Reduced Solar-Loading in Automotive HUD using Micro-Mirror Array Plate (MMAP)

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ABSTRACT

Automotive head-up displays (HUDs) use windshields as part of the display system and are used as partial reflectors for reflecting the images formed inside the dash board towards the driver. The locations of the aerial images are usually at the bumper of the vehicle and beyond, depending on the requirements. One of the major issues with such HUD system is the solar loading created by sunlight shining into the system through the image forming optics with focusing properties especially when the sun is shining into the HUD system in an off-axis manner. This paper describes a HUD system where the imaging system uses a Micro-Mirror Array Plate (MMAP) with an optical design that eliminates the issues associated with the off-axis sunlight. Solar loading is an important design criterion as the HUD optics concentrate the sunlight to levels that can damage the display panel. Based on the aerial imaging properties of MMAP, this design would be applicable to the use of Dihedral Corner Reflector Array (DCRA), and Aerial Imaging by Retro-Reflection (AIRR). Bench-top system has been set up using MMAP from ASKA3D, Japan with the expected imaging properties. A complete prototype is being fabricated and will be reported.

1 Introduction

The two-dimensional retro-reflection of the micro-mirror array plate [1] has the special properties that it transfers an image from one side of the MMAP to the other side of the plate as shown in Figure 1. The rays emitted from the light source is diverging and become converging on the other side of the MMAP, forming the light source in mid-air.

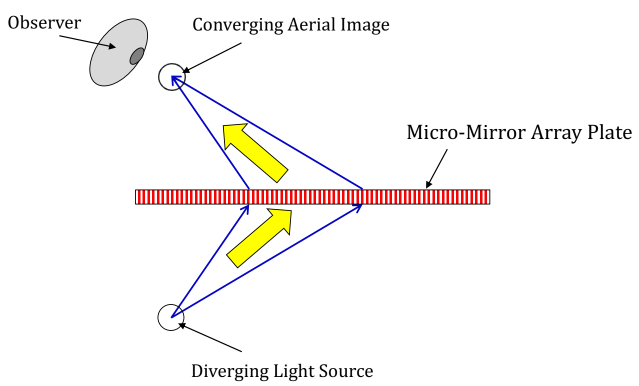

Figure 1 – Imaging Properties of a MMAP Plate

In this paper, instead of divergent light source, the source has converging rays such that the convergence point is at the opposite side of the light source. The convergent rays from the source side of the MMAP will form diverging rays on the opposite side of the MMAP as shown in Figure 2.

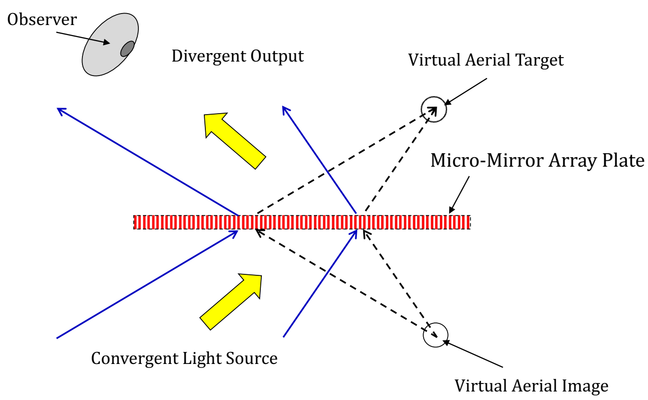

Figure 2 – Imaging of with Converging Rays

With the converging light rays, a virtual aerial target is formed on the opposite side of the light source. The output diverging rays can be extrapolated back to a point, on the same side of the light source, which becomes the virtual aerial image as seen by the observer. Based on this property, this converging ray system can be applied to the automotive HUD system.

2 Traditional HUD with Solar Loading Issues

Figure 3 shows a conceptual drawing of a traditional HUD system using a concave reflector forming a virtual image of the display at a distance from the driver.

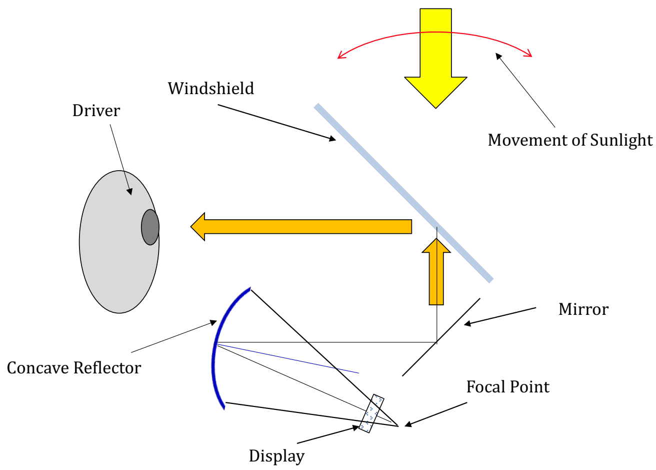

Figure 3 – A Traditional HUD with Solar Loading

When the sun is overhead above the vehicle, the sunlight will be directed towards the concave reflector, which forms the virtual images of the display. For a virtual image to be formed, the focal point is behind the display and the display is out of focus. A linear model with the concave reflector replaced by a lens is shown in Figure 4 with location of the components following the lens formula using parameters F, D1, and D2. The locus of the focused sunlight as the sun moves around the HUD system is a curve as shown, showing that even when the display is not in focus at zero degree, as the sun is shining into the HUD at an angle, the display will be at the focus with increased solar loading.

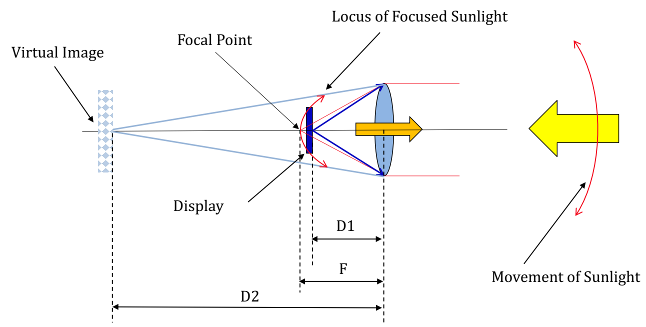

Figure 4 – Linear Model of a Standard HUD with Solar Loading

3 MMAP HUD Overcoming Solar Loading Issues

Figure 5 shows the schematic diagram of a HUD using a MMAP plate with the scheme of converging rays as shown in Figure 2. Using this optical configuration, before the insertion of the MMAP, the projection lens would form a real target image. When the MMAP is inserted at the location as shown, the target image would be transformed into the virtual image source on the display side of the MMAP and would be observed as a virtual image when viewed from the opposite side of the MMAP. With the insertion of the windshield, the virtual image will be reflected and seen in front of the driver at a certain distance beyond the windshield. Since a real image is formed by the projection lens, the focal point of the lens will be between the display and projection lens.

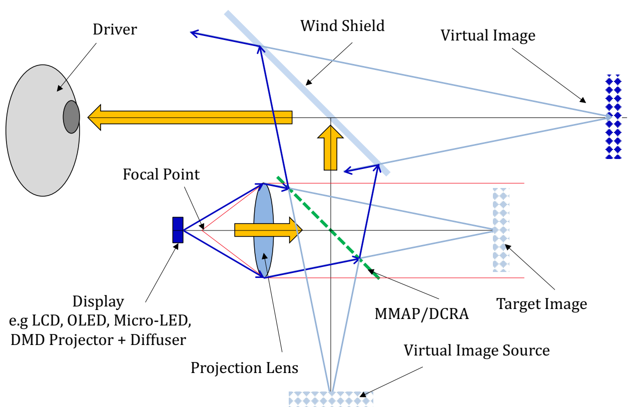

Figure 5 – Schematic Diagram of a HUD using a MMAP Plate

Figure 6 shows a linear model of the HUD with MMAP and the relationship of the focal point with respect to the display also follows the lens formula.

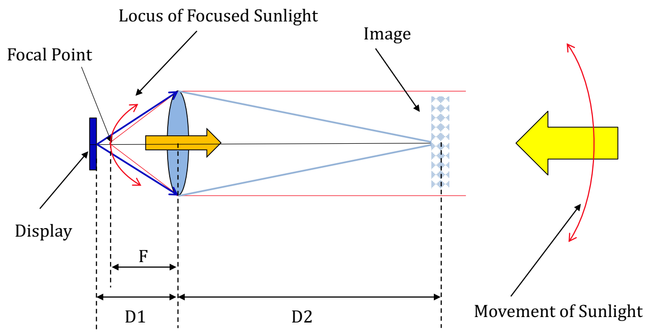

Figure 6 – Linear Model of a MMAP HUD with Solar Loading

As shown in the figure, the locus of the focal point is between the display and projection lens at all angle of sunlight and as a result, would not be focused on the display and increase the solar loading. With this design, component selections criteria can be more relaxed and overheating issues are reduced.

Figure 7 shows a practical system using a concave reflector for forming the image instead of a projection lens.

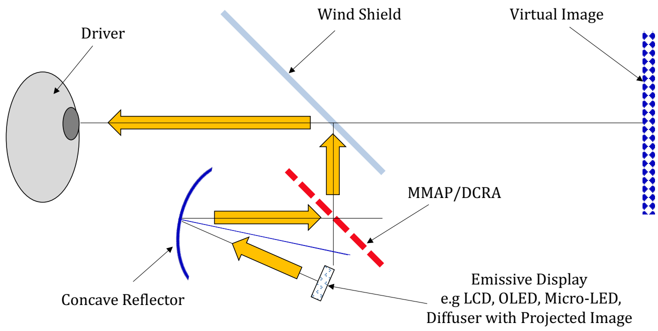

Figure 7 – MMAP HUD using Concave Reflector

4 Conclusions

This paper has presented a HUD system using MMAP such that the solar loading issues are reduced without the issue of focusing the sunlight directly onto the display. Bench-top system has been set up using MMAP from ASKA3D, Japen. Complete prototype is being fabricated and will be reported at the conference.

5 References

1. N. Koizumi, "Simulation of Micro-Mirror Array Plates with Blender", Proceedings of International Display Workshop, Volume 27, FMC3-3. Pp 249-252 (2020)