COMMENTS ON

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TECHNICAL REPORT NO. 695

July 1967

UNIVERSITY OF MARYLAND
DEPARTMENT OF PHYSICS AND ASTRONOMY
COLLEGE PARK, MARYLAND

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CR#97906	16
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

FACILITY FORM 602

COMMENTS ON

"A PROGRAMMED MULTIPULSE RANGE MEASUREMENT SYSTEM*"

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* Work supported in part by the Advanced Research Projects Agency (Project DEFENDER) monitored by the U.S. Army Research Office - Durham under Contract DAHC04 67 C 0023, and the National Aeronautics and Space Administration contract NGR 21-002-109.

Ackerman, Morrison, and Iliff[1] have proposed a method to increase the efficiency of a Q-switched laser radar by extracting a number of Q-switched pulses at selected times during a single pump period[2]. They control the Q-switched device by means of a digital-clock-controlled programmer. The programmer trigger pulses were synchronously-delayed for a period equal to the estimated range time and then were used to trigger the sweep of the range receiver oscilloscope so that the return for each radar pulse would be displayed in the same relative location on the oscilloscope screen to aid in extracting the signal from the noise.

This note points out problems that may arise in practice due to the nature of the laser transmitter. These problems arise due to the short-term temperature changes in the laser rod during the pump cycle. Temperature changes will affect the wavelength of the output pulse[3] and may cause one or more pulses of the multi-pulse to be absorbed in the atmosphere[4]. Temperature changes will also affect the width, shape, energy, and delay from initiation of each of the Q-switched pulses. I have assumed that long-term temperature changes have been eliminated by proper cooling of the laser rod. If not, the problems are enhanced.

Wagner and Lengyel[5] provide a good frame work for the evaluation of these temperature effects. The biggest unknown in the evaluation will be the uncertainty in the short-term temperature rise in the laser rod. The only data I have seen indicate a 2°C temperature rise per 100 μsec during the pump period for a helical lamp input energy of 3600 joules and a 6 cm long, 6 mm diameter ruby rod[6]. A more typical oscillator rod might have a length of 10 cm and a diameter of 1.4 cm and be pumped by the same lamp input energy. Assuming that energy is uniformly dumped in the laser rod (e.g. 25 joules/cc) and that no significant heat loss occurs on this short a time scale, one can still use the 2°C rise per 100μsec. (Note that Ackerman et al[1] have the means to determine the temperature rise in their laser rod as a function of time during the pump period. A measurement of the wavelengths of the Q-switched pulses of one multipulse would yield the temperature of the rod as a function of time). Table I gives the pulsewidth τ_Q , pulse delay τ_D , and energy out, J, of the typical laser oscillator for successive Q-switched pulses whose spacing is 50 μsec. It is assumed that the cavity mirrors are 35% and 100% , that the cavity length is 60 cm, that the pump period is sufficiently long, that the laser is operated at 23°C (long-term average), and that it yields an initial output of 2.1 joules. The ruby linewidth changes with temperature [3] such that the gain coefficient decreases by 1% for each 1°C increase in temperature.

The energy output per pulse drops by a factor of two at the tenth pulse in agreement with Ackerman et al[1]. The full-width at half-maximum of the pulses, τ_Q, increases to 35 nsec by the tenth pulse. The change in wavelength[3] is about 1Å per 27° C near 300°C where the wavelength is 6943.0Å. Water vapor absorption lines[4] occur at about 6943.8, 6942.2,6942.4, and 6941.2 with widths of about 0.2Å. If the ambient rod temperature is maintained at 23°C, no trouble will be encountered with absorption. However, choices of 0°C or 39°C would cause severe absorption in the atmosphere for over half of the pulses.[7] Finally, the delay of a pulse from initiation,τ_D, increases from 205 nsec to 523 nsec from first to tenth pulse. Thus, if the range receiver oscilloscope of Ackerman et al[1] is triggered by the electronic pulse that triggers the Q-switch device, a systematic range error is produced. This systematic error can be eliminated by simply triggering the range receiver oscilloscope directly from a laser output monitor. Then only a systematic error caused by pulse shape distortion would remain. Pulse distortions are very small for the above conditions.

It is concluded that the multi-pulse measurement system of Ackerman et al[1] is practical if sufficient care is given to the laser design and range-timing start pulse.

Work supported in part by the Advanced Research Projects Agency(Project DEFENDER) monitored by the U.S. Army Research Office-Durham under Contract DAHC04 67 C 0023, and the National Aeronautics and Space Administration contract NGR 21-002-109.

1. S. Ackerman, T. S. Morrison, R. L. Iliff, Appl. Optics 6, 353 (1967)

2. A number of workers have used the multiple Q-switched pulse method to increase the efficiency of their optical radars, but have had all their pulses occur during one range resolution element. (e.g. G. Kent, B. Clemesha, and R. Wright, J. Atmospheric and Terrestrial Phys. 29 , 169 (1967).

3. D. McCumber and M. Sturge, J. Appl. Phys. 34, 1682 (1963)

4. R. Long, Proc I.R.E. 51, 859 (1963)

5. W. Wagner and B. Lengyel, J. Appl. Phys. 34, 2040 (1963)

6. M. Hercher, " The Optical Characteristics of Ruby Laser Emission", p 126. Ph. D Thesis, University of Rochester 1963

7. The time delay from lamp-firing to the first Q-pulse has been considered to be small compared to the length of the multi-pulse.

TABLE I

Pulsewidth, Pulse Energy, and Pulse Delay are given for the Typical Laser Oscillator described in the Text as a Function of the Pulse Number of a Multipulse Produced in One Pump Period.

Pulse No.	1	2	3	4	5	6	7	8	9	10
τ_Q(x10^{-9}sec)	23	24	26	28	29	30	31	33	34	35
J (joules)	2.1	2.0	1.9	1.8	1.7	1.5	1.3^+	1.3^-	1.1	1.0
τ_D(x10^{-9}sec)	205	219	235	251	280	322	356	398	450	523