether the reconstruction structure is right or not. A further result of these investigations is also the possibility of recognition of substructures. From a set of offered structures it is possible to eliminate a class of structures. Each eliminated structure contains the searched structure as a substructure. The volume effect improves the quality of reconstruction.

Классификация структур при использовании толстых голограмм

Исследована теоретически классификация точечных линейных структур с использованием для этой цели ассоциативного поведения объемных голограмм.

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