AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910

301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

SAND94-1998
Unlimited Release
Printed August 1994

Distribution
Category UC-~~48~~706

The effect of reusing laser gas on the fission-fragment pumped
1.73 μm atomic xenon laser output

G. A. Hebner
Lasers, Optics and Remote Sensing Department
Sandia National Laboratories
Albuquerque NM 87185-8500

Abstract

Fission-fragment pumped 1.73 μm atomic xenon laser output was measured without changing the laser gas mixture before each reactor pulse. For a Ar/Xe gas mixture at 260 Torr and 0.3 percent xenon, no degradation in laser output was noted for five reactor pulses.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Acknowledgments

The author thanks G. N. Hays, P. S. Pickard and D E. Bodette for numerous helpful discussions. The technical assistance of T. W. Hamilton, D. C. Meister and the SPR reactor staff was critical to the completion of this work. The experiments were performed at Sandia National Laboratories and supported by the United States Department of Energy under contract DE-AC04-94AL85000.

I. Introduction

Fission-fragment pumped lasers have the potential to be scaled to multi-megawatt power levels with long run times.¹ Fission-fragment excitation, also called nuclear pumping, utilizes the kinetic energy of ^{235}U fission products to produce ionization and excitation in the laser gas.²⁻⁴ For example, when ^{235}U , in the form of UO_2 in contact with the laser gas, absorbs a neutron, the nucleus fissions and produces energetic heavy particles with a combined kinetic energy of 160 MeV. A fraction of the fission products exit the coatings and produce ionization and excitation in the gas by collisions and production of secondary electrons. The high gas energy loadings that can be obtained with fission fragment pumping can result in significant gas heating.²⁻⁴ Since elevated gas temperatures can greatly decrease the efficiency of the atomic xenon laser system,⁵ a high power, long run time laser system must cool the laser gas in some manner. The most efficient method of cooling the gas would be to use a closed gas loop with heat exchangers. In such a system, the laser gas would be cooled before use to remove the heat deposited by the fission fragments and then flowed through the active discharge region to produce the laser.

Recycling the laser gas requires that the gas purity be maintained for long periods of time. Previous work has demonstrated that the atomic xenon laser is sensitive to gas impurities. For example, the intentional addition of air to a laser gas mixture in concentrations equal to the xenon concentration (few Torr at atmospheric pressure) reduced the $2.03\text{ }\mu\text{m}$ atomic xenon small signal gain by a factor of approximately 40 percent.³ In addition, previous experiments using one cell design at the Sandia Pulsed Reactor (SPR-III) and two cell designs at the annular core research reactor (ACRR) have noted a 20 to 30 percent decrease in laser output when the laser gas mixture is reused.⁶⁻⁸ The two experiments at ACRR were the Advanced Laser External Cavity

(ALEC) and the flowing laser experiments (FLE). The design of the SPR-III and ALEC laser cells were similar in the respect that they used static gas fills with cell volumes of 1-2 L. FLE utilized a gas flow loop and a gas volume of approximate 50 L.

There are several possible reasons for the decrease in laser output with successive reactor pulses. The first is that the fission-fragments that exit the coatings and excite the laser mixture remain in the gas at sufficiently high concentrations to reduce the laser output on the next reactor pulse. Secondly, the fission fragments may remove water vapor or other surface contaminants from the surface of the fissile oxide or the metal walls of the laser cell. Finally, there may be some mechanical misalignment of the laser cavity from shot to shot that decreases the laser output. If the decrease in laser output is due to misalignment of the cavity, checking the alignment before each reactor pulse should eliminate this effect. If the fission-fragments are liberating contaminants from the walls, then baking the laser cell at high temperatures under vacuum will reduce the amount of contaminants on the walls or in the oxide. However, if the decrease is still observed, then one is left with the possibility that the fission-fragments themselves are responsible for the decrease in laser output. This implies that the laser gas must be cleaned or filtered in some manner between every laser channel in a large system.

In this paper, we report the results of reusing an Ar/Xe gas mixture for several reactor pulses. The effects of baking the cell on the small signal gain and laser output are discussed. A brief description of the experimental apparatus and methods are given in Section II, and the experimental results are given in Section III.

II. Experimental configuration

The experimental apparatus has been previously described in detail.⁵ Briefly, the heated cell is pumped by fission-fragments originating from a 0.5 μm thick $^{235}\text{UO}_2$ coating on two substrates (10 x 60 cm). Excitation volume was 7 x 60 cm with a substrate spacing of 2.5 cm. The cell and all heated components were stainless steel with standard copper gasket seals. The cell was externally heated by heater tapes and the temperature inside and outside was monitored by multiple thermocouples. Energy input into the gas by the fission-fragments was kept small to insure that the gas temperature rise during the reactor pulse was less than 10 °C.

For these experiments, the main modification to the cell was the addition of quartz windows mounted at the Brewster angle. The windows were maintained at room temperature by a water jacket. After the cell windows were replaced, the cell was baked under vacuum for three days at a temperature of 300 °C. The 1.73 μm laser cavity was formed by a 3 m radius of curvature, maximum reflectivity dielectric mirror and a flat dielectric mirror with a reflectivity of 92%. The reflectivity of the curved mirror was less than 10 percent at 2.03 μm to suppress the laser output at wavelengths other than 1.73 μm . A fraction of the laser output was directed outside the reactor containment building and detected on a series of bandpass filtered InAs detectors ($\lambda_0 = 1.7, 2 \mu\text{m}$, $\Delta\lambda = 0.07 \mu\text{m}$; $\lambda_0 = 3 \mu\text{m}$, $\Delta\lambda = 0.5 \mu\text{m}$).

III. Experimental results and discussion

Prior to the laser experiments, the cell had been used for several weeks of reactor experiments that were designed to measure the gas temperature dependence of the atomic xenon laser small signal gain at 1.73 and 2.03 μm .⁵ During the course of those experiments, the cell was

baked under vacuum at temperatures of up to 300 °C for several days. During the course of the initial bake out, gain measurements were performed to observe the effect of baking on the small signal gain. We observed that over the course of several days, the gain steadily improved, presumably as water vapor and other impurities were driven from the walls and UO₂ substrates. After several days, no further improvements were noted and the gain values were reproducible during daily operation over a two week period.

The results of reusing the laser gas mixture are summarized in Fig. 1. The gas mixture was Ar/Xe at a total cell pressure of 260 Torr and xenon concentration of 0.3 percent. Pump rate was approximately 8 W/cm³ and the cell was at a temperature of 20 °C. The laser gas mixture was placed in the cell at approximately 9:30 AM and the last reactor pulse was at 4:30 PM. The five reactor pulses shown were all obtained on one day and the reactor temperature rise (neutron output) during the five pulse run was very constant ($\Delta T_{\text{reactor}} = 273 \pm 3$ °C). The laser cavity alignment was checked and adjusted before each reactor pulse. Both the peak laser output and the total laser energy were constant during this experiment. The peak laser output and energy were normalized to reactor pulse S9484. The normalized laser output was 0.96 ± 0.03 . The constant laser output obtained during this experiment is consistent with previous experiments that observed no decrease in the 1.73 and 2.03 μm atomic xenon gain when a gas mixture was reused for two reactor pulses.

Figure Caption

Fig. 1 Peak laser output (●) and total laser energy (▼) for five reactor pulses. The gas mixture was Ar/Xe at a total pressure of 260 Torr and an xenon concentration of 0.3 percent. Pump rate was approximately 8 W/cm³.

IV. Conclusions

The results of these experiments strongly suggest that baking the cell and substrates at elevated temperatures can eliminate the decrease in laser output that was previously observed when the laser gas is reused. Since the laser output was constant for these experimental conditions, the fission-fragments generated by the UO_2 substrates during a reactor pulse do not appreciably contaminate the laser gas. As a result, fission-fragment excitation is not inherently detrimental to the laser physics. If the laser gas containment vessel can be adequately cleaned and baked, a closed gas flow loop can be used without reducing the gain and laser output of successive laser channels.

References

1. J. R. Felty, R. J. Lipinski, D. A. McArthur and P. S. Pickard, SPIE 2121, 2 (1994).
2. G. A. Hebner and G. N. Hays, J. Appl. Phys. 73, 3614 (1993).
3. G. A. Hebner and G. N. Hays, J. Appl. Phys. 73, 3627 (1993).
4. G. A. Hebner and G. N. Hays, J. Appl. Phys. 74, 3673 (1993).
5. G. A. Hebner, J. W. Shon and M. J. Kushner, Appl. Phys. Lett. 63, 2872 (1993).
6. W. J. Alford, Sandia National Laboratories, private communication.
7. D. E. Bodette and P. S. Pickard, Sandia National Laboratories, private communication.
8. G. A. Hebner and G. N. Hays, unpublished.

Distribution:

Number	MS	Name	Organization
1		J. R. Felty	Dept. of Energy, Defense Programs, DP-241 P.O. Box A, Germantown MD 20874.
1	0601	G. N. Hays	1128
15	0601	G. A. Hebner	1128
1	0601	D. R. Neal	1128
2	1145	P. S. Pickard	6514
1	1145	D. E. Bodette	6514
1	1145	D. A. McArthur	6514
1	1145	R. J. Lipinski	6514
1	9018	Central Technical Files	8523-2
5	0899	Technical Library	7141
1	0619	Technical Publications	7151
10	0100	Document Processing For DOE/OSTI	7613-2

DATE

FILMED

11/2/94

END