Infrared Targets for Testing and Training

G. D. Boreman[†], M. Abdel-Rahman[†], B. Monacelli[†],
G. Zummo[†], D. Mullally[‡], T. Clarke[‡]

[†]Infrared Systems Lab/CREOL
[‡]Institute for Simulation & Training
University of Central Florida
Orlando, FL 32816

boreman@creol.ucf.edu, (407) 823-6815

ABSTRACT

We present a design for an IR scene projector for live-fire training applications, based on modification of a commercial-off-the-shelf (COTS) laser-light-show scanner retrofitted with a CO_2 laser and associated IR optics. Design goals include a reusable or at least very inexpensive shoot-through projection screen. This application calls for a wide projection field as compared to typical IR scene-projection (IRSP) systems intended for hardware in the loop (HWIL) testing.

Keywords: Infrared scene projection, military training systems, computer generated forces, engagement skills trainer, objective individual combat weapon.

1. OBJECTIVE

The objective of our research is to develop an IR scene projector concept specifically for training applications. Infrared night sight systems are becoming more widely employed, on platforms ranging from tanks and fighting vehicles to individual soldier weapon systems, for instance the objective individual combat weapon (OICW), seen in Fig. 1. Appropriate training is critical, since visual cues and operation are different from corresponding day sights. The value of simulation in training is driven by economic considerations,[1] with simulation based training much less expensive than completely live firing. An additional benefit is that difficult sequences can be repeated indefinitely until the desired skill set is acquired satisfactorily. Live-fire training is performed outdoors with live munitions.

Fig. 1: Objective individual combat weapon (OICW) sighting system.

Technologies for Synthetic Environments: Hardware-in-the-Loop Testing VII, Robert Lee Murrer, Jr., Editor, Proceedings of SPIE Vol. 4717 (2002) © 2002 SPIE · 0277-786X/02/$15.00

A scene-projector system is desired that can project dynamic IR imagery on a shoot through screen: either self healing or cheap to replace. In this context, we investigated water, glycerol, sandpaper, and plastic sheeting. The design goals for our demonstration system were to have a relatively wide screen, as far as IRSP applications are concerned (3 to 15 foot screen width desired), and to use COTS components as much as possible.

2. DESIGN

Our original design used Texas Instruments' digital light processor (DLP) chip, seen in Fig. 2, to project frame-based imagery. The DLP is a 2-D (800 × 600) array of small (17 μm) mirrors. Figure 3 shows a projector concept based on our previous work in HWIL IR scene projectors.[2] Each mirror can be tilted individually in response to input video signal, with the result that radiation can be directed either to pass through the projection system to the screen, or to miss the aperture of projection system. Gray levels can be created by pulse width modulation of the mirror tilts.

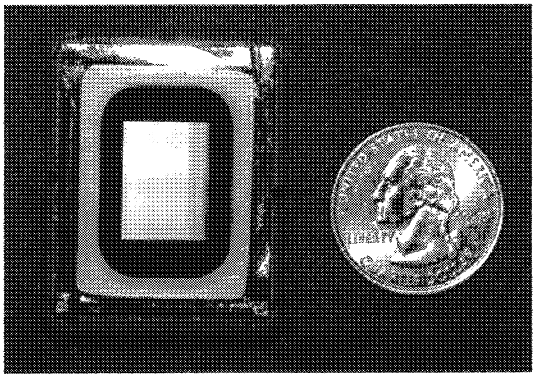

Fig. 2: DLP chip with glass window.

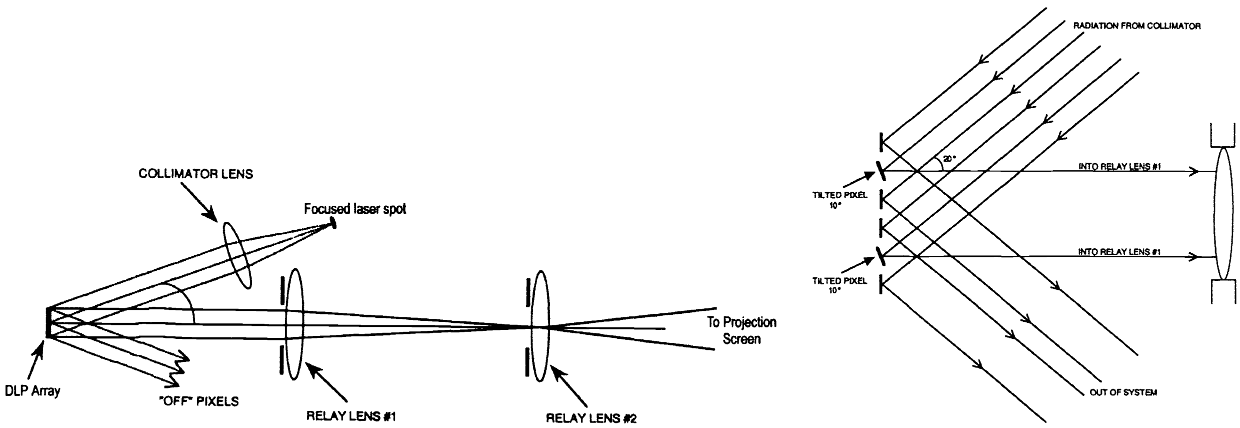

Fig. 3: Original design for the IR scene projector using the DLP.

The main technical challenge to this approach is that the DLP is sealed with a glass window, and we were unable to retrofit an IR window to DLP chips extracted from commercial computer-projector systems. We have since identified a vendor[3] for this semi-COTS component, and future versions of our projector will use this approach.

For an initial proof of concept system, shown in Fig. 4, we used a COTS *xy* scan system[4] intended for laser light show applications, with an IR AO modulator[5]. The receiver is an uncooled pyroelectric[6] FPA camera with a 50 mm lens. We fitted the COTS scanner with lightweight scan mirrors[7] for increased temporal bandwidth. This got rid of "droop" at edges and corners in the image.

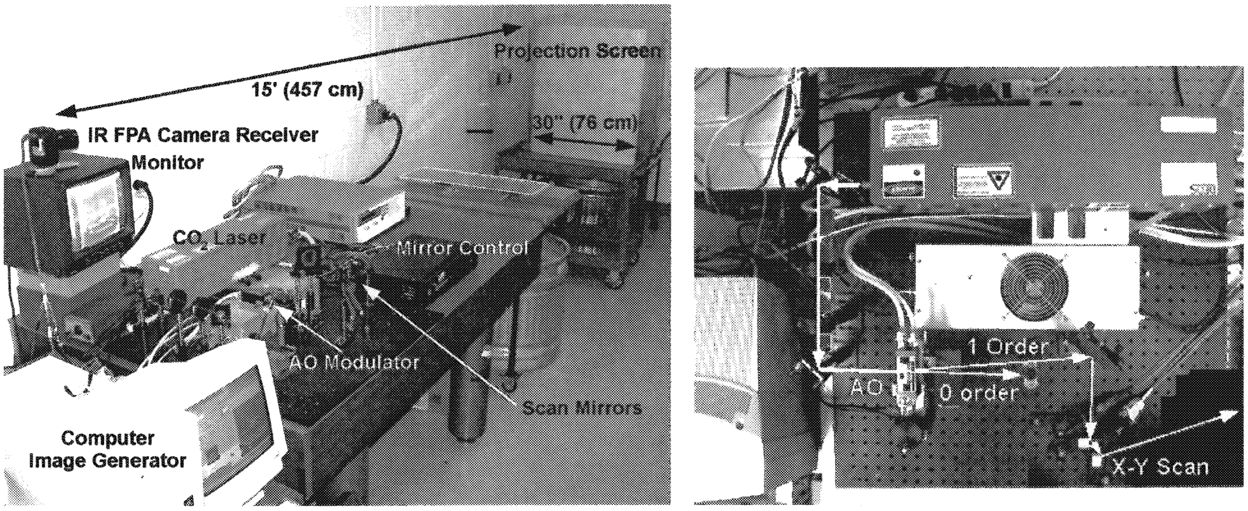

Fig. 4: Proof-of-concept IR projector demonstration system, with sandpaper projection screen.

There were two main drawbacks to *xy* scanned approach, compared to a frame projector using the DLP chip. For scanned imager systems there is excessive flicker. However, for staring imager systems the *xy* scanned projector works well. The master synch signal of the projector was slaved to camera synch pulse, which got rid of the slow rolling line flicker in the video. The other drawback is that video-to-vector-scan image conversion is not a COTS item. The lack of a straightforward conversion from video to vector drive signals made it hard to use existing IR video imagery.

2.1 Radiometry – Laser Power

The laser[8] used in our initial demonstration system is a 35-W CO_2, operating at 10.6 μm. The AO modulator was adjusted for maxmimum (40%) efficiency into the 1st order. These components gave goodsignal level for the 30-inch sandpaper screen, viewed at 15 feet. Use of a 100 W CO_2 laser will allow scaling up to a 5-foot image screen. Larger image areas will be possible, particularly if better screen reflectance can be achieved.

2.2 Radiometry – Screen Issues

Live-fire training applications put severe constraints on the screen design. A shoot-through screen must be self healing (liquid) or at least very cheap to replace. We investigated two main designs – a sandpaper screen and a moving water screen. As seen in Fig. 5, the water screen had placement of nozzle below the screen, which is a better configuration for shoot through applications. The water screen is convenient in places where there is lots of water available, and it has low environmental impact. The problem with the water screen radiometrically is that it has a low reflectance. Measured values of $\approx$ 1% are consistent with standard reflection formulae, given n and k of water at 10.6 μm.

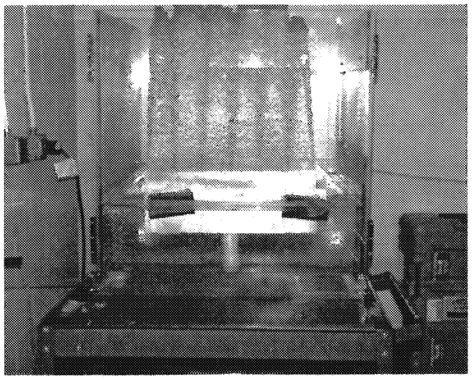

Fig. 5: Water-based IR projection screen.

We investigated various additives in the water to increase the reflectance. Aluminum and brass particles and flakes were not effective, as it was difficult to get the metal to stay on the surface of the water. A number of other additives were tried, of which the most promising was glycerol. In undiluted form, it had about 8% reflectance at 10.6 μm. It can be easily mixed with water in any proportion, giving an intermediate reflectance. The drawback to glycerol is that it is more viscous, requiring larger operating pressures from the pump.

The sandpaper screen seen in Fig. 4 is approximately a lambertian scatterer, in that the reflected signal does not fall off rapidly with angle. Sandpaper has the advantage that it is inexpensive and is available in large sheets. We measured the hemispherical reflectance of uncoated 60 grit sandpaper as about 4%. With an overcoat of COTS metallic paint, this increased to around 11%. This could be increased at the expense of a higher cost metallic coating on the screen. We also tried plastic sheet "tarp" with same metallic paint. The angular response was somewhat more specular, but it could be a good starting point to satisfy hanging sheet screen requirements.

2.3 Image Quality

Spatial resolution for the present system is determined by spot size on screen of about 1 cm, consistent with the divergence of the raw laser beam over the 15-foot distance to the screen. This yields about 70 horizontal resolution elements across the 30-inch screen dimension. The scanner is capable of much higher pointing precision, and the beam could be focused to tighter spot on the screen to take advantage of this. Our measurement of resolution also had a contribution from the IR camera used as the receiver, since we projected a single point image on the screen and measured the spot width in the camera output video.

As seen in Fig. 6, the turbulence of the water screen degrades the image quality by introducing additional spatial noise and increasing the width of the spatial impulse response.

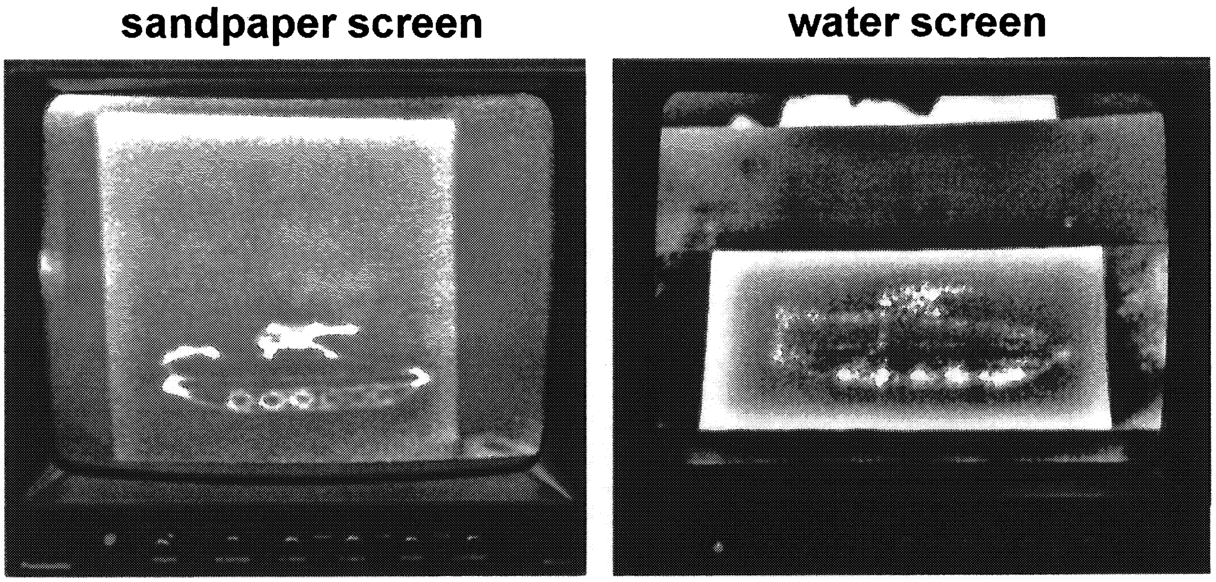

Fig. 6: Received IR image from the sandpaper screen and the water screen.

3. FUTURE WORK

Future efforts on this project will include implementation of the IR DLP chip projection system. We will also develop IR-projection capabilities for STRICOM's Engagement Skills Trainer (EST) seen in Fig. 7, where the target and background scenes are created using computer-generated forces (CGF). In this application, there is not a requirement for a shoot through screen, because the scoring is done with a near IR aimpoint system rather than with live munitions. However, laser safety issues associated with the EST may necessitate rearside IR projection. In this case, the thermal properties of the screen become paramount, while maintaining visible and near IR diffuse reflectance. The lateral thermal conductivity (in plane) should be low, to preserve good spatial resolution. Longitudinal thermal conductivity (through plane) should be high to allow for a large, fast thermal response, and the thermal mass per unit area of the screen should be kept as small as possible.

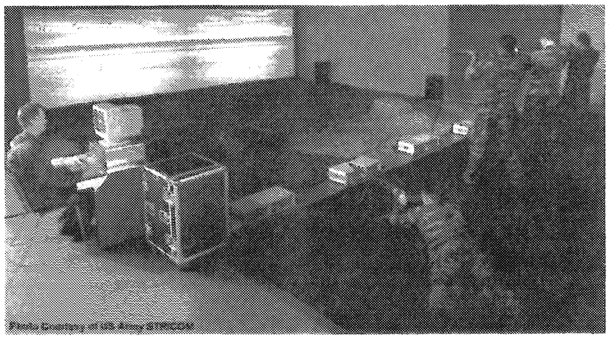

Fig. 7: STRICOM's engagement skills trainer (EST).

ACKNOWLEDGMENTS

This work was supported by the Live Fire Test and Evaluation Program (Annette K Pike, COTR), Naval Air Warfare Center, Orlando FL.

REFERENCES

1. M. Macedonia, "Games Soldiers Play," *IEEE Spectrum*, **39** 3 32-37 (2002).
2. K. Barnard, G. Boreman, and D. Pape, "Crosstalk model of a deformable-mirror infrared scene projector," *Optical Engineering* **33**, 140-149 (1994).
3. Optical Sciences Corp., Huntsville AL
4. Lighting Systems Design, Inc., Orlando FL
5. IntraAction Corp., Bellwood, IL
6. Raytheon, Co., Lexington, MA
7. GSI Lumonics, Billerica, MA
8. DEOS, Bloomfield, CT