The paper considers research and development of arrays of computer-generated multiple-focus phase microholograms for providing given light patterns in the near field zone. Peculiarities of such arrays are discussed.

The main result of the talk is the fabrication of the microhologram array providing the given complex image in the focal plane. The size of the array was 1.54 mm x 1.54 mm, the size of each microhologram was 0.192 mm x 0.192 mm, and the focal length was 2 mm.

1. INTRODUCTION

In the earlier paper [1] we presented the computation of multiple-focus holograms (Fig.1).
When using a discrete Fourier transform the quantization step \( \frac{D}{M} \) of the phase function should be smaller than the minimum feature of the phase structure. Here \( D \) is the side of a square aperture and \( M \) is the dimension of the sampling grid.

Given focal length \( F \), aperture size \( D \), wavelength \( \lambda \), and the number of phase quantization levels \( N \), the dimension of the sampling grid should meet the following inequality:

\[
M > \frac{ND^2}{\sqrt{2\lambda F}}
\]  

(1)

We see that computation of short-focus elements involves large values of \( M \). On the other hand, if the dimension of the sampling grid is given, we have to put a limit on the focal length and the size of the element:

\[
F > F_{\text{min}} = \frac{ND^2}{\sqrt{2\lambda M}}
\]  

(2)

\[
D < D_{\text{max}} = \sqrt{\frac{2\lambda F}{N}}
\]

When the phase profile is divided into just two levels \( (N=2) \), the focal distance \( F=2 \text{ mm} \), wavelength \( \lambda=650 \text{ nm} \) and \( M=64 \), formula (2) gives us the condition \( D<0.24 \text{ mm} \) for the aperture, or \( D/F<0.12 \) for the angular aperture.

2. THEORY

We see that formula (2) does not allow us to use large apertures with short focal distances. This limitation can be overcome by using raster designs, that is, by uniting some multiple-focus structures and making a single phase array. This would allow us to realize complex light patterns over wide areas with short enough focal lengths. In the synthesis of a raster pattern, a particular light distribution in the focal plane is divided into segments each of which is produced by the corresponding phase element. It is clear from Fig.2 that the raster pattern consisted of closely located focusing CGHs results in the quantization grids of particular phase structures overlapping in the focal plane and giving rise to noise.
To avoid the noise in the areas where pattern overlap, we should use only the central part of the quantization grid, which is $\alpha$ times smaller than $M$. Coefficient $\alpha$ determines the ratio of linear size $D_F$ in the focal plane to aperture size $D$ of a particular phase element.

$$\alpha = \frac{D_F}{D} = \frac{\lambda F M}{D^2}$$  \hspace{1cm} (3)

This necessitates the use of a $C \times C$-dimensional quantization grid where $C$, in view of (3), is determined as

$$C = \frac{M}{\alpha} = \frac{D^2}{(\lambda F)}$$,  \hspace{1cm} (4)

and independent of the size $M$ of the quantization grid.

For the example of computations given above ($M=64$, $N=2$, $\lambda=650$ nm, $F=2.0$ mm) formula (4) gives $C=28$ for $D=0.192$ mm.

The fabrication of multiple-focus visible-range CGHs needs high-precision formation of the phase relief: the profile depth should be good to $0.01 \mu$m and positioning accuracy to $0.1 \mu$m [2]. To provide this precision, we employ direct e-beam recording of the phase relief in the electron resist layer followed by chemical and plasma-chemical treatment [3]. The method uses precise exposure doses and allows
the recording of a 2- to 8-level surface relief in the 6x6 mm² electron-resist layer in a single technological cycle with necessary accuracy.

Below are given the results of the computation and fabrication of multiple-focus raster CGHs. Fig.3 shows the calculated phase structures of a few CGHs and corresponding experimental output light patterns. The elements have the following parameters: $F=2\text{mm}$, $\lambda=650\text{nm}$, $D=0.192\text{mm}$, $M=64$, $N=2$. The quantization grid for individual elements is $C\times C$ where $C$, according to (4), is taken 28. This prevents the elements from giving noise when we combine them in a single raster pattern.

Fig.3 Computed phase structures of some multiple-focus CGHs and corresponding experimental output light patterns.
3. CONCLUSION

We have developed the computation method which, unlike conventional methods, allows us to combine multiple-focus CGHs into new short-focus large-aperture elements with particular complex output light patterns.

These raster multiple-focus elements can be effectively used in fiber optics, image processing systems and for developing optical neural networks. In particular, they can help to solve the problem of beam-splitting from single to several fibers (see [4] for example).

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