



## Eyewear and smart glass quality control with HASO Shack-Hartmann wavefront sensor

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### Introduction

APPLICATION NOTE

Eyewear is an essential protection for activities in which the motion is basically faster than a regular walk or if the evolution is made through a different media than air such as water. In activities such as swimming, scuba diving, skiing, mountain biking, shooting, our eyes have to be protected against projections, insects, dust or cold. The eyewear such as snow goggles, safety glasses, colored or not, are protecting our precious eyes against natural threats. The quality of the optics can affect the vision quality and cause ocular fatigue and associated consequences such as headache. Also other wavefront distortions such as astigmatism can affect peripheral vision, cause discomfort and potentially put the safety of the wearer at risk.

In the past few years smart glasses have been made accessible to mass market. Those devices offer several features including hands-free access to all sorts of information directly related to the eye, potentially improving user's safety for a number of applications, professional or not. While reducing the production costs, manufacturers of this type of optical systems have to follow some quality standards defined for safety eyewear by norms such as

- EN166: European Standards for Eye protection
- ANSI Z87.1: Eye protection from The American National Standards Institute
- SANS 1404: Eye-protectors for industrial and non-industrial use in South Africa

Accuracy of vision is one of the four optical clarity classes. It qualifies image distortion through eyewear. The highest level of optical clarity or correctness is defined as Class 1 (0.06 diopters), which insures perfectly clear vision<sup>1)</sup>.

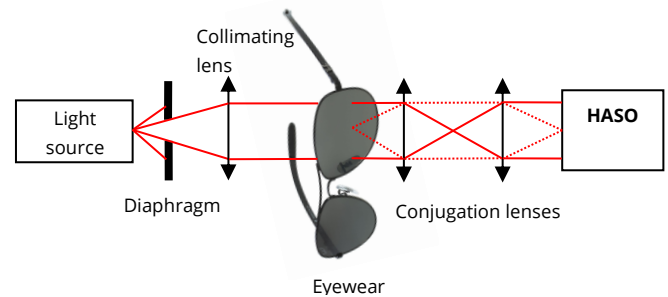
Spiral test is one of the optical clarity determination techniques. This method is performed to locate and assess local prismatic deviations in order to obtain a refractive profile across the entire surface. It can be time-consuming test. **In this application note we describe how a Shack-Hartmann wavefront sensor (SHWFS) can be used to perform a quick and quantitative assessment of the optical quality of eyewear.** SHWFS is a tool of reference in optical metrology. It is used to provide quick, robust and precise assessment of the optical quality of a large spectrum of optical systems and components. Imagine Optic has been improving the original model of the SHWFS to take it to the industrial requirements level in terms of performance and reliability.

SHWFS is based on the association of a lenslet array and a CCD detector. The lenslet samples the incoming wavefront into wavelets that are focused by the lenslet array or sub-pupils on the detector. The wavefront slopes are calculated directly from the position of their corresponding focal spot positions. The slope information is then processed to determine the incoming wavefront or phase distribution of the electromagnetic field. The Shack-Hartman sensor is achromatic and can achieve measurement up to higher than hundredth of a wave ( $\lambda/100$  rms). Imagine Optic has improved the Shack-Hartmann method by developing proprietary techniques allowing to increase the dynamic, accuracy and robustness of the original method. Imagine Optic patented several apparatus such as Dynamic Spot Tracking™ and Auto Spot Finder™, to increase their SHWFS, HASO™ measurement capabilities in order to meet the highest quality standards.

## A simple way to detect optical distortion of eyewear

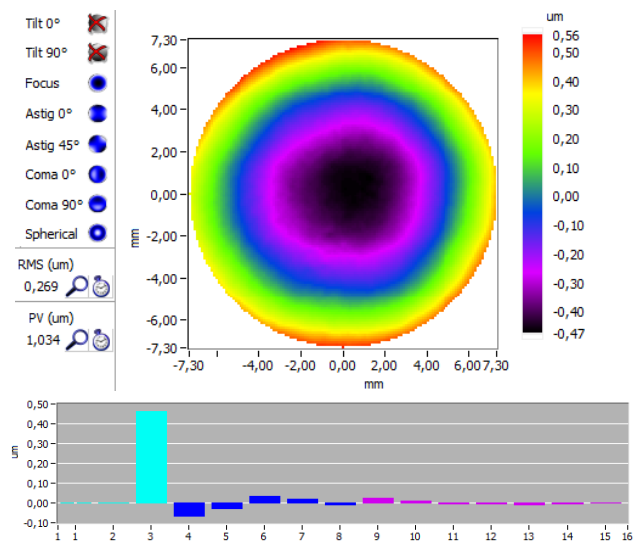
Shack-Hartmann wavefront sensors quantify the aberration of the wavefront after the light went through an object of interest and allows to determine the difference to a perfect optical system with the same specifications. A single-mode fibered laser is used as a light source. The wavelength is chosen accordingly to the application and several could be actually chosen to cover a broad part of the spectrum.

The output of the fiber is collimated for the characterization of the eyewear under test. The eyewear is then conjugated onto the microlens array of the SH sensor see Figure 1.



**Figure 1** Layout of the optical setup for eyewear distortion inspection. Sunglass shows the position of the sample under test.

The magnification is 1 in this setup. A reference wavefront is taken without eyewear in the beam path. Using the HASO3 128GE2, the detection area on the eyewear is 14.6 mm in diameter with a spatial resolution of 110  $\mu\text{m}$ . Two examples of the transmitted wavefront of sport eyewear are shown in Figure 2 and Figure 3.

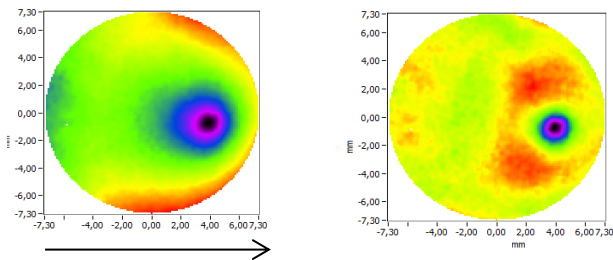


**Figure 2** Transmitted wavefront of ski goggles without tilts. The Zernike coefficients are plotted in the lower graph starting from defocus or  $Z_3$  to the 4<sup>th</sup> order tetrafoil at 0° or  $Z_{16}$ .

A ski goggle or snowboard screen is usually bent with a strong curvature to protect your eyes and at the same time give visibility for wide angles. The bending process or framing can induce some defocus in the center of the

vision area (middle of goggle). This defocus is precisely determined, thanks to the use of Zernikes coefficients. The third coefficient  $Z_3$  is the focus and its value is shown on the bar plot in Figure 2. Zernike's coefficients are used to calculate refractive power with a weight of detecting pupil radius<sup>2</sup>).

This snowboard goggle was sampled on several areas. The refractive power on each area was less than 0.035 dioptres (D), accordingly classified as optical class 1, *i.e.* highest optical quality for that class of optics.

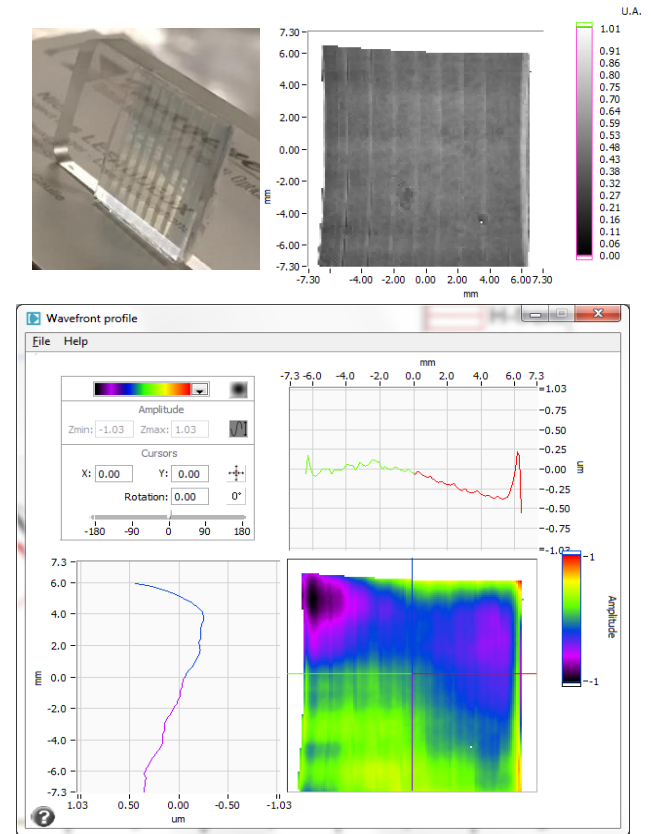


**Figure 3** Transmitted wavefront of swimming goggles without tilts (left) and the first 8 Zernike coefficients filtered out (right).

A defect in the lens fabrication, such as a variation of refractive index can cause some optical distortions. The wavefront in Figure 3 shows a local defect, a spot around  $x=4$  mm, on one side of a swimming goggle. This spot is not visible in the intensity profile when the intensity of the transmitted light is detected for example by a CCD camera. It is clearly seen after filtering low spatial-frequency aberrations, the right-hand side of Figure 3. The wavefront information is therefore essential to understand fabrication processes as well as to avoid such defects.

Another example showing advantages of the wavefront analysis is by using a similar apparatus on a disruptive structure of a smart glasses light guide developed by Optinvent. This structure transmits an image from a tiny screen to the eye, at the same time allowing to see through it. This non-contact and rapid inspection technique shows the wavefront error induced by the substrate structure. The light guide (see Figure 4) is placed at the object plane of the optical setup as shown previously. The HASO measures the wavefront and intensity profiles of the beam after its propagation

through the optics. The phase distortion is quantified, *i.e.*, 2.051  $\mu\text{m}$  PtV and 0.303  $\mu\text{m}$  rms which represents a good performance for see-through quality.



**Figure 4** A photograph (top left), transmitted intensity profile of a structured glass (top right) and wavefront profile (bottom). Both profiles are obtained from the HASO wavefront sensor.

## Conclusion

We presented how to detect optical aberrations induced by the eyewear using HASO Shack-Hartmann wavefront sensor. It is a real-time, accurate and reliable detection technique that can be used for product development and in-line quality control.

## References

- 1) European Standard, "Personal eye-protection - Specifications" EN 166:2001 (2002).
- 2) D. Dai, "Wavefront optics for vision correction" (SPIE, 2008), Chap.3.