Binocular Adaptive Optics Visual Simulator Featuring Full Control over the Complex Pupil Functions

Christina Schwarz, Enrique J. Fernández, Pedro M. Prieto and Pablo Artal

Laboratorio de Óptica, Instituto Universitario de investigación en Óptica y Nanofísica (IUiOyN), Universidad de Murcia, Campus de Espinardo (Edificio 34), E-30100 Murcia, Spain

Christina.Schwarz@um.es, Enriquej@um.es, Pegrito@um.es, Pablo@um.es

Purpose

To demonstrate feasibility and convenience of simultaneously controlling both phase and amplitude of the two complex pupil functions by using liquid crystal spatial light modulators (LC-SLMs) in a binocular adaptive optics visual simulator.

Methods

The instrument is an improved version of the binocular adaptive optics system previously developed in our laboratory [1]. The set-up allows for measuring and manipulating the ocular aberrations of the subject's both eyes under actual binocular vision conditions. One important feature is its relative simplicity as the aberrations of both eyes are measured and manipulated by merely one Hartmann-Shack sensor and one reflective liquid crystal on silicon (LCoS) spatial light modulator [2], respectively. The subject performs visual tasks, such as visual acuity or contrast sensitivity tests under different conditions of object vergence and aberrations. In the new version presented here, we have incorporated an additional LC-SLM of a transmissive type (Holoeye LC2002) which operates in pure intensity modulation under proper polarization control. The device is conjugated with the eyes' pupil plane in order to produce any desired pupil mask in size, location, shape or transmittance. This provides us with full computer based control over the complex pupil function, amplitude and phase, in the two eyes.

Results

The system has been designed, implemented, calibrated and tested. The impact of the diffraction effects on the perceived contrast and the strategies for reduction will be described. The new system correctly simulates a large variety of visual conditions while the subject was performing visual testing. Any modification regarding the pupil plane was straightforward and expeditious to perform (see Figure 1).

Conclusions

A binocular adaptive optics visual simulator has been further developed to provide full control over amplitude and phase of the complex pupil functions. This feature enhances the possibilities of the system to a great extent. The instrument has proven to work reliably and, despite its versatility, to be easily operable. Examples of different vision science experiments will be presented.

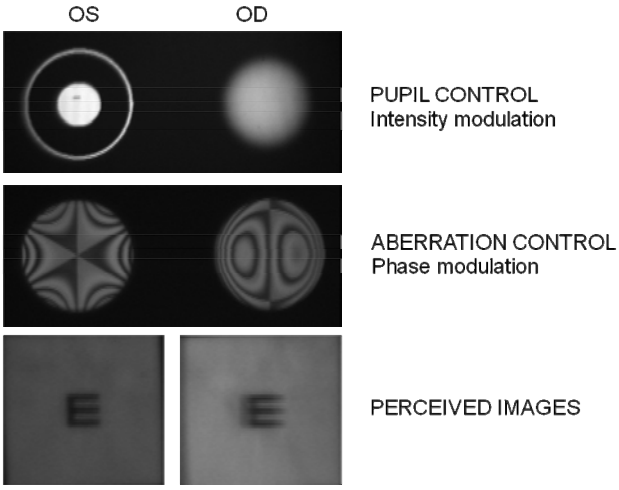

Figure 1: Basically any combination of pupil masks and aberration profiles is possible. The figure shows the perceived image in the left eye (OS) when coupling a ring pupil with trefoil aberration and the image perceived by the right eye (OD) when linking a gradient pupil with coma aberration.

References

1. Enrique J. Fernández, Pedro M. Prieto, and Pablo Artal, "Binocular adaptive optics visual simulator," Opt. Lett. 34, 2628-2630 (2009)

2. Enrique J. Fernández, Pedro M. Prieto, and Pablo Artal, "Wave-aberration control with a liquid crystal on silicon (LCOS) spatial phase modulator," Opt. Express 17, 11013-11025 (2009)