

LEGIBILITY NOTICE

A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although a small portion of this report is not reproducible, it is being made available to expedite the availability of information on the research discussed herein.

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

LA-UR--88-3777

DE89 003485

TITLE AMPLIFIED SPONTANEOUS EMISSION AND PULSE TRAIN
AMPLIFICATION IN A KrF AMPLIFIER

AUTHOR(S): J. R. Ackerhalt
D. E. Hanson

SUBMITTED TO Proceedings of IV International Laser Science Conference

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

By acceptance of this article the publisher recognizes that the U.S. Government retains a nonexclusive royalty-free license to publish or reproduce the published form of this contribution or to allow others to do so for U.S. Government purposes.

The Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy.

Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545



AMPLIFIED SPONTANEOUS EMISSION AND PULSE TRAIN
AMPLIFICATION IN A KrF AMPLIFIER

Jay R. Ackerhalt and David E. Hanson
Los Alamos National Laboratory, T-12, MS- J569,
Los Alamos, NM 87545

Richard G. Adams, T.D. Raymond, Christopher Reiser,
and James K. Rice
Sandia National Laboratory, Albuquerque, NM 87185

Robert B. Michie
Mission Research Corporation, Albuquerque, NM 87106

ABSTRACT

We present modeling studies of pulse-train amplification experiments conducted at Sandia National Laboratory in Albuquerque (SNLA) with an e-beam pumped KrF laser amplifier. The laser geometry is such that the dominant amplified spontaneous emission (ASE) growth is along the propagation axis. Our numerical studies include the propagation of on axis co- and counter-propagating fields for both the pulse train and ASE simultaneously. The time-dependent gain, absorption, formation and quenching rates are obtained from a state-of-the-art kinetics code developed at Los Alamos National Laboratory (LANL).

INTRODUCTION

This paper presents some preliminary results of a collaboration between the experimental groups at SNLA and the theoretical groups at LANL. The SNLA experiments being modeled were conducted using a λ -cell KrF amplifier described elsewhere.¹ The 5.7 cm diameter KrF gas cell was longitudinally pumped over 92 cm of its 1.3 m length by a 20 nsec e-beam. The e-beam profile contained 68% of its energy in the central 30% of the cell area. This results in an average pump rate of 4 MW/cm^3 at a gas pressure of 1 atmosphere. Because of the high aspect ratio we have modelled this system using a plane-wave on-axis co- and counter-propagating representation for the electromagnetic fields in Maxwell's equations, i.e., right and left propagating ASE pulses and a right propagating injected pulse train. Due to the very fast lower-level lifetime we need only model the fields' intensities as opposed to their amplitudes, and have treated the KrF* excited states as the only species present in the cell which can create photons.²

The theoretical model used here is a simplification of our more sophisticated kinetics model³ where we compute the e-beam energy deposition while simultaneously solving 70 kinetics reactions including photon propagation. Because of the long run times for this computer code we have studied the impact of the photon dynamics on the e-beam excitation physics, and have found that it is possible to characterize the KrF* formation rate, both the saturable and non-saturable absorption coefficients, and the KrF* quenching rate almost completely from the strength and temporal profile of the e-beam excitation assuming a uniform transverse profile. Therefore, we simply solve the dynamics of the photon intensities and the upper-state population in a one-dimensional, time-dependent formalism using the look-up tables provided by the kinetics code. The only other quantities that are necessary for describing the dynamics are the stimulated and spontaneous emission rates for the KrF* species and the saturable-absorption saturation intensity. In addition, since we are trying to represent all the dominant ASE as on-axis ASE, we have used a position dependent aperture function to more accurately represent the source of the ASE photons, i.e., the farther a gain sheet is from the end of the cell the smaller the solid angle into which ASE photons are radiated in the near on-axis region.

ASE THEORY AND EXPERIMENT

From a modelling perspective, it is important to calibrate the theoretical model to ASE experiments before beginning calculations for pulse train extraction, as this represents a baseline check of the initial assumptions. Without a pulse-train seed, we measured 2.7 J of ASE from one end of the λ -cell. Agreement between theory and experiment was obtained when the theoretical aperture area was limited to 35% of the cell area. This suggests that the dominant ASE is nearly on-axis and that this model is appropriate for treating the pulse train experiments.

Although the time dependence of the output ASE was not measured in the experiments, the theoretical waveforms show damped oscillations in the ASE intensity. In order to better understand this result we made the e-beam temporal profile flat topped. The results are shown in Figs. (1)-(3). The observed steady state is consistent with well known analytic solutions.⁴⁻¹⁰ A scan of the literature revealed no previous studies of transient ASE. However, in discussing these results with colleagues we have found that other research groups have noticed these relaxation oscillations in their theoretical modelling, but as of today no one has observed them in their experiments.^{11,12} The oscillation period depends primarily on the stimulated emission cross section and to a lesser degree on the

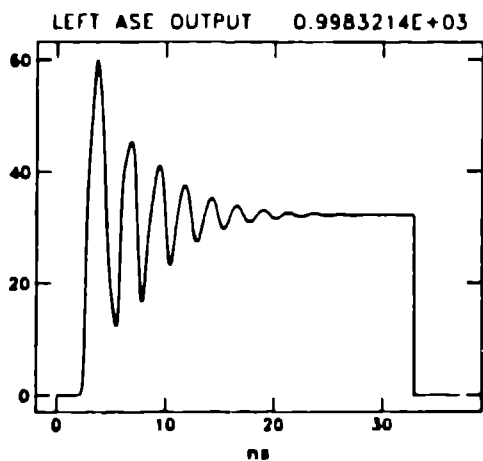


Figure 1. Left ASE intensity on output from the cell vs. time (ns).

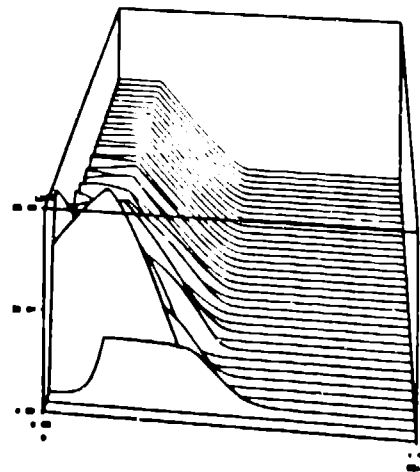


Figure 2. Left ASE intensity within the cell. Each successive trace refers to one nanosecond later in time. The left edge of the cell corresponds to Fig. 1.

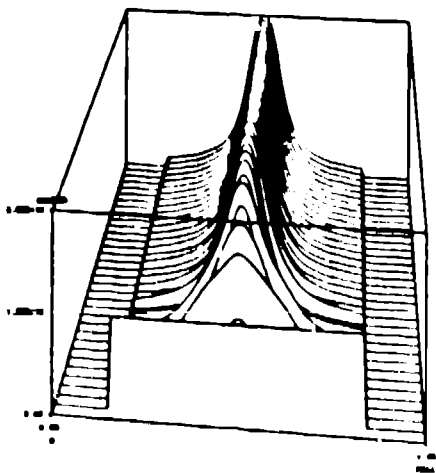


Figure 3. Excited state species within the cell. Each successive trace refers to one nanosecond later in time.

cell length. Whereas, the oscillation's magnitude and fall-off depend most strongly on the pumping rate and damping of the excited-state population.

PULSE TRAIN DYNAMICS

In Figs. (4) and (5) we show measurements of the input and output waveforms, respectively, acquired with 0.5 ns resolution. The theoretical output waveform, calculated using the data from Fig. (4), is shown in Fig. (6). The model predicts strong amplification of the intensity between pulses and over estimates the output energy. Further investigation suggests that the actual baseline intensity is not accurately represented in the data. Data supporting this conjecture is shown in Figs. (7) and (8) where the temporal resolution is 0.2 nsec. In addition to revealing structural details within each pulse, these figures show little baseline intensity between pulses.

Because of these difficulties with the data we began a theoretical study assuming a zero baseline. In Figs. (9) and (10) we show a theoretical simulation of the same pulse train. The pulses are super Gaussian functions with a fourth-order exponent. Notice the high gain on the leading edges of the output pulses. When we repeated the calculation with standard second-order exponent Gaussian functions, the output pulses did not show this high gain on the leading edge. This sensitivity of the output pulse temporal profile with respect to the rise time of the leading edge of the input pulse temporal profile makes modelling of these experiments very difficult. Returning our attention to Fig. (10) notice that the output energy is reduced as compared with Fig. (5), but is still larger than found experimentally. In Figs. (11) and (12) we show the right travelling (co-propagating) ASE and left travelling ASE, respectively. The co-propagating ASE builds up between successive pulses in the train. The counter-propagating ASE has an initial peak with a subsequent tail. Both these results are qualitatively consistent with experimental observations from the λ cell, since the energy in the ASE pulses is not known.

FUTURE WORK

We plan to continue modelling pulse train data from the λ cell with the expectation that modifications in the experimental apparatus and theoretical model will improve the consistency between them. SNIA personnel are currently working to improve the temporal resolution of the input, output, and ASE waveforms. Other suggested experimental improvements include baffling of the electron beam to improve uniformity, and baffling the λ -cell to reduce the ASE reflections at the walls. Possible improvements to the model are the inclusion of ASE bandwidth, off axis ASE propagation, and radial profiles of the e beam and input seed energies. The present code does, however, contain the essential physics of the ASE and pulse train dynamics.

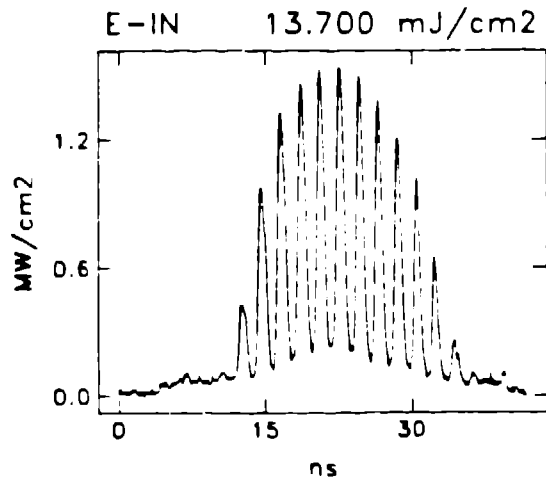


Figure 4. Input pulse train intensity vs. time digitized from a streak camera.

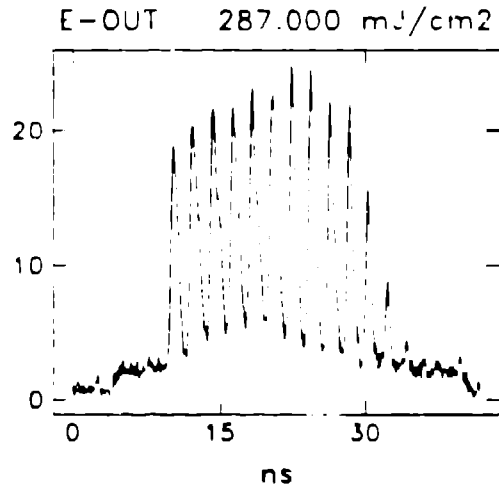


Figure 5. Output pulse train intensity vs. time digitized from a streak camera, corresponding to the input shown in Fig. 4.

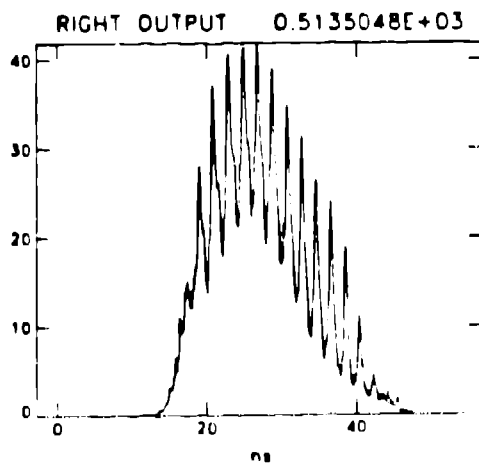


Figure 6. Theoretical output pulse train intensity vs. time for the input pulse shown in Fig. 4, Energy in mJ/cm².

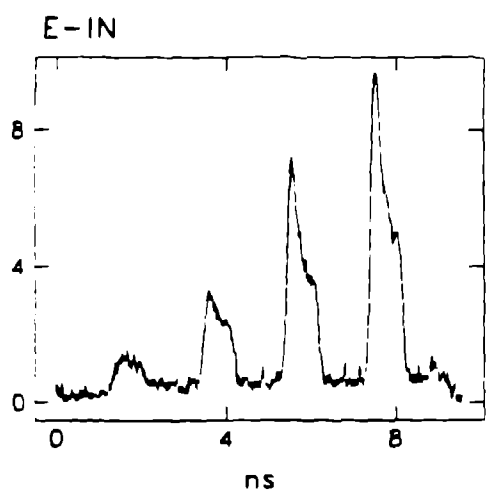


Figure 7. Input pulse train intensity vs. time for a small initial region of a total pulse train. Not the same run as shown in Fig. 4.

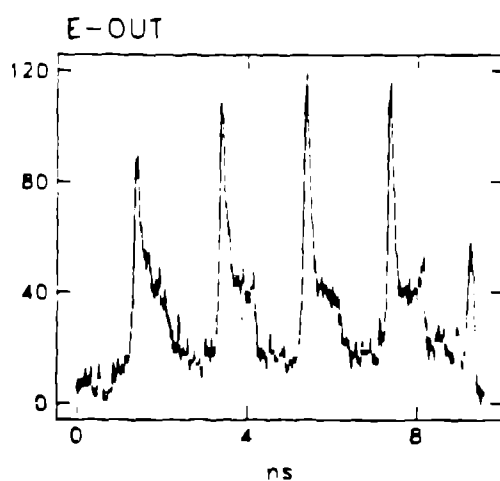


Figure 8. Corresponding output pulse train intensity vs. time from Fig. 7.

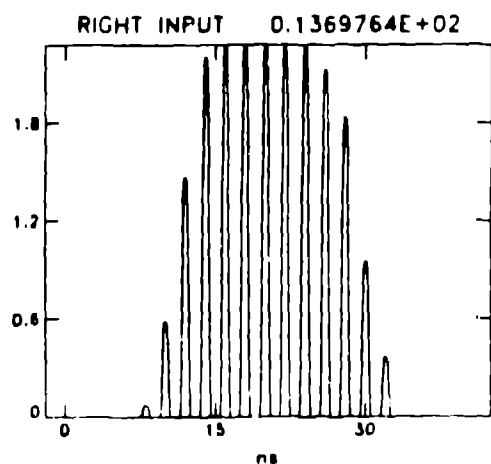


Figure 9. Simulated input pulse train from Fig. 4 with zero baseline. Energy measured in mJ/cm^2 .

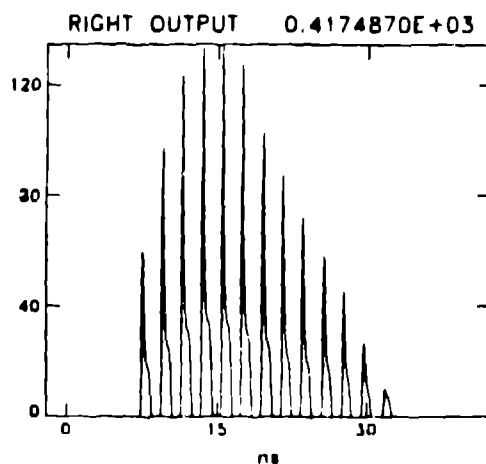


Figure 10. Output pulse train based on input from Fig. (9).

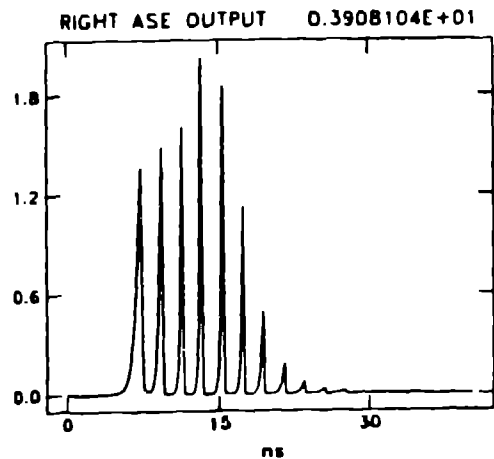


Figure 11. ASE output (co-propagating with the injected pulse train) at the right end of the cell vs. time.

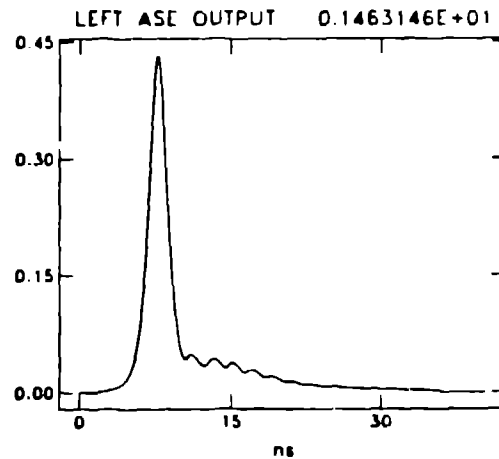


Figure 12. ASE output (counter-propagating with the injected pulse train) at the left end of the cell vs. time.

REFERENCES

1. E.L. Patterson, J.K. Rice, and G.C. Tisone, Appl. Phys. Lett. **36**, 188 (1980).
2. P.W. Milonni, R.B. Gibson, and A.J. Taylor, JOSA B **5**, 1368 (1988).
3. S.J. Czuchlewski, D.E. Hanson, B.J. Krohn, and A.R. Larson, Fusion Tech. **11**, 560 (1987).
4. U. Ganiel, A. Hardy, G. Neumann and D. Treves, IEEE JQE QE-11, 881 (1975).
5. G. Haag, M. Munz and G. Marowsky, IEEE JQE QE-19, 114 (1983).
6. L. Allen and G. Peters, Phys. Rev. **A8**, 2031 (1973).
7. G. DuJardin and P. Flamant, Opt. Commun. **24**, 243 (1978).
8. N. Abraham, J. Huang, D. Kranz and E. Rockower, Phys. Rev. **A24**, 2556 (1981).
9. A. Hunter and R. Hunter, IEEE JQE QE-17, 1879 (1981).
10. D. Lowenthal and J. Eggleston, IEEE JQE QE-22, 1165 (1986).
11. D. Casperson, J. Comly and G. Schappert, private communication.
12. R. Chiao, R. Nathel, R. Minich and J. Garrison, private communication.