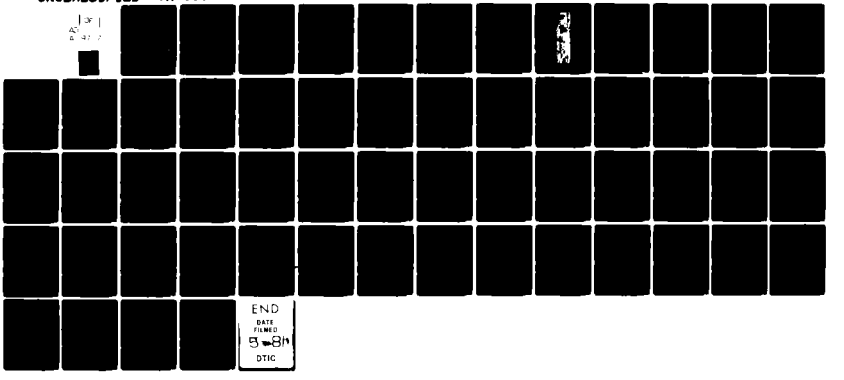
AD-A097 979 AEROSPACE CORP EL SEGUNDO CA AEROPHYSICS LAB F/G 20/5
SUMMARY OF THE AEROSPACE CORPORATION CHEMICAL LASER PROGRAM, 19--ETC(U)
APR 80 W R WARREN F04701-80-C-0081
UNCLASSIFIED TR-0081(6606)-1 SD-TR-81-14 NL



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REPORT SD-TR-81-14

Summary of The Aerospace Corporation Chemical Laser Program, 1968 – 1980

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El Segundo, Calif. 90245

Interim Report

April 1980

Prepared for
AIR FORCE WEAPONS LABORATORY
Kirtland AFB, New Mexico 87117

SPACE DIVISION
AIR FORCE SYSTEMS COMMAND
Los Angeles Air Force Station
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This interim report was submitted by The Aerospace Corporation, El Segundo, CA 90245, under Contract No. F04701-80-C-0081 with the Space Division, Deputy for Advanced Technology Division, P.O. Box 92960, Worldway Postal Center, Los Angeles, CA 90009. It was reviewed and approved for The Aerospace Corporation by M. T. Weiss, Vice President and General Manager, Laboratory Operations. Lieutenant James Garcia, SD/YLXT, was the project officer for Technology.

This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

James C. Garcia, Lt, USAF
Project Officer

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Director of Advanced Space Development

FOR THE COMMANDER

William Goldberg, Colonel, USAF
Deputy for Technology

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: SD-TR-81-14	2. GOVT ACCESSION NO.: AD-A097979
3. RECIPIENT'S CATALOG NUMBER:	
4. TITLE (and Subtitle): SUMMARY OF THE AEROSPACE CORPORATION CHEMICAL LASER PROGRAM, 1968 - 1980	5. TYPE OF REPORT & PERIOD COVERED: Interim
	6. PERFORMING ORG. REPORT NUMBER: TR-0081(6606)-1
7. AUTHOR(s): Walter R. Warren, Jr	8. CONTRACT OR GRANT NUMBER(s): F04701-80-C-0081
9. PERFORMING ORGANIZATION NAME AND ADDRESS: The Aerospace Corporation, El Segundo, Calif. 90245	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 1216
11. CONTROLLING OFFICE NAME AND ADDRESS: Air Force Weapons Laboratory, Kirtland AFB, New Mexico 87117	12. REPORT DATE: April 1980
	13. NUMBER OF PAGES: 58
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Space Division, Los Angeles Air Force Station, Los Angeles, Calif. 90009	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Chemical Lasers	Laser Diagnostics
CW Lasers	Laser Effects
Electronic Transition Chemical Lasers	Laser Eye Safety
High Energy Lasers	Laser Fluid Dynamics
Laser Chemical Kinetics	Lasers for Fusion

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The applied research work since 1968 of Aerophysics Laboratory personnel in high-energy laser-related technology areas has been summarized. The results covered are primarily concerned with hydrogen halide chemical lasers. The eight principal technology areas identified are hydrogen halide laser devices, hydrogen halide chemical kinetics (neutrals), pulsed hydrogen fluoride, HF (and deuterium fluoride, DF) lasers, fluid dynamics -- CW HF (DF) supersonic diffusion lasers, laser device optics, short wavelength lasers, diagnostics -

DD FORM (FACSIMILE) 1473

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19. KEY WORDS *(Continued)*

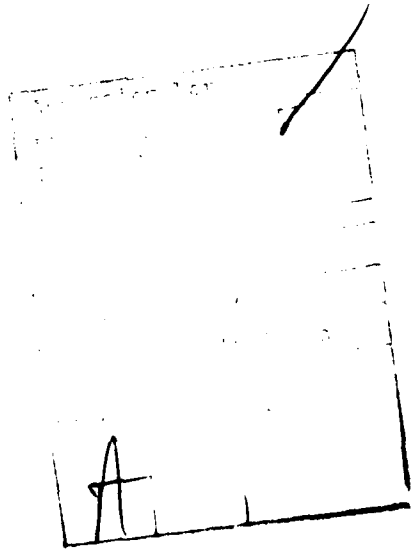
Laser Isotope Separation
Laser Modeling
Laser Propagation
Pulsed Lasers
Rare Gas Halide Lasers
Resonator Optics
Rotation-Vibration Lasers
Supersonic Diffusion Lasers
Vibrational Transition Lasers

20. ABSTRACT *(Continued)*

instrumentation/test techniques, and special studies; several subdivisions are given for each area. A comprehensive Bibliography and a list of laser related inventions are presented; these are cross-referenced to the technology areas and their subdivisions. The experimental and computer capabilities of the Laboratory are described briefly.

CONTENTS

FIGURE



I. INTRODUCTION

This report summarizes approximately twelve years of contributions of personnel of the Aerophysics Laboratory, The Aerospace Corporation, to the development of high-energy laser technology for Air Force and other DoD applications. The work has been primarily concerned with hydrogen halide chemical lasers. Aerospace demonstrated early competence in the field with the invention, in 1969, and the subsequent development, of the supersonic diffusion hydrogen fluoride, HF, (and deuterium fluoride, DF) CW chemical laser. The Aerophysics Laboratory has had two principal functions in this area: first, applied research studies have been conducted in basic and advanced technologies of chemical lasers both to promote the growth of HF and DF chemical lasers to application level devices and to develop new, higher-performance chemical laser concepts; and second, program support and technical review assistance have been provided for government laboratory and contractor programs at the request of the program managers of the supporting government agencies. The latter function has taken several forms: (1) conduction of laboratory experiments, computer analyses, theoretical studies, and field tests in support of contractor and government laboratory programs, (2) lending of laboratory equipment and diagnostic tools to government and contractor laboratories, (3) assistance in the development of experimental techniques at government laboratories and contractor facilities, (4) delivery of operational computer codes to contractors and government agencies (more than 40 cases), (5) participation as technical advisors in proposal review and contractor program meetings. These support and assistance activities are not included in this report except for those cases where original contributions were made to a program but were not related to a laboratory study.

The major source of funding for the Aerophysics Laboratory's chemical laser program has been provided, since FY 1970, by the Air Force Weapons Laboratory (AFWL). Other Department of Defense (DoD) support has been from the Air Force Space Division (SD, formerly SAMSO), the Defense Advanced Research Projects Agency (DARPA), the Navy, the Army, and the AF Geophysics

Laboratory. The support of the DoD agencies is administered through the basic SD contract with The Aerospace Corporation, currently Contract No. F04701-79-C-0030. Funding also has been provided by The Aerospace Corporation under The Aerospace Sponsored Research Program, by the Department of Energy, (DOE) and by the National Science Foundation (NSF). Several studies were partly sponsored by two or more of these agencies. AFWL funding is coordinated each fiscal year through a new Memorandum of Agreement, which is concurred with by the Head, Advanced Radiation Technology Office (AR), AFWL, and by the Vice President and General Manager of the Laboratories Operation, The Aerospace Corporation. Currently, the program managers for AFWL and Aerospace are Lt. Col. D. S. Olson, Head, Chemical Laser Branch (ARAC) and Dr. W. R. Warren, Jr., Director, Aerophysics Laboratory.

The topics referred to in this report comprise many disciplines and types of activities and are presented only in summary and reference form. More than 460 unclassified papers and technical reports have been published on most aspects of the work done in the Laboratory. A bibliography in chronological order is included. Those interested in any aspect of the referenced work are encouraged to contact authors directly for copies of the technical reports and papers and for any discussion of their content.

A list is given of invention disclosures submitted and patents awarded in connection with this work; 29 disclosures were made, 8 U.S. patents and 1 Canadian patent have been issued, and action is pending on 10 disclosures.

The Aerophysics Laboratory occupies approximately 23,000 ft^2 in Building 130 of the Los Angeles Air Force Station, El Segundo, California. Figure 1 is a photograph of the eastern end of Building 130, where the Laboratory is housed; many of the experimental support facilities (gas and liquid storage, Marx bank, vacuum pumps, water cooling towers, scrubbers, gas bottle farm, and substation) are located external to the building. Experimental facilities in the Laboratory involved in laser studies include: three arc-driven CW chemical lasers (less than 5 kW), an electron beam discharge (or electron-beam alone) initiated pulsed chemical laser (1-m length), a 15-cm-diameter shock tube-pulsed laser chemical kinetics facility, several glow discharge flow

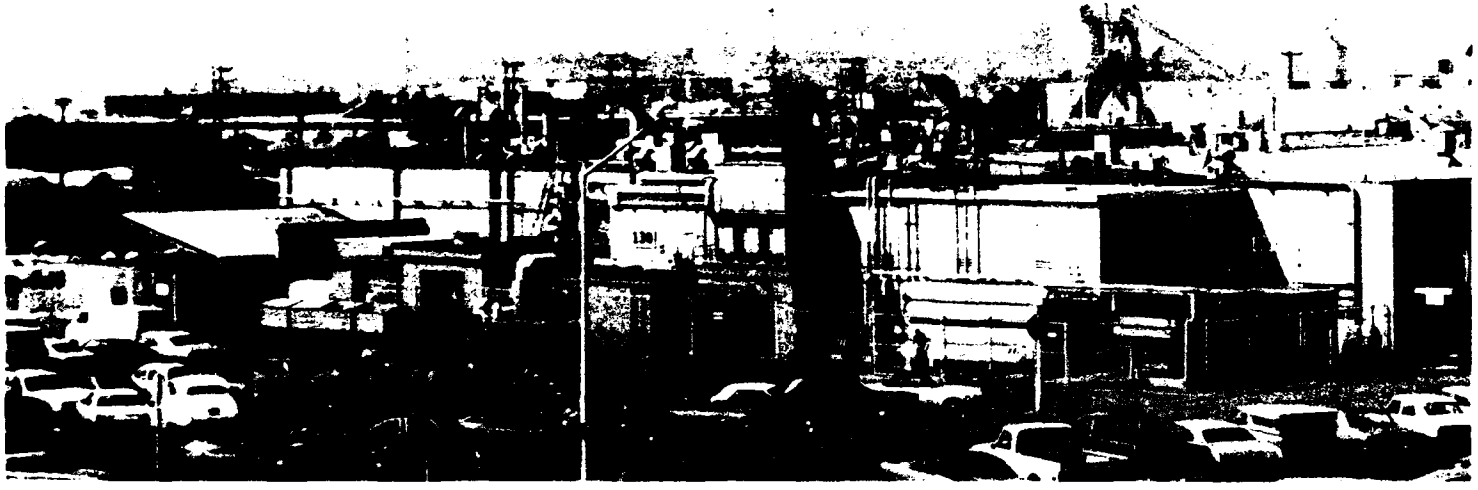


Figure 1. The Aerophysics Laboratory of The Aerospace Corporation. The Laboratory occupies approximately 23,000 square feet in the east end of Building 130 of the Los Angeles Air Force Station in El Segundo, California. Many experimental support facilities are located external to the building and on its roof - gaseous/liquid chemicals storage, Marx bank, vacuum pumps and scrubber system, water cooling towers, toxic gas handling area, gas bottle farm, electric power substation, laser beam transfer system, and vacuum hood exhausts.

tubes, a repetitively pulsed 20-cm-diameter clear aperture CO_2 laser optics test facility, five CW probe chemical lasers, a 43-cm-diameter shock tube-tunnel, several pulsed chemical and excimer lasers, a cylindrical flow chemical laser device, a plasma kinetics facility, an IR vidicon laboratory, a beam transfer and pointing system for projecting low power laser beams through the atmosphere, a laboratory for the measurement of species concentrations with high sensitivity, a vacuum facility for laser effects studies, and a self-contained toxic gas flow facility. Many diagnostic techniques, developed specifically for the Laboratory's laser studies, as well as a large number of state-of-the-art commercial instrumentation techniques, are available for use in experimental laser studies. A mini and microcomputer system utilizing a PDP 11 computer is used in the support of several experimental studies and is continuously being upgraded for new laboratory applications. The Laboratory is supported by the Company's computer center (CDC 7600, IBM 3033, and CDC 6400), machine shop, optics shop, glass shop, and instrument center.

II. SUMMARY OF LABORATORY RESULTS

In this section, chemical laser and related technology areas studied by the Aerophysics Laboratory are divided into eight general categories. There are several subdivisions for each category. Publications by Laboratory personnel related to each technology area are indicated by noting their first authors; the reader is referred to the Bibliography for specifics. Where there is not yet a report or publication for reference, the Aerophysics Laboratory staff member(s) most closely related to the subject is indicated by a private communication (PC) note. Inventions related to areas are also noted; the description and status of each invention is given in the Appendix.

A. HYDROGEN HALIDE LASER DEVICES

Technology	First Author	Publications	Invention Disclosures (ID)
Early Technology Demonstrations (Including Gas Dynamic Lasers)			
1. DF/CO_2^* Transfer Laser	Gross	1969a	
2. $F_2O/H_2/HF^*$ Photolysis and Shock-Driven Lasers	Gross	1968c; 1969b	ID 69-16
	Giedt	1969b	
	Suchard	1971	
3. Arc-Heated Gasdynamic (N_2/CO_2^*) Laser and Applications	Spencer (PC)		
CW Lasers	Gross	1976b	
1. Supersonic Diffusion HF (DF) Laser	Spencer	1969a,b; 1970a,b,c; 1972a,b; 1973c; 1974b	ID 69-22, ID 72-4
	Durran	1970	
	Kwok	1970a,b; 1972b; 1974a	
	Mirels	1970; 1972a; 1976b; 1978	
	Warren	1970; 1971; 1973; 1974; 1975; 1978b; 1979a	
	King	1972	
	APRL**	1972	
	Emanuel	1972a	
	Hofland	1972	
	Klopotek	1973	
	Varwig	1973b; 1975a,b	
	Chodzko	1976e	
	Giedt	1979	
2. MESA Program	Giedt	1970-1974; 1973; 1975	ID 69-22
	Bott (PC)		
	Spencer	1972a	
	Klopotek	1973	
	Kwok	1973b; 1974b,c; 1975a	
	Varwig	1973a	
	Chodzko	1976a,d	
	Nagai	1974	
	Warren	1975	
3. Probe Lasers	APRL**	1972	
	Chodzko	1973a; 1976c	
	Spencer	1973a; 1974a; 1977d	
	Varwig	1973	

**Aerodynamics and Propulsion Research Laboratory

A. HYDROGEN HALIDE LASER DEVICES (Continued)

Technology	First Author	Publication	Invention Disclosures (ID)
CW Lasers			
3. Probe Lasers	Shimabukuro	1976	
	Beggs	1980	
Pulsed Chemical Lasers			
1. Photolysis-Initiated Chain Lasers	Suchard	1972, 1973a,b,d,e; 1974a,e	
	Warren	1974; 1975	
	Hofland	1979	
2. Electrically Efficient Chain Lasers	Kerber	1973c	
	Suchard	1973d	
	Warren	1974	
	Whittier	1974	
3. E-Beam/Discharge Lasers	Hofland	1973; 1974; 1975; 1976	
	Warren	1974; 1975	
	Mirels	1979a	
	Whittier	1979	
4. On-the-Fly F_2 from NF_3 Storage	Warren	1979a	ID 75-18
5. Probe Lasers	Chodzko	1973b	
	Spencer	1973a,d	
6. Discharge/Cold Reaction Lasers	Mayer	1971; 1973	
	Taylor	1971; 1973; 1974	
	Kwok	1972c	

B. HYDROGEN HALIDE CHEMICAL KINETICS (NEUTRALS)

Chemical Systems		
1. H_2/F_2, Other HF Systems - SF_6/H_2; SF_6/HI; NF_3/H_2; ClF, ClF_3/H_2, CH_4	Jacobs	1966
	Bott	1971a,b; 1972a; 1973b,c; 1974a,d,e; 1975a,b; 1976c,f; 1977a,b; 1978a; 1980a
	Cohen	1971; 1972a,b; 1976a,b,c; 1978
	Warren	1971; 1974; 1975
	Wilkins	1971; 1972a,b; 1973a,b,c,d; 1974a,b,c; 1976a,b; 1977a,b; 1978b,c; 1979
	Kwok	1972c; 1975a,b,c,d,e
	Mayer	1973; 1979
	Suchard	1973b,d,f,g
	Taylor	1973
	Heidner	1975a; 1979a; 1980b
2. D_2/F_2	Bott	1972b; 1974b,c,e; 1975a,b,d; 1976a,b,d,f; 1979; 1980b
	Suchard	1973a
	Wilkins	1973b,d; 1974b,c; 1977b; 1978a,b; 1979
	Cohen	1974b; 1976b; 1977
	Heidner	1975a; 1979a; 1980b
	Kwok	1975b,d; 1977b
	Warren	1975

B. HYDROGEN HALIDE CHEMICAL KINETICS (NEUTRALS) (Continued)

Technology	First Author	Publications	Invention Disclosures (ID)
Chemical Systems			
3. DF/CO_2	Bott	1973a; 1976d	
	Kerber	1973a,b	
	Suchard	1974a	
	Warren	1975	
4. H_2/Cl_2, D_2/Cl_2, H_2/Br_2	Jacobs	1968b	
	Giedt	1968; 1969a; 1971	
	Cohen	1969; 1972c; 1974a; 1975; 1976b	
	Emanuel	1973a	
	Taylor	1974	
	Bott	1975c; 1976d,e,f	
	Wilkins	1975a,b; 1976b	
	Heidner	1976	
5. Other Systems -- SF_6, UF_6, H_2S, etc.	Wilkins	1968	
	Gross	1973	
	Bott	1977b; 1978b	
	Cohen	1979; 1980	
Theory/Modeling			
1. Computer Codes (NEST, RESALE, DESALE 1-5, ADM)	Jacobs	1965; 1966	
	Wilkins	1968	
	Cohen	1969; 1974a	
	Emanuel	1972a,b,e; 1973a	
	Kerber	1972; 1973a	
	Turner	1973	
	Adams	1975	
	Foster	1976; 1980	
	Herbelin	1976b	
	Epstein	1979a	
	Warren	1979b	
	Bott	1980b	
2. Analytical Models	Emanuel	1970; 1971; 1972c	
	Kerber	1973b	
	Foster	1976	
	Herbelin	1976b	
	Warren	1979b	
3. Monte Carlo Trajectory Calculations	Wilkins	1971; 1972a,b; 1973a,b,c,d; 1974a,b,c; 1975a,b; 1976a,b; 1977a,b; 1978a,b,c; 1979	
	Kwok	1976	
	Bott	1977b	
4. Einstein Coefficients for Diatomic Molecules	Herbelin	1974a	
Experiment			
1. Vibrational Relaxation, Several v-Levels	Jacobs	1966	
	Gross	1968a,b; 1974a	
	Giedt	1969a	
	Kwok	1970a,b; 1972a,b,c; 1973a,b,c; 1974a; 1975a,b,c,d,e; 1977b	
	Bott	1971a,b; 1973a,b,c; 1974a,b,c,d,e; 1975a,b,c,d; 1976a,b,c,d,e,f; 1978a; 1979; 1980a,b	

B. HYDROGEN HALIDE CHEMICAL KINETICS (NEUTRALS) (Continued)

Technology	First Author	Publications	Invention Disclosures (ID)
Experiment			
1. Vibrational Relaxation, Several v-Levels	Taylor	1971; 1973	
	Warren	1971	
	Bott	1972a,b	
	Cohen	1972a; 1976a; 1979	
	Mayer	1973	
	Suchard	1973a,b,d,f	
	Heidner	1975a	
	Varwig	1975b	
	Wilkins	1978c	
2. High Rotational Levels	Wilkins	1978c	
	Cohen	1979	
	Kwok	1980a	
3. Pumping Rates	Cohen	1969; 1971; 1972; 1975; 1976b,c; 1977; 1978; 1979	
	Giedt	1969a	
	Gross	1969a	
	Taylor	1973; 1974	
	Mayer	1979	
	Heidner	1979a; 1980b	
4. Dissociation, Recombination	Jacobs	1965; 1967; 1968	
	Giedt	1968; 1969a; 1971	
	Wilkins	1968	
	Cohen	1972c; 1979	
CW Chain Laser Performance	Warren	1978b; 1979a	
	Herbelin (PC)		
	Epstein (PC)		
NF_3 Combustion			
1. Efficient F-Atom Production	Warren	1978b; 1979a	ID 77-21
2. Ignition	Briesacher	1979	
	Mirels	1980	
O_2 Kinetics in Pulsed Lasers	Cohen (PC)		
	Hofland (PC)		

C. PULSED HF (DF) LASERS

Plasma Kinetics	Mahadevan	1976; 1978b	
	Epstein	1979b	
Theory and Modeling			
1. Early Modeling	Kerber	1970; 1972, 1976	
	Whittier	1974; 1977	
	Hofland	1975; 1976	
	Warren	1975	
2. Relaxation Oscillations	Hough	1975	
3. Line-Width Sensitivity	Hough	1975; 1977	
4. Rotational Nonequilibrium (SPIKE, SOS, and GSOS Codes)	Hough	1975; 1978a,b; 1979	
	Kerber	1978	
	Whittier	1979	

C. PULSED HF (DF) LASERS (Continued)

Technology	First Author	Publications	Invention Disclosures (ID)
Experiment			
1. Performance and Efficiency	Kerber	1973c	
	Hofland	1974; 1975; 1976a	
	Whittier	1974; 1976a	
	Warren	1975	
	DeBiase	1979	
2. Initiation	Gross	1973	
	Hofland	1973; 1974; 1975; 1976	
	Kerber	1973c	
	Whittier	1974; 1976a	
3. Spectra	Taylor	1971	
	Kwok	1972a,c	
	Suchard	1972; 1974a,e	
	Hofland	1974, 1976	
	Kerber	1978	
4. Uniformity	Hofland	1974	
5. Unstable Resonator/Beam Quality	Whittier (PC)		
Scalability Predictions	Kerber	1973c	
	Hofland	1974; 1975; 1979	
	Mirels	1979a	
	Whittier	1979	

D. FLUID DYNAMICS--CW HF (DF) SUPERSONIC DIFFUSION LASERS

Theory and Modeling			
1. Simplified Kinetics and Mixing Coupling	Mirels	1970; 1972a; 1978	
	Warren	1971; 1973; 1974a,b; 1975	
	APRL	1972	
	Epstein	1979a	
2. Flame Sheet Model	Hofland	1971; 1972	
	APRL	1972	
3. General Scaling Laws	Hofland	1971, 1972	
	APRL	1972	
	King	1972	
	Mirels	1972a; 1975; 1976b; 1978	
	Warren	1973; 1974; 1975; 1978b; 1979a,b	
4. "Exact" Numerical Solutions	King	1972	
	Warren	1972b	
5. Reynolds Scaling	Warren	1973; 1975; 1978b; 1979a	
	Spencer	1974b	
6. Boundary Layer Effects			
a. Supersonic	APRL	1972	
	Mirels	1977	
	Warren	1978b; 1979a	
b. Subsonic and Supersonic	Mirels	1977a	
	Warren	1978b; 1979a	

D. FLUID DYNAMICS--CW HF (DF) SUPERSONIC DIFFUSION LASERS (Continued)

Technology	First Author	Publications	Invention Disclosures (ID)
Theory and Modeling			
6. Boundary Layer Effects			
c. F_2 Recombination and Surface Catalysis	Mirels	1977	
	Spencer	1977a,b,c; 1978a	
	Warren	1978b; 1979a	
7. Heat Release Effects			
a. Confinement - One-D Modeling, Pressure Rise, Const. Area/ Constant P Constraints, Edge Effects/Scaling, Choking	Warren	1970; 1971; 1973; 1974; 1975; 1978b; 1979a	
	Spencer	1973c; 1974b	
	Durran	1975	
b. Reaction Shock Waves	Warren	1973; 1978b; 1979a	
c. Base Relief, Conical/ Radial Flow Expansion Relief	Warren	1970; 1973; 1975; 1978b; 1979a	
	Spencer	1974b	
	Durran	1975	
d. Detonation Criteria/ Models	Warren	1978b; 1979a	
e. Reaction Wakes/ Optical Path Difference Effects	Warren	1978b; 1979a	
f. Aerodynamic Diffusers	Warren	1971; 1973	
	Durran	1975	
8. Cylindrical Flow/Free Standing, Adjusting Normal Shock Front	Warren	1970; 1978b; 1979a	
	Durran (PC)		
9. Rotational Non-equilibrium DESALE Coupling	Epstein (PC)		
10. Nozzle Source Flow Effect on Lineshape	Mirels	1980c	
Experiment			
1. Slit Nozzles-Multipoint Fuel Injection, Double Slit, Triple Slit	Spencer	1969a,b; 1970a,b,h; 1972a,b; 1973c; 1974b	ID 69-22
	Giedt	1970-1974; 1973; 1975a,b; 1979	
	Mirels	1970; 1976b	
	Warren	1971; 1975	
	APRL	1972	
	Kwok	1972b; 1973c; 1974a,c	
	Varwig	1972a; 1973a,b; 1974; 1976	
	Chodzko	1973b	
	Durran	1973	
	Klopotek	1973	
	Gross	1974	

D. FLUID DYNAMICS--CW HF (DF) SUPERSONIC DIFFUSION LASERS (Continued)

Technology	First Author	Publications	Invention Disclosures (ID)
Experiment			
2. Axisymmetric Array Nozzles/Co-Axial Fuel Injection	Durran	1970	
	Giedt	1970-1974; 1975a,b; 1979	
	APRL	1972	
	Spencer	1972	
	Kwok	1974c	
	Warren	1975a	
	Mirels	1976b	
	Varwig	1976	
3. Nitrogen Versus Helium Diluent	Spencer	1972b	
	Warren	1975	
4. Cylindrical Nozzle Bank - Free Standing Normal Shock Front	Durran (PC)		
	Warren (PC)		
5. Gain	Chodzko	1973b; 1976c	
	Warren	1975a	
6. Aerodynamic Diffusers	Durran	1975	
7. MESA Program	Giedt	1970-1974; 1973; 1975a,b	
	Warren	1975	
a. Flow Uniformity	Spencer	1972a	
	Varwig	1972a; 1976a	
b. Performance as Function of Parameters	Spencer	1972a	
c. Base Relief Data	Spencer	1972a	
d. Slit/Axi Nozzle Data Comparisons	Spencer	1972a	
	Warren (PC)		
	Mirels	1976b	
e. Closed Cavity Performance - Variable Mode Length	Spencer	1972a	
	Durran	1974	
f. Reacting Flow Mach Number Data	Giedt	1970-1974	
	Spencer	1972a; 1973c	

E. LASER DEVICE OPTICS

Theory/Modeling			
1. Unstable Resonator Coupled with Gain Medium	Mirels	1972b; 1974	
	Chodzko	1973a; 1974a	
	Warren	1974a,b; 1975	
2. Oscillator/Amplifier Applications	Emanuel	1972d	
3. Chem. Laser Mode-Medium Interaction	Mirels	1976a	

E. LASER DEVICE OPTICS (Continued)

Technology	First Author	Publications	Invention Disclosures (ID)
Theory/Modeling			
4. Inhomogeneous Broadening in Flowing CW Chemical Laser	Mirels	1979b; 1980b,c	
5. Asymptotic Theory/ Unstable Resonator with Continuous Medium Coupling	Ellinwood (PC)		
6. Quantum Theory	Roehrs	1972	
7. Nozzle Source Flow Effect on Lineshape	Mirels	1980c	
Experiment			
1. Stable Resonator - Single/Multiple Modes	Giedt Durran Warren	1973 1974 1975	
2. Unstable Resonators/ Multiline	Giedt Warren	1973 1975	
a. Edge Coupled	Chodzko	1976a,d	ID 73-21
b. Continuously Coupled	Chodzko	1973a	
c. Asymmetric	Chodzko	1976d	ID 73-21
3. Line Selected Resonators			
a. Single Selected Line	Chodzko Spencer Warren Beggs	1973a; 1976c 1973a; 1974a 1975 1980	
b. Two (Multiple) Selected Lines	Chodzko Warren	1974a 1975	ID 73-20
4. Annular Gain Region Resonators			
a. Converging Wave Resonator	Chodzko	1976b	ID 75-2
b. Annular I^* Test Bed	Turner	1977b	
c. 20-cm-Dia. CO_2 Test Bed (Rep Pulsed)	Turner	1980	
(1) Gain Uniformity, Medium Uniformity, Unstable Resonator Beam Quality	Chodzko Turner	1979 1980	

E. LASER DEVICE OPTICS (Continued)

Technology	First Author	Publications	Invention Disclosures (ID)
Experiment			
(2) Half Symmetric Unstable Resonator with Internal Axicon (HSURIA) Beam Quality - Rear Cone, Annular Leg/Compact Leg	Chodzko	1979	
(3) HSURIA Beam Quality-Rear Cone, Polarization Nonuniformity/Scrambling	Chodzko	1979	
(4) HSURIA Beam Quality Rear Flat	Chodzko	1979	
(5) HSURIA Beam Quality Rear Corner Cube	Chodzko (PC) Turner (PC)		
(6) Strut Effects	Chodzko (PC) Turner (PC)		
(7) Surface Figure Effects	Chodzko (PC) Turner (PC)		
(8) Tip Region Flux Levels	Chodzko (PC) Turner (PC)		
(9) Nonlinear Reflaxicon Performance	Chodzko (PC) Turner (PC)		
5. Anomalous Dispersion Effects			
a. Steering, Phase Distortion of Multiline Beam	Chodzko (PC) Mason (PC)		
b. Mode Pulling	Wang Chodzko (PC)	1976b	
c. Index Measurements/ IR Interferometer	Gross	1979	
d. Theoretical Prediction	Mirels	1979b	
6. Frequency Stability			
a. Basic Stability HF Laser	Wang	1975c,e; 1976b	
b. Stability Control/ Anomalous Dispersion Techniques	Wang	1975c; 1976b; 1977d	ID 75-26

E. LASER DEVICE OPTICS (Continued)

Technology	First Author	Publications	Invention Disclosures (ID)
Experiment			
6. Frequency Stability			
c. Mode Stability, Adaptive Control	Wang	1975f; 1976b; 1977d; 1978g,h; 1979b,d; 1980a	ID 78-19
	Varwig	1979	
d. Line Hopping/ Rotational Nonequilibrium	Chodzko (PC) Gross (PC) Bernard (PC)		
Very High Reflectivity Mirror Development	Herbelin	1980a,b,c	ID 78-25
Large Scale Device Concepts			
1. Linear/Cylindrical Geometry Comparisons	Warren (PC)		
2. Phase Matching/Multi-line Lasers			
a. Parallel Internal MOPA - Concept/Equal Path Length Control Technique and Demonstration	Warren Gross	1978a 1980	ID 79-10
b. Master and Slave Oscillator Array - Concept/Mode Stabilization Technique and Demonstration	Wang	1977c; 1979b,d; 1980	ID 79-20

F. SHORT WAVELENGTH LASERS

	Warren	1975
	Sutton	1977
Theory/Modeling		
1. Spectroscopic Compendia	Suchard	1974b,c,d; 1975a; 1976a,b
2. Modeling, Computer Codes - HELP, DELPHI	Herbelin	1974b
	Sutton	1975d,e
	Steinfield	1979
	Kwok	1980b
Experiment		
1. Diatomic Molecule Systems	Capelle	1975; 1976a,b
	Field	1975a
2. Atomic Lasers	Sutton	1975a,b,c,f
	Spencer	1978b
3. N_2^*/SF_6 Long Lifetime Lasers	Heidner	1975a,b
	Suchard	1975b,c; 1976d
NF Chemical Systems		
1. Kinetics	Herbelin	1973; 1976a,c
	Kwok	1977a

F. SHORT WAVELENGTH LASERS (Continued)

Technology	First Author	Publications	Invention Disclosures (ID)
NF Chemical Systems			
2. Direct - NF(a) to NF(x)	Herbelin Kwok	1977a; 1980a,b 1980b	ID 76-21
3. Transfer to NF(b)/ Pumping by I* Laser	Herbelin	1976a; 1977b	ID 76-21
4. Transfer - NF(a) to Atoms/Bi*	Capelle Sutton	1977; 1978b 1978a	
O_2/I* Transfer Chemical Laser	Heidner	1977; 1979b	
Rare Gas Halide Lasers - KrF, XeF			
1. Fast Discharge Pumped Lasers	Sutton Wang	1975g 1975b,d; 1976a; 1978a,b,c,e,f	ID 75-9
2. 2 KHz, 15 W Av. Power Laser Demonstration in Flowing Gas System/ Scalability of Rep Rate and Power	Wang	1977b; 1978a,b,c,e,f	
3. KrF Pumped, Tunable UV Dye Laser	Sutton	1976a,b	ID 76-31

G. DIAGNOSTICS--INSTRUMENTATION/TEST TECHNIQUES

Closed Cavity Calorimeter, Continuously Variable Mode Length	Spencer	1969b; 1970a,b,c; 1972a,b; 1973c	ID 70-10
	Giedt	1970; 1973	ID 72-23
	Mirels	1970	
	APRL	1972	
	Durran	1973; 1974	
	Klopotek	1973	
Pulsed Lasers	Suchard	1974a	ID 69-16
	Hofland	1974; 1975; 1976	
	Whittier	1974; 1976a	
	DeBiase	1979	
Pulsed Probe Lasers	Chodzko	1973b	
	Spencer	1973a,d	
	Suchard	1973a	
CW Probe Lasers	Spencer	1977d	
	Beggs	1980	
1. Gain Measurements - Zero Power, Saturated	Chodzko Warren	1973b; 1976c 1975	
2. Absorption Cell	Spencer	1973a; 1974a	
3. NF Kinetics	Herbelin	1977a,b	
4. Detailed Line Gain/ Absorption Profiles (<10 MHz Resolution)	Gross	1979	
5. Selected Line IR Interferometry	Gross	1979	

G. DIAGNOSTICS--INSTRUMENTATION/TEST TECHNIQUES (Continued)

Technology	First Author	Publications	Invention Disclosures (ID)
CW Probe Lasers			
6. Single Frequency Unstable Cavity	Chodzko	1973a	ID 73-20
7. Heterodyne/Solar Absorption Measurements	Shimabukuro	1976	
MESA Program			
1. Concurrently Operated Test Components - F_2 Handling, Combustor, Nozzles, Flushing, Mirror Isolation, Bank Flows, Cooler, Steam Ejector, Field Test Procedures, Test Flexibility/Duration	Giedt	1970-1974; 1973; 1975a,b	
	Bott (PC)		
	Spencer	1972a	
	Klopotek	1973	
	Kwok	1973b; 1975	
	Chodzko (PC)		
	Nagai	1974	
	Warren	1975	
2. Diagnostic Summaries	APRL	1972	
	Varwig	1972; 1973a,b; 1974	
	Kwok	1974b,c	
	Chodzko	1976a	
Chemistry and Kinetics			
1. Spectroscopy - HF, DF, NF, I, Other Systems	Jacobs	1965; 1966; 1967; 1968a	
	Giedt	1968; 1969a; 1971	
	Gross	1968a,b; 1974a	
	Kwok	1970a,b; 1972a,b,c; 1973a,b,c; 1974a,b,c; 1975a,b,c,d,e	
	Bott	1971a,b; 1972a,b; 1973a,b,c; 1974a,b,c,d,e; 1975a,b,c,d; 1978b	
	Taylor	1972; 1973; 1974	
	Cohen	1972a,c	
	Varwig	1973a; 1974; 1975a,b	
	Mayer	1973	
	Suchard	1973a,b,d,e,f; 1974a,e	
	Heidner	1975a; 1979a; 1980b	
	Spencer	1977b	
	Wilkins	1978c	
	Sutton	1979b	
2. Sensitive F_2 Concentration (He/Cd Laser Abs.) CW/Pulsed	Suchard	1973c	ID 73-38
	Spencer	1977a,c; 1978a	ID 77-9
3. Shock Tube/Fluorescence	Bott	1972a,b; 1973a,b,c; 1974a,b,c,d,e; 1975a,b,d; 1976a,b,c,d,e,f; 1978a; 1979; 1980a,b	
	Cohen	1976a	
4. Large Flow Tubes	Kwok	1973a; 1975b,c,e; 1976; 1977b	
	Heidner	1975a; 1980b	
	Wilkins	1978c	
5. Photon Catalysis (Extreme Sensitivity Concent. Diag. Using Excit. N_2)	Capelle	1977; 1978a	ID 76-24
	Sutton	1978c; 1979a,b	
	Melzer	1979a,b	

G. DIAGNOSTICS--INSTRUMENTATION/TEST TECHNIQUES (Continued)

Technology	First Author	Publications	Invention Disclosures (ID)
Chemistry and Kinetics			
6. Mass Spectrometer/Flow Tube Tech.	Breisacher (PC)		
7. Mass Spectr. with Soft Ionization	Mahadevan Breisacher	1978a 1980	
8. Plasma Cross-Sections/ Drift Tube	Mahadevan	1976	
Visualization - Visible, IR			
1. Flow - Visible, IR Film, IR Vidicon	Kwok Varwig Spencer Warren Cross	1972a; 1973b,c 1972; 1973a,b; 1974 1973b 1973 1978, 1979	ID 75-11 ID 79-3
2. Flow - Shadow, Schlieren, Interferometry	Warren Varwig Bernard	1971 1972 1979a,b	
3. Laser Beam - IR Vidicon Techniques, Liquid Crystals, Fluorescent Surfaces (Near/Far Field Applications)	Kwok Skolnik Chodzko Cross	1972a 1973; 1974 1976a 1978; 1979	ID 73-30 ID 75-11 ID 79-3
Optics	Chodzko	1976c	
1. Variable Area Calorimetry System (VACAS) for Edge-Coupled Unstable Osc.	Chodzko	1976a,d	ID 73-21
2. Tailored Power Out-coupling	Spencer Gokcen	1968; 1970c 1976	
3. Alignment Methods	Chodzko	1973a; 1974a; 1979	ID 78-23
4. Beam Quality - Power in Bucket, Far Field Mode Visualization	Chodzko	1973a; 1974a; 1976a; 1979	
5. Annular Optics Test Beds - CO_2*, I*	Turner Chodzko	1977; 1980 1979	
6. Interferometry (M.Z., T.G., F.P.) - Visible, IR Laser Wavelengths (<10 MHz Resol.)	Varwig Chodzko Gross	1972 1979 1979	
7. "White Light" Interferometry of Multiline Beam (for Path-Length Equalization)	Gross	1980	ID 77-10
8. Single Selected Line Outcoupling	Chodzko Spencer Warren Beggs	1973a; 1976c 1973a; 1974a 1975 1980	
9. Multiple Selected Line Outcoupling	Chodzko Warren	1974a 1975	ID 73-20

G. DIAGNOSTICS--INSTRUMENTATION/TEST TECHNIQUES (Continued)

	Technology	First Author	Publications	Invention Disclosures (ID)
Optics				
10.	Differential Beam Steering	Chodzko (PC)		
11.	Mode Beating, Frequency	Wang Chodzko (PC) Mason (PC)	1976b; 1979b,d	
12.	Frequency Stabilization Anom. Disp., Other Methods	Wang	1975c,f; 1976b; 1977b	ID 75-26 ID 76-18
13.	Beam Spectral Analysis Using IR Vidicon	Kwok Chodzko Cross	1972a; 1975b 1976a 1978; 1979	
14.	Adaptive Cavity Control for Mode/Frequency Stabilization	Wang Varwig	1978g,h; 1979b,d 1979	ID 77-20 ID 78-18
15.	Polarization Techniques	Chodzko Mason (PC) Turner (PC)	1979	
16.	Local Intra-Cavity, Flux (Small Thermocouple Probe)	Chodzko (PC) Turner (PC)		
17.	Phase Front Sensors	Turner Wang	1977a 1979a	ID 79-1
18.	Photon Lifetime Technique for Resonator Losses - Reflectivity, Scattering, etc.	Herbelin	1980a,b,c	ID 78-25
19.	Dye Performance	Sutton Herbelin	1976a,b 1980c	
Fluid Dynamics				
1.	Pitot/Pitot Static P Probes/Rakes	APRL Varwig Kwok	1972 1972; 1974; 1976 1974c	
2.	Stag. T Probes/Rakes	APRL Varwig Kwok	1972 1972; 1974 1974c	
3.	Laser Doppler Velocimeter/Correlator	Wang Bernard	1976c; 1977a; 1978d; 1979c 1979a,b	
4.	Turbulence Spectral Meas. in "Transparent" Fluidized Bed Flow	Wang Bernard	1978d; 1979c 1979a,b	
5.	Cylindrical Shock Location/Motion (Pitot P/Flow Vis./Spectr. T)	Durran (PC)		
6.	Heat Transfer Measurements	Nagai	1974	

G. DIAGNOSTICS--INSTRUMENTATION/TEST TECHNIQUES (Continued)

Technology	First Author	Publications	Invention Disclosures (ID)
Fluid Dynamics			
7. Plenum Temperature	Varwig	1975a,b	
8. Absorption and Scattering Measurements in Turbulent Reacting Flows	Wang	1975a	

H. SPECIAL STUDIES

Eye Safety	Spencer	1972c; 1973b	ID 70-40
Atmospheric Propagation - HF/DF Wavelengths	Spencer Shimabukuro	1973a; 1974a 1976	
Heated Window Distortion of Laser Beam	Skolnik	1973; 1974	
CO Chemical Laser Kinetics	Cohen (PC)		
Evaluation of Sonic Sluing of Laser Beam	Ellinwood	1975a,b	
Laser Effects			
1. Materials Response - CW/Pulsed	Spencer (PC) Gokcen Whittier (PC)	 1976	
2. Sensor Response - CW/Pulsed	Spencer (PC) Whittier (PC)		
3. Pulsed Laser Beam in Vacuum - Energy/Impulse Coupling, Optical Signatures, Sensor Response	Whittier (PC)		
Atmospheric Turbulence Effects on Propagation	APRL Wang	1972 1975e	
Turbulent Laser Medium Effect on Laser Beam	APRL	1972	
Laser Isotope Separation	Mayer Gross Heidner	1971 1974b 1978	ID 74-24
Iodine Laser for Fusion	Gross	1976a	
HF Laser for Fusion	Whittier	1979	

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Mirels, H., Source Flow Effect on Lineshape, TR-0080(5764)-4, The Aerospace Corporation (submitted June 1980).

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Wang, C. P., "Competition of Longitudinal and Transverse Modes in a Chemical Laser," J. Appl. Phys. (in publication process).

[16]See Footnote 1

APPENDIX. INVENTIONS

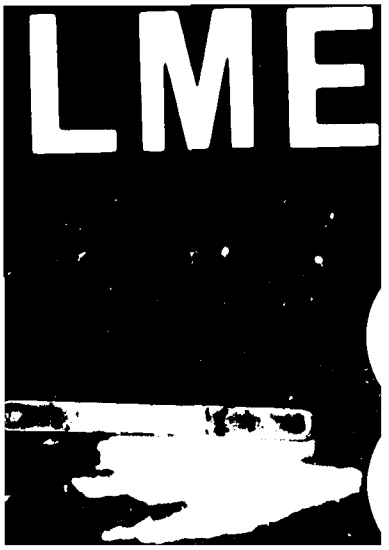
ID No.*	Title	Inventor(s)	Submittal Date Contract No. Date to Government Award Application	Action
69-16	Chemical Laser Mirror Mount	R.R. Giedt R.W.F. Gross	21 Mar 69 F04701-68-C-0200	None
69-22	Continuous Wave Chemical Laser	D.J. Spencer T.A. Jacobs H. Mirels R.W.F. Gross	27 May 69 F04601-68-C-0200 Inventor Award 20 Aug 69 Patent Application 21 Sept 70	Issued 9 Aug 72 U.S. Patent 3,688,215
70-10	Tunable Optical Cavity for Chemical Lasers	D.J. Spencer D.A. Durran H.A. Bixler	3 Apr 70 F04701-69-C-0066 Inventor Award 8 July 71 Patent Application 10 Aug 71	Issued 1 May 73 U.S. Patent 3,731,221
70-40	Laser Radiation Eye Protection	H.A. Bixler	10 Dec 70 F04701-69-C-0066 4 Feb 71	None
72-23	Mirror with Variable Radius of Curvature	D.A. Durran	11 Sept 72 F04701-72-C-0073 3 Oct 72	Patent search showed identical prior art
72-24	Jet Pump Chemical Laser	D.A. Durran	12 Sept 72 F04701-72-C-0073 1 June 73	None
73-20	Multiple Selected Line Unstable Resonator	R.A. Chodzko	22 May 73 F04701-71-C-0072 24 Aug 73 Inventor Award 28 June 73 Patent Application 29 Aug 74	Issued 23 Dec 75 U.S. Patent 3,928,817

*Aerospace Corporation invention disclosure (ID) number (fiscal year submitted - order of submission to patent council).

ID No.	Title	Inventor(s)	Submittal Date Contract No. Date to Government Award Application	Action
73-21	Calorimeter for an Edge Coupled Unstable Resonator	R.A. Chodzko	22 May 73 F04701-72-C-0073 11 Feb 74 Inventor Award 12 Dec 73 Patent Application 11 Dec 74	Issued 10 Feb 76 U.S. Patent 3,937,079
73-30	Multiple Spectral Wavelength Imaging with IR TV System	E.F. Cross M.A. Kwok D.C. Janeska	12 July 73 F04701-71-C-0072 Inventor Award 1 Mar 74 Patent Application 11 Dec 74	Issued 20 Dec 77 U.S. Patent 4,064,535
73-38	Fluorine Pressure Change Monitor	S.N. Suchard L.D. Bergerson	6 Sept 73 F04701-72-C-0073 7 Sept 73	None
74-23	Second Positive N_2 Laser	S.N. Suchard L. Galvan D.G. Sutton	18 Nov 74 F04701-73-C-0074 18 Nov 74 Inventor Award 29 Jan 75	None
74-24	Laser Isotope Separation of Titanium-50	R.W.F. Gross	1 Aug 74	No action by Company; invention deemed to be incomplete conception
75-2	Converging Wave Unstable Resonator	R.A. Chodzko Mason	29 Jan 75 F04701-74-C-0075 29 Dec 75 Inventor Award 7 Aug 75 Patent Application 24 June 77	Issued 21 Nov 78 U.S. Patent 4,126,381
75-9	Fast Electric Discharge for Pulsed Lasers	C.P. Wang O.L. Gibb	1 Apr 75 Inventor Award 9 Sept 75 Patent Application 4 May 76	Issued 2 Aug 77 U.S. Patent 4,039,971

ID No.	Title	Inventor(s)	Submittal Date Contract No. Date to Government Award Application	Action
75-11	Improved Performance IR Camera	E.F. Cross W.A. Garber	15 Apr 75 F04701-74-C-0075 18 Jan 77 Inventor Award 27 Aug 75	
			Company elected not to patent 22 Sept 76	No action by Company
75-18	Fluorine Generator	W.R. Warren, Jr D.A. Durran D.J. Spencer	7 May 75 F04701-74-C-0075 31 Oct 75 Inventor Award 7 Mar 78 Patent Application 21 Mar 78	Issued 15 July 80 U.S. Patent 4,213,102
75-26	Frequency Stabilized CW-HF Chemical Laser	C.P. Wang	1 July 75 Inventor Award 9 July 76	Pending
76-21	Enhanced NF Laser	J.M. Herbelin M.A. Kwok D.J. Spencer	20 July 76 F04701-75-C-0076 28 Mar 77	None
76-24	Analytical Photon Catalysis	G.A. Capelle D.G. Sutton S. Benson	26 Sept 76 F04701-75-C-0076 12 Jan 78 Inventor Award 7 Dec 76 Patent Application 19 Sept 77	Issued 24 Apr 79 U.S. Patent 4,150,951
76-31	KrF Laser Pumped UV Laser	D.G. Sutton G.A. Capelle	22 Dec 76	No action by Company
77-9	Sensitive Laser Spectroscopy Measurement Technique	D.J. Spencer	24 May 77 F04701-76-C-0077 19 Jan 78 Inventor Award 30 Nov 77	Pending

ID No.	Title	Inventor(s)	Submittal Date Contract No. Date to Government Award Application	Action
77-10	Control of Relative Path Lengths of Multiline Lasers	E.B. Turner	13 June 77 F04701-76-C-0077 19 Jan 78	Pending
77-20	Master and Slave Oscillator Array System for Lasers	C.P. Wang	23 Aug 77 Inventor Award 30 Nov 77	Pending
77-21	NF_3 Combustor	W.R. Warren, Jr. N. Cohen	1 Sept 77 Inventor Award 30 Nov 77	Pending
78-19	High Frequency PZT Driver by Means of Laser Doppler Sensor and Rate Feedback	C.P. Wang P. L. Smith	11 Aug 78	No action by Company; invention considered obvious application of known technique
78-23	Laser Beam Alignment Sensor	D.A. Durran	4 Dec 78 F04701-77-C-0078 21 June 79	Pending; Company recommendation deferred until successful reduction to practice
78-25	Measuring Photon Lifetime in a Resonator	J.M. Herbelin J.A. McKay M.A. Kwok R.H. Ueunten D.S. Urevig	13 Dec 78 F04701-76-C-0077 21 Dec 78 Inventor Award 21 Aug 79	Pending
79-1	Laser Beam Wavefront Analyzer	C.P. Wang R.L. Varwig	7 Feb 79 Inventor Award 13 Aug 79	Pending
79-3	Improved Image Sensor Arrays	E.F. Cross W.A. Garber O.L. Gibb	29 Mar 79 F04701-77-C-0078 4 Apr 79 Inventor Award 14 Aug 79	Pending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