ARL-TR-10339 • May 2026

A Device for Enhanced Protection of Eyes Against Laser Beams and Other Intense Sources

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ARL-TR-10339 ● May 2026

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REPORT DOCUMENTATION PAGE

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED	
		START DATE	END DATE
May 2026	Technical Report	1 October 2019	30 September 2022

4. TITLE AND SUBTITLE
A Device for Enhanced Protection of Eyes Against Laser Beams and Other Intense Sources

5a. CONTRACT NUMBER	5b. GRANT NUMBER	5c. PROGRAM ELEMENT NUMBER
5d. PROJECT NUMBER	**5e. TASK NUMBER**	**5f. WORK UNIT NUMBER**

6. AUTHOR(S)
Laura Vanderhoef, Jeffrey Cameron, Aaron Schweinsberg, Colby Adams, Patrick Marine, Thomas Kottke, and George Thomson

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
DEVCOM Army Research Laboratory ATTN: FCDD-RLD Aberdeen Proving Ground, MD 21005	ARL-TR-10339

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
DISTRIBUTION STATEMENT A. Approved for public release: distribution unlimited.

13. SUPPLEMENTARY NOTES
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14. ABSTRACT
This report describes a device to provide eye protection to users of lasers and other intense light emitters. The device does this by combining a digital camera with a visual display in a light-tight head-mounted enclosure that prevents any direct exposure of the eye to the source while allowing a view of the surroundings. It is meant to replace the array of conventional narrow-wavelength bandpass laser filter goggles needed to give protection in facilities that deal with lasers or sources of differing wavelengths. It does this with a single unit that is effective over the spectral range of the camera/display combination employed. The device is self-contained, realistic in presentation, easy to use, and has a wide field of view. It offers unique capabilities in situations where source wavelengths are encountered that are tunable, broad span, multiplicative, or even continuous. It can also present nonhazardous imagery of a single scene to multiple users simultaneously. This report outlines the eye protection device's basic concept, performance, and limitations.

15. SUBJECT TERMS
Terminal Effects, laser goggles, personal protective equipment, PPE, broadband laser protection, first-person video, FPV, laser alignment

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
a. REPORT	b. ABSTRACT	C. THIS PAGE		
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UU	23

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Contents

List of Figures

Acknowledgments

We gratefully acknowledge the outstanding assistance of Jeffrey Ball and Robert Borys in fabricating and testing this device. The continued support and suggestions of Coral Repka, Lorus Miller, Ken Kwashnak, and Stephan Bilyk are much appreciated along with the editorial efforts of ARL Technical Publishing.

1. Introduction

Laboratory and fabrication operations frequently expose personnel to intense electromagnetic radiation from lasers, arc welders, and discharge lamps. This report describes an approach under development at the U.S. Army Combat Capabilities Development Command (DEVCOM) Army Research Laboratory (ARL) that is intended to protect the eyes of users of such devices against accidental exposure to hazards. While it was motivated primarily by laser operations, some of the techniques presented may serve as a starting point for creating countermeasures against threats produced by other sources. The intent is to provide a safe, visual rendition of the surroundings that is as close as possible to that of normal vision while degrading the hazards to a safe level. The display encases the user's entire field of view (FOV) and seals it away from any external light flux. It is also necessary that the unit is comfortably worn and does not interfere with the ability to complete normal tasks. Some emphasis was also placed on cost containment and the maximum employment of commercial off-the-shelf (COTS) hardware. Fortunately, these particular requirements appear in several devices already intended for other purposes. Most notably, in recent years there has been an explosion of interest by hobbyists in the installation of miniature video cameras in model drones and race cars to provide a pilot's or driver's eye view of the events. This is called first-person video (FPV). The discussion centers on a particular device that served as a proof-of-concept (POC) demonstration. However, a host of FPV systems of similar purposes that are currently on the market may be adapted for eye protection. The notions involved formed the basis for disclosure that has been converted into a current patent application.[1]

2. The Problem

When working with lasers, arc lamps, and other intense sources, a user faces several specific vision hazards. Laser eye injuries are common and often very serious. Most frequently, accidents occur when performing alignment and maintenance operations. These procedures often require an inspection of the laser path. To do this, the beam's impact on a target is viewed to make the beam visible while adjustments are made. The user inserts the target into the flux, often via some sort of makeshift hand-held gadget. For visible wavelength lasers the target may be a simple card, while for IR or UV systems it may be liquid crystal or a fluorescent-coated surface, respectively. Currently, in this situation and in most other laser laboratory operations, eye protection is provided by donning a set of ordinary goggles with lenses made of transparent materials containing dyes that are opaque to the laser's emission wavelengths. Such devices are only effective for one or, at most, a few wavelengths. Employing a laser with a different wavelength emission spectrum requires an additional unique set of goggles. As a result, many laser laboratories must maintain a substantial inventory of goggles and must ensure that everyone in the area uses the appropriate set. In addition, many of the dyes or dopants found in conventional laser goggles also absorb and transmit light to some extent at wavelengths outside their primary bandpass, giving the scene an unrealistic chromatic tint. In recent years, a multitude of lasers appeared that emit at more than one wavelength, are wavelength tunable, or produce bands of wavelengths. Protection for these systems requires a large segment of the spectrum to be blocked. This is often impractical due to the high degradation of the surrounding scene. In other words, if many of the laser wavelengths are blocked, then there may be little or no light left by which to see anything.

The concept of using a video camera in conjunction with imaging goggles originated in ARL's laboratory in response to the multiple emission wavelengths offered by several recently available lasers. Subsequent literature searches revealed two earlier approaches similar in objective but in quite different configurations. One approach by Quercioli[2,3] uses a cell phone camera to image the scene and displays it on a set of goggles used for gaming. While very inexpensive, it does not take advantage of the many features, such as recording, image magnification, and image manipulation, offered by FPV devices. The second approach, by Mathieu et al.,[4] uses two separate cameras to capture the images separately from a vantage point in front of the right and left eye and processes them with a PC. While offering the additional benefit of depth perception, it is expensive, complex, and requires carrying an unwieldy PC. Neither approach has found widespread commercial or laboratory application. The present approach is focused on taking maximum advantage of COTS components and putting them into a fieldable format at reasonable cost.

3. Technical Approach

The basic device consists of two major components: a set of virtual reality goggles and a small video camera. They are connected via an RF link. In the present case, both components were adopted from a hobbyist remote video system, specifically the DJI digital FPV system.[5] The DJI system was later found to not be the ideal starting point for developing laser personal protective equipment (PPE). Initially it was selected on the recommendation of drone hobbyists, but it soon became apparent that what constitutes a good drone controller was not the best configuration for laser PPE. Some considerable modifications were required for the PPE evaluation. Photographs of the basic components of the modified goggles are shown in Figures 1–3. The first two figures show oblique views, and the third shows a rear view. Figures 1 and 2 show the same view of the device for two different operating configurations. The first is used when the video camera is in the standard normal position, that is, attached to the goggles worn by the user and mounted on their forehead while pointed forward. The second is used when the camera may be removed from the goggles and placed at a substantial distance away. The two configurations differ in that the latter requires external antennas, while the former does not.

Figure 1. An oblique view of the camera device configured for small camera-to-goggles separations.

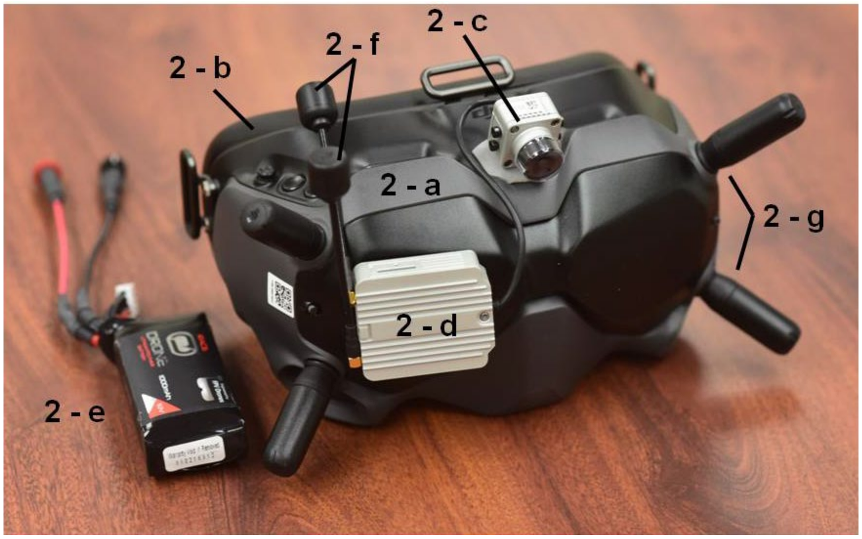

Figure 2. An oblique view of the device configured with antennas to allow for the camera (2-c) and transceiver (2-d) to be separated from the goggles (2-a) and placed hundreds of meters away. The transceiver battery (2-e) is also shown.

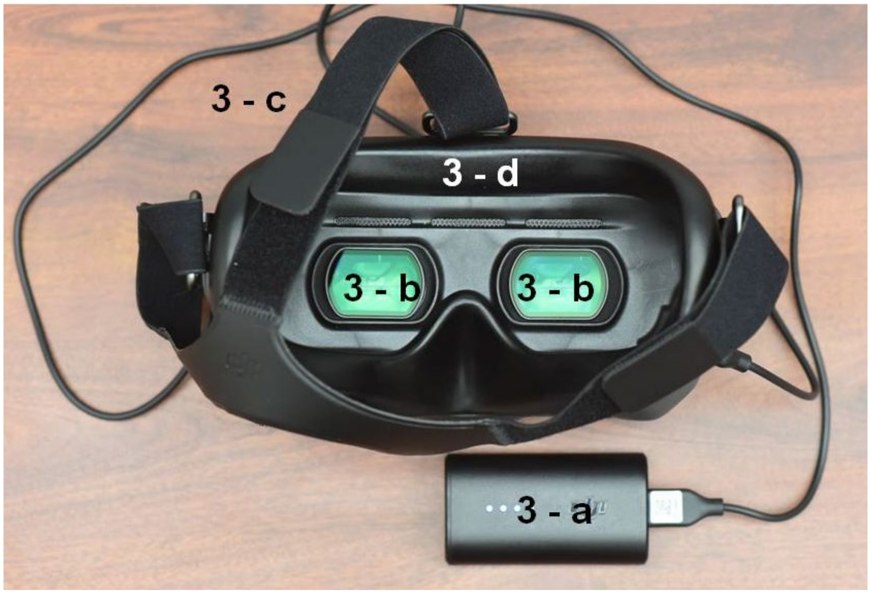

Figure 3. A rear view of the device showing the mounting straps (3-c), the LED displays (3-b), the face seal (3-d), and the goggle battery (3-a).

Figure 3 shows the goggle display. During operation, the user dons the goggle portion of the PPE device (Figures 1-a and 2-a) over their head, making sure that the face seal (Figures 1-b and 2-b) forms a leak-proof barrier over their skin. With that in place, the user can power up the display in the device (Figures 1-a and 2-a) using the energizing battery pack (Figure 3-a). The display shown in Figure 3-b shows a set of startup options indicating that it is ready to receive signals from the camera (Figures 1-c and 2-c) via the transceiver box (Figures 1-d and 2-d). The transceiver is powered independently by a small battery pack (Figure 2-e [not shown in Figure 1]). In normal operation, signals are transmitted via an RF link from the transceiver antennas (Figure 2-f) to the goggle antennas (Figure 2-g). The video signals are displayed on LED arrays (Figure 3-b) on the internal surfaces of Figures 1-a and 2, located in front of the user's eyes, and give a rendition of what the camera is detecting. The significant advantage of this system is that the user is never exposed to hazardous radiative flux. With the camera positioned on the "forehead" surface of the device (Figures 1-a and 2-a), the displayed visual scene closely resembles what the user would see without the goggles.

Alternatively, the camera can be set up at a separate location so that the user can monitor the state of some object in a remote or non-line-of-sight position. Other FPV systems on the market allow the RF signals to be captured by more than one set of goggles. This permits coworkers, advisors, supervisors, and safety personnel to be aware of the operation's current state and allows positive or negative feedback. Other hobbyist systems are available, such as the Skyzone FPV or Flysight FPV, that have a fixed forward-facing camera mounted between the user's eyes and a second camera that can be placed independently. The user can then choose to view the output of either camera singly or in a picture-in-picture mode for simultaneous input. The DJI system employed in our POC testing allows the imagery captured at the camera (Figure 1-c) to be recorded on an internal serial digital interface (SDI) card recorder as well as the imagery presented to the LED arrays. This feature is extremely useful for documenting the actions taken during the operation and the information that was presented to the individuals responsible for carrying them out. All the aforementioned devices are compatible with this approach. Unfortunately, the DJI system used in our PPE device has little cross compatibility between the components of various manufacturers, making interchange difficult.

3.1 DJI Digital FPV System

The following discussion describes the features of the DJI digital FPV system used in our laser PPE study and is limited to it only. That system will be henceforth referred to simply as the PPE. Starting with the camera, it has a 0.8-cm complementary metal oxide semiconductor (CMOS) array with about 4 million effective pixels and is about 22.1 × 21.1 × 20.1 mm in size with a mass of 8.2 g. Light is captured by a 2.1-mm, f/2.1 lens that yields a 150° diagonal (122° H × 93° V) FOV. It feeds into a transceiver (Figures 1-d and 2-d) that sends video output in MP4 format in one of eight selectable channels between 5.660 and 5.839 GHz. The transceiver is 44 × 37.8 × 14.4 mm in size with a mass of about 37.6 g. It is powered by a rechargeable 12.26-V 1000-mAh battery (Figure 2-e). The transceiver and the camera tend to become warm during use, requiring some thought about the best way to mount them to goggles (Figures 1-b and 2-b) or elsewhere while not contributing to the user's discomfort. The transceiver is also equipped with two small elbow antennas (Figure 2-f) for remote transmission. The combination of the camera (Figure 2-c), transceiver (Figure 2-d), and goggles (Figure 2-b) is rated to have a range of hundreds of meters when operated with their respective antennas (Figures 2-f and 2-g). This far exceeds the present requirements. If only having the camera mounted on the goggles is wanted, then the antennas (Figures 2-f and 2-g) may simply be unscrewed and left off. The system is capable of a framing rate of at least 60 fps and a latency of 28 ms. This compares favorably with the latency and rate of human vision but is still noticeable.

3.2 DJI FPV Goggles V2(DJI)

The goggles (Figures 1-b and 2-b) shown in Figure 3 are held on the user's head by a set of rubber straps (Figure 3-c) and adjusted to make a good face-shield seal. The manufacturer also sells a set of softer seals for improved exclusion. The entire structure has a mass of 420 g. It is powered by a rechargeable 9-V, 1.5-amp lithium battery (Figure 3-a) that can be recharged via a 5-V USB-C connection. Once on, the effective screen size is 25 × 25 mm with a single-screen resolution of 1440 × 810 pixels. The goggles display FOV from the user's perspective is electronically adjustable between 30° and 54°. There are also many other camera and goggle combinations on the market that offer a wide range of features that may be very useful.

The goggles, designated by their manufacturer as DJI FPV Goggles V2(DJI), are intended to be used as one component of a four-item system comprising the following:

- DJI FPV Goggles V2
- DJI air unit consisting of the video camera and associated radio transceiver
- DJI FPV drone quadcopter
- DJI remote controller 2 (handheld controller)

In the current application, only the first two of the above elements are used. When purchased, the goggles are not activated, which is to say, they do not contain the software drivers that allow them to operate. Activation involves hooking up the goggles to a PC with internet connectivity and accessing the DJI website. The limited instructions provided by the manufacturer for activating the goggles assume that the user has all four components and guides the user to the DJI website[*]. However, this website cannot be used to activate goggles if only the first two listed components are used, but the site does provide an additional link labeled DJI Assistant 2 (DJI FPV series)[†]. It can be used to activate the goggles as required in the current application. When activated in this mode, that is, without the remote control, many of the functions that allow the user to adjust the goggles to the conditions of illumination at hand are lost. The unit reverts to a default set of operating parameters that include built-in automatic gain controls.

3.3 Laboratory Scenes

In any eye protection device, it is necessary that the view seen by the user closely resembles the scene under consideration. To test this, views of a laboratory scene were taken with an iPhone 13 Pro. The scene contains a low-power 532-nm laser beam. The first image was acquired through conventional 532-nm narrow bandpass

[*] https://www.dji.com/downloads/softwares/assistant-dji-2

[†] https://www.dji.com/downloads/softwares/dji-assistant-2-dji-fpv-series

attenuated goggles with the iPhone placed where the user's eyes are normally situated. The same scene was then acquired through the FPV goggles. The results are shown in Figures 4 and 5, respectively. In the image taken through the FPV goggles (Figure 5), the laser beam is clearly visible as a slightly descending green line starting about 60% of the way up from the left edge. It is part of and superimposed upon the "natural" scene. It results from the beam scattering from normal ambient particulates along its path. The image acquired using the conventional goggles does not show the beam at all. This illustrates one of the most important aspects of the present device. The user can know the location of the beam while maintaining complete eye protection. This aspect is particularly important when doing alignments and system repairs. It should be noted that beam visualization may not occur when fast-pulsed beams fall within those short periods when the focal plane array is not exposure enabled.

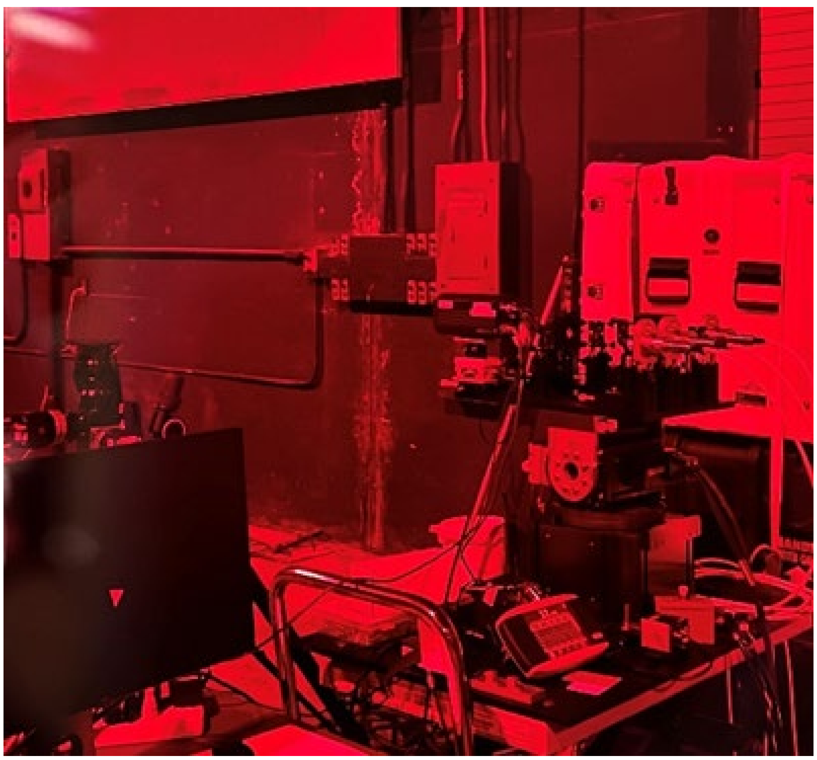

Figure 4. Laboratory scene taken through conventional goggles.

Figure 5. The same area taken through the FPV goggles.

3.4 Eye-Protection Mission

Given that the basic mission of this device is eye protection, it was decided to explore this in detail even to a perhaps unneeded extent. Two features in the device may come into play in providing protection: 1) the opacity to laser radiation of the goggles themselves, and 2) the LED display. Even at maximum brightness with every pixel on 100% of the time, it never reaches a level where the output is harmful to the eyes. Additionally, the camera incorporates automatic gain controls as a feature to improve user comfort and protect the camera against exposure to intense conventional sources such as the sun.

A series of tests were performed to demonstrate protection at work. The basic setup is shown in Figure 6. It starts with a 7-mW, 532-nm laser directed at the input aperture of the FPV camera. The FPV output is sent to the goggles, where they produce the scene display. The goggle display was recorded using a Mikrotron EoSens CL high-speed camera equipped with a 90-mm lens operating at f/2.4. It was located where the user's eyes would normally be positioned. The EoSens camera in turn drives a CameraLink cable into an EPIX V3.8 frame grabber installed on a Dell Optiplex 960 PC where the image of the flux and its ambient surroundings are recorded. The EoSens and EPIX were employed because they both produce JPEG images and a direct readout of the collected intensity at each of its pixels. It is also easy to restrict its consideration to a selected region of interest in its 1280- × 1024-pixel display.

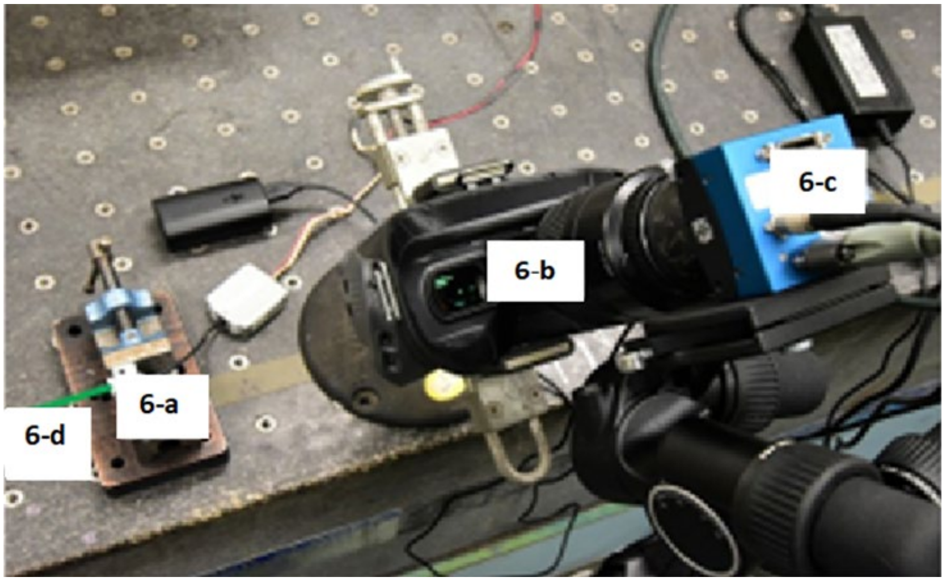

Figure 6. The FPV camera (6-a), DJI goggles display (6-b), and Mikrotron EoSens camera (6-c) array were used to record goggle images. The green laser beam (6-d) enters from the left. The EoSens camera is normally mounted directly on the goggles. For purposes of illustration, in this figure they are not.

However, under intense flux, the pixels in the FPV camera's CMOS array may be overdriven, causing leakage into adjacent pixels—a phenomenon known as blooming. The characteristics of blooming and saturation were examined in two tests. In each test, the laser was turned on and its output into the FPV camera adjusted by interposing combinations of neutral density (ND) filters into the laser to FPV camera path one after the other in order of decreasing optical density until extensive blooming was observed. The first test illustrated the spatial extent of the blooming in the FPV camera while guarding against being misled by saturation in the EoSens camera. To do this, each image was acquired with the EoSens's exposure time set to a level where the highest-intensity goggle pixel was well within the EoSens camera's 8-bit (255) range. Thus, any observed blooming was from the FPV camera alone. Three sample goggle images taken with interposed ND filters appear below in Figure 7. Note that at the two lower NDs the images are severely bloomed.

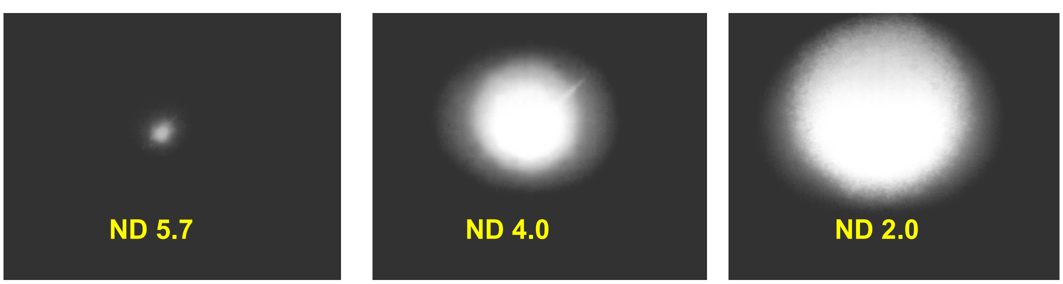

Figure 7. Images from the goggle display taken with various levels of attenuation.

The effects of saturation were revealed in the second set of measurements. EoSens images of the goggle display were acquired for ND filters placed in front of the FPV camera input in combinations ranging from ND 9 to ND 2. In contrast to the preceding set, the EoSens exposure time was the same for all. The total pixel counts contained in each EoSens goggle image were recorded and Figure 8 shows the results. Clearly, at the highest levels of flux onto the camera (lowest ND) there is a pronounced saturation effect in the FPV camera/goggle combination.

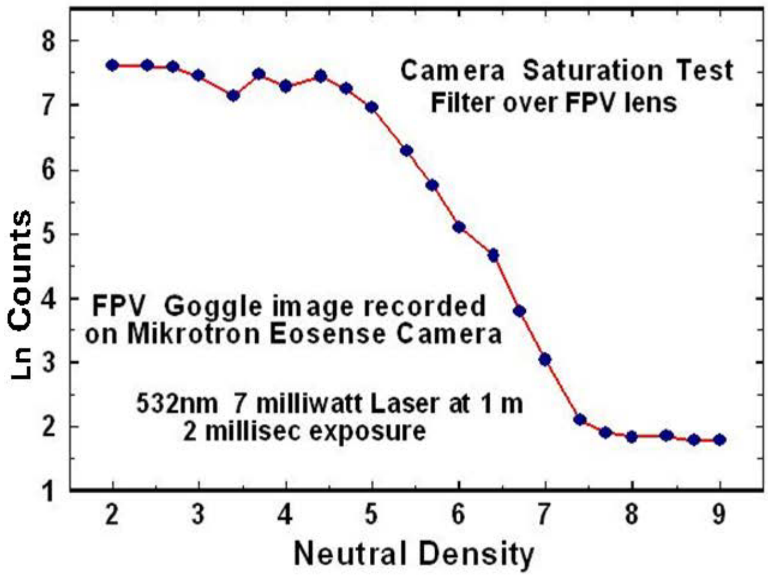

Figure 8. Total pixel counts recorded on the goggle display with various levels of ND filters interposed between the laser beam and the FPV camera.

To further confirm that the illumination behind the goggles at the normal position of the user's eyes was not hazardous under all conditions, the irradiance at that position was measured with a UDT Instruments S471 Optometer equipped with a model 221 detector head. The measured levels were 6.20, 5.43, and 4.57 μW/cm^2 with ND 1, ND 2, and ND 3 filters, respectively, while the value for an ND 4 filter was 1.35 μW/cm^2. The first three situations came from images featuring extensive saturation/blooming, while the latter does not. An irradiance of 6.20 μW/cm^2 is well within the applicable safety margins and is approximately that of good conventional room illumination. These results are consistent with the goggle manufacturer's claims that their LED array is incapable of producing hazardous intensity levels in the user's eyes. When the device's automatic gain controls are activated in saturation, that activation may be used to signal that a hazardous condition has been detected outside the goggles, even if the user is unaware of it. Appropriate measures can then be taken. Of course, the appearance of a large bloom spot should also be taken as a cause for immediate concern. It is interesting that once a saturated condition is reached, the total number of counts in the EoSens image and the irradiance reported by the optometer undergo only modest increases when the flux reaching the FPV lens increases over more than 2 orders of magnitude (ND 4 vs. ND2). Protection is thus assured.

Similarly, with conventional laser goggles, a source of potential protection failure of the FPV goggles is leakage around the face seal of the goggles. It may be revealed by turning off the camera and shining a bright light around the edges of the seal and asking the person wearing it if they see any penetrating light. This procedure must be carried out at intervals during each session of extended use.

The device used in the PPE responds in the visible light range (400–700 nm) and not to the short-wave (1400–3000 nm), mid-wave (3–5.5 µm), and long-wave (7–14 µm) IR regions. To work in these regimes, the lens/camera must be able to respond to the incident illumination and be put into a goggle display. There are no known appropriate COTS combinations that meet these requirements outside of military applications such as night-vision goggles. If such a capability is needed, the user will have to interface the nonvisible camera with a set of goggles. A possible exception is in the near-IR (700–1100 nm) band. Almost all FPV systems have filters to exclude near-IR and keep it off their silicon-based camera pixels, which can in fact respond in this band. If the filter can be removed, a near-IR capability can be derived. This region is particularly important because it is the operating band for many laser range finders and military systems such as target designators. Quercioli describes attempts to separate a filter from a lens that, while successful, did produce some damage.[3]

To test how well the PPE performed while completing the alignment of a laser, a rudimentary optical path was set up in the laboratory using a 532-nm laser pointer (Figure 9). Team researchers were timed with a stopwatch while completing the alignment with both the PPE and the pair of standard laser eye protection used in Figure 4.

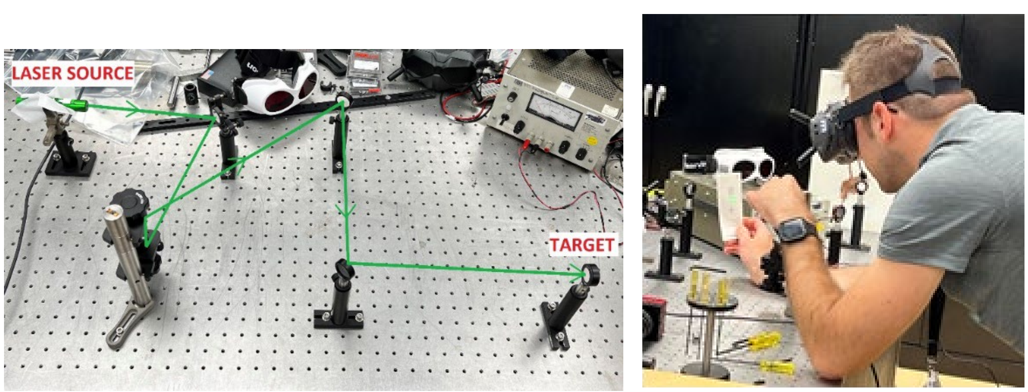

Figure 9. (Left) A rudimentary optical setup devised for PPE testing and (right) a researcher wearing the PPE while aligning the green laser.

Each researcher preferred wearing the PPE instead of the traditional laser safety eyewear, stating that the view was much better with the PPE. On average, aligning the laser was accomplished in about half the time required with the traditional eyewear. The latter's images of the beam were so dark that it could barely be viewed even with an alignment card. The PPE allowed closer inspection of the beam and the researchers could maneuver their faces around the optics to obtain a view of the beam from a better vantage point. In addition to the better view, the PPE also offered more reassurance to the researchers that they were fully protected from the laser beam. Another frequently stated benefit was that the PPE includes a small fan that continuously blows air across the display, eliminating the common issue of goggles fogging up after a few minutes. This benefit was most acutely felt by researchers who also wear corrective eyewear. All researchers stated that the resolution of the display and comfort of the PPE were sufficient for accomplishing their alignment task. Two items the researchers stated that need improvement are 1) the PPE must be made wireless, and 2) the fisheye lens in the camera must be replaced with a lens yielding an image that more closely resembles a human eye's natural FOV.

4. Conclusion

This device provides laser users with eye protection and enhanced beam visualization/detection when working in environments that contain known or suspected hazardous laser radiation. The device offers complete broadband eye protection, permitting the wearer to carry out normal laboratory, industrial, and military operations without a direct exposure pathway to the eye. It is a "near universal" protective device that provides broad-spectrum eye protection without reducing available visible light or altering color perception for task execution and locomotion. Previously, to achieve durable protection over wide wavelength bands, multiple molecular dyes would need to be placed within the protective eyewear matrix (often polycarbonate or glass) to absorb optical radiation. The number and concentration of such molecular dyes needed to achieve higher optical densities (ODs) would severely limit available visible light for sensing and locomotion within the eye hazardous environment. Such severe light diminishment could lead to 1) the temporary removal of the protective eyewear by the wearer to better see the work environment leading to an exposure or 2) secondary injuries such as falling into or tripping over objects that were not seen due to the limited transmitted light. In essence, the traditional protective googles themselves became a hazard.

Due to this tradeoff between visible light for task execution/locomotion and eye protection needs, the laser eyewear would often only be ordered with high ODs at a few known bands to preserve visible light transmission (VLT) to levels above

20%. This tradeoff resulted in the procurement and maintenance of many differently rated laser eyewear good for only certain applications and required the wearers to be trained in proper protective eyewear selection as well as to know what hazardous wavelengths were present.

The device described in this report does not suffer from the traditional "protection versus VLT tradeoff" or color filtering effects that transmission-based eyewear does and replaces a myriad of conventional laser protective goggles, each tuned to a specific narrow wavelength band. Instead, the wearer is protected even if the characteristics of the optical source are unknown. The device also provides other benefits such as overall cost reduction, a reduction in training related to proper PPE selection, and the ability to view the general environment including the laser beam itself and information displays/indicators in full brightness (or electronically amplified brightness). The device enables the wearer to see laser emission at wavelengths outside the range of human perception that corresponds to the sensitivity range of the chosen camera. Lastly, this device provides the ability to record and magnify what is being observed at normal or high speeds, operate remotely, and correlate imagery from different aspect angles. This technology represents a paradigm shift in eye protection philosophy from passive transmission filtering technologies to blocking/indirect viewing technologies with electronic enhancement.

5. Future Work

A second related technology has sprung up around devices to aid the visually impaired. ARL is currently evaluating their use and having modifications made to them as deemed necessary. These devices offer the ability to present magnified images and an improved ability to adjust brightness and contrast. They also interface with standard HDMI video format so that they can be used in a classroom setting, enable easy editing, and provide simple recording.

6. References

1. Vanderhoef L et al., inventors; United States Army, assignee. Protective eyewear for high intensity sources. United States patent application US 18536504. 2025 June 12.

2. Quercioli F. Beyond laser safety glasses: augmented reality in laser laboratories. Appl Opt. 2017;56(4):1148–1150. https://doi.org/10.1364/AO.56.001148

3. Quercioli F. Augmented reality in laser laboratories. Opt Laser Technol. 2018;101:25–29. https://doi.org/10.1016/j.optlastec.2017.10.033

4. Mathieu E, Farrugia J-P, Grivollat A. Technical report on the development of video glasses for eye protection. 2016; CNRS-Lyon (69); INSA Lyon; UCBL. Report No.: hal-01271587.

5. Triple-lens camera drone. DJI MAVIC 3 PRO. DJI; c2026 [accessed 2026 Apr 14]. https:/www.dji.com

List of Symbols, Abbreviations, and Acronyms

ARL	Army Research Laboratory
CMOS	Complementary Metal Oxide Semiconductor
COTS	Commercial Off The Shelf
DEVCOM	U.S. Army Combat Capabilities Development Command
FOV	Field of View
fps	Frames Per Second
FPV	First-Person Video
GHz	Gigahertz
HDMI	High-Definition Multimedia Interface
IR	Infrared
JPEG	Joint Photographic Experts Group
LED	Light-Emitting Diode
ND	Neutral Density
nm	Nanometer
OD	Optical Density
PC	Personal Computer
POC	Proof of Concept
PPE	Personal Protective Equipment
RF	Radio Frequency
SDI	Serial Digital Interface
USB	Universal Serial Bus
UV	Ultraviolet
VLT	Visible Light Transmission

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