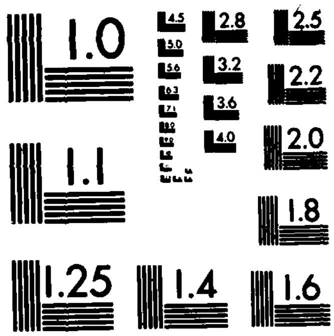
AD-A128 280 STUDY OF SHORT PULSE MERCURY BROMIDE LASER(U) 1/1
WESTINGHOUSE RESEARCH AND DEVELOPMENT CENTER PITTSBURGH
PA C S LIU ET AL. 14 FEB 83 N00014-82-C-0318

UNCLASSIFIED F/G 20/5 NL

END
FILMED
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

C. S. Liu, S. C. Leslie and I. Liberman

FINAL REPORT

(Period between March 15, 1982 and November 30, 1982)

Contract No. N00014-82-C-0318

Office of Naval Research

February 14, 1983

Westinghouse R&D Center
1310 Beulah Road
Pittsburgh. Pennsylvania 15235

STUDY OF SHORT PULSE MERCURY BROMIDE LASER

C. S. Liu, S. G. Leslie and I. Liberman

FINAL REPORT

(Period between March 15, 1982 and November 30, 1982)

Contract No. N00014-82-C-0318

Office of Naval Research

February 14, 1983

Westinghouse R&D Center
1310 Beulah Road
Pittsburgh, Pennsylvania 15235

TABLE OF CONTENTS

Page

RE: Proprietary Class 2 on Page 1 of Document
Delete statement. Document is approved for
public release per Dr. M. B. White, ONR/Boston
Detachment

LIST OF FIGURES

Research Report 83-9C7-SHORT-R1 [redacted]

STUDY OF SHORT PULSE MERCURY BROMIDE LASER

C. S. Liu, S. G. Leslie, and I. Liberman

Westinghouse R&D Center
1310 Beulah Road
Pittsburgh, Pennsylvania 15235

1. INTRODUCTION

This report summarizes research work performed at the Westinghouse R&D Center under ONR Contract No. N00014-82-C-0318 for the period between March 15, 1982 and November 30, 1982. The major effort was to perform experimental studies of the generation of a short laser pulse (< 10 ns) from a cavity dumped HgBr laser.

In this report, we will describe a cavity dumped HgBr laser emitting 8 ns (FWHW) laser pulses with output energies of 11.5 mJ/pulse at a cavity dumping efficiency of 58%. Finally, we will discuss the problems related to the cavity dumping of a high energy HgBr laser and possible solutions to these problems.

2. EXPERIMENTAL ARRANGEMENTS

The optical configuration of cavity dumping is illustrated schematically in Figure 1. The HgBr laser discharge tube is a UV-preionized self-sustained $HgBr_2$ discharge with a gain volume of approximately 40 cm^3. Typical gas fill for the laser is a mixture of 10% N_2 and 90% Ne at a gas density of 1.5 amagats. The operating temperature is about 170°C which is equivalent to a $HgBr_2$ vapor density $\sim 10^{17}/cm^3$. Under normal laser operation with a stable resonator (output coupling = 50%), the laser output pulse is near 20 mJ/pulse at ∿80 nsec pulsewidth. In the cavity dumping mode, inserted within the laser resonator is a combination of a Pockels cell and a polarization element which acts as an optical switch to allow the optical energy stored in the resonant cavity to be diverted when the stored energy reaches its peak value. The polarizer used is a thin film-multilayer dielectric stack which reflects over 99% of the s-polarization and transmits over 95% of the p-polarization. Mirrors M_1 and M_2 have total reflectivities, constituting a high-Q cavity for the p-polarization. The Pockels cell used is a large aperture (25 mm diameter) KD*P. The Pockels cell is a birefringent electrooptic crystal oriented so that, without applied voltage, the crystal does not affect the plane of polarization of the transmitted light. When a voltage is suddenly applied to the Pockels call, the birefringence of the crystal is altered, and the polarization of the transmitted light is changed. In Figure 1, since the polarizer is located between the HgBr laser discharge tube and the Pockels cell, the voltage applied to the Pockels cell is adjusted to rotate the polarization 45° during each pass. After a double pass through the Pockels cell, the optical flux now has the s-polarization and is consequently reflected out of the cavity by the polarizer. The theoretical minimum cavity-dumped pulse length is equal to the photon round-trip transit time inside of the cavity, namely 2L/c, Dwg.7779A04

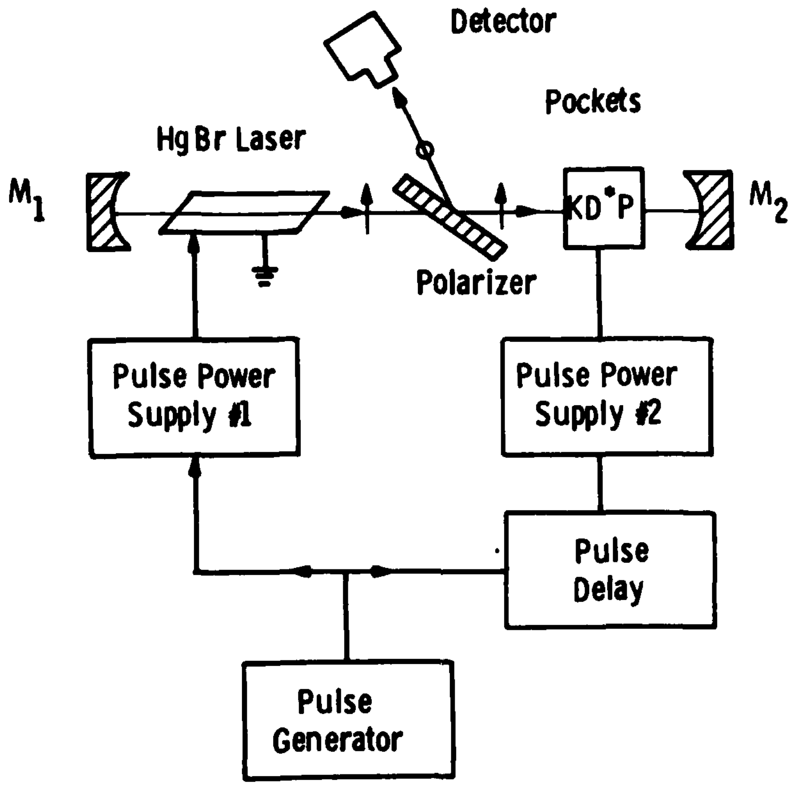


Figure 1. Schematic Diagram of a Cavity-Dumped HgBr Laser.

where L is the separation between mirrors M_1 and M_2. In the case of this study the cavity length is a minimum of 1.2 meters, corresponding to a pulse width of 8 nsec.

3. EXPERIMENTAL RESULTS & DISCUSSION

Short output pulse duration of 8 nsec from a cavity dumped HgBr laser was obtained. It should be noted that in order to provide high efficient dumping, the risetime of Pockels cell must be short compared to the photon cavity transit time, 2 L/c, and the optical losses in the cavity dumping configuration must be kept to an absolute minimum. The voltage risetime of the Pockels cell used is less than 2.5 nsec and the single pass cavity loss in the cavity dumping configuration is $\lesssim 7\%$. Laser output energies for three resonator configurations are compared in Table 1.

Table 1. OUTPUT ENERGIES FOR THREE RESONATOR CONFIGURATIONS

Resonator Configuration	Output Energy
1) Normal (M_2 = 50% R)	20 mJ
2) Pockels cell & Polarizer Added But Not Energized, (M_2=50% R)	14 mJ
3) Cavity-Dumped (M_2 = 100%)	11.5 mJ

The cavity dumping efficiency,[1] defined as the ratio of the cavity-dumped output energy to the normal resonator output energy, is $\eta = \frac{(2\ L/c)}{\gamma_N \tau_N} \cdot \frac{\phi_D}{\phi_N}$, where γ_N is the round trip factional photon loss for the normal mode of operation, τ_N is the normal laser duration and ϕ_D and ϕ_N are peak cavity photon densities of cavity-dumped and normal laser operations, respectively. Since $\gamma_N \simeq 1$ for this study, the relative cavity dump efficiency is essentially the ratio of the round trip photon transit time in the cavity to the normal laser pulse duration times the ratio of the peak cavity densities. Taking our experiment as an example, the ratio of 2 L/c (8 nsec) to the normal laser output duration (80 nsec) is 1/10. The cavity dumping efficiency for this system would be

$$\eta = \frac{1}{10} \frac{\phi_D}{\phi_N}$$

In order to obtain high cavity-dumping efficiency, the peak cavity photon density in the cavity-dumped mode should be 10 times higher than in the normal mode. The peak photon density in the cavity-dumped mode is extremely sensitive to the round trip cavity loss as well as to the correct timing for the switching of the Pockels cell. The cavity flux for the Pockels cell voltage unswitched case and under different timing conditions of the Pockels cell switch are shown in Figure 2. The decay of the cavity flux follows the decay of the discharge current, indicating the presence of appreciable cavity losses.

The delay between the Pockels cell voltage pulse and the circulating cavity flux was adjusted to obtain maximum output and the cavity flux output waveforms are shown in Figure 2(b). Since the Pockels cell was switched on to dump the cavity and then was switched off 80 nsec later, the rebuilding of the cavity flux does occur if the Pockels cell was switched early and sometimes even for the correctly switched case. A primary pulse is extracted followed by a train of weaker pulses with a spacing of 2 L/c. However, the secondary pulses either do not appear in the laser output or are very weak since the polarizer exhibits high reflectivity only at s-polarization. As the delay time is increased excessively, the amplitude of the primary pulse decreases because of high losses in the cavity. The relative output intensity of the primary pulse is plotted in Figure 3 as a function of the output switching delay. The output intensity exhibits a broad maximum centered around a delay time corresponding to switching at the peak of the circulating cavity flux.

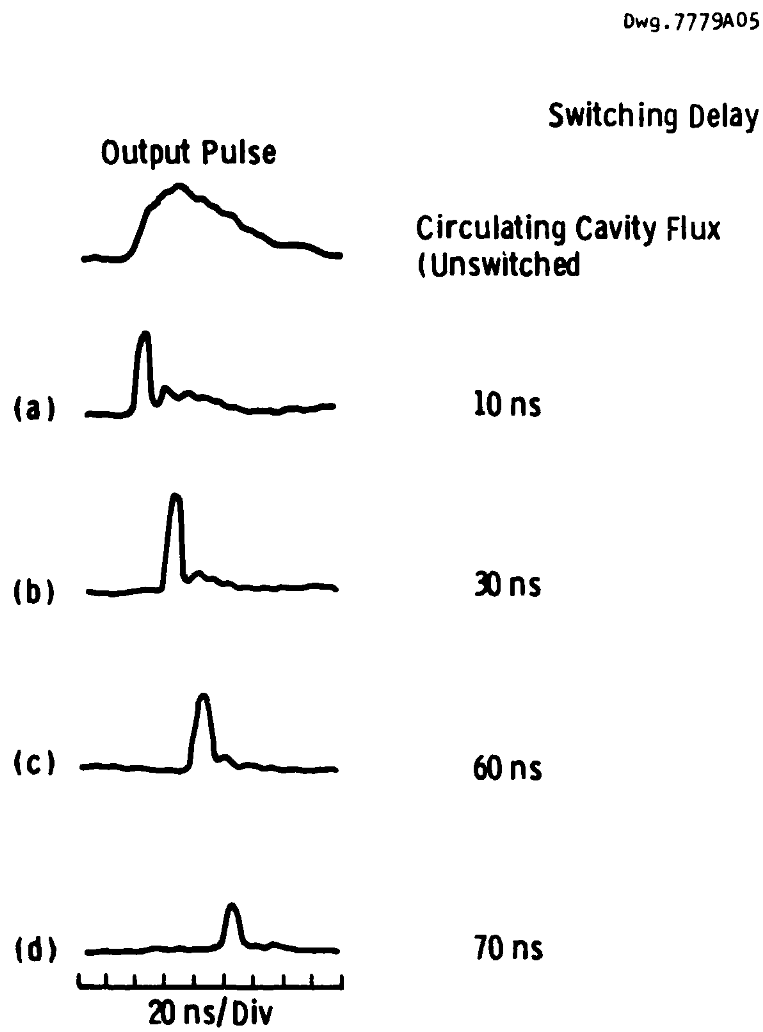


Figure 2. Effect of switching delay on the cavity flux.

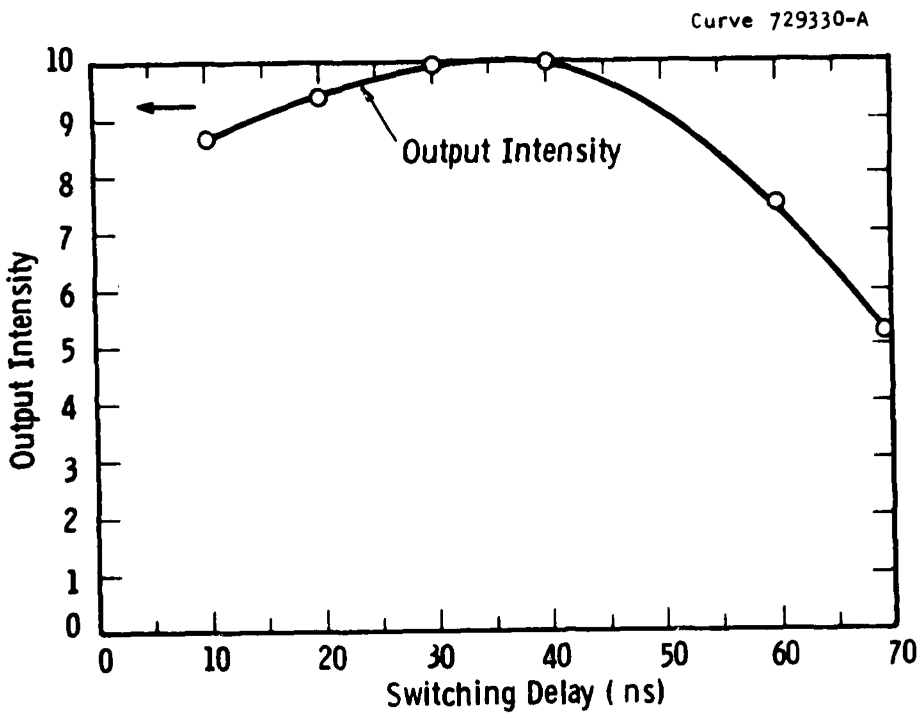


Figure 3. Output intensity vs. switching delay.

The output pulsewidth was measured as a function of the cavity length L and the data are plotted in Figure 4. The agreement between measured pulsewidth and theoretical pulsewidth 2 L/c is seen to be good. Unfortunately, the physical length of the resonator in this study could not be made smaller than 1.2 m because of oven design. This set the lower limit of the pulsewidth at 8 nsec. Cavity dumping efficiency at 8 nsec pulsewidth, relative to the normal mode, was 58%. Moreover, the 30% loss out of a total 42% loss in the 8 nsec cavity dumped mode is due to the insertion loss of the Pockels cell and polarizer. This means that if one can reduce the insertion loss of the Pockels cell and polarizer to an absolute minimum, the cavity dumping efficiency of this system can be improved to 80% or better.

Cavity dumping of a high energy HgBr laser needs a large aperture Pockels cell for the switch. Since the capacitance of a conventional Pockels cell increases with the aperture size, so does the risetime. There are several approaches one can employ to solve the switching problem for high energy HgBr laser cavity dumping; 1) new design of Pockels cells to reduce the capacitance, 2) improved electric circuitry to increase the voltage risetime or, 3) reduction of beam size by using a low loss compact lens system. All these methods are feasible but not trivial, therefore, more work is needed. Finally, one can also use a MOPA system to generate high energy short duration HgBr laser pulses. A short pulse low energy HgBr cavity dumped oscillator is already demonstrated. Its output can then be amplified through a large aperture gain cell. This approach is relatively straightforward and has minimal technological risk and effort.

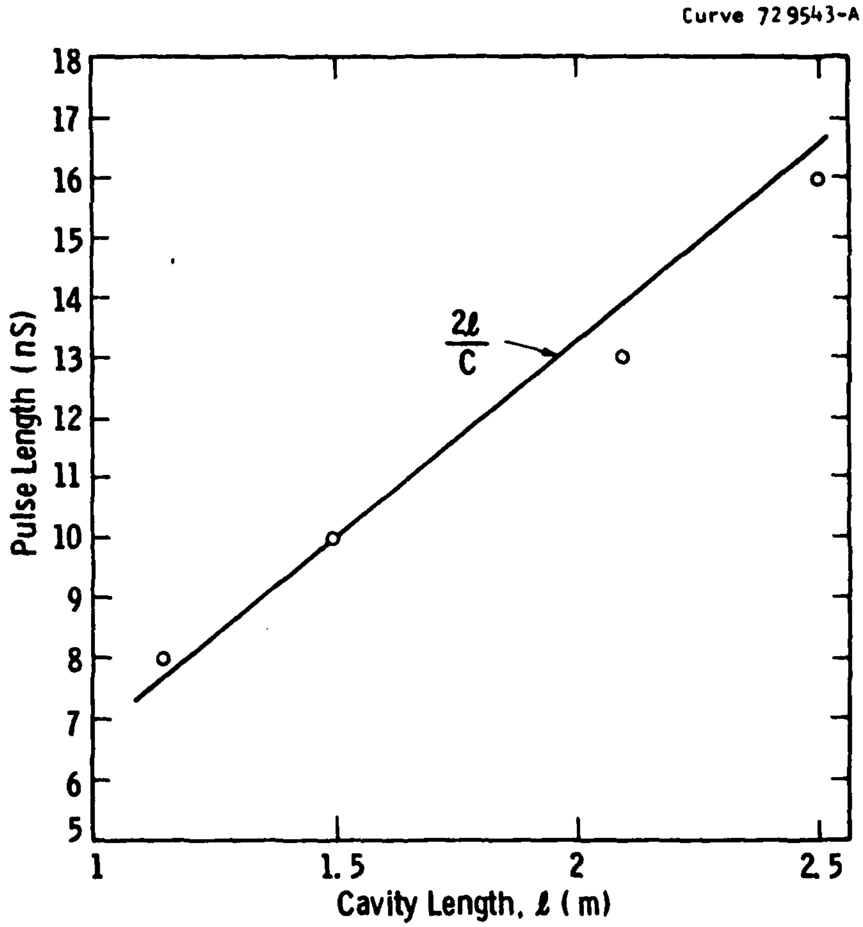


Figure 4. Output pulselength vs. optical cavity length.

4. CONCLUSIONS AND SUMMARY

The technique of cavity dumping has generated 8 nsec output pulses from a HgBr discharge laser normally emitting 80 nsec pulses with a conventional stable resonator. The minimum pulse width was limited by the length of the existing resonator and could be further reduced by decreasing the size of the discharge gain cell. Output energy of 11.5 mJ/pulse were measured, yielding cavity dumping efficiencies of 58%. The cavity-dumped efficiency was limited by the insertion loss of the Pockels cell and polarizer. A 80% cavity dumping efficiency is possible by reducing the insertion loss to an absolute minimum. To cavity-dump a high energy (>1 J/pulse) HgBr laser oscillator, a large aperture Pockels cell will be needed. Since the capacitance of the Pockels cell is proportional to the aperture area, the risetime is linearly increasing with the aperture. High cavity dumping efficiency can only be reached if both the insertion loss is low and fast Pockels cell switching can be achieved. Consequently, future work should concentrate on improving large area Pockels cells, compressing the beam through small Pockels cells, or a MOPA configuration.

5. ACKNOWLEDGMENTS

The authors would like to thank Dr. E. Schimitschek and Dr. M. White for their constant interest. In addition, they are grateful to Mr. G. Ferguson for loaning his Pockels cell and polarizer and for valuable discussions concerning the Pockels cell alignments and switching.

This report was typed by B.P. Toth.

6. REFERENCES

1. R. G. Morton, M. E. Mack, and I. Itzkan, "Efficient Cavity-Dumped Dye Laser," Applied Optics, 17 p. 3268 (1978).

ND