AEROSPACE REPORT NO.
ATR-76(7501)-2

19

Lasers

SLL 80 136/P
copy 19

LVL

Fast-Discharge-Initiated KrF Laser

Prepared by D. G. SUTTON, S. N. SUCHARD, O. L. GIBB, and C. P. WANG
Aerophysics Laboratory

15 December 1975

Prepared for ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
Washington, D. C. 20545

VICE PRESIDENT AND GENERAL MANAGER
LABORATORY OPERATIONS

Contract No. AT(04-3)-1056

Laboratory Operations
THE AEROSPACE CORPORATION

LABORATORY OPERATIONS

The Laboratory Operations of The Aerospace Corporation is conducting experimental and theoretical investigations necessary for the evaluation and application of scientific advances to new military concepts and systems. Versatility and flexibility have been developed to a high degree by the laboratory personnel in dealing with the many problems encountered in the nation's rapidly developing space and missile systems. Expertise in the latest scientific developments is vital to the accomplishment of tasks related to these problems. The laboratories that contribute to this research are:

Aerophysics Laboratory: Launch and reentry aerodynamics, heat transfer, reentry physics, chemical kinetics, structural mechanics, flight dynamics, atmospheric pollution, and high-power gas lasers.

Chemistry and Physics Laboratory: Atmospheric reactions and atmospheric optics, chemical reactions in polluted atmospheres, chemical reactions of excited species in rocket plumes, chemical thermodynamics, plasma and laser-induced reactions, laser chemistry, propulsion chemistry, space vacuum and radiation effects on materials, lubrication and surface phenomena, photosensitive materials and sensors, high precision laser ranging, and the application of physics and chemistry to problems of law enforcement and biomedicine.

Electronics Research Laboratory: Electromagnetic theory, devices, and propagation phenomena, including plasma electromagnetics; quantum electronics, lasers, and electro-optics; communication sciences, applied electronics, semiconducting, superconducting, and crystal device physics, optical and acoustical imaging; atmospheric pollution; millimeter wave and far-infrared technology.

Materials Sciences Laboratory: Development of new materials; metal matrix composites and new forms of carbon; test and evaluation of graphite and ceramics in reentry; spacecraft materials and electronic components in nuclear weapons environment; application of fracture mechanics to stress corrosion and fatigue-induced fractures in structural metals.

Space Physics Laboratory: Atmospheric and ionospheric physics, radiation from the atmosphere, density and composition of the atmosphere, aurorae and airglow; magnetospheric physics, cosmic rays, generation and propagation of plasma waves in the magnetosphere; solar physics, studies of solar magnetic fields; space astronomy, x-ray astronomy; the effects of nuclear explosions, magnetic storms, and solar activity on the earth's atmosphere, ionosphere, and magnetosphere; the effects of optical, electromagnetic, and particulate radiations in space on space systems.

THE AEROSPACE CORPORATION
El Segundo, California

Accession Number: 4043

Publication Date: Dec 15, 1975

Title: Fast-Discharge-Initiated KrF Laser

Personal Author: Sutton, D.G.; Suchard, S.N.; Gibb, O.L.; Wang, C.P.

Corporate Author Or Publisher: Aerospace Corporation, El Segundo, CA 90245 Report Number: ATR-76(7501)-2

Report Prepared for: Space and Missile Systems Division, Air Force Systems Command, Los Angeles, CA 90045 Report Number Assigned by Contract Monitor: SLL 80 136

Comments on Document: Archive, RRI, DEW

Descriptors, Keywords: Fast Discharge Initiate KrF Krypton Fluoride Laser Molecule Chemical Reaction Circuit Pressure Spectrum Analysis Pulse Emission

Pages: 08

Cataloged Date: Dec 09, 1992

Document Type: HC

Number of Copies In Library: 000001

Record ID: 25550

Source of Document: DEW

Aerospace Report No.
ATR-76(7501)-2

FAST-DISCHARGE-INITIATED KrF LASER

Prepared by

D. G. Sutton, S. N. Suchard, O. L. Gibb, and C. P. Wang
Aerophysics Laboratory

15 December 1975

Laboratory Operations
THE AEROSPACE CORPORATION
El Segundo, Calif. 90245

Contract No. AT(04-3)1056

Prepared for

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
Washington, D.C. 20545

VICE PRESIDENT AND GENERAL MANAGER
LABORATORY OPERATIONS

Report No.
ATR-76(7501)-2

FAST-DISCHARGE-INITIATED KrF LASER

Prepared

D. G. Sutton

S. N. Suchard, Associate Head
Chemical Kinetics Department

O. L. Gibb

C. P. Wang

Approved

H. Mirels, Head
Aerodynamics and Heat Transfer Department

W. R. Warren, Jr., Director
Aerophysics Laboratory

ACKNOWLEDGMENT

The authors thank R. Bradford for many useful discussions and the use of his laser mirrors for preliminary measurements and L. Galvan for his excellent technical assistance.

ABSTRACT

Intense laser emission has been observed from the KrF molecule formed by a chemical reaction initiated by fast-discharge circuitry. With a gas mixture of He:Kr:NF_3 = 500:50:1 and a sample pressure of 700 Torr, an output energy of 0.8 mJ was measured from a 25-nsec laser pulse (FWHM). Spectral analysis of the laser emission indicated laser action at 248.5 and 249.5 nm.

CONTENTS

FIGURES

FAST-DISCHARGE-INITIATED KrF LASER

Laser action in the rare gas halide molecular system was first predicted[1] and observed[2-7] within the last year. To date, however, all of these lasers except for the XeF,[5,6] have been initiated by high-energy electron beams[2-4] or electron-beam stabilized discharges.[7] Laser action in the KrF^* molecule produced by a chemical reaction initiated by fast-discharge circuitry is reported here. The significance of these results is that an electrically efficient, high-power, high-repetition-rate KrF^* laser appears to be attainable by scaling a rather simple fast-discharge device, an option not possible, because of foil heating problems, when electron beams are used for initiation.

Discharge initiation of the reaction that leads to laser action in the rare-gas halide molecules offers many advantages over electron beam and electron beam stabilized discharge initiation. When an electron beam is used in the initiation of a nonchain reaction laser process, the transmission of the electrons through the foil separating the electron-gun vacuum chamber from the laser cavity is a limiting factor in the determination of highest average laser power. A pinching of the electron beam because of its self-magnetic field limits the laser volume that can be initiated, and heating of the foil limits the maximum repetition rate at which the laser can be operated. Direct-discharge initiation does not suffer from either of these problems; consequently, if a volumetrically uniform discharge can be maintained, this form of initiation has the possibility of producing lasers of higher average power than those employing some form of electron-beam initiation.

The discharge characteristics and construction of the fast-discharge apparatus have been described elsewhere.[8] The discharge apparatus is of Blumlein-type construction with an active volume of 0.6 cm × 0.33 cm × 50 cm = 10 cm^3, where 0.33 cm is the discharge height. The discharge risetime is 5 nsec, and the duration (FWHM) is 10 nsec. The discharge voltage can be varied from 5 to 20 kV and the gas pressure from 20 to 700 Torr. The most important feature of this type of discharge device, however, is its flexibility. Both line impedance and electrode spacing can be varied, making it capable of operating at high sample pressures without arc formation.

The laser cavity for these experiments consists of two dielectrically coated mirrors (Valpey Corporation). One mirror has a 4-m radius of curvature and a reflectivity of 98.5%. The other mirror is flat, with an antireflective coating on its back surface and a reflectivity of 95%, which yields an output coupling of 5%. Both mirrors are internally mounted to avoid losses resulting from the windows and are separated by 90 cm.

Initial experiments were performed with a gas mixture and input energy similar to that used to produce fast-discharge-initiated laser action in the XeF^* molecule;[7] gas ratios of He:Kr:NF_3 = 100:3:1 were used. These experiments proved to be inconclusive. The discharge, which had been relatively uniform in the XeF experiments, became highly striated with considerable arc and streamer formation.

In order to determine the optimal gas pressure and composition conditions to demonstrate laser action, preliminary experiments were performed to monitor the KrF^* chemiluminescence produced in a discharge apparatus described elsewhere.[9] The detection system consists of an optical multichannel analyzer (SSR 1205A) with a silicon intensified head for increased sensitivity as the detector mounted on a modified 1/4-m spectrograph (Jarrell-Ash). The detection system was placed within a double-walled screen room to minimize electrical pickup. All gas samples were prepared by mixing the components in a 3.8-l stainless-steel sample bottle with a mixing sting to ensure uniform mixing. As further assurance of proper sample mixing, the He gas, which accounted for 90% of the mixture, was added last. Emission on the KrF $^2\Sigma^+_{1/2}$ - $^2\Sigma^+_{1/2}$ transition was monitored.

The results of these studies indicate that KrF^* chemiluminescence increases with increasing gas sample pressure (fixed composition) to 700 Torr. Standard conditions of He:Kr:NF_3 = 100:3:1 were chosen, and the gas composition was varied. Variations in the He:Kr ratio indicate a maximum chemiluminescence output at He:Kr $\cong$ 10 with the intensity decreasing slowly with changes in the He:Kr ratio. Variations in Kr:NF_3 ratio at He:Kr = 10 produced much greater changes in the chemiluminescence output. The maximum intensity was found at Kr:NF_3 $\cong$ 50:1, decreasing rapidly on either side of this ratio. By means of these experimental results, a gas composition of He:Kr:NF_3 = 500:50:1 was determined to be optimal for the production of KrF^* in our electrical discharge device.

With this optimal gas composition and a sample pressure of 400 Torr (below this pressure the gas sample provided insufficient insulation and spontaneous discharges occurred), laser action on the $^2\Sigma^+_{1/2}$ - $^2\Sigma^+_{1/2}$ transition in KrF^* was observed when the gas mixture was initiated with the fast-discharge device. Laser output was found to be exceedingly sensitive to the alignment of the optical cavity, which indicates that the laser was not operating in a superfluorescent manner, even though the radiative lifetime of the upper laser level ≅ 20 nsec.[7]

The lasing output was found to increase linearly with increasing gas sample pressure to 700 Torr, the maximum pressure allowable in our device. Maximum output energy to date is 0.8 mJ measured with a pyroelectric joulemeter (Molectron J3-05) at a sample pressure of 700 Torr and a charging voltage of 8 kV. Since the overall electrical energy input to the discharge circuitry was 1.5 J and the active volume 10 cm^3, an output energy of 0.8 mJ corresponds to an output energy density of 80 mJ/l and a "wall plug" efficiency of 0.04%. As has been discussed previously,[8] however, because of the mismatch of discharge impedance with the plasma impedance, only a small fraction of the energy in the discharge is actually deposited in the gas sample; the remainder is dissipated as heat in the Blumlein itself. Consequently, from the analysis of Ref. 8, the electrical energy deposited in the gas sample equals one-half the average discharge current times the product of the discharge voltage and the pulse duration. By a comparison of this input energy (matched line and plasma impedances) with the measured laser output energy, an electrical efficiency of 0.25% was found.

The laser temporal history was monitored by means of a fast-vacuum photodiode (ITL, 100 psec risetime) and an oscilloscope (Tektronix 7844). The risetime of the detection system was calculated to be <3 nsec. Typical KrF^* laser temporal histories are shown in Fig. 1, which is a multiple exposure of three consecutive shots. The laser pulse durations were found to vary by $<5\%$, with a pulse duration (FWHM) $\sim$25 nsec. On the basis of the observed pulse shape and laser output energy, the peak laser power was calculated to be 32 kW. Repetition rates of $\leq$20 Hz have been demonstrated, with little or no power degradation. The laser emission was sufficiently intense to produce bright fluorescence from a dye cell filled with Rhodamine 6G placed behind the output coupling mirror.

The spectral distribution of the laser output was measured with a 1/2-m grating spectrograph (Jarrell-Ash). Figure 2 is a typical photograph of the spectrum. The short lines are the laser output, and the long lines are Hg arc lines superimposed as calibration. Laser action is observed on two lines; the stronger at 248.5 nm, and the weaker at 249.5 nm. The reason for the double-line laser emission is presently unknown; however, it may possibly be due to the spin-orbit splittings in either the F or Kr

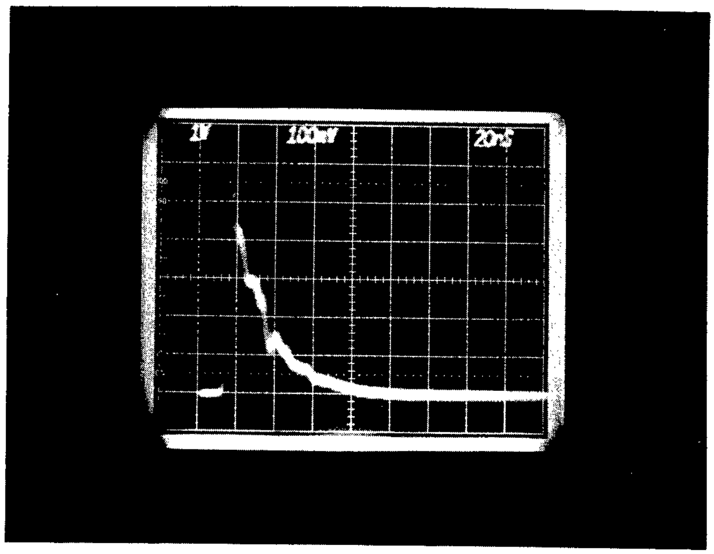

Fig. 1. Temporal History of KrF Laser Pulse. Sensitivity was 1 V/cm. Sweep speed was 20 nsec/cm. Laser emission was viewed through a uv filter centered at 2537 Å with a 200 Å bandwidth.

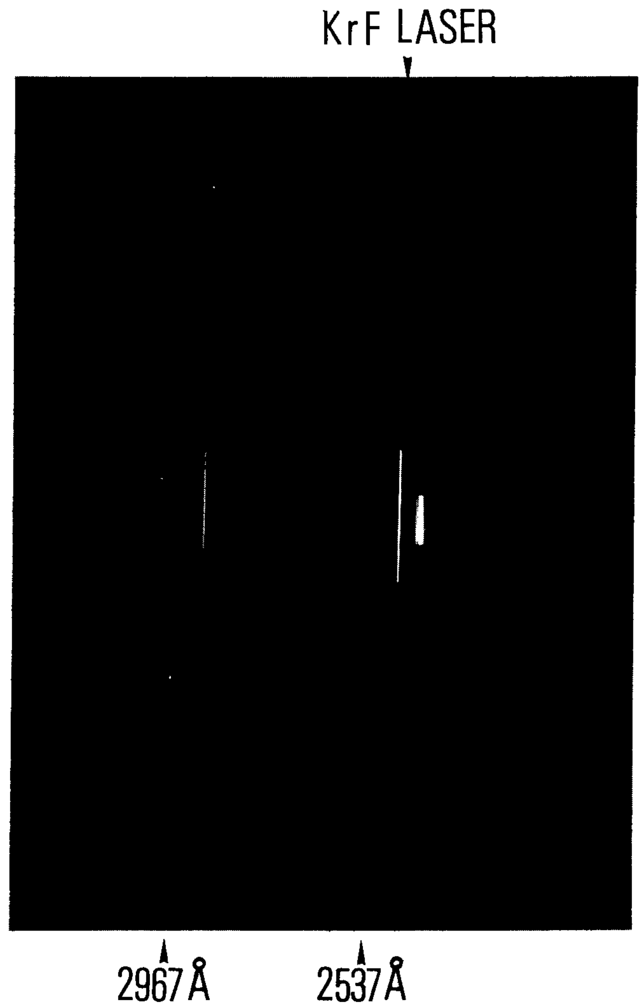

Fig. 2. Spectrum of Laser Emission. Short lines are the result of laser emission (1-shot exposure with 50-μm slits). Long lines are from Hg calibration lamp.

atoms in their ground or first excited states. Similar laser lines have been observed by Mangano et al.[7] in an electron-beam-stabilized discharge; however, only the 248.5-nm laser line has been observed in direct electron-beam-initiated devices.[3]

REFERENCES

1. J. E. Velazco and D. W. Setser, J. Chem. Phys. 62, 1991 (1975).
2. S. K. Searles and G. A. Hart, Appl. Phys. Lett. 27, 243 (1975).
3. J. J. Ewing and C. A. Brau, Appl. Phys. Lett. 27, 350 (1975).
4. E. R. Ault, R. S. Bradford, and M. L. Bhaumik, Appl. Phys. Lett. 27, 413 (1975).
5. R. Burnham, D. Harris, and N. Djeu, "Transverse Electric Discharge Lasers in N_2^+ and XeF," presented at the Second Summer Colloquium on Electronic Transition Lasers, Woods Hole, Mass. 17-19 September 1975 (to be published).
6. C. P. Wang, H. Mirels, D. G. Sutton, and S. N. Suchard, ATR-76(8210)-2, The Aerospace Corporation, El Segundo, California (15 November 1975).
7. J. A. Mangano and J. H. Jacob, Appl. Phys. Lett. 27, 495 (1975).
8. C. P. Wang, Rev. Sci. Inst. 47, 56 (1976) (to be published).
9. S. N. Suchard, L. Galvan, and D. G. Sutton, Appl. Phys. Lett. 26, 521 (1975).