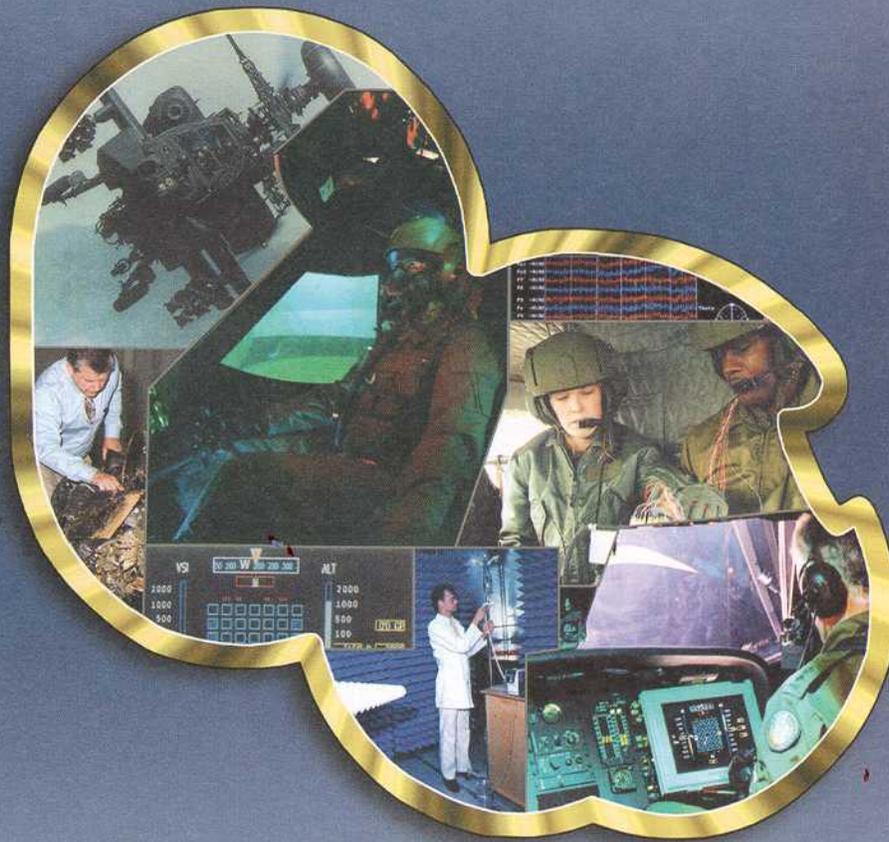


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# Evaluation of the Seattle Photonics Light Shape Diffuser

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Aircrew Health and Performance Division

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## Introduction

As part of the Cooperative Research and Development Agreement between Seattle Photonics (Seattle, Washington) and the U.S. Army Aeromedical Research Laboratory (Fort Rucker, Alabama), the following evaluation of the Seattle Photonics' Light Homogenizing Sheet (LHS) is provided. The LHS is designed to take a light source and spread the light from the source uniformly over a well-defined area with high light efficiency. This technology, if proven useful, could have applications in various technological areas (e.g., uniform backlights for liquid crystal displays, imaging technologies, etc.). Seattle Photonics provided two demonstration units for this evaluation.

The first demonstration unit (DEMO 1; Figure 1) consisted of two 30-degree diffusion screens, a lens, and an array of light emitting diodes (LEDs) as the light source. One of the screens was the LHS, and the other was a Light Shape Diffuser (LSD™) from Physical Optics Corporation (Torrance, California). The LSD was provided as it represents the current technology used in diffusing light sources. The LED array allows for either one or ten LEDs to be turned on at one time. Data were collected for both light conditions.

The second demonstration unit (DEMO 2; Figure 6) consisted of a 30-degree LSD, a 33-degree LHS, and an LED array.

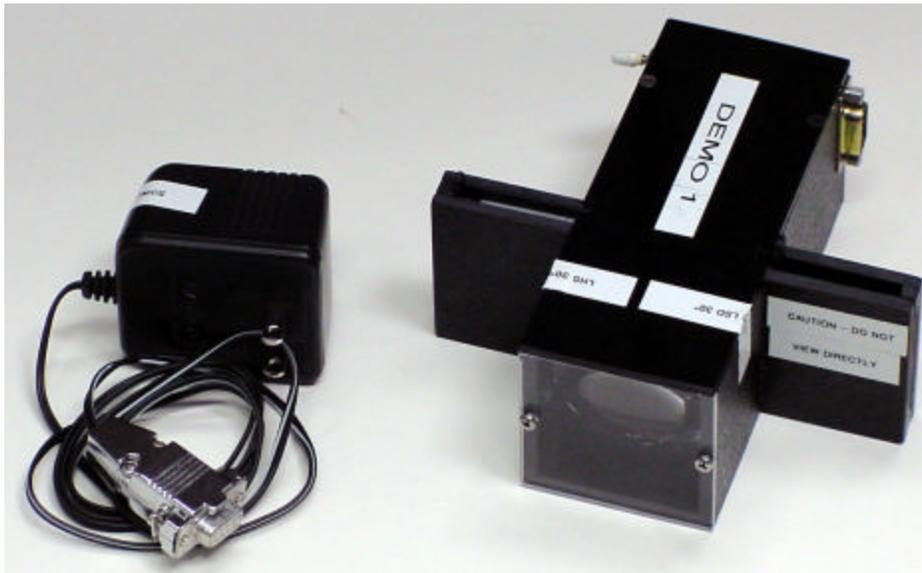


Figure 1. DEMO 1 unit showing the slide-out holders for the two diffusion screens and the power supply.

### Evaluation of DEMO 1: Light efficiency

DEMO unit 1 was constructed to test light efficiency. With the LHS screen in place, the focusing lens projected a hexagon-shaped area that could be well focused. With the LSD in place, best focus could not be achieved since the unit produced a Gaussian profile. Any linear blurring of a Gaussian profile results in a Gaussian profile.

Light efficiency was measured under two conditions: Hexagonal Circumscribed and Hexagonal Inscribed Case as shown in Figure 2. The measurements were taken by positioning the DEMO 1 unit in front of the Melles Griot integrating sphere (model 13PDH003) with a Melles Griot Universal Optical Power Meter (model 13PDC001). An aperture was positioned between the integrating sphere and the DEMO unit as shown in Figure 3.

The light output from the selected light source (10-LED or 1-LED) was directed into the integrating sphere. As defined, light efficiency is the light output through the LHS or LSD screen divided by the total unfiltered light output, expressed as a percentage. Table 1 shows the resulting system efficiencies for the LHS and the LSD screens.

The LHS had a greater light efficiency under all conditions. As expected, the data were fairly consistent for the two light sources. The average LHS light efficiency was 66.5% compared to only 38% for the LSD. As expected, the light efficiency of the LHS increased greatly from 58% to 75% with increased aperture. The relative light efficiency ratio between the LHS and LSD results ranged from 1.7 to 1.8 (refer to Table 1).

We essentially found the same results with DEMO 2. For DEMO 2, the light efficiency ratio between the LHS and LSD ranged from 1.8 to 1.9 when evaluated under the same settings. The data are shown in Table 2.

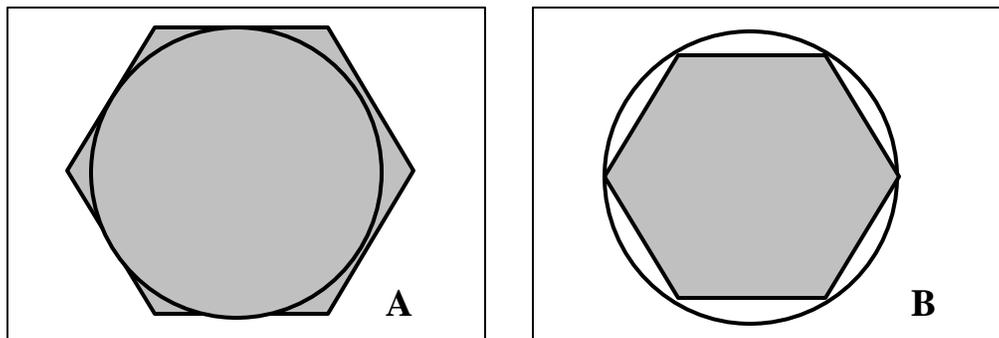


Figure 2. Diagram profile for DEMO 1 with an aperture set at best focus for the Hexagonal LHS output to the illumination plane with LHS (A) Hexagonal Circumscribed Case and LHS (B) Hexagonal Inscribed Case. Same conditions were applied for the LSD.

Table 1.  
DEMO 1 unit system light efficiencies for LHS and LSD.

	Hexagonal Circumscribed Case (A)		Hexagonal Inscribed Case (B)	
	10 LED	1 LED	10 LED	1 LED
LHS Efficiency	58 %	57 %	75 %	80 %
LSD Efficiency	32 %	31 %	44 %	49 %
Relative Utilization Eff LHS/LSD	1.8	1.8	1.7	1.7

Table 2.  
 DEMO 2 unit system light efficiencies for LHS and LSD.

	Hexagonal Circumscribed Case (A)		Hexagonal Inscribed Case (B)	
	10 LED	1 LED	10 LED	1 LED
LHS Efficiency	90 %	74 %	83 %	83 %
LSD Efficiency	52 %	40 %	47 %	44 %
Ratio of Utilization Efficiencies (LHS/LSD)	1.8	1.8	1.8	1.9

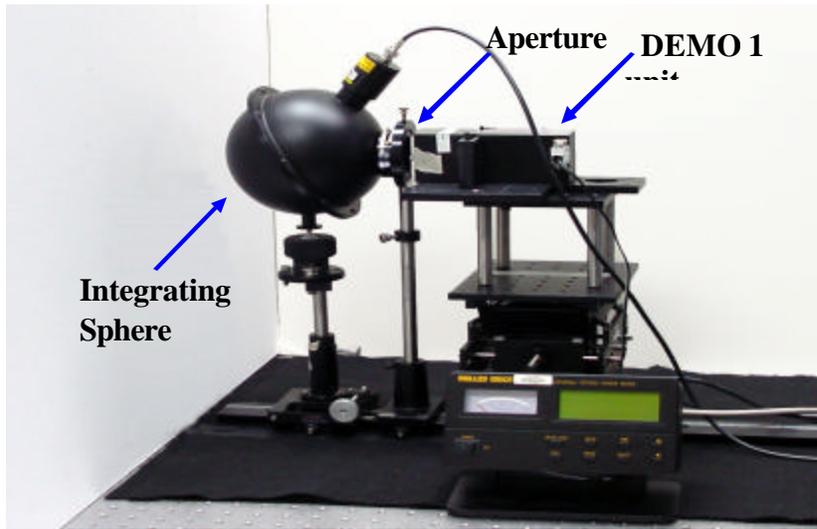


Figure 3. DEMO 1 unit measurement setup.

Figure 4 shows the light profiles for the two screens using the 10-LED source. The images were captured by projecting the light onto a rear-projection screen and photographing the light distribution with a high resolution (10-bit gray level) CCD (charge coupled device) monochrome camera (DVC-1310M-FW-TE) with a Schneider Variogon lens (CM123). The camera has good linearity and a cooling unit that minimizes image noise. Using Matrox Image Inspector software, the photographic images were analyzed to yield average line profiles through the vertical and horizontal meridians. Figure 5 shows graphs of the line profiles for the light profiles shown in Figure 4.

Evaluation of DEMO 2: Illumination uniformity

Figure 6 is a photograph of DEMO 2, which looks identical to DEMO 1. The only difference is the lack of a focusing lens.

The DEMO unit was mounted on a fixed stage, was positioned some distance in front of the DEMO unit, and has a concave lens with a photodiode located at the lens focal length. Light

from the DEMO unit was focused on the photodiode such that the light filled the collection area of the diode. A neutral density filter also was placed in front of the concave lens to eliminate over ranging. All were mounted on a rotating arm whose center of rotation was collocated with the center of the last surface of the DEMO unit.

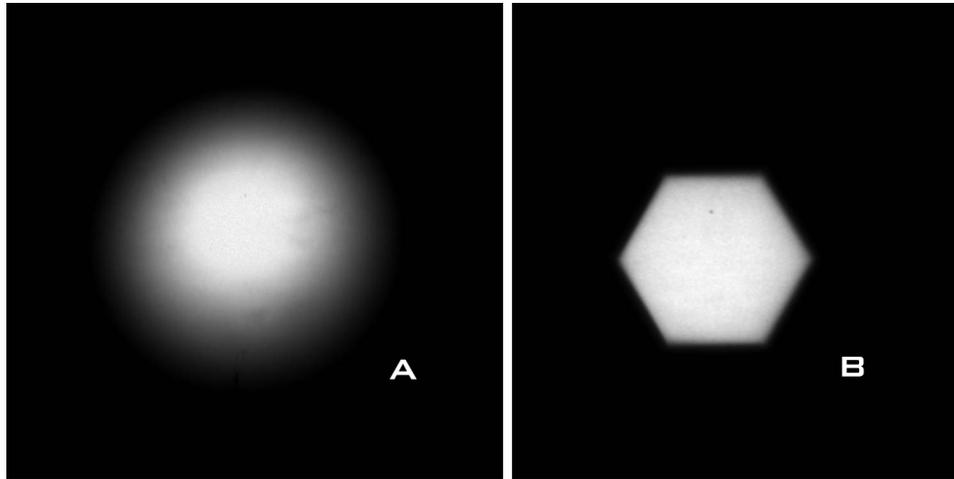


Figure 4. Light profiles from the 10 LEDs for DEMO 1 with the LSD (A) and the LHS (B) in the light path

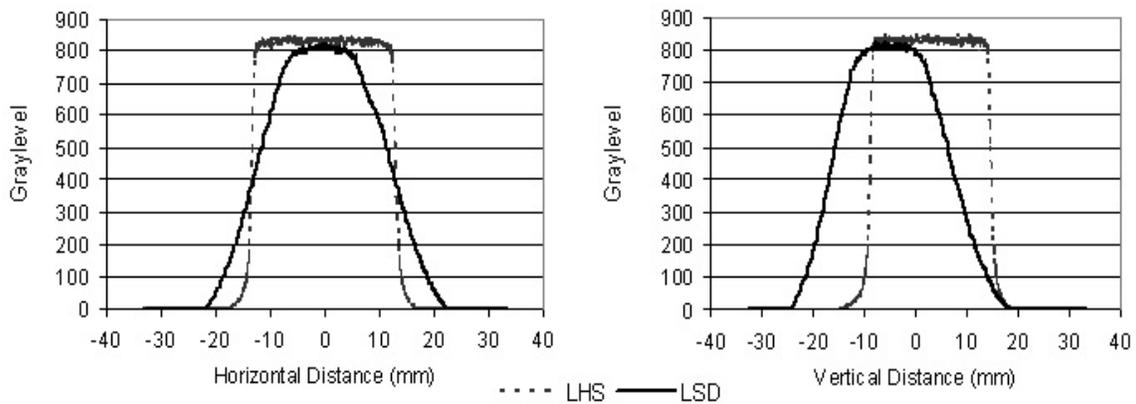


Figure 5. Line profiles of the horizontal and vertical meridians for the light profiles shown in Figure 2.

By rotating the arm that the photodiode, lens and filter were mounted on, light intensity was measured as a function of angular position. Figure 7 presents the setup for the angular profile measurement. Figure 8 shows the vertical and horizontal angular profiles for the two screens using the 10-LED light source.

In Figure 8, the LHS's horizontal and vertical profiles show a greater uniformity in the center region represented by the rather flat curves. On the other hand, the LSD's line profile showed a bell-shaped curve. Gaussian curves were fit to both the vertical and horizontal data using a least

squares method, and a summary is presented in Table 3. By comparison, the LHS produced a light pattern that over a considerable range resulted in a rather uniform distribution.

The same analysis was repeated for the single LED light source. Figure 9 shows the angular profiles for the single LED condition. The profiles are similar to the 10-LED condition. A more prominent flattop line profile for the LHS is noticeable while the LSD maintained its Gaussian profile. Table 4 has the standard deviation for best Gaussian fit for the LSD line profile shown in Figure 9.

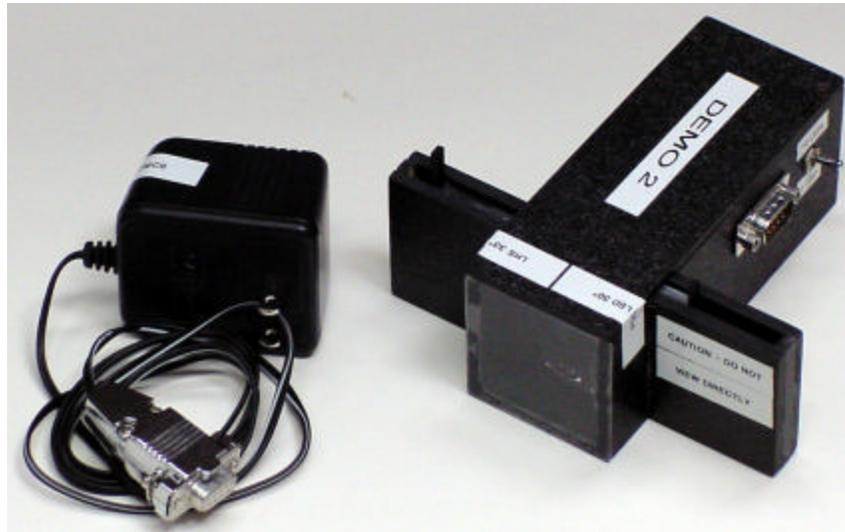


Figure 6. DEMO 2 unit showing the slide-out holders for the two diffusion screens and the power supply.



Figure 7. Photograph image of the photodiode, the concave lens and neutral density setup.

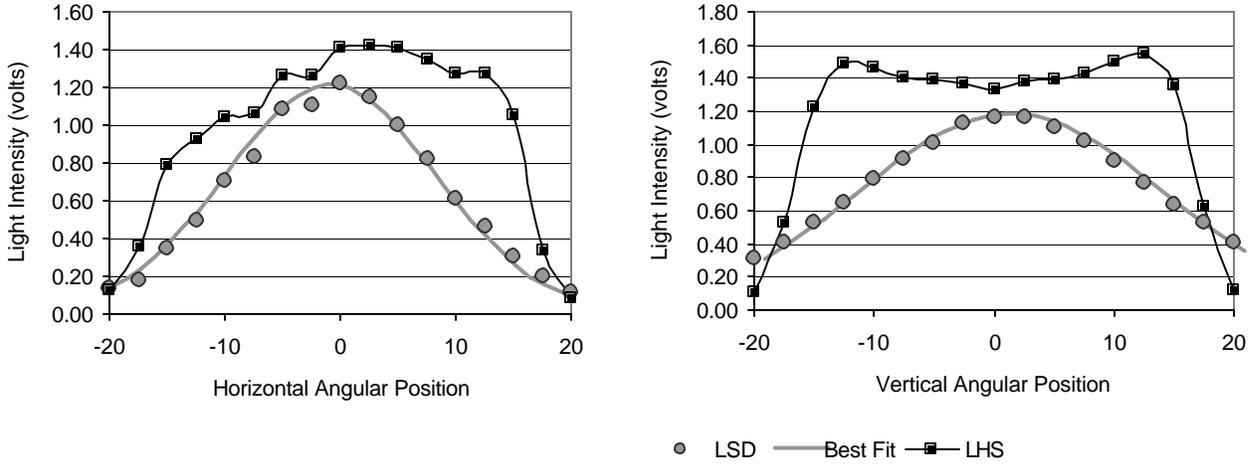


Figure 8. Line profiles for the horizontal and vertical angular positions versus light intensity.

Table 3.

Standard deviations for best Gaussian fits to the LSD line profiles shown in Figure 8.

	Horizontal	Vertical
Standard Deviations	9.095	12.47

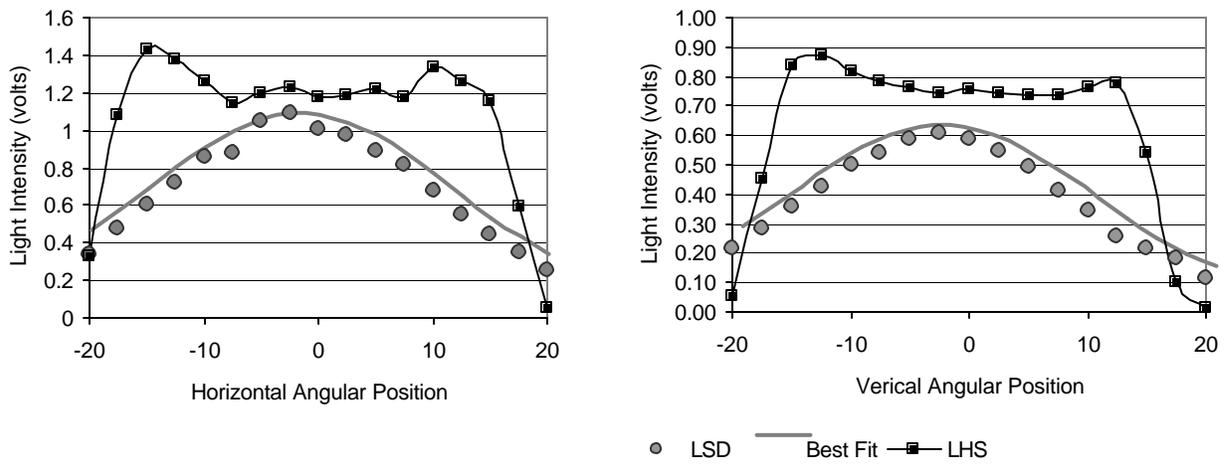


Figure 9. Line profiles for 1-LED horizontal and vertical angular positions versus light intensity.

Table 4.

Standard deviations for the best Gaussian fits to the LSD line profiles shown in Figure 9.

	Horizontal	Vertical
Standard Deviations	13.20	12.54

## Summary and discussion

The Seattle Photonics Light Homogenizing Sheet contained in both DEMO 1 and DEMO 2 produced greater illumination uniformity and light efficiency than did the comparable Light Shape Diffuser (LSD <sup>TM</sup>) from Physical Optics Corporation, which represented current technology.

It is clear from the data presented here that the LHS offers an improved light uniformity while also increasing light efficiency. Under the conditions of our tests, the LHS in both DEMO 1 and DEMO 2 produced about a 1.7 to 1.9 times greater light efficiency than did the LSD. The illumination from the LSD screen is best described as a Gaussian distribution as characterized by well-fit Gaussian curves. The LHS produces a more uniform distribution as seen in Figures 8 and 9.

It is our conclusion, based on these evaluations and the data presented here, that the LHS does indeed offer an advantage for applications requiring greater illumination uniformity and/or light efficiency.

Appendix.

List of manufacturers

Digital Video Camera Company (DVC)  
10200 Highway 290 West  
Austin, TX 78736-7735

Matrox Electronic Systems  
1055 St. Regis  
Dorval (Quebec)  
Canada H9P 2T4

Melles Griot  
2985 Sterling Ct.  
Boulder, CO 80301

Physical Optics Corporation  
20600 Gramercy Place  
Building 100  
Torrance, CA 90501-1821

Schneider Optics Inc.  
285 Oser Ave.  
Hauppauge, NY 11788

Seattle Photonics  
7215 Dayton Avenue North  
Seattle, WA 98103-5030