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Wavefront-shaping-based correction of optically simulated cataracts: supplementary material

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This document provides supplementary information to "Wavefront-shaping-based correction of optically simulated cataracts," https://doi.org/10.1364/OPTICA.7.000022. It shows the physical simulation of the effects of the wavefront-shaping (WS) based correction of advanced cataracts on imaging by using a commercial diffuser.

The effect of the WS correction of advanced cataracts on the imaging can be visualized by using a commercial diffuser. After this correction, the optimized ocular PSF corresponds to a diffraction-limited spot over a background of speckle. The PSF associated to the round glass diffuser DG-1500 (Thorlabs GmbH, Germany) mimics that morphology, as shown in Figure S1a.

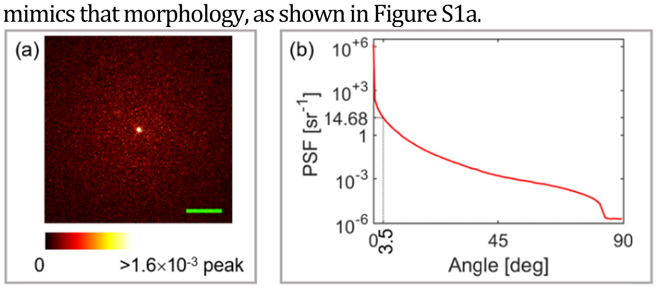

Fig. S1. PSF of the DG-1500 diffuser: (a) over-exposed two-dimensional map and (b) normalized wide-angle radial profile. Length of green bar is 5 arcmin.

The radially averaged profile of the PSF of the diffuser, over the whole angular range, is provided by the manufacturer[1]. However, the intensity value at zero degrees was corrected, according to our measurements. The normalized wide-angle PSF is shown in Figure S1b. The amount of straylight generated by this diffuser is $Log_{10}(s)=2.25$ at 3.5 degrees. It can be associated to a corrected advanced cataract, although its PSF profile does not follow the angular course of the glare function for a standard observer, according to the CIE[2].

The ratio between the peak height (I_{peak}) and the averaged energy around (I_{around}) in the PSF's diffuser is 4500 and it can be associated to a WS optimization using a specific size of segment (b). To find that size, those ratios were initially calculated from the numerically optimized PSF profiles (see Figure 6) when the amount of generated straylight is $Log_{10}(s)=2.25$. Figure S2 shows the relationship between the logarithmic values of the ratios and the sizes of the segment whose equation of the linear fitting is $Log_{10}(b)= -0.44Log_{10}(I_{peak}/I_{around})+3.23$. Thus, the diffuser physically simulates a WS correction performed with a size of the segment of 41 µm, approximately.

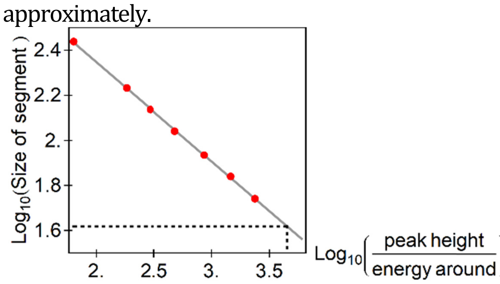

Fig. S2. Relationship between the size of segment and the ratio of the optimized PSF's peak and its vicinity. Linear fitting is depicted by the gray line.

To register the effect of a corrected advanced cataract, the original scene is acquired by using a camera with the diffuser placed in front. In a real scenario, the quality of the correction for polychromatic illumination will be affected by: the longitudinal and transversal chromatic aberrations, the wavelength dependence of the straylight, the temporal changes of the scaterers (or dynamic light scattering) and the wavelength dependence of the depth of phase modulation in the SLM (the LCoS device[3], in our case). Hence, the height of the PSF's peaks will be lower at wavelengths different to the used one during the correction[4] which in turn leads a contrast reduction of the projected image at retina. As this work is aimed to show the highest benefits of WS, only monochromatic illumination is considered. Then the image of the physical simulation is converted to gray and displayed by the green channel in the RGB color space to simulate the monochromaticity.

Finally, the image with the uncorrected effects of cataracts is simulated by applying a digital gaussian filter to the acquired image behind the diffuser. It blurs the image, mimicking the effect of the low-spatial frequency phase perturbations.

References

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