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# DESIGN AND PERFORMANCE OF AN EYE-SAFE LASER RANGEFINDER

by

Werner Fabian, Kenneth J. Grant and Shane A. Brunker





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## DESIGN AND PERFORMANCE OF AN EYE-SAFE LASER RANGEFINDER

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SUMMARY

An eye-safe laser rangefinder has been designed and constructed for use in signature measurement applications. It is based on an erbium:glass laser operating at 1.54 μm, and has characteristics specific to its role. The design parameters are discussed, and results are presented of the performance and accuracy of the system.

This General Document is a paper presented at the 8th Conference of the Australian Optical Society, held at the University of Sydney, NSW, in February 1993.



MAY 1993



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## FIGURES

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# 1 INTRODUCTION

An eye-safe laser rangefinder has been designed and constructed for use in signature measurement applications. The unique requirements of this application prevent the use or adaptation of off-the-shelf systems:

(1) a relatively wide field-of-view (FOV) of 50 mrad (3°) precludes the use of low power systems used in survey work, and

(2) military rangefinders are not designed to cope with a FOV greater than a few milliradians.

This rangefinder is a variation of the traditional time-of-flight system, with additional characteristics designed specifically for its rôle. This paper discusses the design parameters of the rangefinder, which is partitioned into three major sub-systems, viz.

(i) laser transmitter,

(ii) receiver, and

(iii) range counter and control electronics.

Figure 1 is a photograph of the rangefinder and readout, and a system block diagram is shown in Figure 2. Results are presented of the performance and accuracy of the system.

# 2 SYSTEM DESCRIPTION

The transmitter employs a flashlamp-pumped Q-switched erbium:glass laser operating at the 'eye-safe' wavelength of 1.54 µm, and has a nominal ocular hazard distance of zero range [1]. The laser output is typically 10 mJ in a 30 ns full-width at half maximum (FWHM) pulse, corresponding to a peak power of 300 kW. Because the laser is air-cooled, the repetition rate is limited to 0.5 Hz. Although liquid cooling can increase the repetition rate limit to 20 Hz [2], this would significantly increase the complexity and cost of the rangefinder.

The receiver sub-system consists of two detector/amplifier modules with range-activated electronic switching between the two. The only difference between them is the diameter of the collecting fresnel lens. The near-field signal is detected by a 15 mm lens with a 3° FOV, but for distances greater than 3 km the 50 mm aperture with a 1° FOV is used. This arrangement has superior performance to a single receiver and allows simpler optics to be used. Although the lightweight fresnel lenses are less efficient than high quality glass ones, they offer acceptable performance at a lower cost.

A more conventional laser rangefinder generates a narrow output beam (typically < 1 mrad), and this allows most of the beam to be projected onto the target. Neglecting atmospheric attenuation, this means that total power on the target is range independent. The power back-scattered onto the receiver aperture follows the normal inverse square law relationship, and hence such a system will follow an inverse square law of power detected versus range.

In the present system, the wide beam divergence coupled with small retro-reflector gives rise to an additional square law relationship, resulting in an overall inverse fourth power relationship between signal power and range. This is closer in general characteristics to a radar system. The two receiver design is a compromise which overcomes some of the difficulties of working with such a large dynamic range, by using a lower sensitivity receiver in the near field.

The time-of-flight technique is employed, and range resolution is one clock period which corresponds to 1 m with the 150 MHz oscillator used. The counter is initiated by the firing of the laser, and under normal operation a return pulse is detected and the counter stops. At first the near-field receiver is used, but at 3072 counts this is toggled to the high sensitivity receiver. The range is displayed on an external control/display unit. This unit is used to trigger the rangefinder, and also shows the status of several 'flags' which monitor the performance of the system. Triggering may be single shot or continuous at a rate of 0.5 Hz. Provision is also made for remote triggering and monitoring of range and status flags eg. by computer.

Absolute maximum range is limited by the counter to a nominal 16 km, but in practice this will be determined by the size and characteristics of the retro-reflector used. Ranges in excess of 11 km have been measured using a 38 mm corner cube and reflective tape. In the far field, the measured ranges are in agreement with the surveyed ones to within 0.1%. Details of the rangefinder's performance are given below.

## 3 SYSTEM PERFORMANCE

The rangefinder was tested at the Australian Army's Proof & Experimental Establishment at Port Wakefield, South Australia. This has points which have been surveyed with an accuracy of ±1 cm, with a clear line-of-sight in excess of 11 km. Two types of target were used, viz. a 38 mm corner cube, and a range of sizes of reflective tape (3M 'Scotchlite' Reflective Sheeting Diamond Grade series 3970G). This tape is similar to the type used in traffic control signals.

Figure 3a shows the measured distances versus the surveyed ones, for each of the targets. The plot is linear, with a slope of almost exactly 1. It was possible to range out to 11.6 km using the corner cube and 1.0 $m^2$ tape. The differences between measured and surveyed distances are shown on an expanded scale in Figure 3b. These discrepancies are partially the result of a systematic error in over-estimating distances by 0.07%, which is due to the clock frequency of 150 MHz. To correspond more closely to the speed of light, this frequency should be 149.896 MHz.

## 4 SUMMARY

A eye-safe rangefinder based on an erbium:glass laser has been designed and constructed. The design is optimised for aircraft tracking applications, and has the novel design features of a relatively wide FOV, and twin receivers. It has been tested in a static situation and shown to have an accuracy of better than 0.1% in the far field. Distances of 11.6 km have been measured using a corner cube and reflective tape.

## ACKNOWLEDGEMENTS

The authors gratefully acknowledge the assistance of Efisio Mancini, Fred Buttignol, and John Bridgman in the field testing of the rangefinder.

## REFERENCES

1. ANSI Z136.1-1986, Table 5

2. H.S. Keeter, D.S. Dewald and M.A. Woodall "Report on repetition-rated erbium:glass lasers", *Solid State Lasers III*, G.J. Quarles (Ed.), Proc. SPIE 1627, 21-5 (1992)

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Figure 1 Eye-safe laser rangefinder and readout.

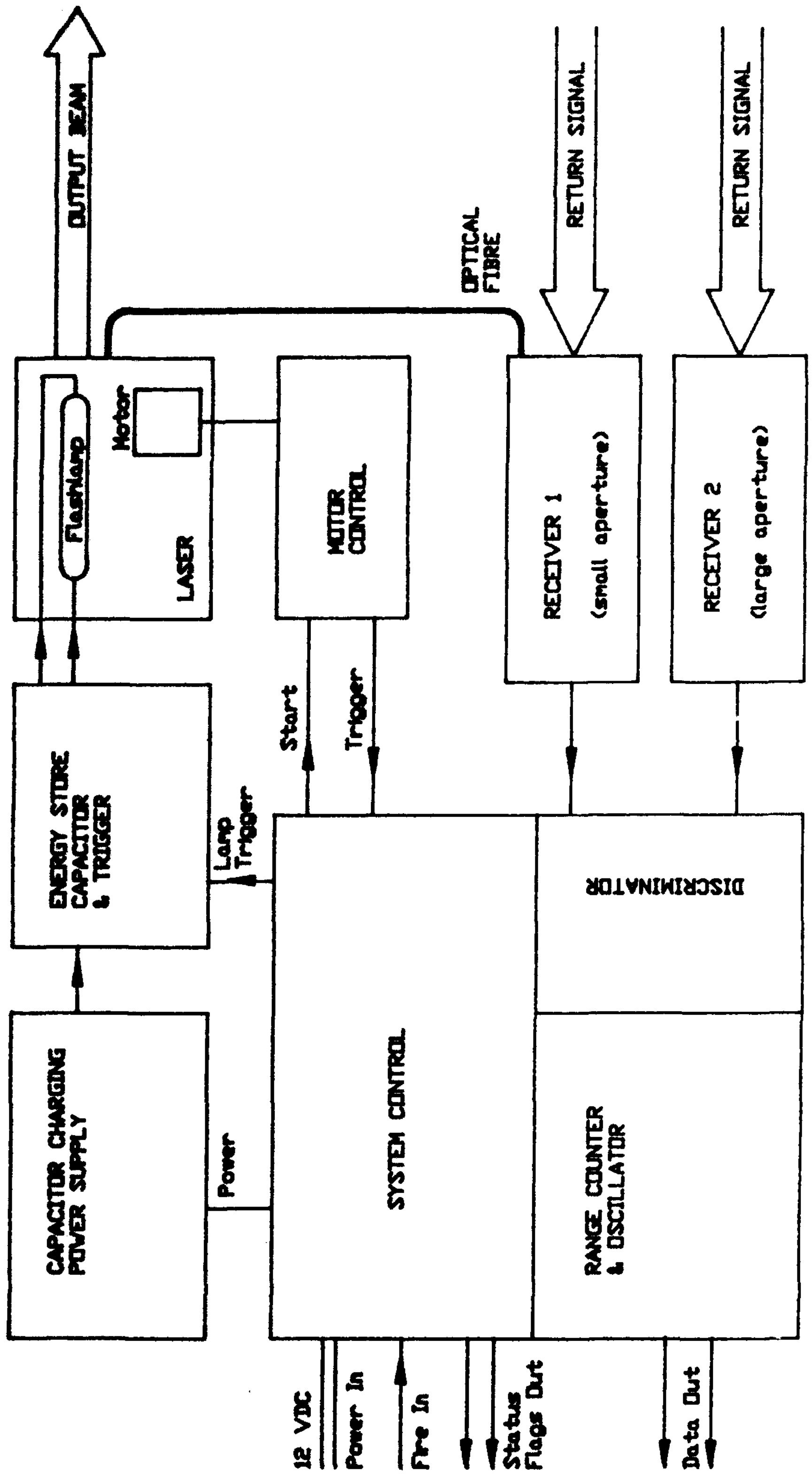


Figure 2 System block diagram.

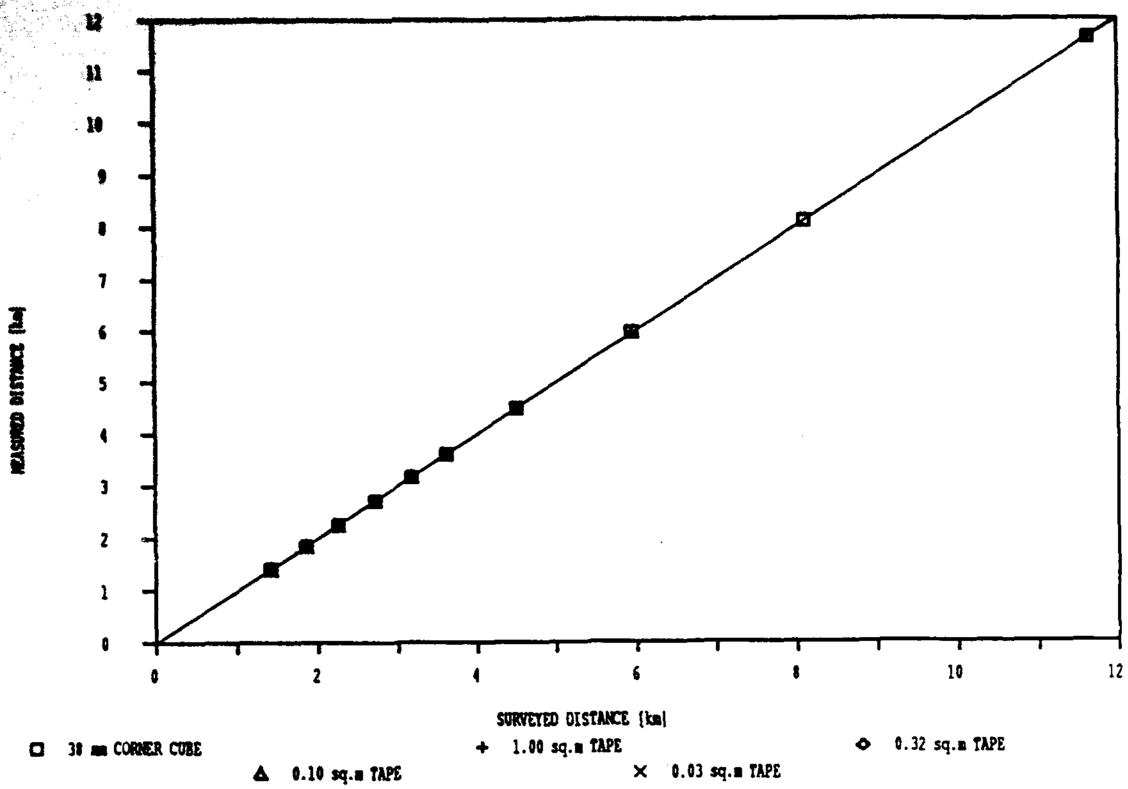


**Figure 3a** Measured distances vs the surveyed ones. The line has unity slope.

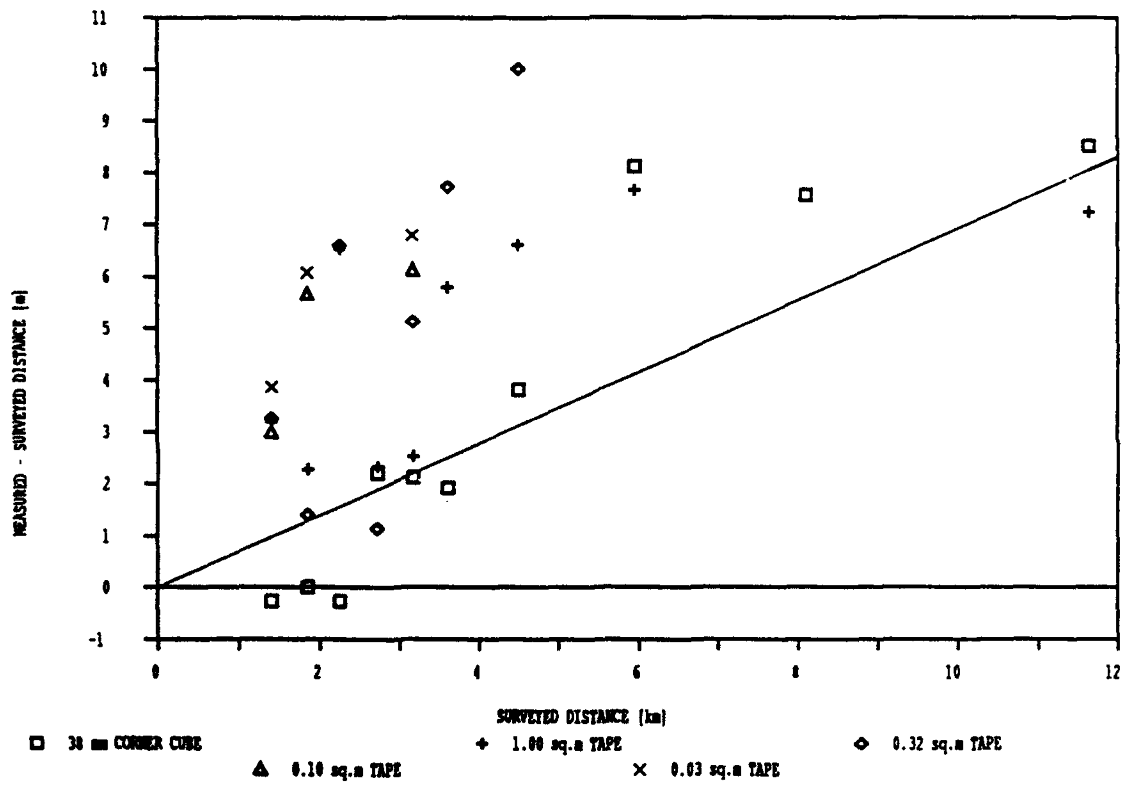


**Figure 3b** Error in measured distances vs surveyed distance. The line indicates the systematic error due to the clock speed.

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