Visual impact of interference gratings created with a liquid-crystal spatial light modulator

Sara Castillo, Brian Vohnsen

Advanced Optical Imaging Group, School of Physics, University College Dublin, Dublin 4 (Ireland)

sara.castillo@ucd.ie, brian.vohnsen@ucd.ie

Purpose

Interference gratings have been used for visual testing where they can override the impact of ocular aberrations and in the ultimate limit probe visual acuity at the level of individual photoreceptors. Thus they have been used to study what is commonly known as the Campbell effect, i.e., a reduced visual acuity of gratings observed through de-centered small pupils [1]. In turn, the Stiles-Crawford effect describes a reduced visibility to light that enters the eye near the pupil rim being due to the angular sensitivity dependence of the photoreceptor cones. Both effects have been discussed in relation to photoreceptor light coupling [2] and a direct sensitivity to the wavefront slope at the retina has been demonstrated for coherent light [3]. The purpose of this study is to produce interference gratings using a programmable liquid-crystal spatial light modulator (SLM) and use them for visual testing in relation to the Campbell and the Stiles-Crawford effects.

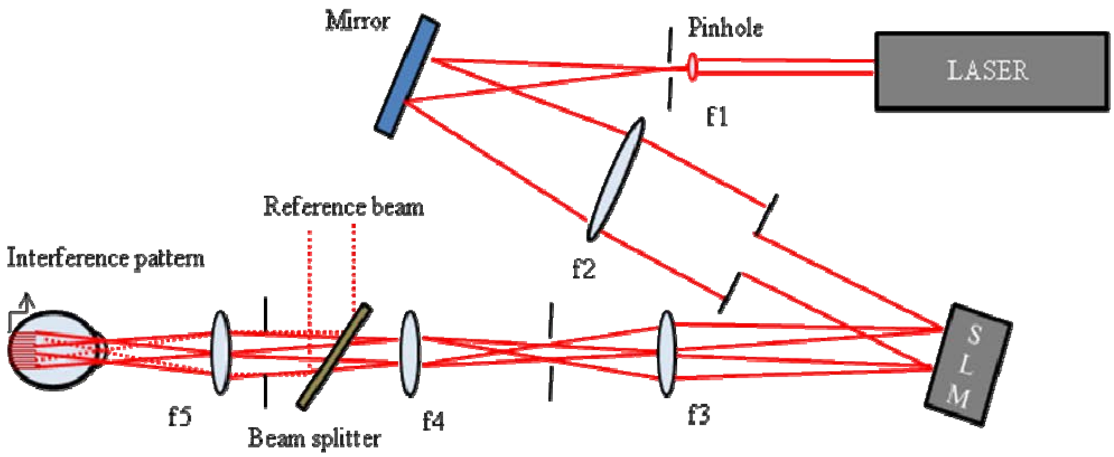

Fig. 1. Experimental setup with a spatially-filtered 632.8 nm HeNe laser incident on the SLM and with the diffracted orders projected onto the eye pupil. For simplicity the full path of the reference beam is not shown. The irises shown are used to limit the beam diameter, block unwanted higher diffraction orders, and also to control the viewing angle seen by the subject to about 1.5 visual degrees.

Methods and results

The setup used for this study is shown schematically in Fig. 1. The programmable SLM creates diffracted orders obtained with a variety of phase gratings: (i) a sinusoidal grating, (ii) a blazed grating, and (iii) a mirrored blazed grating. As a result two coherent Maxwellian sources (either equally bright or with a notable difference in brightness) are projected onto the eye pupil and their spacing as well as their angle can be adjusted in real time. To reduce the visual impact of speckle the coherent source-points can be rotated at speeds limited only by the response time of the modulator to about 10 Hz. The visibility of the resulting interference pattern (with and without rotation) as judged by the subject is determined in comparison with that of a centrally-located Maxwellian reference.

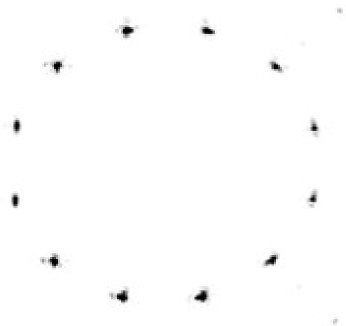

Fig. 2. An example of a set of images of Maxwellian sources projected onto the eye pupil (shown with inverted contrast) when a set of rotated phase gratings was sent in sequence onto the SLM. This image was registered with a CCD camera placed in the eye pupil plane and the zero'th order has been filtered out.

The approach confirms that suitable interference gratings can be generated with an SLM useful for visual testing of the Stiles-Crawford and Campbell effects. The fact that the grating period can be comparable to the size of the individual photoreceptors may, however, also complicate the interpretation of the experimental results.

Conclusions

Computer-configurable interference gratings for visual testing have been generated with an SLM and used to study the classical Campbell and Stiles-Crawford effects. Results of this work are discussed in relation to the waveguide coupling model for the cone photoreceptors [2].

Financial support from Science Foundation Ireland (grants: 07/SK/B1239a and 08/IN.1/B2053) is gratefully acknowledged.

References

1. F. W. Campbell and D. G. Green, "Optical and retinal factors affecting visual resolution," J. Physiol. 181, 576-593 (1965).

2. B. Vohnsen, "Photoreceptor waveguides and effective retinal image quality," J. Opt. Soc. Am. A 24, 597-607 (2007).

3. B. Vohnsen and D. Rativa "Absence of an integrated Stiles-Crawford function for coherent light," J. of Vision, 11(1), 1-10 (2011).