Defence Science Journal, Vol. 57, No. 4, July 2007, pp. 361-365

High-angular Resolution Laser Threat Warner

Sushil Kumar, S.P. Gomekar and A.K. Maini

Laser Science & Technology Centre, Delhi–110 054

ABSTRACT

In this paper, the design and development aspects of a high-angular resolution laser-threat warner developed at the Laser Science & Technology Centre (LASTEC), Delhi are presented. It describes a high-angular resolution laser-threat warner capable of giving warning with a resolution of $\pm 3^\circ$ when it is exposed to laser radiation from visible and near-IR pulsed solid-state laser source. It has a field of view of 90° in the azimuth direction, whereas the elevation coverage is between -5° and $+25^\circ$. It is capable of handling multiple types of laser threats covering wavelength from 400 nm to 1100 nm and has an operational range of 4 km for a Q-switched laser source energy (10 ns) of 10 mJ/pulse and output beam divergence of 1 mrad. The paper also describes its simulated evaluation process and field-testing which it has undergone. The result of field-testing confirms that it meets all its performance specifications mentioned above.

Keywords: High-angular resolution laser threat warner, angle-of-arrival accuracy, field of view, operational range, single-pulse detection capability, false alarm rate, weapon platform, laser-guided munitions, visible and near-IR-pulsed solid-state laser, azimuth and elevation direction, defensive and offensive electrooptic counter measure, EOCM

1. INTRODUCTION

Modern warfare includes extensive use of laser-based devices and laser-guided weapons. Use of lasers for range finding, target designation, and munitions guidance has been established beyond doubt. A laser constitutes an indispensable component of any weapon platform, be it land-based, aerial or ship-borne. The laser used for such applications is almost invariably a Q-switched solid-state laser. Though, at present, it is neodymium: Yttrium-aluminium garnet (*Nd*:YAG) or *Nd*:Glass type of solid-state laser with its emission around 1064 nm, the band is likely to be extended to 1540 nm in 5-10 years from now. Emission (1540 nm) is relatively more eye-safe for the users of the equipment. This large-scale use of lasers on different weapon platforms on one hand has increased the fighting potential of the forces; on the other hand, it has also rendered these platforms more vulnerable to attacks by laser-guided munitions. Such a situation underlines the importance of timely detection and the recognition of laser threats from the typical battlefield lasers and using this information for initiation of a suitable countermeasure action such as creating smoke/aerosol screen to block the incoming radiation. This necessitates that the friendly-platforms are equipped with a suitable laser-warning sensor that would provide information about the incoming-laser threat with high-level of angle-of-arrival accuracy. This would enhance the survivability quotient of the platform in the battlefield.

Revised 28 August 2006

2. DESCRIPTION OF BUILDING BLOCKS

Figure 1 shows the block schematic arrangement of the high-angular resolution laser-warning sensor. Different building blocks are briefly described here:

2.1 Front-end Assembly

The front-end assembly of a high-angular resolution laser-warning sensor contains a double convex lens and an array of photo detectors. The focal length of the lens and the separation of the individual photodiodes are chosen in such a manner so as to get the desired field of view in both azimuth and elevation without having any dead zone. The incident laser falls on the lens and gets focused on to the photo detector array. The front-end assembly converts the intensity of incident laser beam into corresponding voltage. The front-end assembly employs a very high-speed photodiode used in the photoconductive mode to enhance its response speed so as to detect very narrow Q-switched laser pulses. These narrow pulses are fed to a pulse stretcher circuit. This stretching serves dual purpose. Firstly, it eliminates the use of very high-speed devices for further pulse-processing and secondly, it gives sufficient time for taking samples of all the channels. Also, the use of low-speed devices reduces the cost of overall circuit. All the stretched pulses are then fed to an analog multiplexer that multiplexes the channels one by one and feeds them to an analog-to-digital converter (ADC).

2.2 Comparator Circuit

This circuit consists of high-speed comparators, which compare all the channels of input signal to check which of the input signal is active. This way, the unit continuously scans all the channels and if any of the channels is activated, the multiplexer circuit is activated by giving address and clock signals.

2.3 Multiplexer and Analog-to-digital Conversion

The processed signal is fed to the multiplexer unit, which multiplexes the signal one by one and feeds them to input of the ADC, which digitises the signal. The digitised signal is then fed to the digital-logic controller. The ADC section consists of a buffering, a scaling and an analog-to-digital conversion. The input signal voltage is scaled down to the level required by the ADC. The ADC converts the input signal amplitude into the digital data. The number of bits of ADC chosen decides the amplitude resolution of the sensor. A fast ADC is selected so that it can easily scan all the channels within the available time equal to the maximum repetition rate of input. The maximum repetition rate can be as high as 50 Hz looking into the trends of laser designators that are available or will be available in the near future.

2.4 Digital-logic Controller

The digital logic-controller used here is a micro-controller. It could even be an Field Programmable Gate Array (FPGA) or a Digital Signal processor (DSP). It operates the following functions:

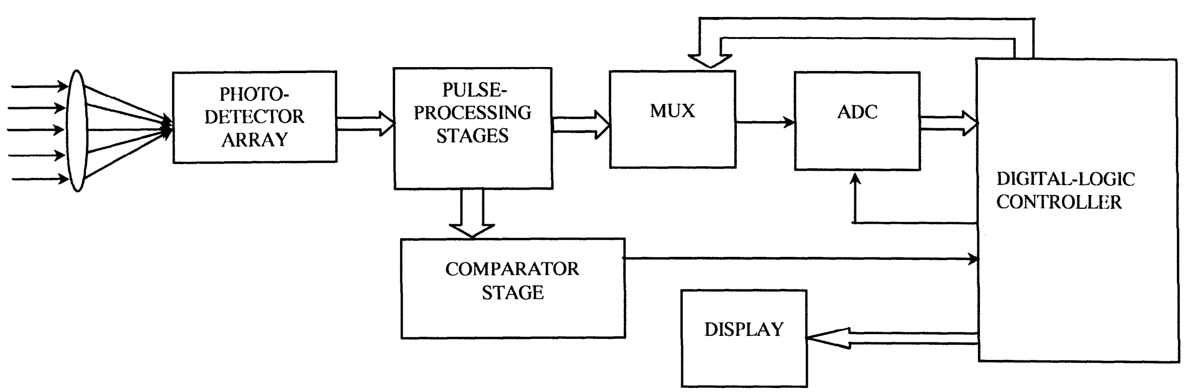

Figure 1. Block diagram of high-angular resolution laser-threat warner.

- To generate the addresses for the multiplexer
- To calculate the angle-of-arrival of the incident laser
- To generate the necessary control signals for ADC and peripheral devices
- To store the amplitude of active channels.

In this case, the microcontroller-used is a very fast one and operates at 100 MHz. The microcontroller first reads the amplitude information of all the channels and then determines the channel corresponding to maximum amplitude. It then rejects all the channels having amplitude less than 50 per cent of the maximum amplitude. Next, it again rejects all the channels which are neither adjacent to the one having maximum amplitude nor adjacent to any of its directly adjacent channels. It then employs the weighted centroid formula after assigning an angular weight to each of the channels to calculate the angle-of-arrival of laser threat.

These calculated angles are then sent to the LCD display, which is a 16 × 2 alphanumeric display. This display unit displays azimuth and elevation angular values on every laser threat received. An audio alarm is also generated simultaneously upon receiving the threat. The sensor also generates a demultiplexed Transistor-Transistor Logic (TTL) pulse as an input to the interface assembly for deploying suitable countermeasures in the direction of the incident laser threat.

3. EXPERIMENTAL PROCEDURE

Laser-warning sensor developed at the LASTEC (Fig. 2) was subjected to a series of in-house tests as well as field tests to verify its performance parameters like operational range, field-of-view, single-pulse detection probability and false alarm rate. The sensor was tested with a 10 mJ/pulse, Q-switched laser range finder (10 ns) and a 700 mJ/pulse, Q-switched *Nd*-YAG laser source (10 ns) having both fundamental (1064 nm) as well as frequency doubled output (532 nm). Both the sources had a divergence of about 1mrad. The in-house testing was done by simulating a range of 1 km, 2 km, 3 km, and 4 km by expanding the laser beam using a diverging lens. The sensor was placed on a pan with tilt arrangement. The scheme of the experimental setup is shown in Fig. 3.

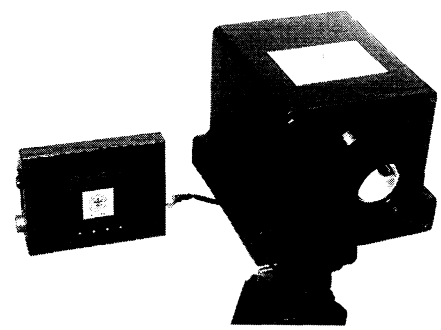

Figure 2. High-angular resolution laser warner.

Before starting the test, the sensor was aligned with the zero degree reference line. Readings of the measured angle in the display unit of the sensor were taken by rotating the sensor in steps of 6°. Table 1 shows four different sets of measured angles obtained for a set of given physical angles by which the sensor was rotated for an elevation angle of 0° and a simulated range of 4 km.

After successfully evaluating the laser-testing warner (LTW) within the laboratory, it was then tested in the field. The LTW-3 was successfully field-tested with the user participation (PMO SURAJ) at the Terminal Ballistics Research Laboratory (TBRL) Ranges, Chandigarh and at the Air force Station, Hindon. Recently, the engineered prototypes have been field-evaluated using the actual battlefield tank rangefinders at the Suratgarh Ranges (Rajasthan).

4. CONCLUSION

The high-angular resolution laser warner was developed and tested successfully at the LASTEC. Delhi. The trials were successfully carried out using the available laser sources for all the performance specifications of the sensor. The system has potential use as a part of defensive electrooptic counter measure (EOCM) system in the battlefield to protect the user-friendly forces from the impending laser threat.

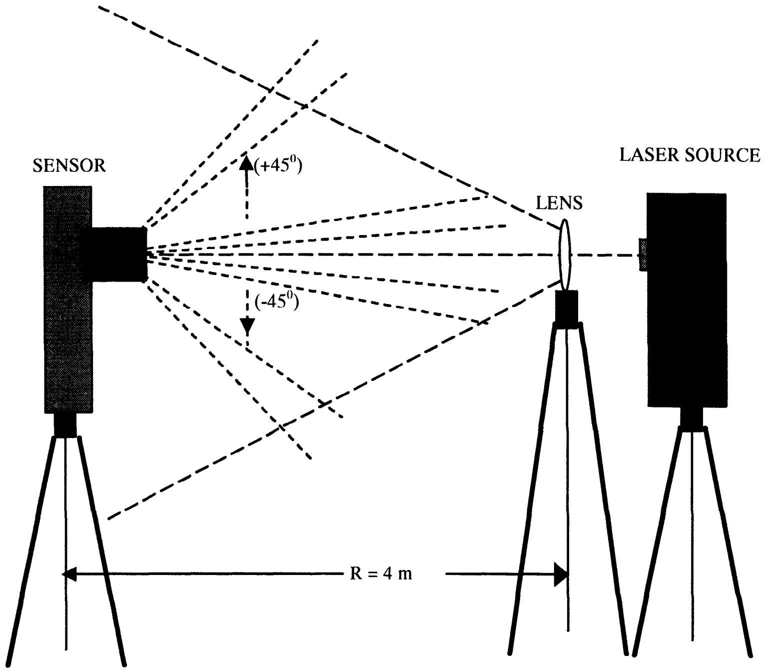

Figure 3. Scheme of experimental setup to evaluate LWS under simulated range.

Table 1. Experimental readings

Angle on pan with tilt = 0° (deg)	Measured angle 1		Measured angle 2		Measured angle 3		Measured angle 4	
	Azimuth (deg)	Elevation (deg)	Azimuth (deg)	Elevation (deg)	Azimuth (deg)	Elevation (deg)	Azimuth (deg)	Elevation (deg)
0	-1	-2	-1	-2	-1	-2	-1	-2
6	6	-2	6	-2	6	-2	6	-2
12	11	-2	11	-2	11	-2	11	-2
18	15	-1	15	-1	15	-1	15	-2
24	21	0	21	0	21	0	21	0
30	27	0	27	0	27	0	27	0
36	33	0	33	0	33	0	33	0
42	40	0	40	0	40	0	40	0
45	45	3	45	3	45	3	45	3
-6	-8	0	-8	0	-8	0	-8	0
-12	-14	2	-14	2	-14	2	-14	2
-18	-21	0	-21	0	-21	1	-21	0
-24	-24	0	-24	0	-24	0	-24	0
-30	-30	-1	-30	0	-30	-1	-30	-1
-36	-33	-1	-33	-1	-33	-1	-33	-1
-42	-42	-3	-42	-1	-42	-3	-42	-2
-45	-45	0	-45	-2	-45	0	-45	0

ACKNOWLEDGEMENTS

Authors are thankful to the Director, LASTEC, Delhi, for his keen interest and inspiration throughout this work and his kind permission to publish this work.

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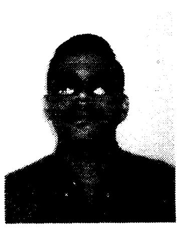
Contributors

Mr Sushil Kumar obtained his BE (Electronics and Communication Engg) from the Birla Institute of Technology, Mesra, Ranchi and is presently working as Scientist C at the Laser Science & Technology Centre (LASTEC), Delhi. He has been working in the field of laser-warning sensors.



Mr S.P. Gomekar obtained his BE (Electronics and Communication Engg) from the Visvesvarayya Regional College of Engineering (VRCE), Nagpur and is presently working as Scientist E at the LASTEC, Delhi. He has given new design methodology for frequency stabilisers for gas lasers. Presently, he is working on laser-warning activity.

Mr A.K. Maini obtained his BSc Engg (Electronics and Communication) from the Punjab Engineering College, Chandigarh, in 1977. He has been with DRDO since 1978. He has also given new design methodologies for building electronics packages for solid-state lasers and frequency stabilisers for gas lasers. Presently, he is the Head of EOCM & Optoelectronics Systems Division at the LASTEC, Delhi. He has more than 200 technical articles and papers to his credit. He has authored eight books.