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# COMPACT EYE-SAFE RANGEFINDER

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## Abstract

A simple and cheap Q-switched TEM<sub>00</sub> Er<sup>3+</sup>,Yb<sup>3+</sup> codoped glass laser end pumped by a broad-area high-power laser diode is used as source for a laser rangefinder based on fly-time. Bearing and resolution have been estimated respectively around 700 m and 3 m.

## 1 Introduction

An eye-safe pulsed 1.5  $\mu\text{m}$  laser compact and low cost can be used in range-finding system. A laser emission can be obtained at this wavelength :

- from broad-area high-power laser diodes. Their output power is limited at about 1 W in CW and few 10 W in QCW. The beam quality is rather poor ( $M^2 \gg 50$  : the angular divergence is 50 times under the diffraction limit).
- from Optical Parametric Oscillators (OPO) pulse generator whose peak power depends on the pump laser characteristics.
- from erbium doped solid-state laser pumped by laser diode, ...

The use of an erbium glass laser pumped by a broad-area high power laser diode seems to be a good solution for short range telemetry applications. The Q-switch system must be rugged to be low cost. In this field, we have already demonstrated the Q-switch trigger by inserting a mechanical chopper in the laser cavity [1]. But this device is difficult to insert in a small volume. Moreover the disc diameter can't be reduced without trigger efficiency reduction. The second system we retained is the tuning fork chopper.

The simple mechanical Q-switch systems are not efficient as those normally used (acousto-optic, electro-optic, ...) which are not suitable for our cavity configuration. We have a few millimeters long plano-plano cavity stabilized by the gain guiding and thermal lenses created in the material. With a cavity length in exceed of 2 or 3 cm (dimension of a standard trigger system) the laser does not operate or emits several transversal modes. A 3 % maximum gain can be obtained in this material is about 3% for a back and forward in the cavity, the losses introduced in the cavity by the trigger system would be less than 1% or 2% for back and forward which is very difficult to obtain with a standard switching system.

## 2 Experimental system

The optical fiber output is focused in the erbium glass with a X2 magnification lens (see Figure 1). The erbium glass disc is 2 mm thick. One face is high reflectivity coated at 1540 nm ( $R > 99.9\%$ ) and the

transmission at 980 nm is about 95%. The other disc face is antireflection coated at 1540 nm ( $R < 0.03\%$ ). The output mirror reflection is estimated to be around 99% at 1535 nm. The overall cavity length is about 5 mm and the tuning fork chopper is inserted between the erbium glass and the output mirror. The output beam is collimated by a 50 mm focal lens.

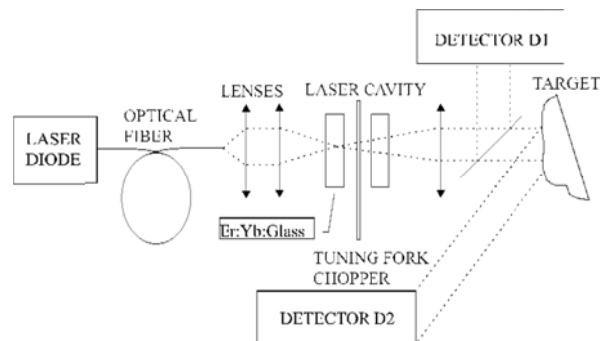


Figure 1 : Rangfinder scheme.

Under a 700 mW CW pump power, we obtain a TEM<sub>00</sub> laser mode. The output mean power is 18 mW with a 800 Hz repetition rate. The output wavelength is 1.535  $\mu\text{m}$ . The system doesn't generate one single pulse but three pulses due to the long switching time of the mechanical Q-switch system:

- a 100 W peak power pulse with 90 ns FWHM
- a second pulse about 1  $\mu\text{s}$  after the first with 60 W peak power and 130 ns FWHM
- and a third pulse about 3  $\mu\text{s}$  after the second with 25 W peak power and 230 ns FWHM

The rangefinder operation is not disrupted when there is more than one pulse.

The rangefinder is based on the fly time measurement of a light pulse. D1 detects the initial pulse and when the voltage delivered by D1 is higher than a given level a counter is released. The backscattered flux by the target is collected by a 6 cm diameter Fresnel lens which focuses the beam on D2. The detection of the back pulse stops the counter. From the back and forward time of the light pulse between the source and the target and the velocity of light, we can derive the distance between them :

$$d = \frac{\Delta t \cdot c_0}{2}$$

d : distance between source and target

$c_0$  : velocity of light

$\Delta t$  : delay time of the light pulse.

### 3 Experimental results

The range can be derived from the minimum detectable power of the receiver which is governed by the detection power noise.

$$SNR = \frac{S^2 P_S^2}{P_D B + J}$$

SNR : signal to noise ratio.

S : detection sensitivity (V/W)

$P_S$  : received power (W)

$P_D$  : noise power without optical signal in a 1Hz bandwidth (W/Hz)

B : detector bandwidth (Hz)

J : shot noise

The shot noise is negligible (not measurable) for this detection system.

With SNR=50,  $P_D=1,2 \cdot 10^{-18}$  W/Hz, B=100 Mhz et S=6540 V/W, a 12 nW minimum detectable back signal is calculated. The range is given by the Bouguer law [2] which permit to calculate the backscattered power by a lambertian target (albedo  $\rho = 0.1$ ).

$$P_S = \rho \frac{P_{laser} \phi^2 T_{atm}}{4d^2} \text{ (see Figure 2)}$$

$\rho$  : backscattered power of the target.

$\phi$  : reception lens diameter.

d : source-target distance.

$P_{laser}$  : laser peak power.

$T_{atm}$  : atmospheric transmission at the operating wavelength.

With a target characterized by an albedo of 0.1, a 700 m range is evaluated. This range can be increased by reducing the detection bandwidth in order to increase the signal to noise ratio in preserving a good response of the detection system. With  $B \frac{0.1}{\tau}$  where  $\tau$  is the FWHM of the pulse, the signal is reduced to take care of this fact in the equation we take an equivalent bandwidth for the SNR calculus :  $B_{eqb} = \frac{0.8}{\tau}$

The minimum detectable radiant power is 3 nW. The target albedo is difficult to define because some parts diffused the light and some parts reflect it. A relatively unfavorable mean of 0.1 is taken corresponding to a dark wall albedo. For this value, a 1300 m system range is calculated.

The resolution is limited by the counter clock frequency f since the measurable minimum time corresponding to the minimum distance is the clock period. With f=60 MHz, the resolution is  $r = \frac{c_0}{2f}$  where  $c_0$  is the light velocity.

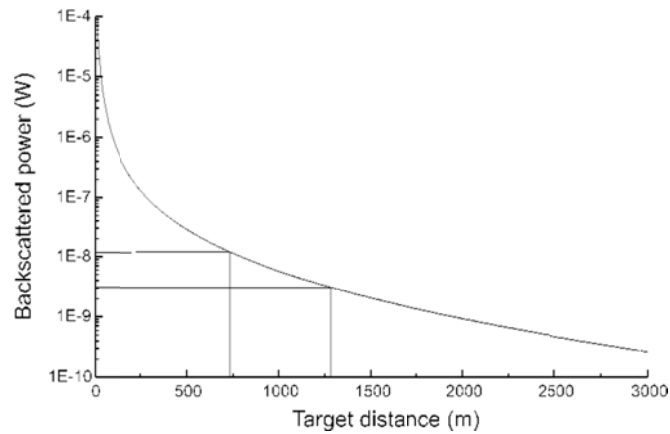


Figure 2 : Backscattered power by a lambertian target (albedo 0,1) versus distance for a 100 W emitted peak power.

### Conclusion

We have described an eye-safe rangefinder based on a simple mechanically Q-switched laser which has been realized and tested. The laser peak power and pulse width performances are in good agreement with obstacles detection and mobile-target localisation.

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### References

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