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Laser application in weapon guidance and active imaging

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An important phase of Laser application for Defence purposes has been in the guidance of weapons whereby the object to be destroyed is illuminated by the laser radiation and the weapon is homed onto the target along the direction of scattered radiation. The development started in the late sixties and practical devices called the Smart bombs have been in operation in the later phase of Vietnam War (Verble 1974). Though considerable development has taken place since then, lot of money and effort is still being put in to extend the capabilities of these systems The high accuracy of attack and overall cost effectiveness make the system of Laser designation worthy of serious consideration. Modern low flying aircrafts used for ground attack are now fitted with suitable Laser instrumentation to provide (a) range finding and target designation capabilities for seeking the target, (b) measuring its range and sending the weapon onto it, thereby reducing the human element to the minimum. Recently 10·6 micron radiation has been used to improve the capability of the system under atmospheric conditions of fog, smoke, haze etc. (Taylor 1977, Rudko 1977).

One of the most recent applications of Laser for Defence has appeared in the field of active imaging. Following the development of Laser Scanners (Phelan 1971, Reiche 1973) Laser beams have now been used for imaging distant targets during day and night (Arapov 1975). Both CW and pulsed radiation can be used. Image can either be photographed (Neumann 1965) or stored in the form of electrical pulses and displayed at will. Suitable signal processing can be employed for improving the image or extraction of information regarding the range and depth of the target. Using high power repetitive pulsed laser, images of distant targets upto a few km can be stored or viewed in real ti)me. Infrared lasers at 1·06 micron or 10·6 micron can be used (Sculf 1975, Courtoney 1976, Lamberts 1976). The systems have been demonstrated in laboratories and the availability of practical devices for field use is imminent.

Laser guidance

The principle of laser guidance is illustrated in Figure 1. The target selected with the help of an optical sight is illuminated with the radiation from a laser

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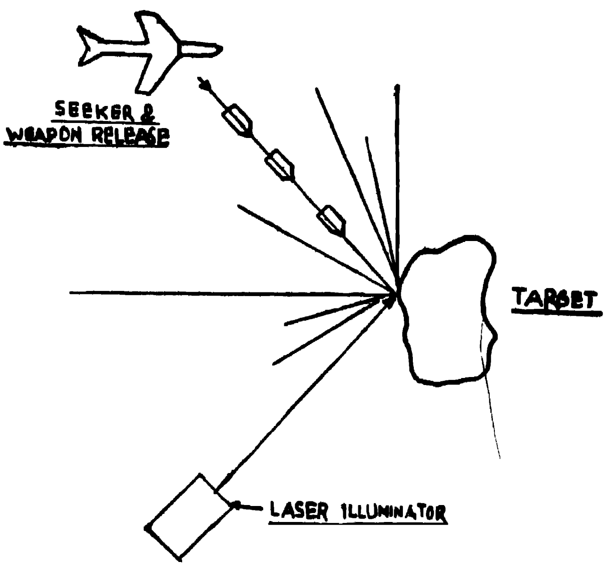

Figure 1. Designation of target by Laser Illumination.

source which may be a high rep. rate pulsed NdYAG or a 10·6 micron TEA CO_2 laser. The area selectively illuminated by the beam does not exceed one or two square meters for ranges upto several kilometers so that the target is perfectly designated. When the target is illuminated it effectively becomes itself a source radiating in all directions. This scattered radiation provides to the receiver the information that is required for locating the target and guidance of weapon on it. The receiver has a quadrant type of detector (Figure 2) in which the unbalance current from opposite quadrants provides the sense of direction in which the radiation is coming to the receiver. The detector output is coupled to a closed loop servo system which brings the detector in line with the direction of received radiation so as to bring a null. In this position the spot of received radiation fills equally all the four quadrants and the receiver points in the direction of the target. Through the use of an interference filter the receiver is made sensitive to only the laser wavelength, thus cutting out the background and making the detection of target possible both during day and night.

The laser illuminator is generally a high rep. rate pulsed laser source in the infrared which sends the laser radiation onto the target. The selection of target is done by a viewing telescope which forms a part of the illuminator. One such

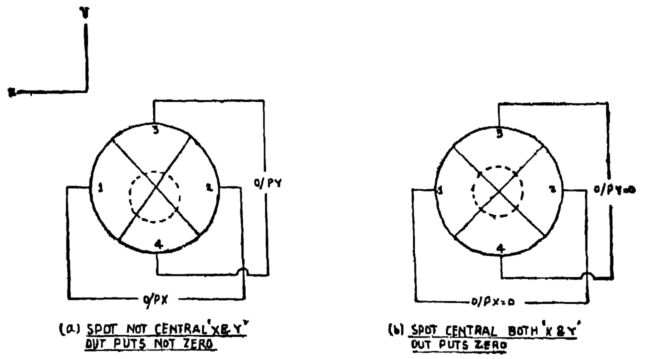

Figure 2. Direction sensing by Quadrant Detector.

arrangement is shown in Figure 3. Depending on the particular requirement of the guidance system desired, the illuminator can be either (a) ground mounted, (b) hand held by the person proceeding ahead for the selection of target, (c) placed in the attacking aircraft or (d) mounted in the remotely piloted vehicle (RPV).

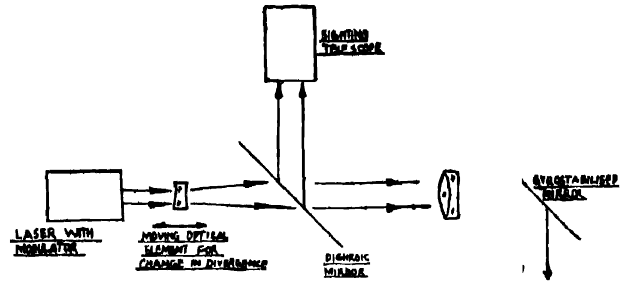

Figure 3. Block diagram of Laser Illumination.

The detection system that seeks the target can either be (a) simple direct view telescope system, (b) direct view infrared system using image intensifier tube or (c) low light level TV system. This detection system forms an integral part of the servo loop that guides the direction of the weapon onto the target. The guided weapons can either be (a) glide bombs i.e , free falling gravity bombs or (b) missiles or (c) artillery projectiles.

The laser guidance of missiles and arty. projectiles can be done by either of the three ways illustrated in Figure 4. The choice of particular system depends upon the conditions prevailing at the time. Since these weapons are very fast moving, a quick acting sensing and control mechanism is required for guidance.

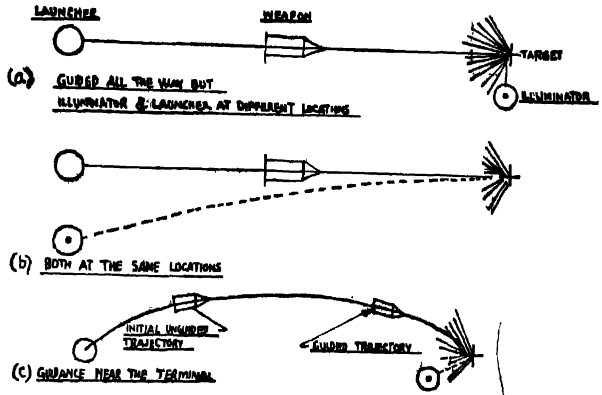

Figure 4. Methods of guidance of missiles and projectiles.

In considering the cost effectiveness of laser guided weapon system it is to be remembered that the seeker and control system which is added onto the weapon also gets destroyed alongwith the weapon. Therefore the weapon cost increases. But still if the number of weapons and number of trials required to destroy a particular target is taken into account the overall cost effectiveness is found to be in favour of the laser guided system. In this connection following points are relevant:

(a) Pin pointed targets are destroyed and even targets in populated areas can be attempted—accuracies of 5–10 meters are achieved.

(b) First round hit is almost assured and therefore lesser No. of bombs have to be used. This reduces the cost due to transportation and storage of the heavy bombs in the battle area.

(c) Lesser number of attempts by the bomber have to be made so that the risk involved in the destruction of the attacking aircraft is reduced.

Laser imaging

As early as 1965 it was pointed out that using a giant pulsed laser for illuminating a target for photography has certain advantages; the exposure of the camera can be for a very short time (30–50 ns, corresponding to the laser pulse duration) and that this exposure can be delayed by a known amount thus reducing the back scatter. Also knowledge of the adjustable known delay gives information about the range of the target. This is apart from the fact that nano second exposure of the object remains almost undetected by the object particularly when infrared laser is used. Also use of interference filter at the laser wavelength enables the operation both during day and night.

Range gated photography was first done by using a Q-switched ruby laser (Neumann 1965). A decade later, a similar experiment was performed by using a Nd glass laser at 1·06 micron (Arapov 1975). For reasons of less scattering, infrared laser is preferable and range gating techniques (Figure 5) increases the contrast of the viewed object because of reduction in back scattering intensity.

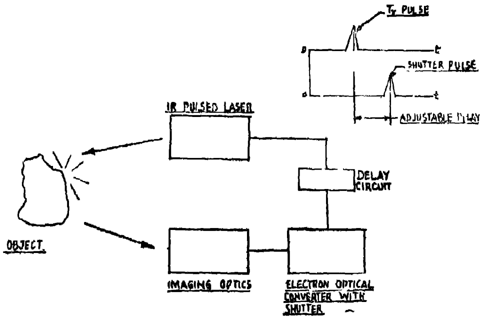

Figure 5. Range gated imaging by Laser Illumination.

A repetitively pulsed TEA CO_2 laser has been used recently to image an object by scanning (Courteney 1976). A servo controlled gimballed mirror positioned on the laser axis is used to aim the radiation at the target. The beam is advanced by small angular steps in azimuth and at each successive position a laser pulse is emitted. At the end of a horizontal line the beam is depressed by a small angle and then stepped back across the target scene. A matrix of 32×24 points in the target scene are thus illuminated in succession. Because the prf is 1 pps the signal return from each pulse transmission is stored. This method of imaging allows signal processing to be done in order to improve the quality of the low resolution (spatial) image by modifying the intensity profile of each picture element to produce gray scale interpolation between adjacent elements. This makes object easier to recognise.

Using high average power Nd YAG laser, a long range imaging system based on direct detection of scattered laser light from a laser scanned object has been demonstrated (Lamberts 1976). A Q-switched laser operating at 25 KHz prf is used with x and y scanning mirrors operating at 100 Hz and 2 Hz respectively. The output beam is 2–5 cm in dia and the object is viewed with an aiming telescope fixed alongside the laser transmitter. The detection system uses a large aperture Fresnl lens with 1 cm dia photodiode YAG 444. An interference filter is used before the detector to cut down the back ground. The resolution of the system is determined, by the divergence of the scanning laser beam and the sensitivity is determined, among other things, by the dia. of the receiver aperture. The detected video is first amplified and then passed through gating electronics. Both the delay and gating time can be adjusted. A t^2 amplifier provides a time variable gain to compensate the R^2 dependance of the reflected laser power. The display is obtained by intensity modulation of CRT and a TV like image of the object is obtained. The results show that it is possible to get good rangegated images of targets upto 1·5 km.

The laser imaging systems described above have given credence to the possibility of using high rep. rate pulsed laser for illumination, and consequent imaging, of distant targets, particularly at night, when considerations of object distance and image quality make the use of passive night viewing, using image intensifier tubes (II Tube) rather limited. The use of II Tubes is restricted to the night viewing condition. The laser scanned imaging on the other hand can be effected both during day and night by the use of interference filter. Also there is scope of electronic signal processing of the scanned image in order to extract the desired information from the received image, and this can be done almost in the real time domain. Further, when performed in desert environment, where problem of shimmering and refractive index variation with space and time are present, this method is likely to give better results. This is because the time of exposure is so small that the medium is almost frozen in time for each observation. Therefore the smearing effect on the image, observed when viewed on CW basis, is likely to be considerably reduced.

In conclusion, the importance of laser illumination of a target, for its imaging, and guidance of weapons onto it, has been duly recognised during the last decade. Systems have been demonstrated with potential advantages and development is in progress for further improvement of the instrumentation involved. Though both the fields of laser imaging and laser guidance are important to the Defence Sector, the active imaging of objects by laser illumination is equally significant to the peace time users.

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