A Performance-Efficiency Switchable Near-Eye Display with Variable Internal Optical Paths

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Abstract

A pinhole-based lightfield (PBLF) near eye display (NED) is regarded as the simplest way to realize the compact NED with minimum cost. In this paper, we propose a novel scheme to switch the operation of the PBLFNED between the performance and the efficiency without changing the formfactor.

Author Keywords

Lightfield; Switchable near eye display; Variable internal optical paths.

1. Introduction

A pinhole-based lightfield (PBLF) near eye display (NED) is one of the methods to realize a practical solution for extended reality (XR) with a compact formfactor [1-3]. However, it has a bottleneck that the resolution of the retinal image depends on the thickness of the system. It means that the resolution of the retinal image is enhanced as the display panel locates farther from the pinhole array [4]. In other words, the performance of the basic PBLFNED is in a trade-off relation with the thickness (formfactor) of the system, which is an important aspect for customers. In this paper, we propose a performance-efficiency switchable PBLFNED which can support various modes respecting the preferences of the user. The goal can be accomplished by realizing variable optical path lengths with a switchable pancake optics and polarization control. Results of preliminary experiments are also provided to support the proposed scheme.

2. Principle

The concept to realize a switchable system is to adopt a pancake optics which can extend the internal optical path between the display panel and the pinhole array. The pancake optics is an optical system expanding the optical path [5]. It consists of two quarter wave retarders (QWR) with perpendicular fast-axis, a beam splitter (BS), and a polarizing beam splitter (PBS) which the light of the horizontal linear polarization (LP) passes and the vertical LP light is reflected. If the light of the vertical LP is incident on the pancake optics, it will pass through the optical system after a round-trip between the BS and PBS. Thus, in high-performance (resolution) mode of the proposed scheme, the internal optical path can be extended to make the optical image of the display panel locates farther from the pinhole array than its real position as shown in Fig. 1. As a result, the user can enjoy resolution-sensitive contents such as text-based documents, static pictures, and high-quality movies/games. However, extending the internal optical path sacrifices the optical efficiency since the light passing the pancake optics enters the BS twice while entering and being reflected inside. Thus, it is necessary that the display panel consumes more power to compensate the decreased optical efficiency. As a result, the system is suitable for indoor usage with continuous power supply.

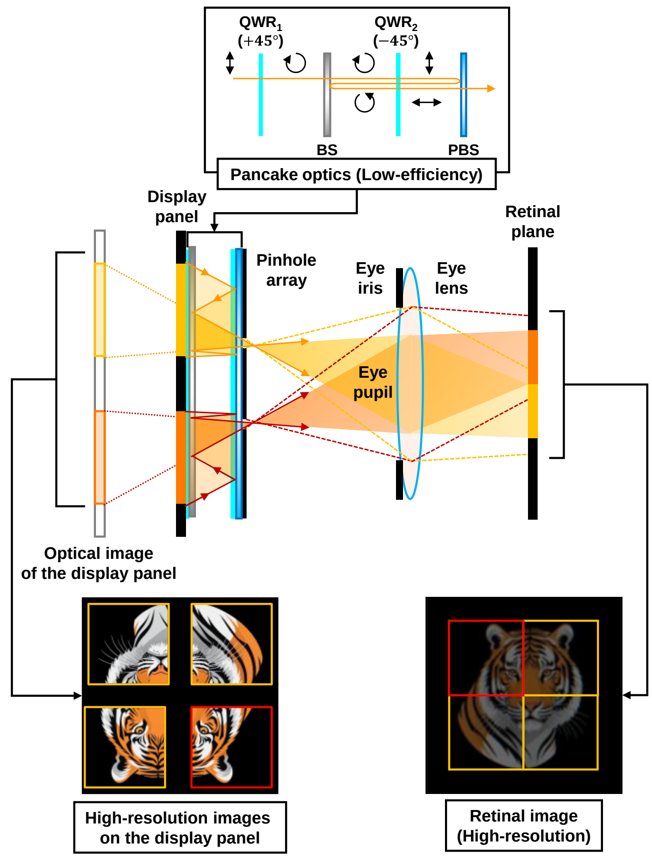

Figure 1. Principle of the proposed scheme in high-performance mode.

In contrast, the proposed system can be switched to high-efficiency mode by making the incident light with horizontal LP pass through the pancake optics at once. In this case, the pancake optics has no role in expanding the internal optical path length so that the display panel looks like where it really is as shown in Fig. 2. Thus, the system can work in a high-efficiency (brightness) mode because the incident light experiences minimum loss in passing through the pancake optics although the resolution of the retinal image keeps the same with the basic PBLFNED. Considering the aspects above, it is expected that the high-efficiency mode is suitable for an outdoor usage scenario with limited battery power and resolution-insensitive contents such as fast-moving pictures or gaming experiences.

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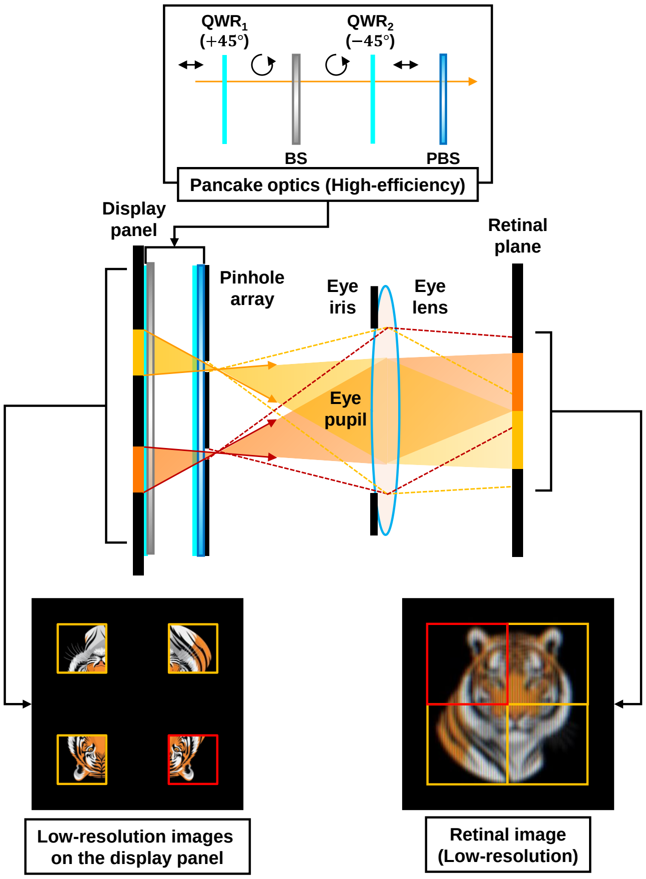


Figure 2. Principle of the proposed scheme in high-efficiency mode.

In case that both modes described above are out of the satisfaction of the user, we also propose an intermediate mode which optimizes the performance and efficiency by time-multiplexing. In that mode, the system switches its operation between the high-performance and the high-efficiency modes by every frame as shown in Fig 3.

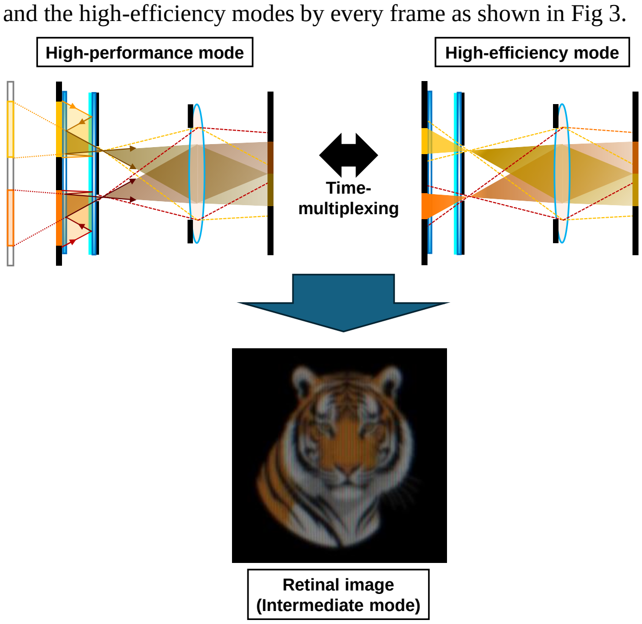
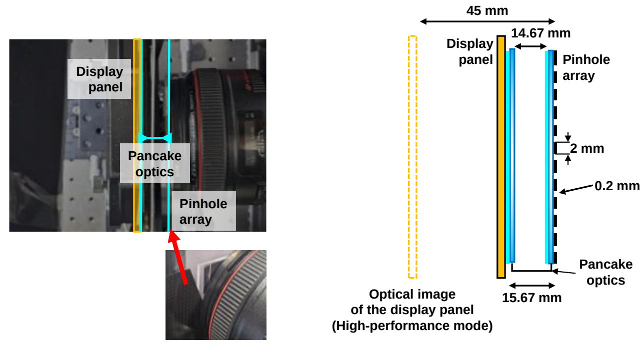


Figure 3. Principle of intermediate mode with time-multiplexing.

3. Experiments

We conducted preliminary experiments to verify the proposed principles. Figure 4 shows the experimental setup and parameters. The experimental setup is composed of a display panel with a pixel size of 31.5 um, a pinhole array with the pinhole diameter of 0.2 mm and a 0.2 mm gap between the pinholes, and the pancake optics. The gap between the display panel and the pinhole array is 15.67 mm and the inner gap of the pancake optics is 14.67 mm. Accordingly, the elemental images of the display panel will be located 45 mm away from the pinhole array.



(a) Experimental setup (b) Parameters

Figure 4. Experimental setup and parameters.

Figure 5 shows the results comparing the high-performance mode (upper), the high-efficiency mode (lower), and the intermediate mode (center). In the results of Fig. 5, each mode provides expected detail (performance) and brightness (efficiency). Though the results of intermediate mode in our preliminary experiment is an image compounding of the high- and low-resolution modes to imitate time-multiplexing, we expect that the active time-multiplexing can be easily implemented by adopting an active polarization switching device such as a single-cell liquid crystal panel.

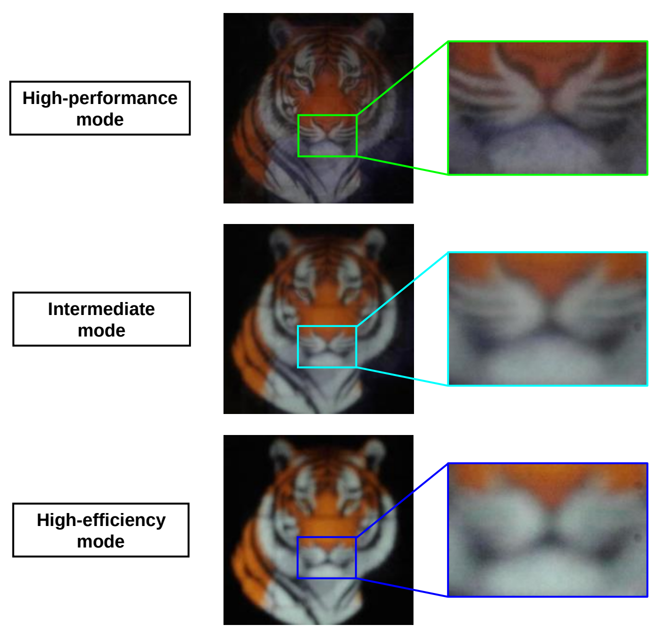


Figure 5. Comparison of preliminary experimental results.

4. Conclusion

With the increasing popularity of head-mounted displays, the demand for NED technologies offering an enhanced viewing experience with more comfort increases. Among various technologies, The PBLFNED is expected to satisfy the demands of compact formfactor as well as low manufacturing cost. With our proposed technique, the PBLFNED can support multiple operations of high-performance, high-efficiency, and intermediate modes which can satisfy various kinds of usage scenario and preferences of the users. We expect that the proposed method can expand the available applications of PBLFNED and contribute the expedition of practical NED commercialization.

5. Acknowledgements

This work was supported by the faculty research fund of Sejong University in 2023.

6. References

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