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ABSTRACTS

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Quality and measurement aberrations on holographic lenses (#268)

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Abstract

We have evaluated the quality of holographic lenses stored in an environmentally friendly photopolymer. Optical quality metrics has been used to test them. The negative asymmetrical holographic lenses showed the best optical quality.

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Abstract: In this paper, we have evaluated the quality of holographic lenses stored in an environmentally friendly photopolymer. Optical quality metrics has been used to test the holographic lenses. The metrics values obtained shows that the negative asymmetrical holographic lenses have the best optical quality.

Keywords: holographic lenses, aberration, optical quality metrics, image quality

1. Introduction

Holographic optical elements (HOEs) are optical elements produced using holographic imaging processes or principles. HOEs can be approximated as holograms of point sources or collimated beams of light, such that light from one source is imaged onto the other. In this work, holographic lenses (HLs) have been fabricated in a photopolymer with biocompatibility called Biophotopol [1].

Two types of HLs have been fabricated, symmetrical and asymmetrical, each with the same focal length (93 mm at 473 nm) and 12 mm of recording diameter. For each type, we registered both positive and negative focal length to evaluate the image quality. These HLs have the advantage of being low cost due to their simple design, small size and light weight.

HLs also suffer from aberrations just like diffraction lenses. The diffraction efficiency is not an adequate optical parameter to measure the HLs quality. For this reason, we have evaluated the quality of the HLs with aberration-based methods, image quality of Impulse Response, and Fourier domain [2].

2. Results and conclusions

We have studied these metrics using a Hartmann Shack wavefront sensor to record the wavefront. The HLs were illuminated using a 473 nm laser. The results obtained can be seen in Table 1 and Figure 1, it shows the worst and the best results obtained for positive symmetrical and negative asymmetrical geometry, respectively, and 2D Wavefront aberration for both type of HLs.

Monochromatic aberrations occur in quasimonochromatic light. These aberrations do not consider the light frequency effect on its propagation through a system. There are five primary monochromatic aberrations (also called Seidel aberrations), but only three of them, Spherical aberration, Coma and Astigmatism, (the aberrations that deteriorate the image) have been studied [3,4].

Optical quality metrics based on the aberrated wavefront emerging from optical system such as Zernike and Seidel coefficients, root mean square (RMS), and critical pupil fraction (PF) have been analyzed. In this work it has been considered as a quality criteria that the HLs must have an RMS of 0.1. Therefore, the positive symmetrical HLs recording diameters have been reduced from 12 to 3 mm to fulfill this criteria. For all these optical quality metrics the values obtained are higher for the symmetric HLs.

In addition, the Strehl Ratio (SR) and the Entropy metrics based on the impulse response have also been analyzed. As for SR, it is considered good image quality when SR 0.7, which is not the case for symmetrical LHs. With respect to entropy, a lower value is indicative of better image quality.

Finally, the metrics based on the Fourier domain have been calculated, as well. The cutoff frequency (CF) can be considered as the spatial frequency of a grid test whose contrast in the image reaches zero and the details have completely disappeared. As with all other metrics, the best CF value has been obtained for asymmetric LHs.

	Positive symmetrical HLs					Negative asymmetrical HLs				
Zernike coef. (µm)	C_4^0	C_2^{-1}	C_3^1	C_4^0	C_4^0	C_4^0	C_3^{-1}	C_3^1	C_4^0	C_4^0
	$-9\cdot10^{-3}$	$1.1\cdot10^{-1}$	$-2.2\cdot10^{-2}$	$-1.8\cdot10^{-1}$	0	$-6\cdot10^{-3}$	$2.3\cdot10^{-2}$	$-6\cdot10^{-3}$	$-1.5\cdot10^{-6}$	$-7\cdot10^{-6}$
Seidel coef. (µm)	S		C		A	S		C		A
	$8.05\cdot10^{-5}$		$2.21\cdot10^{-3}$		$6.06\cdot10^{-2}$	$-8.05\cdot10^{-5}$		$-1.94\cdot10^{-5}$		$3.01\cdot10^{-7}$
RMS Zern (µm)	0.209					0.030				
RMS Seid (µm)	0.011					$1.56\cdot10^{-5}$				
PF	0.063					0.25				
SR	0.124 (12%)					0.856 (86%)				
Normalized Entropy ($\cdot10^{-3}$)	7.7					1.7				
CF Theoretical (cycles/degree)	68.2					110.7				

Table 1 Summarize the values obtained for the worst and the best results obtained for positive symmetrical and negative asymmetrical geometry, respectively.

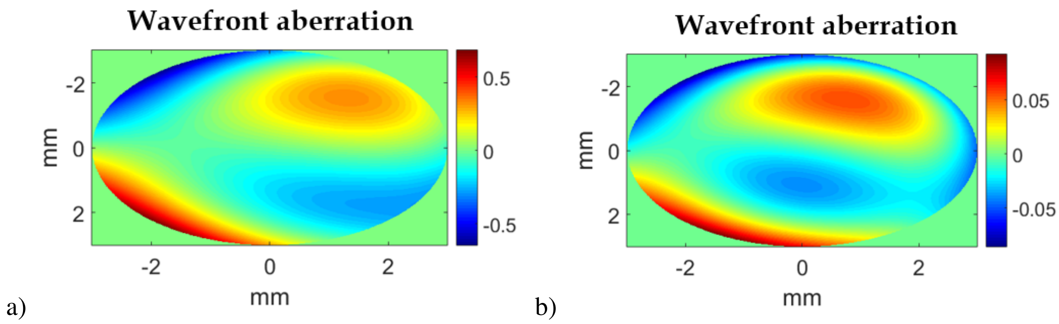

Figure 1 2D Wavefront aberration for: a) positive symmetrical HLs, b) negative asymmetrical HLs.

As we can be seen there are a good agreement between metrics related to optical quality, to impulse response and metrics in Fourier domain. We can conclude that the negative asymmetric HL has less aberration than the positive symmetric one, both reconstructed at 473 nm. The calculated quality metrics allow us to quantify the presence of aberrations in an optical system. Due to the agreement among the metrics, we can choose one indistinctly or select it depending on the information that it gives us. In addition, Figure 1 shows that there is an order of magnitude difference in the wavefront aberration function.

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References

[1] T. Lloret, V. Navarro-Fuster, M.G. Ramírez, M. Ortuño, C. Neipp, A. Beléndez, and I. Pascual, "Holographic Lenses in an Environment-Friendly Photopolymer", Polymers. **10** (3), 302 (2018).

[2] P. Artal, *Handbook of Visual Optics* Vol. II (CRC Press, Abingdon UK, 2017).

[3] J.N. Latta, "Computer-Based Analysis of Hologram Imagery and Aberrations II: Aberrations Induced by a Wavelength Shift" Appl. Opt. **10**, 609–618 (1971).

[4] T. Lloret, V. Navarro-Fuster, M.G. Ramírez, M. Morales-Vidal, A. Beléndez, and I. Pascual, "Aberration-Based Quality Metrics in Holographic Lenses", Polymers. **12** (4), 993 (2020).