

Next Generation PVB Interlayer for Improved HUD Image Clarity

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ABSTRACT

Head-up display (HUD) technology creates inherent driver safety advantages by displaying critical information directly in the driver's line of sight, reducing eyes off road and accommodation time. This is accomplished using a system of relay optics and windshield reflection to generate a virtual image that appears to hover over the hood near the bumper. The windshield is an integral optical component of the HUD system, but unfortunately the windshield-air interface causes a double image ghost effect as a result of refractive index change, reducing HUD image clarity. Current technology uses a constant angle wedged PVB windshield interlayer to eliminate double image at a single driver height. However, the HUD double image persists for all other viewing locations. Eastman Chemical Company has developed a new interlayer technology which eliminates the double image at all driver locations by tuning the wedge angle as a function of driver occupant seated height. The purpose of this paper is to discuss this exciting technology and its application to produce best in class HUD image clarity.

CITATION: Spangler, L., Hurlbut, J., Cashen, D., Robb, E. et al., "Next Generation PVB Interlayer for Improved HUD Image Clarity," *SAE Int. J. Passeng. Cars - Mech. Syst.* 9(1):2016, doi:10.4271/2016-01-1402.

INTRODUCTION

Head-Up-Displays (HUD) technology uses a system of relay optics to create a transparent virtual image. This transparent virtual image provides the ability to display critical vehicle or safety information without requiring the user to look away from the road, hence the name Head-Up-Display. HUDs also have the inherent advantage that the user's eyes do not need to refocus from the real world scene to the HUD virtual image thereby reducing eyes off road time. [1] As shown in Figure 1 below, the HUD component includes various mirrors including at least one concave mirror. The concave mirror magnifies the HUD display creating a larger virtual image in front of the vehicle.

The windshield plays a critical role as a mirror in the HUD optical system to reflect the HUD image into the driver's Field-of-View (FOV). Fortunately for the driver but unfortunately for the HUD, the windshield is fundamentally not designed to be a mirror. The HUD windshield is not an ideal mirror because it is not flat and more importantly, is not very reflective.

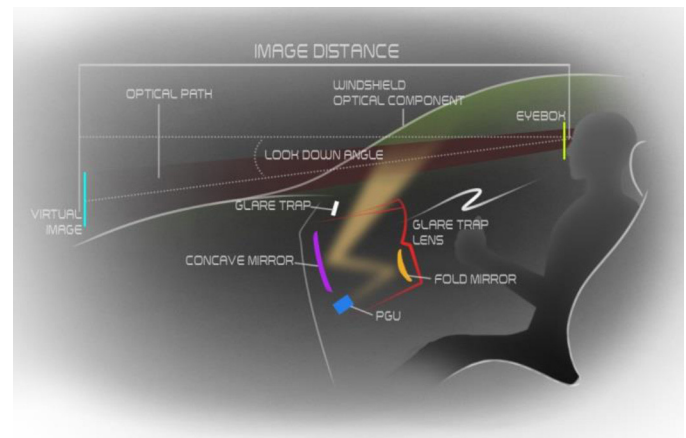


Figure 1. HUD Optical System

Consider a practical example where an automotive windshield consists of two panes of soda-lime glass separated by a PVB interlayer. This construction produces two interfaces from air to glass and two reflections/refractions as shown in Figure 2 assuming that the PVB has the same optical material properties as the glass. Both interfaces produce reflections and refractions whose angles are governed by the Snell equation (1) shown below:

$$\frac{\sin \theta_1}{\sin \theta_2} = \frac{n_2}{n_1}$$

(1)

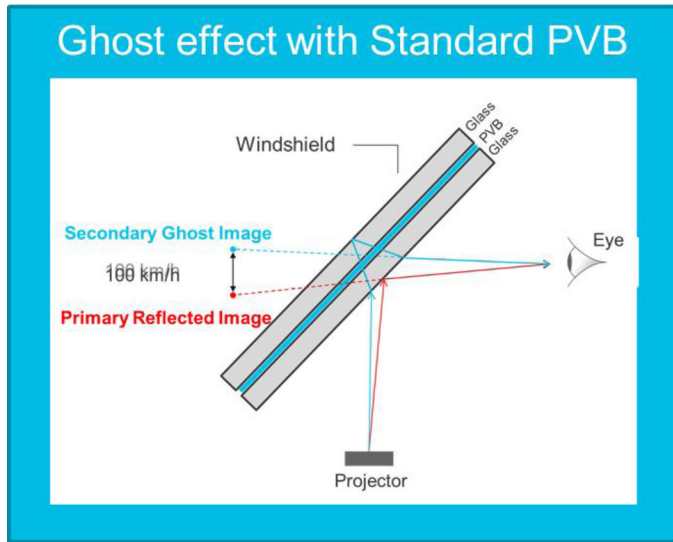


Figure 2. Non-HUD Windshield example of ghosting or double imaging

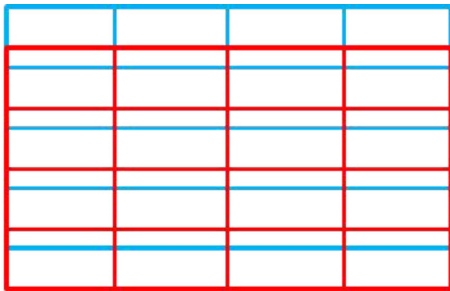


Figure 3. Simplified Ghosting Images for Non HUD Windshield: Grid and Graphic

Applying the Snell law to an air glass interface it is clear that the angle of refraction is more normal to the glass surface than the angle of incident. This phenomenon is especially important in terms of HUD optics because the refraction through the glass produces two paths from the driver's eye location to the same point on the display, meaning that the driver sees the same image in two different places as shown in Figure 3. This second image is referred to as ghosting or double imaging and is shown in the grid pattern below as a blue grid compared to the red primary image grid.

Windshields used for HUD applications today use a technique called wedging to align both optical paths to the same point. This means that both optical paths from the display to the eye point start and end at the same 3D location superimposing the two images for a single design point as shown in Figure 4. This is accomplished by rotating the outer pane of glass through the use of a wedged PVB interlayer such that the primary image shown below in red and the secondary image shown below in blue overlap. For additional background refer to US Patent 5,013,134 [2].

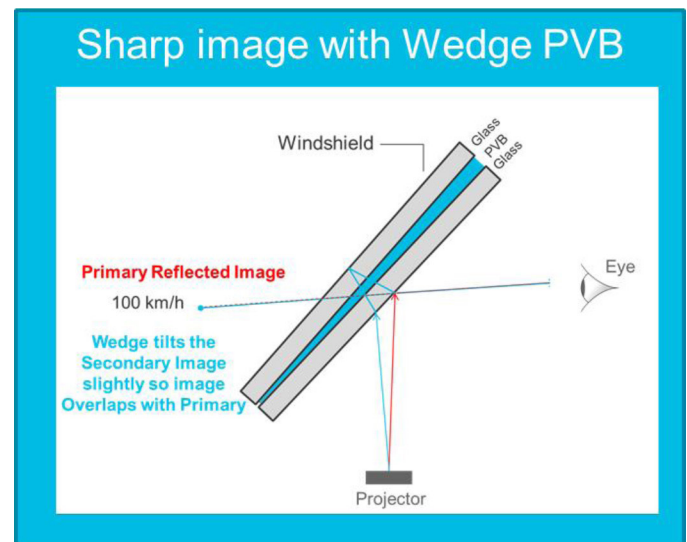


Figure 4. HUD View for Current Wedge Windshield: Graphic



This approach has a noticeable limitation in that the two different optical paths are only aligned at a single eye point location. Different drivers view the HUD image from different heights at different angles producing a double image for all driver heights except the height at which the wedge angle is optimized. This produces the ghosting anomaly as shown in Figure 5 and represents the limitation of current technology.