AD-A059 574 ARMY MISSILE RESEARCH AND DEVELOPMENT COMMAND REDSTO--ETC F/G 17/7
DATA ACQUISITION FOR LASER GUIDANCE SYSTEM SIMULATION.(U)
JUN 78 W E WEBB

UNCLASSIFIED DRDMI-T-78-70 NL

1 OF 1
AD
A059 574

END
DATE
FILMED
-12-78
DDC

AD A059574

DDC FILE COPY

(14) DRDMI-T-78-70

(12) NW

(9) TECHNICAL REPORT [redacted]70

LEVEL II

(6) DATA ACQUISITION FOR LASER GUIDANCE SYSTEM SIMULATION

# U.S. ARMY MISSILE RESEARCH AND DEVELOPMENT COMMAND


(10) William E. Webb
Advanced Sensors Directorate
Technology Laboratory




(11) 29 Jun[redacted]78

(12) 19p.

Redstone Arsenal, Alabama 35809

Approved for Public Release;
Distribution Unlimited.

78 09 29 039

DMI FORM 1000, 1 APR 77

393 427

Gu

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|---|
| 1. REPORT NUMBER<br>T-78-70 | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle)<br>Data Acquisition for Laser Guidance System Simulation | | 5. TYPE OF REPORT & PERIOD COVERED<br>Technical Report |
| | | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s)<br>William E. Webb | | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Commander<br>US Army Missile Research & Development Command<br>ATTN: DRDMI-TEO<br>Redstone Arsenal, Alabama 35809 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 11. CONTROLLING OFFICE NAME AND ADDRESS<br>Commander<br>US Army Missile Research & Development Command<br>ATTN: DRDMI-TI<br>Redstone Arsenal, Alabama 35809 | | 12. REPORT DATE<br>29 June 1978 |
| | | 13. NUMBER OF PAGES<br>14 |
| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) | | 15. SECURITY CLASS. (of this report)<br>UNCLASSIFIED |
| | | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release.
Distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Capabilities and Limitations for Predicting Laser Beam Cross-Sections
Requirements for Beam Cross-Section Measurements

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In this report we assess the capabilities and limitations of existing systems for measuring the beam profile of a laser designator. The assessment is made largely on the basis of information gathered by on-site inspection of operational systems at White Sands Missile Range, New Mexico and Hughes Aircraft Corporation, Culver City, California. Visits were also made to the Naval Postgraduate School, Monterey, California, Naval Weapons Center, China Lake, California, Southern Research Institute, Birmingham, Alabama and USAMIRADCOM, Redstone Arsenal, Alabama, in order to discuss laser spot mapping with



JW

20. Abstract (continued)

personnel at these installations.

In addition to evaluating the existing hardware, we have investigated the requirements for future laser profile measurement systems. Estimates of the required dynamic range are given.

Finally, some effort has been devoted to assessing the capability of existing propagation theory in predicting the statistics of the instantaneous beam cross-section.

# TABLE OF CONTENTS

# 1. INTRODUCTION

The US Army MIRADCOM is currently engaged in developing a system for simulating laser designator weapons (LDWSS). In order to perform the simulation it is necessary to model the energy distribution of the laser beam on the target. As a first approximation one can assume that the laser beam retains a gaussian profile which is spread by the atmosphere. This assumption is very poor, however, since it is well known that even moderate atmospheric turbulence completely destroys the gaussian beam profile. A more realistic approach would be to use a nongaussian intensity distribution which can be computer generated using appropriate statistical models of the atmosphere. In either case it is necessary that the assumed beam distribution accurately represent a real, atmospherically distorted beam since it is thought that in certain cases small variations in the beam profile may significantly affect the performance of a laser terminal homing system.

For the purpose of this report it is assumed that 95 percent of the total energy in a designator pulse must be accounted for in order to have a valid simulation.

Because of the sensitivity of the guidance system simulation to the energy distribution on the target, it is necessary to experimentally verify the accuracy of the atmospheric model used in the simulation. This is to be done by measuring the intensity profiles of laser beams which have been broadened by atmospheric turbulence. The primary purpose of these measurements will be to determine the pattern of energy scattered into the wings of the intensity distribution.

One purpose of the research reported here was to evaluate the capability of existing atmospheric propagation theories and computer codes to describe an atmospherically distorted laser beam to determine if this description would be adequate for the proposed weapon system simulation. A second objective was to evaluate the capabilities and limitations of existing hardware for measuring laser beams cross-sections. The third objective was to determine the technical



PRECEDING PAGE BLANK

requirements of a system for measuring the cross-sections of laser beams such that at least ninety-five percent of the total laser energy will be measured and to determine a method of validating the measuring systems performance. Each of these three objectives are discussed in a following section of this report.

## 2. ASSESSMENT OF THE CAPABILITIES OF EXISTING PROPAGATION THEORIES AND COMPUTER CODES IN STATISTICALLY DESCRIBING THE INSTANTANEOUS CROSS-SECTION OF A LASER BEAM.

### A. Propagation Theory

Using statistical propagation theory we may compute the fraction of the energy in a beam which lies inside an area S. It is given by

$$f_j = \iint_S I_j(\vec{r})\,d\vec{r} \qquad (1.1)$$

were $I_j$ is the intensity distribution of a single pulse, j, $\vec{r}$ is the coordinate normal to the direction of propagation, and $f_j$ is the *fraction of the energy* passing through the cross sectional area S. We will assume that I is normalized so that the total beam energy is unity. Now the average energy through S for a large number of pulses is given by

$$\bar{f} = \langle f_j \rangle = \langle \int_S\int I_j d\vec{r} \rangle$$

$$= \int_S\int \langle I_j \rangle \, d\vec{r}. \qquad (1.2)$$

Here $\langle\ \rangle$ represents an ensemble average over a large number of pulses.

We have made use of the fact that since integration and averaging are linear operations their order may be interchanged.

The variance $\sigma_f^2$ of f can also easily be found.

$$\sigma_f^2 = \left\langle (f_j - \bar{f})^2 \right\rangle \qquad (1.3)$$

$$= \left\langle \left( \int_S\int (I_j d\vec{r}) - \int_S\int \langle I \rangle d\vec{r} \right)^2 \right\rangle$$

$$I_o = \left\langle I(\vec{r}) \right\rangle \qquad (1.4)$$

then

$$\sigma_f^2 = \iint_S (I(\vec{r}) - I_o(\vec{r}))\,dr \qquad (1.5)$$

$$\cdot \iint_{S'} (I(\vec{r}') - I_o(\vec{r}'))\,dr'$$

$$\sigma_f^2 = \int_S\int\int_{S'}\int \langle (I(\vec{r}) - I_o) \qquad (1.6)$$

$$(I(\vec{r}') - I_o) \rangle \, dr\,dr'$$

$$\sigma_f^2 = \int_S\int\int_S\int C_I(\vec{\rho})\,d\vec{r}\,d\vec{r} \qquad (1.7)$$

where $C_I(\vec{\rho})$ is the intensity covariance and $\vec{\rho} = r - r$. Since $C_I(\rho)$ is in principle known for a given turbulence structure constant and beam geometry, $\sigma_f^2$ can be found.

The computation of $\bar{f}$ and $\sigma_f$ for a given area may be of considerable interest — for example it allows one to compute the amount of energy which spills over a given size target — however it does not allow one to find directly the dynamic range needed to measure a prescribed fraction of the energy. To find the dynamic range one will have to let S in equation 1.1 be the area enclosed by the contour

$$I = I_{min} \tag{1.8}$$

where $I_{min}$ is the minimum detectable intensity then equation 1.2 becomes

$$\bar{f} = \left\langle \int\int_{S(I_{min})} I_j(r)dr \right\rangle \tag{1.9}$$

Now since S is a function of the individual pulse shape we cannot proceed with the calculation by interchanging the operation of integration and ensemble averaging. Thus we cannot find $I_{min}$ for a given f.

From the preceding considerations we conclude that it is not possible to determine the dynamic range required from propagation theory in a straight forward way. This is not to say that it cannot be done for certainly the information is contained in the statistics of the laser beam fluctuations. However, to pursue this analysis further is beyond the scope of this task.

### B. Propagation Codes

We have been unable to obtain sufficient information about the existing propagation codes (computer programs) to form a reasonable assessment of their accuracy.

## 3. ASSESSMENT OF THE CAPABILITIES AND LIMITATIONS OF EXISTING HARDWARE FOR MEASURING LASER BEAM CROSS-SECTIONS

To the best of our knowledge there are two groups of researchers actively involved in measuring laser beam cross-sections. These are Dr. David Rockwell's group at Hughes Aircraft Corp. (HAC), Culver City, California and Mr. William Shaws group at ARMTE, White Sands Missile Range, New Mexico. Researchers at the Naval Weapons Center, China Lake, California, have also proposed to make laser beam cross-section measurements and have done some work to demonstrate this capability; however, they are not actively engaged in laser spot mapping at the present time.

In order to assess the capabilities and limitations of the existing laser spot mapping systems we have visited the HAC, ARMTE and NWC laboratories to observe this equipment and to discuss its operation with the researchers actively involved in laser spot mapping. These visits were made between August 16 and August 19, 1977, in the company of Mr. Aubrey Presson from T&E Directorate, US Army MIRADCOM. We have also visited Southern Research Institute (SRI), Birmingham, Alabama, to discuss the SRI laser scoring system with Mr. Al Thomas.

The ARMTE laser spot scanning system ($LS^3$) consists of an RCA gated SIT camera sensitive to the wavelength of interest. The SIT camera is gated by the pulse from a separate photo detector so that one frame of video is produced for each laser pulse. This is necessary since the laser is fired asynchronously with the 30 frame/second video rate. The output of the SIT camera is recorded in the field on a standard video tape recorder. When the video recording has been returned to the laboratory the data is transferred from video tape to a 306 frame video disk. The data is then passed through an A/D converter and recorded on digital tape for subsequent analysis on a UNIVAC 1108 computer. The computer analysis consists of determining the X and Y coordinates of the energy centroid and producing a detailed spot map.

In addition to a digital output the $LS^3$ system provides two visual displays as an aid in visualizing the intensity distribution in the laser pulse. The two displays are an isometric display and an 8 level pseudo-video disk by means of equipment manufactured by Interpretation Systems, Incorporated, Lawrence, Kansas.

The $LS^3$ system digitizes on a $680 \times 512$ element grid giving a total of 348160 data points per frame. However, to conserve data processing time digitization is usually performed on a smaller window of $200 \times 200$ or $100 \times 120$ pixels. The system has a recording rate of 15 frames per second or one-half of the basic video frame rate. This limitation is imposed by image persistence in the SIT tube. The dynamic range of the system, (defined as the ratio of peak signal to peak noise) is on the order of 48:1[1]. Earlier dynamic range measurement yielded results a value of 56:1[2]. The sensitivity of the system has been quoted as 10 n watts/cm$^2$ at the wavelength of interest.

[1]Shaw, W. private communication

[2]Shaw, W., Wemeking T., Robason R., Schuck M., Laser spot scanning system performance validation

[3]Rockwell, D. A., and Garvell, D. N., "A New System for Accurate Laser Intensity Profile Analysis". TRMS No. 7-CO-RD7-WS1-001, Army Material Test and Evaluation Directorate, WSMR, N.M.

The HAC Laser Intensity Profile System (LIPS) is essentially similar to the ARMTE/WSMR $LS^3$ system, the principal differences being due to the fact that LIPS is intended for measuring laser spots in the laboratory and not in the field. The LIPS camera is a silicon target vidicon which is blanked between laser pulses. An electrical signal from the laser firing circuit is used to unblank the camera and trigger the scan at the appropriate time. The image of the laser pulse is stored directly on video disk rather than using video tape for intermediate storage. The data is digitized on a 64 × 64 grid. Digital data is analyzed to determine the laser spot centroid coordinates and also to determine the radius of the circle which will enclose 90 percent of the total energy. This provides a measure of the laser beam divergence.

In addition to digital data processing the LIPS includes an image analyzer that produces isometric and level slice (intensity contour) displays. An Interpretation Systems, Incorporated image analyzer is used; thus this part of the LIPS is identical to the visual displays on the $LS^3$.

The LIPS is capable of recording pulses at a rate of 10 pps. and has a dynamic range of less than 100:1[3]. It is claimed that the image distortion is less than 1-3% over the field of view.

The researchers at China Lake Naval Weapons Center (NWC) have proposed to make laser spot map measurements using a system which would be very similar to the ARMTE/WSMR $LS^3$ and the HAC LIPS. Although NWC has not actually made laser range measurements they did demonstrate the feasibility of their proposed system using video recordings of a laser spot which had been collected for another purpose. The video data was digitized in a 64 by 64 raster with 16 gray levels and analyzed using a system that had been developed as part of a target recognition project. No attempt was made to calibrate the system. As far as we can determine there is nothing in the NWC proposal that is not already implemented in the $LS^3$ and LIPS.

The proposed Southern Research Institute system is also similar to the ARMTE and HAC systems. The main difference is that the SRI system uses an image tube consisting of an S-1 photocathode followed by a photomultiplier to provide front-end gain. The photomultiplier is followed by a P20 phosphor. The image from the phosphor is transferred to either a vidicon or a silicon array CCD by means of a fiber optics bundle. The main advantage of the SRI system is high sensitivity due to the photomultiplier gain. Also the gain can be adjusted to allow for a wide range of light levels. While this is an advantage it does not increase the dynamic range for a particular gain setting since this is still limited by the dynamic range of the vidicom or CCD camera.

In reviewing the various existing laser spot mapping systems it becomes clear that the main limitations of these systems are in the areas of (1) dynamic range, (2) pulse separation rate, (3) data handling capability, and (4) problems with system calibration.

## A. Dynamic Range

All of the existing systems use a Silicon vidicon or SIT camera which are inherently low dynamic range devices. In discussing these systems with their users it became clear that most of them had not performed careful measurements of their systems dynamic range. However, all of these researchers gave estimates of dynamic range in the neighborhood of 40:1 to 50:1. This approximated one-half the dynamic range claimed by most camera manufacturers but it is probably a good estimate of the dynamic range that is actually obtained in practice. The systems which are used in the field may experience an even further reduction in dynamic range because of the use of video tape for recording data. Most video tapes have dynamic ranges on the order of 20:1. This is not a problem, of course, if the data is recorded directly on disk.

As we will see in the next section of this report, a dynamic range of 50:1 is marginal for our purpose and 20:1 is clearly too small. Methods of improving the dynamic range will be discussed below.

## B. Pulse Repetition Rate

Internal persistence in the Silicon vidicon tubes limit the maximum repetition rate to about 10 to 15 frames per second. If this limitation could be overcome (by use of a CCD camera for example) the data rate would be limited by the basic video frame rate. Rates of 10 to 15 frames per second are not adequate for recording subsequent pulses at the currently used laser designator pulse repetition frequencies.

## C. Data Handling Capability

Both the ARMTE and HAC systems use a video disk for intermediate data storage. This disk will hold only about 300 frames. Although this may be sufficient at present we foresee that increased dynamic range requirement and higher pulse repetition rates might put severe demands on a systems ability to record and store large amounts of data.

### D. System Calibration

The laser spot mapping systems are subject to several types of systematic error. These include optical distortion, nonlinearity and variation in sensitivity over the field of view. Thus, unless the system is carefully calibrated and corrections made for these errors, the accuracy may be severely impaired.

## 4. REQUIREMENTS OF A SYSTEM FOR BEAM CROSS-SECTION MEASUREMENT

### A. Dynamic Range

The primary reason for needing laser designator beam cross-section measurement is to assure that small but significant amounts of energy are not scattered at large angles resulting in more spill over than is predicted by theory. Therefore, it is necessary to measure accurately the low intensities in the wings and side lobes of the atmospherically distorted beam profile. This means that if the system is to also measure the intensity in the central position of the beam then it must have a very large dynamic range. However, it has been seen that the present systems use relatively low dynamic range detectors; thus, improvement in dynamic range is one of the principal concerns in developing a new laser spot mapping system.

If the laser beam had a gaussian intensity profile it would be an easy matter to determine the required dynamic range. Unfortunately, a laser designator beam usually departs significantly from an ideal gaussian mode, and even if the designator beam were initially gaussian the shape would be destroyed by atmospheric effects. Even though the assumption of a gaussian beam is clearly invalid it is nevertheless useful to compute the dynamic range for a gaussian beam since this at least represents an absolute minimum requirement.

Let us assume a beam profile given by

$$I = I_o \exp(-r/r_o)^2 \qquad (4.1)$$

where r is the radius from beam center, $r_o$ is the radius to the $1/e^2$ points, I is the intensity, and $I_o$ is the intensity at beam center. Also let $I_{min}$ be the minimum detectable intensity and R be the radius at which I(R) equals $I_{min}$ as shown in *Figure 1*. Now the energy contained in a circle of radius r is.

$$E(r) = \int_o^{2\pi} \int_o I_o \exp(-r/r_o)^2 r \, dr \, d\theta \qquad (4.2)$$

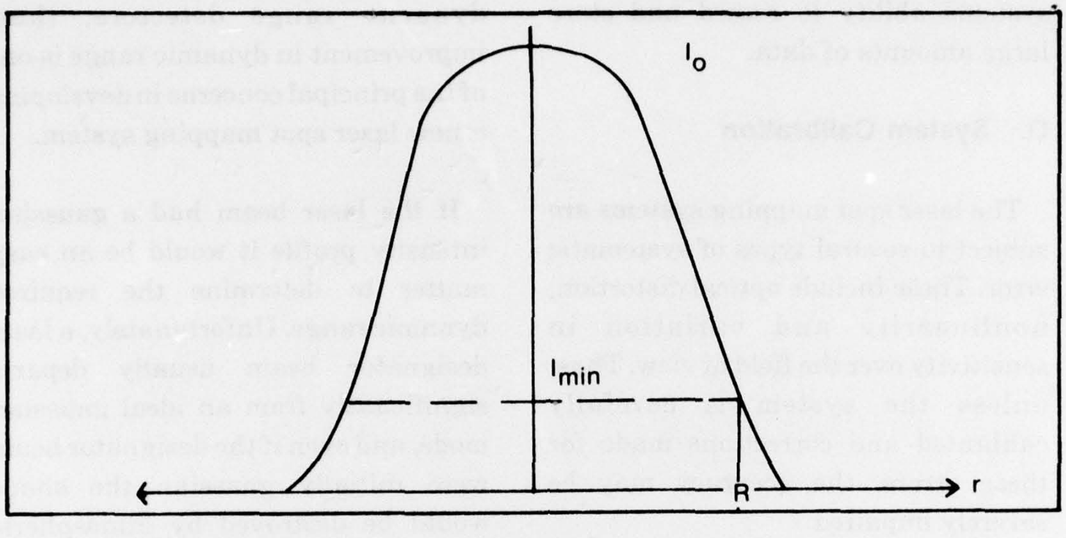


**Figure 1**

**hence**

$$E(r) = \Pi\, I_o^{\,2}\, r_o^{\,2}\, [1-\exp(-r/r_o)^2] \quad (4.3)$$

**the total energy E is found by letting r approach infinity.**

$$E = \Pi\, I_o^{\,2}\, r_o^{\,2} \quad (4.4)$$

**The fraction of the energy (f) within a circle of radius R is then**

$$f(r) = E(r)/E = 1 - \exp(-r/r_o)^2 \quad (4.5)$$

**The fraction of the energy lost is then just the energy in the beam at radius r greater than R., i.e.**

$$f_L = 1 - f = \exp(-R/r_o)^2 = I_{min}/I_o \quad (4.6)$$

**If every laser pulse had the same beam width then the required dynamic range for a given fraction of the total energy lost would be given by**

$$D.R = I_o/I_{min} = 1/f_L \quad (4.7)$$

**If the beam width varies from pulse to pulse (beam breathing) then $I_o$ used to compute the dynamic range must be the largest possible value of $I_o$, i.e., the value of $I_o$ when $r_o$ is a minimum. Likewise $I_{min}$ must be the smallest possible value of $I_{min}$, i.e., the value of**

$I_{min}$ when $r_o$ is a maximum. Assuming that the pulse energy E does not change from pulse to pulse we may write.

$$I_o(\max) = \frac{E}{\Pi\, r_o^2(\min)} \quad (4.8)$$

now

$$f_L = \frac{I_{min}(\min)}{I_o(\min)} \quad (4.9)$$

$$f_L = \frac{I_{min}(\min)}{\dfrac{E}{\Pi\, r_o^2(\max)}}$$

Combining 4.10 and 4.8

$$f_L = \frac{I_{min}(\min)}{I_o(\max)} \quad (4.11)$$

$$\frac{E/\Pi\, r_o^2(\min)}{E/\Pi\, r_o^2(\max)}$$

hence

$$f_L = \frac{1}{DR} \cdot \frac{r_o(\max)}{r_o(\min)} \quad (4.12)$$

Since $r_o$ is proportional to the beam spread angle ( $\theta$ ) equation 4.12 can be rewritten as

$$D.R. = \frac{1}{f_L}\, \theta(\max)/\theta(\min) \quad (4.13)$$

We may approximate $\theta(\min)$ by tne beam divergence angle in the absence of atmospheric effects and $\theta(\max)$ as

$$\theta_{max} = \theta_{min} + \Delta\theta_s$$

where $\Delta\theta_s$ is the mean short term beam spreading due to atmospheric turbulence. These are fairly rough approximations but should be adequate for our purpose now. $\Delta\theta_s$ can be estimated from turbulence theory[4], thus providing an estimate of the minimum dynamic range required.

In a recent report[5] we have computed the average beam spread for several laser designator systems. The worst case for which computations were performed was for a beam having initial parameters of 4 inches diameter and .13 milliradians divergence. At a range of 5 km in strong turbulence ($C_N^2 = 10^{12}$) the atmospheric beam spreading was found to be 1.018 milliradians. Thus, the ratio of $\theta_{max}$ to $\theta_{min}$ is 7.8. Then from equation 4.13 it is seen that for 95 percent of the

[4] Fante, Ronald L., Electromagnetic Beam Propagation in Turbulent Media. *Proc. IEEE. 63*, 1669 (1975).

[5] Webb, W. E., Effect of Atmospheric Spreading on a Laser Beam. *US Army MIRADCOM Tech. Note.* Redstone Arsenal, AL (1976).

energy measured (i.e., $fL$ = .05) the required dynamic range is 157.1. For a less severe case (5 km. $C_N^2 = 6 \times 10^{-14}$) the required dynamic range was found to be 36:1.

This analysis is admittedly crude. First, the beam is not gaussian. Secondly, the maximum beam divergence angle for an individual pulse can be greater than the mean short term beam divergence angle used for $\theta_{max}$. However, the calculation does give us some insight for the magnitude of the numbers involved.

If we relax the assumption of a guassian beam profile then there is little that can be done analytically to estimate the required dynamic range. R. G. Buser[6] has approached the problem by analyzing 300 laser profiles generated on a digital computer using a statistical model of the atmosphere. Dr. Buser's results indicate that a dynamic range of 205.6:1 was required to measure 95% of the energy of all 300 pulses. A dynamic range of 41.6:1 was required to measure the pulse with the least dynamic range and 79.8:1 was required to measure one-half of the pulses. It is interesting to note that these values are reasonably close to the values that were obtained from a gaussian beam analysis.

From the above it is concluded that a system to measure 95 percent of the laser beam energy should have a dynamic range of at least 150:1 or 200:1, and to be on the safe side 300:1 might be desirable. Dynamic ranges on this order could be obtained with a Si Array CCD camera. CCD cameras are reported to have usable dynamic range of 250:1 or higher. However, the CCD camera has several disadvantages viz: (1) the dynamic range of 250:1 may not be adequate in all cases; and certainly it leaves little margin in system performance. (2) Since video tape has a limited dynamic range and video dish are generally not suitable for use under field conditions there may be some problem with recording data at the increased dynamic range. (3) CCD cameras are reported to have large (15%) variations in sensitivity across the field of view. This would clearly complicate the problem of system calibration. Also, (4) some workers believed that there would be problems in synchronizing the CCD camera with the laser pulse.

A second technique that has been proposed for extending the dynamic range of a laser spot mapping system is to use two cameras. One would be adjusted to cover the maximum

[6]Buser, R.G. Laser Technical Area, Combat Surveillance and Target Acquisition Laboratory, Ft. Monmouth, New Jersey, Private communication.

intensities expected and the second would be adjusted so that its maximum level corresponded to the minimum level of the first camera. Thus, the dynamic range of the two cameras together would be the product of the dynamic ranges of each individual camera. With two cameras each having a dynamic range of 20:1 a combined dynamic range of nearly 400:1 could be obtained. With an easily obtainable dynamic range of 40:1 a combined range of 1600:1 could be realized.

In our estimation the two camera system has two advantages over a single CCD camera. First, it allows ample dynamic range where as the best obtainable with a single camera may be barely enough. Secondly, since each camera has a modest dynamic range and each can be recorded, separately excessive demands on the dynamic range of the recording media are avoided. The two camera system also avoids any problem with synchronization.

The possible disadvantage of a two camera system is that it can complicate the calibration procedure.

### B. Pulse Repetition Rate

As previously stated, the existing systems do not have an adequate prf to allow for the recording of consecutive pulses. However, for the purpose of validating a computer simulation there is no reason for recording consecutive pulses that we can see.

## 5. METHOD OF VALIDATING SYSTEM

System validation means demonstrating with reasonable certainty that the system is in fact measuring 95 percent (or other specified fraction) of the total energy in the beam. A straight forward way of doing this would be to measure the total energy in a pulse and compare this to the energy detected by the spot mapping system. This would require (1) A beam splitter and power meter on the designator to measure the energy in a given pulse. (2) That the spot mapping system be calibrated in terms of absolute intensity so that the intensity distribution could be integrated to give total energy. (3) That a correction be applied to account for atmospheric attenuation.

In our estimation, accounting for the beam energy as suggested above would be very difficult to do with the required accuracy.

An easier but less rigorous way of validating the system would be as follows. If the system had a dynamic range of N:1 then the intensity profile could be quantized into N gray levels.

Now each pixel could be assigned to a gray level. If there were an appreciable number of the lowest nonzero gray levels empty then it would be unlikely that the pixels assigned to the zero energy level could actually contain an appreciable amount of energy. This is not a certainty and in fact one can construct intensity distribution for which it is not true. However, one would not expect to encounter these distributions in practice and would therefore be fairly confident that the measurement was valid.

## 6. CONCLUSIONS

On the basis of our evaluation of existing propagation theory and laser spot measurement hardware, we conclude the following.

- Existing propagation theory does not rigorously predict the dynamic range expected in a laser pulse.

- Estimates of the dynamic range required for a laser beam cross-section measurement based on computer models and estimates based on the assumption of a guassian beam profile both lead an estimate of about 200:1 for the minimum dynamic range required to measure 95 percent of the laser energy.

- Existing hardware for measuring laser beam cross-section does not provide the required dynamic range.

- The required dynamic range could be obtained by using either a CCD camera or two conventional vidicons. We tend to prefer the use of two vidicons since they will provide much greater dynamic range than a single CCD camera.

# DISTRIBUTION

| | No. of Copies |
|---|---|
| Defense Documentation Center<br>ATTN: DDC-TGA<br>Cameron Station<br>Alexandria, Virginia 22314 | 12 |
| Commander<br>US Army Missile Research Office<br>P. O. Box 12211<br>Research Triangle Park<br>North Carolina 27709 | 1 |
| Headquarters<br>DA (DAMA-ARZ)<br>Washington, D.C. 20310 | 1 |
| Director of Defense Research<br>and Engineering<br>Engineering Technology<br>Washington, D.C. 20301 | 1 |
| Director<br>Defense Advanced Research Projects<br>Agency<br>1400 Wilson Boulevard<br>Arlington, Virginia 22209 | 1 |
| Commander<br>US Army Electronics Research and<br>Development Command<br>ATTN: DRSEL-CT, Dr. R. Buser<br>Ft. Monmouth, New Jersey 07703 | 1 |
| Director<br>US Army Night Vision Laboratory<br>Fort Belvoir, Virginia 22060 | 1 |

| | No. of Copies |
|---|---|
| Commander<br>US Army Harry Diamond Laboratory<br>2800 Powder Mill Road<br>Adelphi, Maryland 20723 | 1 |
| Commander<br>US Air Force Avionics Laboratory | |
| ATTN: R. Becker AFAL/RWM-2 | 1 |
| Maj. Gagnon AFAL/RWM-2<br>Wright Patterson Air Force Base, Ohio 45433 | 1 |
| IIT Research Institute<br>ATTN: GACIAC<br>10 West 35th Street<br>Chicago, Illinois 60616 | 1 |
| DRSMI-LP, Mr. Voigt | 1 |
| DRDMI-T, Dr. Kobler | 1 |
| DRDMI-TG, Mr. Huff | 1 |
| DRDMI-TGT, Mr. Leonard | 1 |
| Dr. Yates | 1 |
| DRDMI-TBD | 3 |
| DRDMI-TI (Reference Copy) | 1 |
| DRDMI-TI (Record Set) | 1 |
| DRDMI-ET, Mr. Black | 1 |
| DRDMI-ETR, Mr. Priddy | 1 |
| Mr. Crocker | 1 |
| DRDMI-ETP, Mr. Northrop | 1 |
| Mr. Presson | 5 |
| DRDMI-TEO, Dr. Curtis | 5 |