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Polarized Illuminator for Very-Near Infrared Imaging

by John Furey and Cliff Morgan

PURPOSE: This note describes the development of a polarized illuminator system for providing continuous broad beam of very-near infrared (VNIR) radiation to be used in imaging polarimetry applications. This system was developed for field characterization of geo-environmental surfaces (e.g., soil and vegetation), and discrimination of these surfaces from objects of military interest (e.g., unexploded ordnance and mines).

BACKGROUND: Prior work has shown the efficacy of narrow beam polarimetry to discriminate mines (Ballard et al. 1992; Cremer et al. 2002) and unexploded ordnance (Bennett et al. 1998) in the field. This line-scanning technology was previously shown to successfully characterize small areas of regular surfaces, but often caused difficulties in alignment and registration when collected data were post-processed for imaging applications.

In the course of developing a system for spectral imaging of particulate contaminants in the field (Furey et al. 2008), the need for a broad beam polarized illumination source for several wavelength bands, especially the VNIR band near 800 nm, became apparent. Because no system was commercially available for that VNIR band, a relatively inexpensive polarized illuminator system using a combination of "off-the-shelf" and customized components was constructed.

TECHNOLOGY DESCRIPTION: The component technologies are rigidly custom mounted on an aluminum housing for use with the Engineer Research and Development Center Environmental Laboratory Multispectral Infrared Camera Acquisition (MICA) System. The illuminator is co-aligned with the camera line of sight, so that the illumination beam is transverse to the imaging plane, and the illumination components are offset 30 cm from the detection components (Figure 1). This rigid mounting of the continuous broad beam illumination source allows for continuous signal detection at video rates through a VNIR-sensitive charge coupled device (CCD) direct imaging camera, thereby obviating the difficulties in alignment and registration of previous line-scanning technology.

Figure 1. The polarized illuminator (below center) is mounted offset from the MICA camera head (a portion is shown top left).

Illumination Components. The primary component of this illumination technology is the high-power (20 W) industrial laser diode bar stack provided in a LI-20 laser illuminator, originally manufactured by 20 Twenty, Inc. (Kingston, RI), now Integrated Security Corporation (Walled Lake, MI). The narrow band spectral output of the laser diode stack exhibits a peak wavelength of 808 nm, with a full width at half maximum (FWHM) of 4 nm. A molded acrylic light pipe directs the output through a lens system and diffusive optics, yielding a roughly elliptical field of illumination (FOI) of nominal size (FWHM) 10° × 20°. The intensity distribution is maximum at the center of the FOI, and is roughly constant (± 5 percent) within 5° of the center of the FOI.

Because of the high spectral power, a thermally stable polarizer is required. A custom glass plate wire grid polarizer (Moxtek, Inc., Orem, UT) is front-mounted after the diffusive optics to provide uniform linear polarization across the FOI. The efficiency of the polarizer is 90 percent at 808 nm, and the extinction ratio is > 10^4:1. The intensity of illumination was measured with a PM120 handheld optical power meter (Thorlabs, Inc., Newton, NJ) to be 10 μW/cm^2 in the center of the FOI at a distance of 10 m.

Detection Components. The primary component of the detection technology is an Illunis XMV (Illunis LLC, Minnetonka, MN) 12-bit monochrome camera with a CCD of 1360 × 1024 pixels. The peak efficiency of this CCD is in the VNIR band, approximately 800 nm, with decreasing efficiency through 1000 nm. A 25-mm lens (Canon Inc.) produced an effective field of view on the CCD of approximately 12° × 16°.

Polarization detection is achieved through a pair of 25-mm linear polarization filters (LPVIS, Thorlabs, Inc., Newton, NJ). The efficiency of these polarizers is 80 percent at 808 nm, and the extinction ratio is > 10^4:1. The filters are mounted in front of the camera in a filter wheel (True Technology Ltd., Berks, England). One detection filter is aligned so its polarization direction is parallel to the illumination polarization, and the other detection filter is aligned so its polarization direction is crossed to the illumination polarization.

EXAMPLE APPLICATIONS: The typical application of this technology system is to provide active polarized reflectance measurements of imaged surfaces. When most surfaces are illuminated by polarized light, the reflected light is not completely polarized due to surface depolarization effects. Many natural geo-environmental surfaces such as soil and vegetation have large VNIR depolarization (Egan 2000), while surfaces of man-made objects tend to have smaller depolarization (DeBoo et al. 2005).

For a single direction of linear polarization, the measured polarization of the reflected light is defined as

$$\sigma = \frac{(p-c)}{(p+c)} \tag{1}$$

where p is the parallel polarized component received and c is the cross-polarized component received. Within limits defined by the response of the CCD, the measured polarization σ is independent of the intensity of illumination, and independent of the diffuse reflectance ρ (Goodson et al., in preparation).

Mine Detection. Similar to prior applications of a similar technology, imaging polarization can enhance detection of mines and other threat objects (Figure 2).

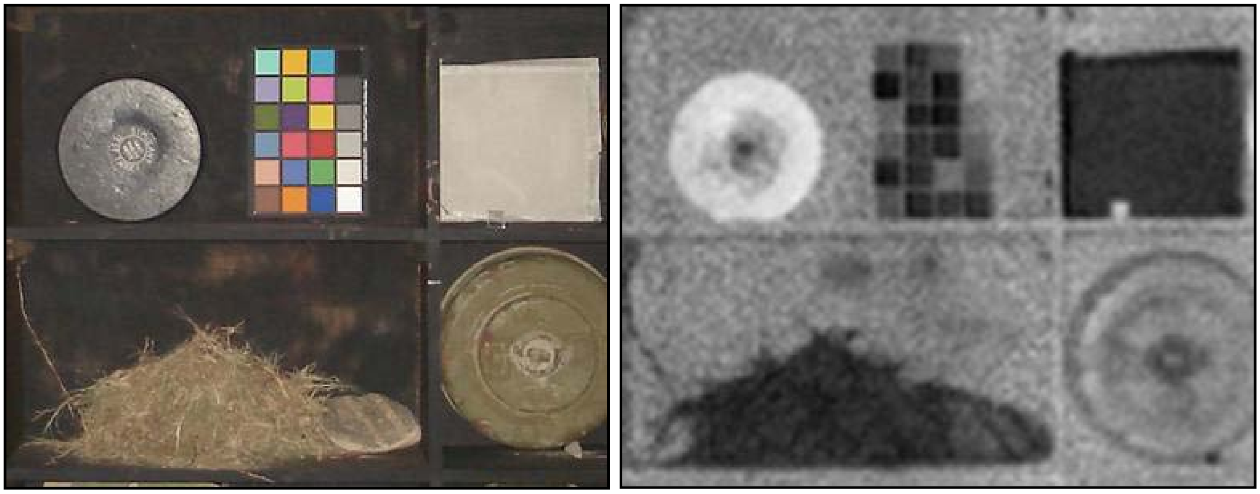

Figure 2. A color photograph (left) and the reflected polarization σ at 808 nm (right) of an image with several natural and man-made objects.

Contaminant Detection. This technology is currently being used to examine its potential to enhance the detectability of particulate contaminants in the field (Figure 3).

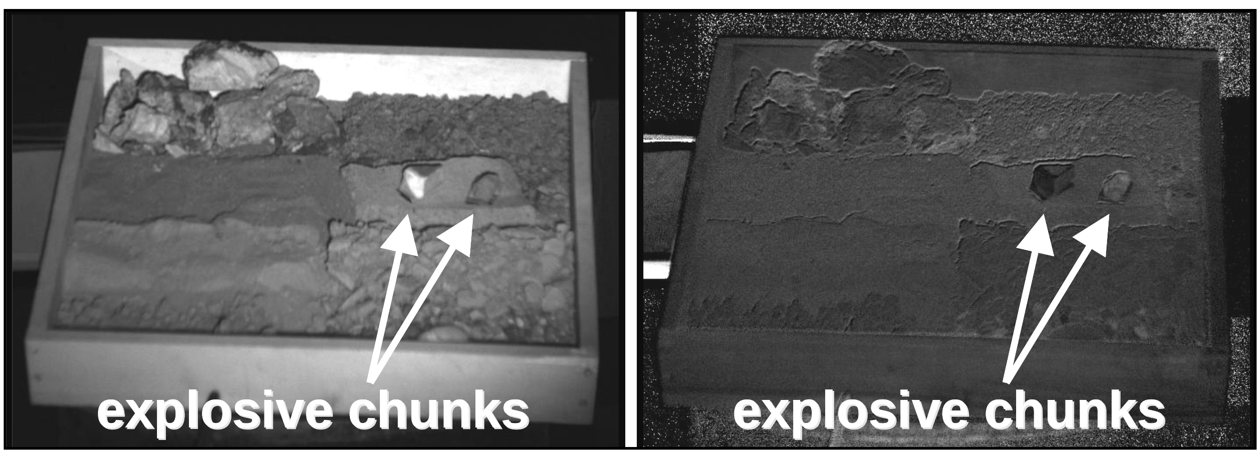

Figure 3. Images of reflectance (left) and polarization (right) at 808 nm of scene with several natural and man-made surfaces including particulate explosives (arrowed).

CONCLUSIONS AND RECOMMENDATIONS: Active imaging polarimetry greatly outperforms passive imaging polarimetry for characterization of geo-environmental surfaces such as soil and vegetation and classifying objects of military interest (Tyo et al. 2006). The development of this technology to deliver and measure a continuous broad beam of polarized VNIR radiation for imaging polarimetry advances the ERDC capabilities in environmental sensing.

The current illumination system is single narrow band VNIR, and provides sufficient intensity to enhance detection and discrimination abilities at moderate distances up to 100 m. At larger distances, a narrower beam and different detection lenses would be advisable.

ADDITIONAL INFORMATION: This technical note was prepared by John Furey, Research Physical Scientist, and by Cliff Morgan, Research Physicist, Environmental Laboratory, U.S. Army Engineer Research and Development Center. The technology was developed as an activity of the Environmental Quality Technology Research and Development Program (EQT). This technical note should be cited as follows:

> Furey, J., and C. Morgan. 2010. *Polarized illuminator for very-near infrared imaging*. ERDC TN-EQT-10-1. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

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