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Techniques for Checking As-Worn Alignment of Eyewear with Display Optics or Progressive Prescription Lenses

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Abstract:

Fitting eyewear with display optics to a user's head can be problematic because lenses of the eyewear are typically not on hand during product development. This can cause problems with alignment of eyeboxes of the lenses when the user wears the eyewear with finished display optics. Generally, the eyebox of a lens or display optic is a volume within the lens such that parameters of image quality criteria is met. For example, if the eyeboxes of the lenses do not align correctly with the user's eyes, then the eyewear does not fit or align with the user's head. Incorrect alignment can cause degraded image quality, dimming, and/or clipping of corners of a displayed image of the eyewear, and may cause an unsatisfactory and unpleasant experience for the user. This problem of alignment may also occur with respect to progressive prescription lenses. Accordingly, techniques to build an eyebox simulator and check as-worn alignment of eyewear with display optics or prescription lenses (*e.g.*, progressive lenses) are provided.

Keywords: Alignment of lenses, eyewear, display optics, progressive lenses, prescription lenses, eyebox alignment, head-worn display.

Background:

Today's diamond-turned optics or molded optics take a long time to manufacture. The manufacturing process for these optics can take on the order of months to produce the finished optics. Eyewear displays that implement diamond-turned optics or molded optics are typically designed, planned, and developed without the optics on hand. Developing eyewear displays without the optics on hand can result in problems related to how the eyewear display would fit on a user's head and/or how the optics align with the user's eyes. Without having the optics on hand, effective alignment of the optics can be difficult to determine during development of the display. Due to the long manufacturing time to produce diamond-turned optics or molded optics, it would be beneficial to simulate alignment of the eyewear as worn by various users, without having the optics on hand for testing and confirmation.

Similarly, eyeglasses or frames are fitted a user's head without progressive prescription lenses installed. Typically, a user selects the frame they wish to purchase and obtains a prescription for parameters of the progressive lenses that will be placed in the frames. The progressive prescription lenses are then tooled and installed into the frame at a later date to complete the assembly of the eyeglasses. Thus, alignment of the progressive prescription lenses cannot be determined with respect to the user's eyes until the assembly of the eyeglasses is complete and then worn by the user.

Description:

To address the problem of determining whether eyewear with display optics or progressive prescription lenses properly fit a user's head or align with the user's eyes, an eyebox simulator and associated techniques are described herein to enable checking as-worn alignment of eyewear with display optics or progressive prescription lenses. Generally, eyewear with display optics feature a small eyebox, which is a volume within the lens such that parameters of image quality criteria is met. For example, the parameters of the image quality criteria can include non-uniformity and resolution. The non-uniformity may be defined locally or globally, and in either case a non-uniformity value of one results in clipped corner.

As such, when the eye of the user moves outside an optimal eyebox position (*e.g.,* in-plane motions or out-of-plane motions), the image quality of the eyewear is degraded or impaired which can include dimming of the image and/or clipping of the corners of the image. For example, a virtual reality (VR) or augmented reality (AR or mixed reality) headset display worn on the user's head can slip or shift position and the user can still view at least some of a displayed image, which in turn can cause a poor viewing experience due to degradation, dimming, and/or clipping of corners of the displayed image. Similar or same issues also exist with respect to alignment of progressive prescription lenses relative a user's eyes.

Figs. 1A and 1B illustrate general configurations of an eyebox simulator in accordance with one or more aspects. To address the problems described above, an eyebox can be simulated in hardware to check how an eyewear display with optics or progressive prescription lenses will fit on a user's head (or align with the user's eyes). As illustrated in Fig. 1A, the eyebox simulator includes a lens with eye facing cylinder holes drilled along marginal rays from edge points of an unvignetted eyebox. Further, as shown in Fig. 1B, the eyebox simulator includes light sources and collimation optics mounted on the lens that outputs collimated light rays through the drilled cylinder holes, such that the eye of the user receives one or more of the collimated light rays. Although not shown, any or all of the collimated light ray may be provided as same or different colors to better facilitate verification of the eyebox or fitment.

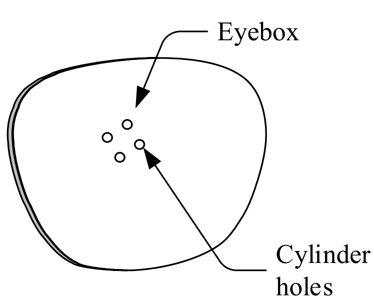

Fig. 1A

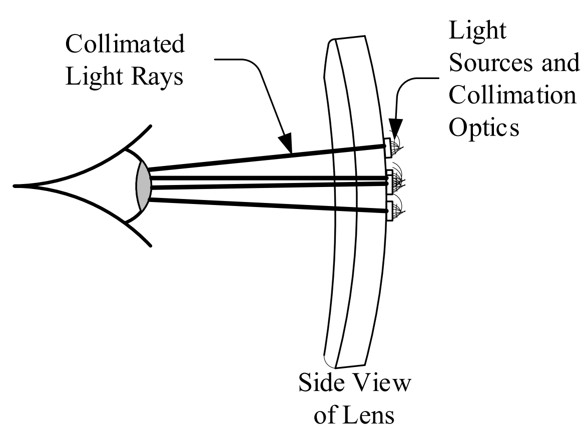

Fig. 1B

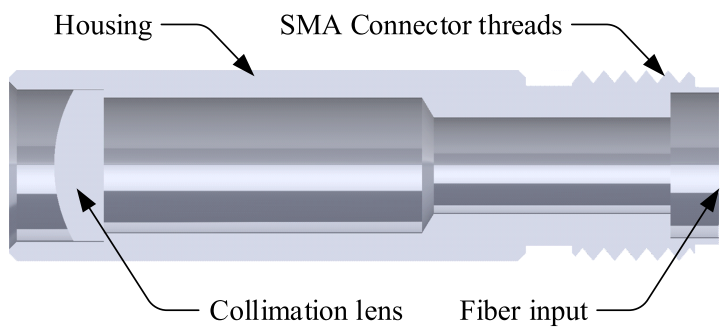

Fig. 1C

The light sources and collimation optics of the eyebox simulator illustrated in Fig. 1B can be implemented by various methods. For example, an off-the-shelf fiber optic collimator shown in Fig. 1C and fiber optics cable (not shown) can be used to output the collimated light rays. In another implementation, a light emitting diode (LED) and a collimating lens can be used to output the collimated light rays.

Figs. 2A and 2B illustrates an example of the eyebox simulator that is installed in an eyeglass frame. As illustrated, Fig. 2A shows a front view of the assembled eyebox simulator with fiber optic collimators mounted on an outer surface of the lens. Fig. 2B illustrates a view of the assembled eyebox simulator that shows the fiber optic collimators mounted on the lens with reference to the cylinder holes of the eyebox simulator.

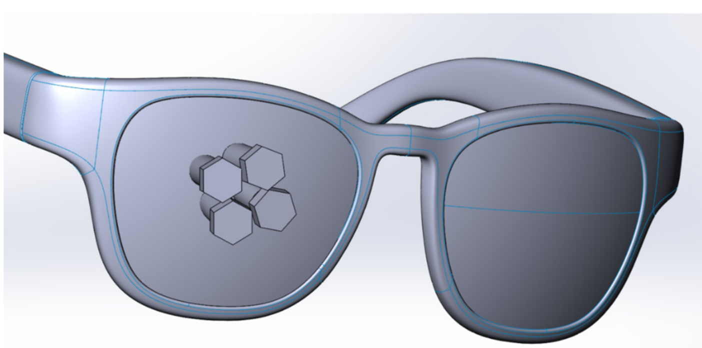

Fig. 2A

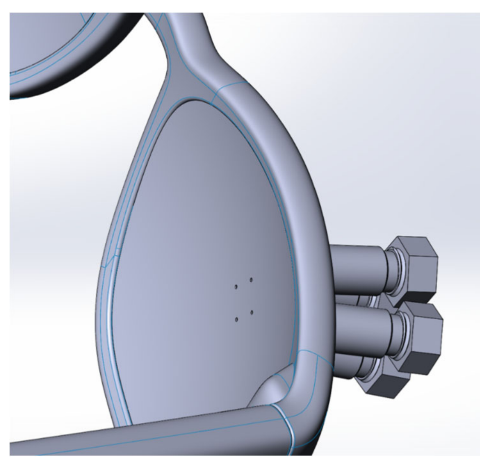

Fig. 2B

Having described example implementations of the eyebox simulator, Fig. 3 illustrates steps of an example technique for building an eyebox simulator in accordance with one or more aspects. The technique starts with a simulation of an unvignetted pupil to raytrace edge field points that represent limiting points in the field of view. The marginal ray can be chosen for the limiting field points via the simulation and cylinder holes are drilled along the marginal ray directions. A light source or fixture is then selected for the eyebox simulator to provide collimated light rays. As described herein, fiber optics, LED light sources, and/or LED lenses can be used to provide or output the collimated light rays of the eyebox simulator. Next, the eyewear lens is 3D printed, prototyped, or otherwise constructed with the marginal ray cylinder holes. In some cases, the 3D printed eyewear lens is installed into a frame with collimated optics to complete assembly of an eyebox simulator as shown in Figs. 2A and 2B.

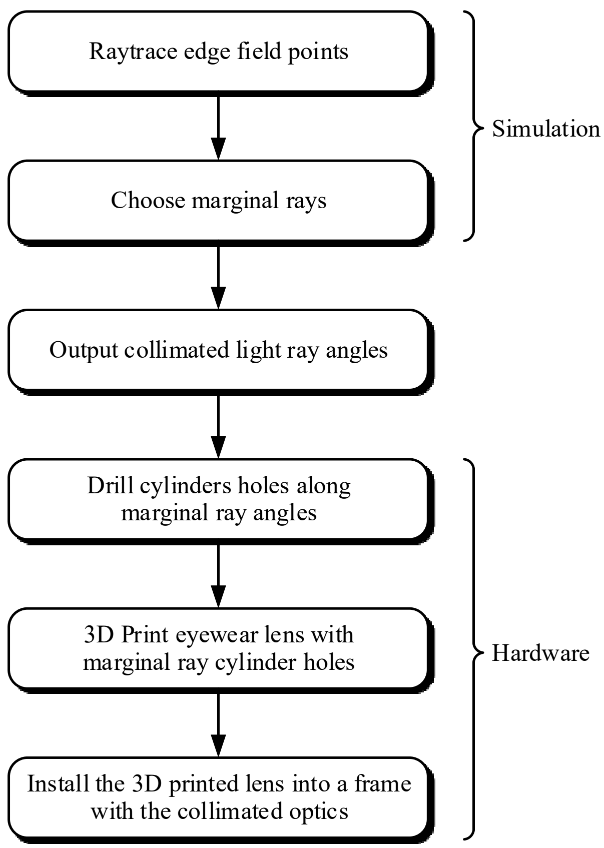

Fig. 3

As another example, consider Fig. 4 which illustrates steps of another example technique that can be implemented to check as-worn alignment of eyewear with display optics or progressive prescription lenses using an eyebox simulator. In some cases, the eyebox simulator described with reference Figs. 1A, 1B, 2A, and/or 2B to can be used to perform the technique described. Generally, a user wears the eyebox simulator to determine how many dots are visible to the user, such as given the position of the eyebox simulator relative the user's head and eyes. One or more dots visible to the user correspond to the collimated light rays that travel through the cylinder holes of the eyebox simulator and/or along the marginal ray directions, such as shown in Fig. 1B. A comparison can be made between a number of dots visible to the user and a number of light sources providing collimated light to the cylinder holes. If the number of dots visible to the user is the same as the number of light sources (the "yes" path), then the eyewear lens of the eyebox simulator fits the user. In at least some cases, this provides an indication that optics of similar configuration will also fit the user or provide correct eyebox alignment.

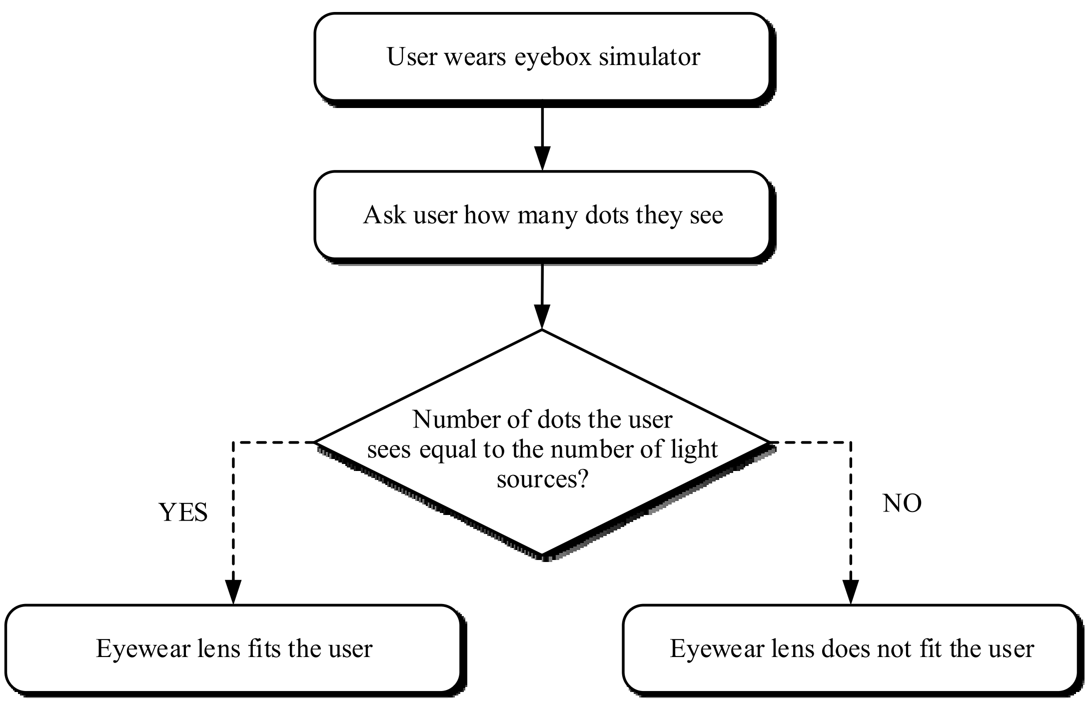

Fig. 4

Thus, it can be determined that the display optics or progressive lenses will fit the user without having the actual lenses on hand for verification, which may save considerable time and money associated with lens prototyping and fitment verification. Alternately, if the number of dots visible to the user is not the same as the number of light sources (the "no" path), then the eyewear lens does not fit the user.

The techniques discussed above describes emulating an experience a user has with eyewear with display optics or progressive lenses. Another problem that arises with the eyebox simulator configurations and/or techniques discussed above is that minimal feedback is provided to a person (*e.g.,* a developer or optician) that is tasked with adjusting and/or selecting frames such that the user perceives the displayed or intended image correctly. Additional techniques for assessing the as-worn fit can be used to better adjust the fit of the eyewear display product, progressive glasses, or head-worn displays as described herein.

Fig. 5 illustrates an example alignment device for adjusting a fit of eyewear with display optics, progressive glasses, or head-worn displays in accordance with one or more aspects. The alignment device includes an opaque lens with collimating groves to allow incoming light to pass through points of the lens other than the intended eye position to adjust the fit of an eyewear display product or progressive glasses. Instead of aligning the incoming light rays along a principal or chief ray such that all light rays are visible from the intended eye position, the light rays can be parallel or converging on known, misaligned positions to determine the user's eye position. As illustrated in Fig. 5, color filters are positioned in front of the opaque lens to filter the incoming light with different colors. This enables the user to express their actual eye location by stating the visible color they are seeing. The user's eye shown in Fig. 5 is positioned such that it aligns with the left collimating groove and the user sees the incoming light as red due to the red color filter.

However, if the user's eye is positioned between any of the collimating grooves of the opaque lens, then the user sees a hue shift of visible light rays. This color filtering technique allows a developer or optician to determine the actual position of the user's eye based on feedback from the user reporting the color of visible light rays. This feedback from the user can then be used by the developer or optician to make a fit adjustment to correct alignment with respect to the user's actual eye location. Alternatively, instead of the color filtering technique, a temporal filtering technique can be used such that turning on different light sources at different times enables the developer or optician to determine the actual position of the user's eye based on feedback from the user.

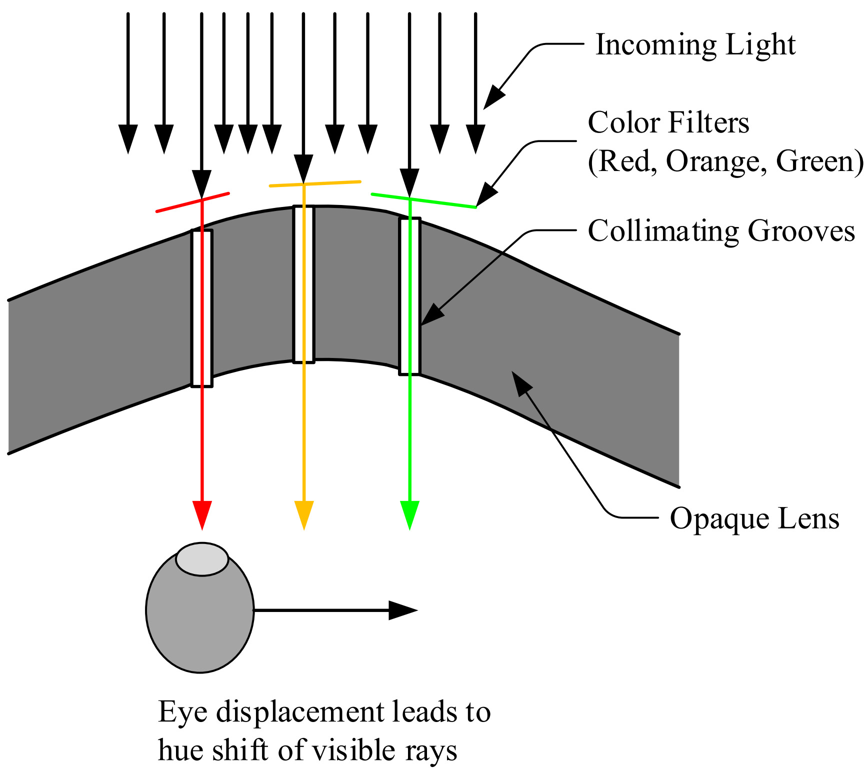

Fig. 5

The techniques discussed with respect to Fig. 5 may be implemented based on feedback reported by the user of the visible light they are seeing accurately in order for a developer or optician to make appropriate adjustments of the lens for proper alignment. Next, consider Figs.

6A and 6B in which an example targeting device is illustrated that enables a developer or optician to make fitting adjustments without requiring feedback from the user being fitted. The targeting device can create a fitting that is applied in place of the lens, or stacked on top of the lens, that can be used to create a reference point. As shown in Fig. 6A, the example targeting device includes thread crosshairs that intersect along the lens' optical axis and is coincident with the user's pupil. During proper alignment of the user's eye with the two sets of crosshairs of the targeting device, the developer or optician sees a single crosshair superimposed with the eye of the user. As illustrated below, the developer or optician sees that the center of the single crosshair is below and to the left the user's pupil during proper alignment. This crosshair position indicates that a fit adjustment is needed to move the lens down and left for proper alignment of the lens to the user.

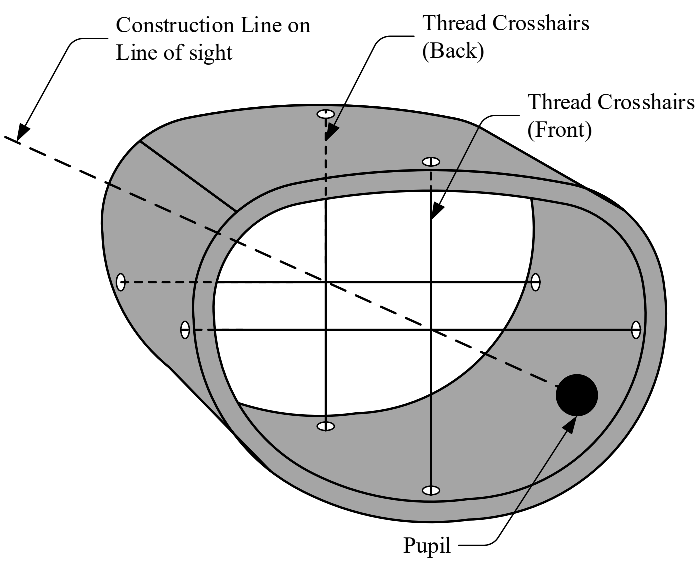

Fig. 6A

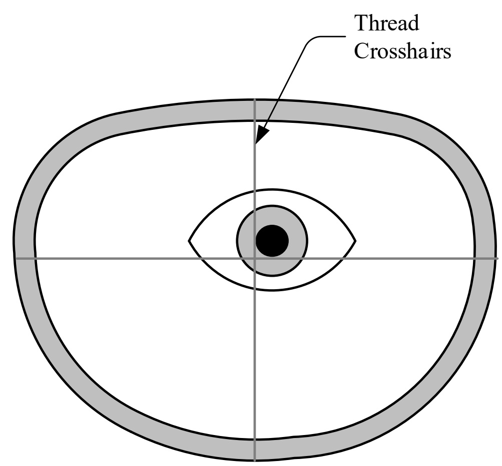

Fig. 6B

The lens is properly aligned when the optician positions their line of sight so that the two crosshairs superimpose and the intersection of the fused crosshair is centered on the user's pupil, which in turn confirms that the user's eye is on the optical axes of the lens. In other implementations, the targeting device uses displaced threads and the parallax to position the eye relief at the targeted position.

Accordingly, the eyebox simulator configurations, alignment device, targeting device, and/or the techniques described herein to check and adjust as-worn alignment can facilitate rapid development iterations of eyewear with display optics, progressive prescription lenses, or head-worn displays. In some aspects, this provides the ability to check and adjust as-worn alignment for how the lenses will fit on a user without having the finished lenses on hand or waiting for the lenses to be constructed. Additionally, various sizes or shapes of frames, displays, and/or lens can be quickly developed to target various users of different physical size or characteristics. For example, an eyewear display product can be developed with various optical configurations and frame sizes, such as small, medium, and large. By using the eyebox simulator, alignment device, targeting device, and techniques describe herein, development of the various configurations and sizes without the lenses on hand can aid in planning for multiple stock keeping units (SKUs) of eyewear display products. This can also be done without incurring the delay and costs involved with each iteration of the glass lens construction and testing, thereby enabling more efficient and quicker development of eyewear display products and progressive glasses.