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High Speed Cooled CCD Experiments

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ABSTRACT

Experiments were conducted using cooled and intensified CCD cameras. Two different cameras were identically tested using different Optical test stimulus variables. Camera gain and dynamic range were measured by varying microchannel plate (MCP) voltages and controlling light flux using neutral density (ND) filters to yield analog digitized units (ADU) which are digitized values of the CCD pixel's analog charge. A Xenon strobe (5 μ s FWHM, blue light, 430nm) and a doubled Nd:yag laser (10ns FWHM, green light, 532nm) were both used as pulsed illumination sources for the cameras. Images were captured on PC desktop computer system using commercial software. Camera gain and integration time values were adjusted using camera software. Mean values of camera volts versus input flux were also obtained by performing line scans through regions of interest. Experiments and results will be discussed.

BACKGROUND

An imaging system has been designed for recording a variety of dynamic radiography experiments at Los Alamos National Laboratory (LANL) in support of the Department of Energy's Science Based Stockpile Stewardship (SBSS) program. The system records proton or x-ray shadow graph images of shock propagation properties of strategic materials in explosive environments. Two camera systems were evaluated. One, the Pixel Vision camera was a mix of commercial and LANL designs. The other was a totally commercially available system from Stanford Computer Optics. Either basic camera system combines a cooled slow scan CCD camera coupled to a gated MCP based image intensifier (MCPII) for shuttering (Reference 1). Electro-optic shuttering of MCPIIs by gating their photocathode emission was used. The intensifiers also provided gain for weak photon flux experiments and provide wavelength shifting between input and output images for optimum spectral matching to the CCD. For dynamic radiography several such cameras are time-phased to record temporal and spatial evolution of shock wave fronts.

CAMERA SYSTEMS

The LANL CCD camera is manufactured by Pixel Vision Inc. of Oregon and utilizes front-illuminated Full Frame SITe CCD arrays of 512 x 512 comprised of 24-micron square pixels. The camera is interfaced to a Dell Pentium desktop computer via a PCI BUS. The 512 x 512 CCD cameras are fiber coupled (with Incom or Schott 25-17.4 mm tapers) to MCPIIs manufactured by DEP Inc. The image intensifiers are generation II MCPIIs. The salient characteristics of the LANL/Pixel Vision CCD camera and image intensifier are given in Table 1. The cooled CCD camera design requires operation in either a vacuum or dry gas

environment to avoid condensation at temperatures colder than ambient. LANL designed the vacuum-hermetic seal housing for coupling the intensifiers to the CCD. The Pixel Vision cameras are personal computer (PC) controlled, and use a 16-bit digital input interface to PCI, ISA, or PCMCIA buses. We used a Dell Pentium 233-Mhz PC with 60 megabytes of memory, a Windows 95 operating system and a PCI bus, which has serial fiber-optic transmitter/receiver links to allow remote control and data acquisition of the cameras at distances of approximately 220 ft. The camera has control, calibration, graphics, and analysis software. Controls include pixel binning, region-of-interest (ROI) for image area truncation, readout rate, amplifier gain, and integration or exposure interval. Calibration controls include two-point corrections for dark current and QE variances from pixel to pixel in the arrays. Analysis software includes derivation of statistical variables such as mean, variance, standard deviation, minima, and maxima of stored images. The DEP MCPiIs have quartz input faceplates and photocathodes with an electrically conductive undercoating to allow shuttering in the 5-50ns range. This reduces their basic QE by approximately 30-50%, depending upon the light transmission of the undercoat.

Table 1. Salient Characteristics of the LANL/Pixel Vision CCD camera and image intensifier.

CCD		MCPiI	
Image Sensor	SITe SI502AB	MCPiI	DEP PP0340AE
Image Size	12.3 mm x 12.3 mm	Spectral Sensitivity	50.2 mA/W @400nm
Active Pixels	512 (h) x 512 (v)	Quantum Efficiency	~16%
Pixel Pitch	24 (h)x 24 (v) microns	Luminous Gain	2000-5000
Full Well Capacity	> 350,000 electrons	Spatial Resolution	32 lp/mm
Read Out Speed	50KHz	Shutter Speed	< 50 ns

The Stanford Computer Optics (SCO) camera is manufactured by Stanford Computer Optics, Inc. The SCO is also interfaced with a PC through an RS 232 cable. The intensified image is transferred through a relay lens from the phosphor screen of the MCP intensifier to the CCD camera. The number of pixels of the CCD chip is 768 (h) x 494 (v), EIA, or 752 (h) x 582(v), CCIR, depending on selected CCD chip. When coupling MCP to CCD the image area is factory adjustable from 6 x 4.5 mm to 20 x 15 mm for 25 mm MCP, or 14.4 mm x 10.8 mm for 18 mm MCP. The voltage to control the MCP gain can be adjusted with 15-bit resolution over a range of 0 - 1000 V. The voltage is controlled via the RS 232 serial port. The amplifier's video and digitizer gains can also be set via the RS 232 port.

EXPERIMENTS

The initial tests with the LANL/Pixel Vision cameras were the calibration of two cameras, i.e. camera # 1 and # 2. They were first set up without the image intensifiers, with the F/O taper (25mm: 17.4mm) onto the CCD, which was cooled, to 250°K. The camera gain and integration times were changed using the software on the desktop. The dynamic range was determined by using a pulsed strobe light source and an aperture for image, and attenuated light with ND filters, to generate CCD only (unintensified) transfer curves. Both cameras were re-tested using same setup but with image intensifier coupled to camera. The strobe pulse of ~150us duration was used with 100ns wide gate on the MCPiI, which was roughly

centered on the middle of the strobe emission. To setup the camera for making the transfer curves, the operating point of the camera was first determined. Putting in a ND of 1.0 and adjusting the MCPII gain pot to 300 tested the MCP Voltage gain vs. pot. When this was done, the mean value in the center doubled. When the MCPII gain pot was set to 350, the mean doubled again. At MCPII gain pot at 365, there was soft saturation in parts of image. When a series of MCP gain pot vs. optical gain measurements were done a mean value of ~10,447 ADUs resulted from a gain pot value of 400 and ND 2.0. The MCPII gain pot was then adjusted to 600 and a dynamic range test with aperture was done. The highest gain on camera and intensifier was found to be the best mode of operation. The max MCP voltage that the DEP MCPII could handle was ~780 Volts. The image corresponding to limited photon statistics occurred at ND 4.0 or less with a 100ns gate. Therefore, a 500ns gate or greater was used to allow measurements of the full dynamic range. Test results are in figure 1. Dynamic range tests were repeated using laser for source and obtaining radiometric values for measurement. These data are in figure 2.

A comparison with the LANL/Pixel Vision cameras was done to see how Stanford Computer Optics model # 4 Quik 05 camera compared. For camera 4, the dynamic range was tested at MCP Voltage 780 Volts, gate at 100 ns, camera gain at 10 and digitizer gain at 13. At MCP Voltage of 700, MCP was partially saturated. For camera 5, the dynamic range was tested with MCP Voltage at 600 Volts, video gain at 3, gate at 500ns and digitizer gain at 13. The transfer curve for camera #5 is shown in figure 3. Dynamic range tests were repeated using laser and retrieving radiometric values, similar to those obtained for LANL/Pixel Vision camera in figure 2.

Figure 1. Transfer Curves for Pixel Vision Cameras MCP Gain=170, Voltage=780 V

Figure 2. Radiometer Readings for Pixel Vision Camera #1 Laser Transfer Curve

Figure 3. Dynamic Range from laser for SCO Camera #5 MCP Voltage = 600 Volts

The dynamic range transfer curves obtained using the laser illumination for both cameras are plotted in figure 4. The curves obtained using the strobe illuminations are in figure 5.

Figure 4. Dynamic Range from laser for Pixel Vision Camera and SCO Camera;
MCP Gain = 400, Voltage = 610 Volts

Figure 5. Transfer Curves for SCO Cameras #4 and #5 and Pixel Vision Cameras #1 and #2

References

1. G.J. Yates et al, "An Intensified/Shuttered Cooled CCD Camera for Dynamic Proton Radiography," LA-UR-98-112.