Comparative Analysis of Mixed Reality Screen Extensions and Laser Safety Goggles in Laser Laboratories

Conference Paper

Author(s):
Cheng, Long; Schachtler, Daniel; Schreiner, Michael; Kunz, Andreas

Publication date:
2024

Permanent link:
https://doi.org/10.3929/ethz-b-000703026

Originally published in:
https://doi.org/10.1109/ISMAR-Adjunct64951.2024.00090

Comparative Analysis of Mixed Reality Screen Extensions and Laser Safety Goggles in Laser Laboratories

Long Cheng*
RhySearch
ETH Zurich

Daniel Schachtler
RhySearch

Michael Schreiner
RhySearch

Andreas Kunz †
ETH Zurich

Abstract

In laser laboratories, user ergonomics and visibility are key concerns. Users must concentrate on small surfaces by watching telescope-generated images displayed on the screen to conduct measurement. Through a mixed reality head-mounted display (MR-HMD), they see the real world while being physically separated from hazardous laser radiations and can view telescope images on the HMD at the same time. In this poster, we conducted a comparative analysis of an MR screen extension versus a traditional laser safety goggle (LG) during an optical observation task in a laser laboratory. Results from our user study indicate that the MR condition significantly outperformed the LG condition in terms of speed and user preference.

Index Terms: Mixed Reality, Laser Experiments, Virtual Reality, Human Factors

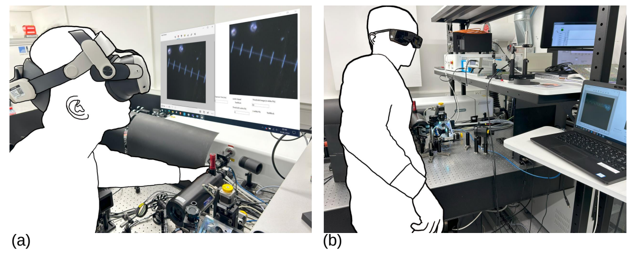

Figure 1: Comparative overview of MR-HMD and laser safety goggle. (a) The MR setup, showing the virtual screen integration. (b) The LG condition, featuring the desktop screen on a table.

1 Introduction

High-energy lasers are commonly used in laser laboratories. Depending on the laser wavelength, LGs with varying optical densities and filtering capabilities are mandatory for experimenters within the laser lab. These goggles protect against direct and scattered laser radiation and are indispensable for safety. However, increased protection from LGs results in more extensive wavelength filtration, reducing the amount of visible light and altering color perception, making it hard to read information from computer screens.

The MR-HMD enables users to view the real world while providing physical separation from hazardous laser radiation. Quercioli [4, 5] has introduced MR-HMD in laser experiments and found its ability to visualize infrared lasers. Additionally, Li et al. [3] conducted a user study that demonstrated significant improvements in task completion of a color recognition task. However, no research was done how MR-HMDs accelerate the workflow by displaying additional computer screen content together with the laser tasks.

This study compares the efficacy of an MR-HMD equipped with a virtual screen against traditional LG in a real-life optical observation task within a laser laboratory (see Fig. 1). Results from our study indicate that the MR-HMD not only reduces task completion time, but also improves user preference over the LG. Specifically, the MR-HMD is preferred in comfort, safety, and desktop screen viewing.

2 Experiment

The experimental setup features a simple yet representative optical observation system designed to detect small, laser-induced damages on optical surfaces. It comprises a camera attached to a Cassegrain Telescope, capable of live observation of a 600 µm x 400 µm field with micrometer resolution. Given the high magnification, additional lighting is necessary; thus, a halogen lamp illuminates the surface being examined. Scattered light from defects or particles is captured by the camera-telescope system, which is linked to a desktop computer. To have a direct feedback on the telescope, users need to look at the desktop display. For precise positioning of the optical component, a three-axis microstage, controlled via LabVIEW software on a second computer, adjusts the object along two lateral directions.

We outline our optical experiment in three steps, as illustrated in Fig. 2. To establish a clear objective for the user study, we captured screenshots of several well-illuminated, precisely focused, and accurately positioned telescope still images to serve as target solutions. Users had to adjust the system so that they achieve similar images with the setup.

1. Illuminate the surface of the optical component: Move the lamp and focus the light onto the surface of the optical component (Fig. 2 (e)).

2. Align the telescope's focal plane with the surface of the optical component: This adjustment ensures a sharp, clear image on the camera, minimizing blurriness of surface features. The focal plane of the telescope is adjusted using a screw on the backside of the telescope (Fig. 2 (f)).

3. Reposition the optical component: Use keyboard and mouse to interact with a microstage software to move the component to a predefined position (Fig. 2 (g)). The optical component is already at the predefined position and this process includes a fine-tuning of its position. Correct position of the optical element can be detected by the comparison of the acquired camera image with the given solution images. To accommodate the MR-HMD's limited camera resolution, the desktop screen is magnified by 200% for both MR and LG conditions.

We employed a counterbalanced within-subject design for the user study, featuring two conditions: the MR condition and the LG condition. In the MR condition, participants utilized the Meta Quest 3 headset connected to a desktop computer. The virtual desktop application Immersed[1] was used to extend the desktop screen into the MR environment, with the virtual screen's size and position pre-set by the experimenter. In contrast, the LG condition required

*e-mail: long.cheng@iwf.mavt.ethz.ch
†e-mail: kunz@ethz.ch

[1] https://immersed.com/, accessed on 04 Jul, 2024

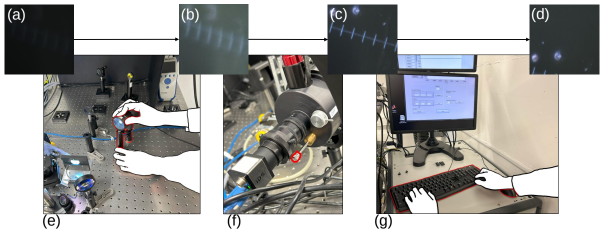

Figure 2: Task Overview. (a) - (d): views of the telescope: (a) starting with a dark image, (b) illuminating the surface with a lamp, (c) focusing on the surface plane, and (d) positioning the object at the region of interest. (e) - (f): three steps with interactions marked in red: (e) illuminating the surface. (f) focusing the telescope, and (g) positioning the object.

participants to wear LaserVision P1L07 goggles for protection while performing the tasks and looking at screen displays. This goggle, despite with a 10% visible light transmission, is commonly used in our laser lab and covers a broad wavelength range from 180 to 1210 nm[2].

Participants completed questionnaires before and after their sessions, assessing various aspects of their experience. The questionnaires included the NASA Task Load Index (TLX) [1] to measure task load, the System Usability Scale (SUS) [2] for usability assessment of the complete task, and additional preference surveys. Task Completion Time (TCT) was recorded as an objective metric, defined as the duration from the initiation of the first step to the identification of the correct coordinate solution using the microstage software. Participants were randomly assigned to start with either the MR or LG condition, with task solutions also randomized.

Our data analysis was conducted using the Wilcoxon signed-rank test in R Studio (see Fig. 3). The user study recruited 18 participants, averaging 39.6 years in age with a standard deviation of 12.4 years. The majority (15) possessed at least basic knowledge of physics and alignment, including three student participants. For safety reason, laser was switched off during the study.

3 Results

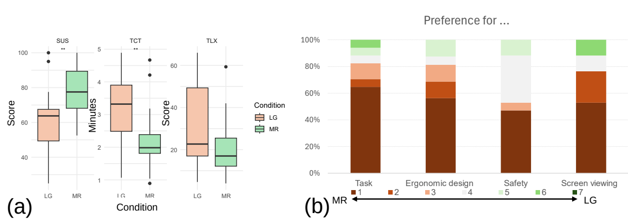

Figure 3: Statistical analysis of the user study results. (a) Box plots depicting SUS, TCT, and TLX scores, with significant differences marked with asterisks where $* = p < 0.05$ and $** = p < 0.01$. Higher SUS scores, lower TCT, and lower TLX scores indicate better outcomes. (b) Bar chart illustrating participant preferences across task execution, ergonomic design, safety, and screen viewing. Scale: 1 strongly favoring MR, 4 neutral, and 7 strongly favoring LG.

The objective data indicate that the MR condition significantly outperformed the LG condition in terms of task completion time, with a noticeable statistical significance ($p = 0.0011$).This improvement is attributed to the enhanced size of the screen extension and the comparatively farther position of the physical screen. Subjectively, participants showed a preference for the MR condition, citing a lower cognitive load ($p = 0.059$) and significantly greater usability ($p = 0.0071$). The MR condition was favored for its comfort, safety, and enhanced desktop screen viewing capabilities.

During the informal interviews, participants noted some limitations of the MR condition. They reported difficulties in viewing text on the physical screen and typing on the keyboard due to the camera's insufficient clarity. Additionally, the peripheral environment appeared blurry, and the hand position was inaccurately perceived, likely due to the camera's offset from human eyes. Despite these issues, the virtual screen was regarded as larger and more accessible, especially for some older participants with reduced vision. In contrast, the screen in the LG condition was perceived darker, smaller, and farther from the operation.

The differences between the two conditions shown in Fig. 3 corroborate findings from Li et al. [3], indicating the substantial potential of MR-HMD in laser experiments. Although the physical desktop screen in the LG condition is not optimally positioned, reflecting current real-world settings, the virtual screen offers advantages as it is not constrained by physical space and incurs no additional cost or support requirements. Furthermore, the reduction in cognitive load, though not significant, suggests benefits from viewing a larger, undistorted screen display, which is essential for tasks requiring frequent checks of the camera system in the telescope. In addition to screen position, elderly participants noted ergonomic advantages of MR-HMDs, primarily due to their large screen size, and highlighted the challenges of using laser goggles with glasses. Latency issues, including photon-to-photon latency of the video see-through camera and the indirect wireless connection, were not noticable during the study. Given the increasing prevalence of full-color cameras in HMDs, it is important to further investigate the feasibility of different MR-HMDs for use in laser labs.

4 Conclusion

We evaluated the effectiveness of a MR screen extension compared to traditional laser safety goggles in an optical observation task within a laser laboratory. Results indicated that the MR condition not only significantly reduced the task completion time, but was also preferred by participants, despite some reported distortions and a blurry environment. Looking ahead, we plan to explore the application of MR technology in more complex tasks within the laser lab. Additionally, integrating both operational software into a single computer could simplify the setup. Implementing dual virtual screens within the MR-HMD, eliminating the need for user interaction with a physical desktop, may further validate and strengthen our findings.

References

[1] S. G. Hart and L. E. Staveland. Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. *Advances in Psychology*, 52(C):139–183, 1 1988. doi: 10.1016/S0166-4115(08)62386-9 2

[2] John Brooke. SUS: A 'Quick and Dirty' Usability Scale. In *Usability Evaluation In Industry*, pp. 207–212. CRC Press, London, UK, 6 1996. doi: 10.1201/9781498710411-35 2

[3] K. Li, A. Choudhuri, S. Schmidt, T. Lang, R. Bacher, I. Hartl, W. Leemans, and F. Steinicke. Stereoscopic Video See-Through Head-Mounted Displays for Laser Safety: An Empirical Evaluation at Advanced Optics Laboratories. In *Proceedings - 2022 IEEE International Symposium on Mixed and Augmented Reality, ISMAR 2022*, pp. 112–120. Institute of Electrical and Electronics Engineers Inc., Singapore, Singapore, 2022. doi: 10.1109/ISMAR55827.2022.00025 1, 2

[4] F. Quercioli. Beyond laser safety glasses: augmented reality in optics laboratories. *Applied optics*, 56(4):1148, 2 2017. doi: 10.1364/AO.56.001148 1

[5] F. Quercioli. Augmented reality in laser laboratories. *Optics & Laser Technology*, 101:25–29, 2018. doi: 10.1016/j.optlastec.2017.10.033 1

[2] https://www.uvex-laservision.de/en/laser-safety-eyewear/laser-safety-filter/plastic-filters/laser-safety-filter-p1l07/, accessed on 20 Aug, 2024