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Letters to the Editor

Estimation of the radiation power at the output of holographic memory system

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The aim of this paper is to determine the light intensity distribution after the passage of a laser beam through the particular sub-assemblies of the optical holographic system. On this basis we want to determine the laser beam power necessary for respective reading in and reading out the information.

Keywords: memory, radiation.

1. Introduction

In optical holographic memory system in the form of photosensitive recording medium storing holograms of researched objects, there are optical elements, which shape and determine laser radiation beams. The light emitted from the source passes through the laser radiation beam expander, afocal system and deflector system [1] and then falls on the page composer in the form of electrical signals representing object information. The light wave leaving page composer is an object wave, which after being transformed by Fourier transform lens adds to reference beam in the area of photorefractive medium creating and storing corresponding Fourier holograms.

During the reconstruction, the beam recorded in the first diffraction order is focused on the detector array plane, which consists of photodiodes used to reading out information stored in the memory. According to results of published experiments, the estimation of laser light beam intensity after the passage through a page composer is a 45% attenuation of the incident light beam. It is, however, problematic to provide the power, which is necessary to record given information in holographic memory. Hence, in this paper we intend to illustrate and determine radiation power at the output of the holographic memory system.

2. Energetic hologram efficiency

2.1. Hologram efficiency

The diffraction hologram efficiency is measured by the ratio of flux deflected light in the first diffraction order (creating reconstruction image) to the incident flux light. In case of hologram formed by the usage of plane waves light: object and reference, we obtain the system of interfering pattern in the form of diffraction plane grate with constant of grate

$$p = \frac{\lambda}{\sin\theta_R - \sin\theta_O} \tag{1}$$

where θ_R, θ_O are incident angles of reference wave and object wave, respectively. The diffraction efficiency of spatial holograms analysed by KOGELNIK [2], supported by conjugate waves theory for ideal Franhofer hologram point object, was determined at sinusoidal change of refractive index

$$n = n_0 + n_1 \cos\frac{2\pi}{d}(x\sin\gamma + z\cos\gamma) \tag{2}$$

where γ is the angle which is formed by normal to the diffraction grate with the normal to hologram (axis z). The diffraction efficiency of the recorded hologram, when taking into account of $\xi = 0$ [1], [3], can be written in the form

$$\eta_H = \sin^2\left(\frac{\pi n_C d}{\lambda\sqrt{\cos(\theta_R')}}\right) \tag{3}$$

where $n_C = D/N$, while D is a linear range of the material dynamics (for $LiNbO_3$ it is 3×10^{-3}), and N is the number of holograms which are stored within the crystal volume. The θ_R' denotes the angle at which the holograms are recorded, but d is the thickness of medium.

2.2. The efficiency of optical system

The expanded laser beam of light divided to two parts in a cube of beamsplitter, is introduced to the reference and object wave arms. If the intensity of the light beam at the output of reference wave arm and at input of object wave arm is denoted as I_R and I_O, respectively, then the system efficiency in both arms can by written in the form:

$$\eta_R = \frac{I_R}{I_I}, \qquad \eta_O = \frac{I_O}{I_I} \tag{4}$$

where I_I is the light intensity of beam at the input to the proper arm of the system.

3. The power of radiation laser light

The storage of information in the recording medium with the help of laser beam light with the proper power causes the sinusoidal change in his refraction index. These changes can be caused by the radiation power of range from several milliwatts to several watts. The best situation is when the laser light beam power of the data at reading in and reading out are the same.

3.1. Reading out the information

Suppose that we want to read out information with the rate r [bit/s]. The parameter r is connected with the capacity and resistance of the loop of radiation detector [2]. Each hologram is read out during a time period

$$t_0 = \frac{K}{r} \tag{5}$$

where K is the capacity of a buffer device applied to a detector matrix. There exists a possibility of saving about 10 megabytes of data in it while applying a parallel processing of r bites of information per second. The required laser power P used for reading out is given by the relation

$$P = \frac{SK}{\alpha t_0 \eta_H \eta_R \eta_O}, \tag{6}$$

αt_0 is the fraction of time necessary for the reaction of the detector to the incident light signal. The final necessary power when reading out the information is

$$P = \frac{Sr}{\alpha \eta_H \eta_R \eta_O} \tag{7}$$

where S is the photodiode sensitivity. Let us note that the required laser power is independent of the number of bites saved in each cell of the hologram memory. If K is increased the time of the information reading out cycle is also increased so that the required power remains constant.

3.2. Reading in the information

The data are read in with the rate of r [bites/s]. If βr is the time fraction necessary for applying the voltage pulse to page composer, the remaining time determined by the relation $(1-\beta)r$ is an average value of the time necessary for recording the hologram. The laser power necessary for reading in this information can by obtained in the form

$$P = \frac{S_{\mathrm{mat}} r(\eta_O G + \eta_R)}{(1+G)\eta_H \eta_R \eta_O (1-\beta)p^2} \tag{8}$$

while p^2 [bits/cm^2] is the recording packing density in the material, where G is the ratio of the reference beam intensity to the object beam. The formula (8) says that the power depends mainly on the material sensitivity S_{mat} [J/cm^2] and is inversely proportional to the recording packing density. If G is great and when $\eta_O = \eta_R$, the laser power is almost independent of the object beam efficiency. When the parameter β takes a small value, the laser of continuous operation is used. However, while the parameter β becomes great, the application of the pulsed laser appears a necessity.

4. Results

Tables 1 and 2 show how the laser light beam power drops from the source to the recording medium using methods of angular and wavelength multiplexing,

Table 1. Energetic magnitudes in a system based on angular multiplexing technique (powers needed for read out data – 0.1 W and for read in data – 0.06 W).

Sub-assembler	Relative power of radiation	Efficiency of system elements
Laser	1.000	
Objective 1	0.838	
Light-dividing cube	0.362	
Objective in the object arm	0.253	$\eta_O = 0.11$
Deflectors 2	0.205	
Mirror	0.205	
Page composer	0.084	
Objective lens	0.040	
Mirror of the reference arm	0.362	$\eta_R = 0.56$
Deflectors 2	0.251	

Table 2. Energetic magnitudes in a system based on wavelength multiplexing technique (powers needed for read out data – 1 W and for read in data – 0.09 W).

Sub-assembler	Relative power of radiation	Efficiency of system elements
Laser	1.000	
Objective 1	0.838	
Light-dividing cube	0.362	
Objective in the object arm	0.2535	$\eta_O = 0.11$
Deflectors 2	0.2045	
Mirror	0.2045	
Page composer	0.0840	
Objective lens	0.040	
Mirror of the reference arm	0.2507	$\eta_R = 0.56$
Deflectors 2	0.2054	

respectively (in holographic memory system proposed in paper [1]). For that reason, the following values of system parameters were accepted: the output power of the laser light beam equal 7 W, the detector diode sensitivity is 10^{-12} J/bit, the reading out rate is 10 Kbit/s, the sensitivity of material is 30×10^{-3} J/cm^2, $\alpha = 1/2$, $\beta = 1/2$, the diffraction efficiency of the reference and object beams is the same in case of the wavelength and angular multiplexing method, respectively, and is $(\eta_R)_\lambda = (\eta_R)_\alpha = 0.56$ and $(\eta_O)_\lambda = (\eta_O)_\alpha = 0.11$, while the hologram efficiency obtained in the angular multiplexing is $(\eta_H)_\lambda = 1\times10^{-7}$ while that in the wavelength multiplexing method – $(\eta_H)_\alpha = 3\times10^{-6}$. The significant difference in hologram efficiency in both cases is caused by the fact, that using wavelength multiplexing method we obtain bigger number of holograms than in the angular multiplexing method. In practice, the change of material diffraction efficiency may by obtained by changing linear range of material dynamics. Basing on the values of parameter presented in this paper, it may by stated that the laser power necessary to read in and readout information using angular multiplexing method is 0.06 W and 0.1 W, respectively, while for wavelength multiplexing method is 0.09 W and 1 W, respectively.

5. Summary

On the basis of the performed calculations the light intensity distribution in the particular parts of the holographic memory system has been obtained. This allowed us to calculate the respective laser light beam powers necessary when reading in and reading out the information. Note that for both the methods of multiplexing similar values of laser light powers can by used for reading in the data. For this reason there exists a possibility of reading in the information with both the techniques without the necessity of changing the laser power. The necessary power for the processes of reading out can increase when the detectors of less sensitivity are applied and the capacity of the buffer devices is increased.

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