A SURVEY OF ELECTRIC LASER CODES(U) LOCKHEED MISSILES AND SPACE CO INC HUNTSVILLE AL HUNTSVILLE R. F C WANG JUN-83 LMSC-HREC-TR-D784124 DRSMI/RH-CR-83-6 UNCLASSIFIED DAAH01-80-C-1289 F/G 20/5 NL
TECHNICAL REPORT RH-CR-63-6

A SURVEY OF ELECTRIC LASER CODES

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JUNE 1983

Prepared for
Directed Energy Directorate
US Army Missile Laboratory

Contract DAAH01-80-C-1289

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35898

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USE OF TRADE NAMES OR MANUFACTURERS IN THIS REPORT DOES NOT CONSTITUTE AN OFFICIAL ENDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL HARDWARE OR SOFTWARE.
This report summarizes information gathered on a survey conducted by the Lockheed-Huntsville Research & Engineering Center under Tasks I and II, Contract DAAH01-80-C-1289, on available computer codes which can be used to analyze electric laser devices. The laser systems include CO, CO₂, and excimers, operating in either the CW or pulsed modes. Technical areas surveyed include kinetics, optics, and gas dynamics.
FOREWORD

This report summarizes information gathered on a survey conducted by the Lockheed-Huntsville Research & Engineering Center under Tasks I and II, Contract DAAH01-80-C-1289, for the U.S. Army Missile Command, Redstone Arsenal, Alabama. This work was monitored by T. A. Barr, Jr. The period of performance covered by this report was from 1 July 1980 to 30 November 1980.

The author acknowledges many valuable conversations, assistance and encouragement provided by T. A. Barr, Jr., and J. Thoenes, as well as many others throughout this work. The author is also grateful to T. G. Roberts for his efforts in making publication of this report possible.
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</tbody>
</table>
1. INTRODUCTION

Computer modeling has contributed greatly toward development of advanced technologies such as lasers and is expected to play an even more important role in the future. This is true as the computer models become more realistic, computation costs decrease, and as the number of design parameters increases, making optimization by laboratory search almost impossible.

Through the years, many computer codes have been developed for the analysis of laser systems and their components. Most of these codes are in the public domain, and individuals who wish to obtain copies of these codes can usually do so. However, due to the large number of codes available, selection of a proper code to fit the individual's need may be a difficult task.

Each computer code has been developed with its own purpose and its inherent limitations. Depending on the phenomena included, and the details of treatment of these phenomena, applicability of different codes vary. There are simple codes for laboratory data analysis. There are detailed engineering design codes. There are also systems codes which provide an end-to-end analysis. An understanding of the capabilities and limitations inherent in each computer code is thus important to the prospective user.

Besides the analytical treatment of the various phenomena involved in the code, the prospective user will require certain general information on how to use the code. The computer language used, the core memory requirement and the computer run time all influence the suitability of using a specific code.

To alleviate this difficulty, laser computer codes were surveyed. As part of the Army High Energy Laser 6.1 effort, a survey of laser propagation codes was performed in 1979 by J. P. Reilly of W. J. Schafer Associates, Inc. This survey was published by D. W. Howgate, C. M. Bowden, and T. G. Roberts (editors), in "New Laser Concepts Evaluation—Review," MIRADCOM
Technical Report DRCMP-HEL-79-4, Redstone Arsenal, Alabama, in February 1979. Unfortunately, the distribution of this report was limited to Government agencies only. An excellent survey of Continuous Wave Chemical Laser codes was performed by C. Wiggins, D. Mansell, P. Ulrich, and J. Walsh, and was published as "Chemical Laser Code Survey," BDM/TAC-79-769-TR-R1, BDM Corporation, Albuquerque, New Mexico, July 1980. More recently, two additional surveys were performed for electric laser codes and for pulsed chemical laser codes. The survey of electric laser codes reported herein, and the pulsed chemical laser code survey performed by Melvin Epstein and Robert R. Giedt of the Aerospace Corporation, were part of the Army High Energy Laser 6.1 effort.

In this study, we surveyed the industry for available codes which can contribute to the analysis of electric laser devices. The laser systems treated include CO, CO₂ and excimers, operating in either the CW or pulsed modes. The initiation may be self-sustained, E-beam initiated or UV-initiated. The flow system may either be open system, closed system or closed cycle. Technical areas surveyed thus include kinetics, optics, and gas dynamics.

Section 2 presents a general description of a high power electric laser system and its key components. The technical areas covered in this survey are then delineated. Section 3 presents a summary of the survey and its results. A general classification of the codes surveyed is also attempted. Section 4 presents the detailed return of all surveyed codes. Section 5 contains the references.

Participation in these surveys was voluntary, and therefore some existing codes may not be included. Also, as was pointed out by A. Garscadden in a private communication, references to the data banks and overview publications are not included. The reader may find many interesting references in the Selected Bibliography, Page 113.

This survey complements other previous code surveys covering areas of laser beam propagation (Ref. 1), chemical laser devices (Ref. 2), and pulsed chemical lasers (Ref. 3).
2. PREPARING THE SURVEY

2.1 COMPONENTS OF AN ELECTRIC LASER SYSTEM

A high power electric laser system can be delineated into different components as shown schematically in Fig. 1. The portion included in this survey is enclosed in the box entitled "Laser Device." It contains such components as gas supply and preparation subsystem, injector and mixing subsystem, cavity resonator, exhaust treatment and recirculation system, acoustic attenuation subsystem and electric power supply subsystem. Computer codes which can be used to provide analysis for processes and phenomena occurring in one or all of the above mentioned components are subjects of this survey.

2.2 AREAS OF COVERAGE

A set of questionnaires was prepared to cover the technical areas of interest as well as information related to computer usage. A format similar to that used in Ref. 2 was adapted for use in this survey. Survey questions were grouped under the four headings of General Information; Optics; Kinetics; and Gasdynamics. Many of the questions used in the BDM survey are retained in this study.

Under the heading of GENERAL INFORMATION, questions are asked that relate to the purpose, unique capability, and limitations of the code. Questions are asked that relate to the availability of the code and its supporting documentation, as well as its computer compatibility. A key contact at the code residing organization is defined who may or may not be the originator of the code. No special effort was expended to identify the originators on all the codes surveyed, although in many cases it was necessary to communicate with the originators in order to obtain technical details about the code.
Fig. 1 - High Power Electric Laser System Components
Following the GENERAL INFORMATION section are questions grouped according to the technical areas covered by the code. Thus, a code return may contain any or all of the questions under Optics, Kinetics and Gasdynamics.

The questions under the heading of OPTICS deal primarily with the treatment of wave propagation within the laser resonator. Questions used in Ref. 2 were retained if they applied to the electric laser configurations.

The questions under the heading of KINETICS deal primarily with the treatment of plasma dynamics, lasing kinetics, and power extraction processes. Boltzmann codes used for electron energy distribution calculation and energy deposition codes for E-Beam systems are also included.

Questions under the heading of GASDYNAMICS deal primarily with the treatment of gas flow through the system and its interaction with the various components. The treatment of viscous mixing in the cavity, the acoustic propagation and its attenuation for a pulsed system, and pressure drops through the recirculation system are all included in this category.
3. A SUMMARY OF ELECTRIC LASER CODE SURVEY

3.1 INFORMATION GATHERING

A list of survey recipients was compiled from information obtained from several sources including the Army Missile Command, Naval Research Laboratory, Air Force Weapons Laboratory, and Air Force Wright Aeronautical Laboratories. This initial list of recipients was supplemented with additional names and organizations as the survey progressed, making a total of 55 organizations identified as survey recipients. These organizations include government laboratories, academic institutions, and private industries throughout the country. After having identified one or two individuals at each organization as the contact point for the survey, questionnaires were sent to all the identified organizations.

Phone conversations and personal visits to some survey recipients followed the initial mailing in order to speed up the survey return, to discuss fine points on the survey, and to clarify questions on the returned questionnaires. In spite of all these followup activities, returns of the survey were slow. After much effort, 42 returned questionnaires were obtained. These returns, after being reviewed and retyped, are presented in Section 4. A summary of the survey results is given in the following subsection, in which an attempt is made to classify these codes.
3.2 A CLASSIFICATION OF SURVEYED CODES

Forty-two of the electric laser related codes that were surveyed are generally classified as follows:

<table>
<thead>
<tr>
<th>Classification of Codes</th>
<th>No. of Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>LASER KINETICS</td>
<td>21</td>
</tr>
<tr>
<td>General excimer laser code</td>
<td>5</td>
</tr>
<tr>
<td>Specific excimer laser code</td>
<td>3</td>
</tr>
<tr>
<td>CO$_2$ laser code coupled to physical optics</td>
<td>2</td>
</tr>
<tr>
<td>CO$_2$ laser code</td>
<td>7</td>
</tr>
<tr>
<td>General vibrational-rotational laser code</td>
<td>1</td>
</tr>
<tr>
<td>CO laser code</td>
<td>3</td>
</tr>
<tr>
<td>PLASMA KINETICS CODE</td>
<td>6</td>
</tr>
<tr>
<td>ELECTRON KINETICS CODE</td>
<td>6</td>
</tr>
<tr>
<td>PULSE FORMING NETWORK CODE</td>
<td>1</td>
</tr>
<tr>
<td>LASER GASDYNAMICS</td>
<td>7</td>
</tr>
<tr>
<td>Cavity gasdynamics</td>
<td>4</td>
</tr>
<tr>
<td>Closed cycle gasdynamics</td>
<td>3</td>
</tr>
<tr>
<td>GENERAL OPTICS</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
</tr>
</tbody>
</table>

A brief summary of all the codes surveyed is given in Table 1. Detailed returns of all codes are given alphabetically in Section 4. In the succeeding paragraphs, summaries for the different classes of codes are given.
The laser kinetics codes calculate the upper and lower state populations for the given lasing transition under the operating condition. The code may either be programmed to accept only a specific lasing transition or it may be more general in order to accept different reaction mechanisms from input data. Depending on its complexities, the code may contain mechanisms for the calculation of plasma kinetics, energy deposition, power extraction and gasdynamics. Most codes treat at least the Fabry-Perot resonator, a few (TDF1-EDL and UNSEDL2) have coupled physical optics which can treat other types of resonators as well. The laser kinetics codes are summarized in Table 2, where the applicable gas systems, the type of operation, and initiation method included in each code are listed. Also listed are comments related to specific features of the code.

The plasma kinetics codes deal with energy deposition into the cavity gas for either an E-beam discharge (E-BEAM TRANSPORT, EBAM2, and EBM2D) or discharge only (DENSITY, HGX80 and KINBOLTZ). Some may also be coupled to the pulse forming electric circuits (e.g., EBEAM2).

The electron kinetics codes are used to calculate the electron energy distribution function by solving the Boltzmann equation. Transport properties are then obtained from the distribution function. These codes are usually linked to the plasma kinetics codes or the lasing kinetics codes, thus forming a coupled code. Because of the different types of collision processes treated, the usage of these codes is thus considered case dependent.

The pulse forming network (PFN) codes provide electric current for the discharge pulse. Since the gas properties in the laser cavity affect the outside current, the analysis of PFN is usually coupled with the plasma kinetics codes for energy deposition calculation.

The gasdynamics codes are classified as either a cavity gasdynamics code or a closed cycle system gasdynamics. The cavity gasdynamics code treats the cavity gas medium homogeneity as the result of flow mixing in the
cavity, the acoustic wave generation due to the pulsed operation or non-uniform energy deposition. The system gasdynamics codes deal specifically with thermodynamics of closed gas systems. It provides transient analysis as well as steady state solution for the flow loop. The gasdynamics codes are summarized in Table 3 where the flow equations used and the special features treated are listed.

Of all the codes surveyed, only two have physical optics coupled with the lasing kinetics. This might be the result that many an analysis has been done with separate kinetics and optics codes. Extensive survey of optics codes as applied to resonator analysis and design has been conducted by BDM (Ref. 2) for chemical lasers. No duplication is intended in this study. A general optical system optimization code (ILLOPT) is included in this report.
<table>
<thead>
<tr>
<th>Code</th>
<th>Residing Organization</th>
<th>Key Contact</th>
<th>Principal Purpose</th>
<th>Available Documentation</th>
<th>Comments</th>
</tr>
</thead>
</table>

This table summarizes the 42 codes surveyed. Listed under each code is information pertaining to: the residing organization; the key contact; the principal purpose of the code; available documentation; and comments. Detailed returns of all codes are given alphabetically in Section 4.
### Table 1
#### SUMMARY OF ELECTRIC LASER CODE SURVEY

<table>
<thead>
<tr>
<th>Code Name</th>
<th>Residing Organization</th>
<th>Key Contact</th>
<th>Principal Purpose of Code</th>
<th>Code Classification</th>
<th>Documentation</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>atory Astrophysics</td>
<td></td>
<td>port, excitation, and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(303) 492-7850</td>
<td></td>
<td>ionization coefficients</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>from cross-section data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMLASE</td>
<td>Westinghouse R&amp;D</td>
<td>Lyle Taylor</td>
<td>To model the laser kinetics of</td>
<td>Laser Kinetics</td>
<td>T</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>Center</td>
<td></td>
<td>a pulsed 14 μm and 16 μm CO₂</td>
<td>(CO₂)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>laser, and to predict its performance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BOLTZ</td>
<td>AFWAL</td>
<td>CPT Gary L. Duke</td>
<td>To predict electron transport</td>
<td>Electron Kinetics</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>properties, excitation pumping</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>rates from given E/N and cross-section data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCUBE</td>
<td>U. of Alabama in</td>
<td>Gerald R. Karr</td>
<td>To compute flow properties</td>
<td>System Dynamics</td>
<td>RP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Huntsville</td>
<td></td>
<td>throughout a closed circulator for a steady state CW laser</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COLASE</td>
<td>Westinghouse R&amp;D</td>
<td>Lyle Taylor</td>
<td>To model the laser kinetics of</td>
<td>Laser Kinetics</td>
<td>T, U</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Center</td>
<td></td>
<td>a pulsed, electric dis-</td>
<td>(CO)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>charge CO laser, and to predict its performance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DENSITY</td>
<td>AFWAL</td>
<td>CPT Gary L. Duke</td>
<td>To determine the time de-</td>
<td>Plasma Kinetics</td>
<td>None</td>
<td>Time-Depend.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>pending species concen-</td>
<td>(XeCl)</td>
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<td>Discharge</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>tration voltage, and current in an XeCl laser plasma</td>
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<td></td>
<td>Model</td>
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<tr>
<td>E-Beam</td>
<td>R&amp;D Associates</td>
<td>T. K. Tio</td>
<td>To model the E-Beam trans-</td>
<td>Plasma Kinetics</td>
<td>T, U, L</td>
<td>2-D E-Beam</td>
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<tr>
<td>Transport</td>
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<td></td>
<td>port in the L-D discharge gap of</td>
<td>(CO₂)</td>
<td></td>
<td>Model</td>
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<tr>
<td></td>
<td></td>
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<td>an EDL under prescribed</td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>E-field and B-field</td>
<td></td>
<td></td>
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<tr>
<td>EBEAM</td>
<td>MICOM</td>
<td>Arthur Werkheiser</td>
<td>To compute time history of</td>
<td>Laser Kinetics</td>
<td>L, U</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CO₂ electric laser power output for E-Beam lasers</td>
<td>(CO₂)</td>
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<td></td>
</tr>
<tr>
<td>EBEAM2</td>
<td>MICOM</td>
<td>Arthur Werkheiser</td>
<td>To compute time history of</td>
<td>Plasma Kinetics</td>
<td>In Preparation</td>
<td>Time-Depend.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>E-Beam gun and sustainer</td>
<td>(CO₂)</td>
<td></td>
<td>E-Beam</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>voltage and current from a given power supply</td>
<td></td>
<td></td>
<td>Model</td>
</tr>
<tr>
<td>EBM2D</td>
<td>MICOM</td>
<td>Arthur Werkheiser</td>
<td>To compute 2-D distribution</td>
<td>Plasma Kinetics</td>
<td>T</td>
<td>2-D E-Beam</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>of electron density, E-field, and power deposited in an electric laser cavity for a given potential difference and current</td>
<td>(CO₂)</td>
<td></td>
<td>Model</td>
</tr>
<tr>
<td>EDLAMP</td>
<td>Lockheed-Huntsville</td>
<td>Jürgen Thoennes</td>
<td>To predict cavity perfor-</td>
<td>Laser Kinetics</td>
<td>T, U</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>mance of an E-Beam controlled EDL</td>
<td>(CO₂) Coupled with Gasdynamics</td>
<td></td>
<td></td>
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<tr>
<td>EDLNOD</td>
<td>AFWL</td>
<td>CPT Robert F. Walter</td>
<td>To predict small signal gain and energy extraction for CO₂ EDLs</td>
<td>Laser Kinetics (CO₂)</td>
<td>L, RP</td>
<td></td>
</tr>
</tbody>
</table>

*T = theory, U = user's manual, L = listing, RP = related publication, P = proprietary.

(Continued)
<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
<th>Residing Organization</th>
<th>Key Contact</th>
<th>Principal Purpose of Code</th>
<th>Code Classification</th>
<th>Documentation</th>
<th>Comment</th>
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</thead>
<tbody>
<tr>
<td>EDLSL</td>
<td>AFWL</td>
<td>Tetra Corp.</td>
<td>Henry J. Happ, III</td>
<td>To model the kinetics of photon production by a glow discharge in an EDL cavity</td>
<td>Laser Kinetics (CO₂)</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>EED</td>
<td>ELECT</td>
<td>Northrop R&amp;T Center</td>
<td>William B. Lacina</td>
<td>To solve the steady state electron distribution function using the Boltzmann equation</td>
<td>Electron Kinetics</td>
<td>T, U, L</td>
<td></td>
</tr>
<tr>
<td>ELECT</td>
<td>A.T. Gavrielides</td>
<td>Henry J. Happ, III</td>
<td>(505) 256-3595</td>
<td>To provide an analysis of electron kinetics for an arbitrary gas mixture (possibly including excited species) as a function of electric field</td>
<td>Electron Kinetics</td>
<td>T, U, L</td>
<td></td>
</tr>
<tr>
<td>ELENDEF</td>
<td>AFWAL</td>
<td>CPT Gary L. Duke</td>
<td>(513) 255-2923</td>
<td>To compute electron distribution function, mean electron energy drift velocity, and rate coefficient</td>
<td>Electron Kinetics</td>
<td>T, U, L</td>
<td></td>
</tr>
<tr>
<td>ETRANV</td>
<td>Air Force Institute of Technology</td>
<td>LTC William F. Bailey</td>
<td>(513) 255-2012</td>
<td>To provide time dependent solution of master equation for vibrational energy exchange for modeling of vibrational-rotational laser systems</td>
<td>Laser Kinetics (General)</td>
<td>RP</td>
<td></td>
</tr>
<tr>
<td>FRESL</td>
<td>R&amp;D Associates</td>
<td>Peter Crowell</td>
<td>(905) 844-3013</td>
<td>To compute development of free shear layer at interface of primary cavity flow and secondary injected beam duct flow in a confined channel</td>
<td>Cavity Gas Dynamics</td>
<td>T, L</td>
<td></td>
</tr>
<tr>
<td>GALEK</td>
<td>Joint Inst. for Lab. Astrophysics</td>
<td>L.C. Pitchford</td>
<td>(303) 492-9255</td>
<td>To predict electron transport and excitation-ionization coefficients from cross-section data</td>
<td>Electron Kinetics</td>
<td>L, RP</td>
<td></td>
</tr>
<tr>
<td>HGX80</td>
<td>United Technologies Research Center</td>
<td>William L. Nighan</td>
<td>(203) 727-7596</td>
<td>To compute laser discharge properties in electrically excited rare-gas halide and mercury-halide lasers</td>
<td>Plasma Kinetics (Excimers)</td>
<td>L, RP</td>
<td>Discharge Model</td>
</tr>
<tr>
<td>ILLOPT</td>
<td>Westinghouse R&amp;D Center</td>
<td>Johanna Schruben</td>
<td>(412) 256-3611</td>
<td>Illumination evaluation and optimization of optical systems</td>
<td>General Optics</td>
<td>T</td>
<td>P</td>
</tr>
<tr>
<td>KINBOLTZ</td>
<td>Tetra Corp.</td>
<td>Henry J. Happ, III</td>
<td>(505) 256-3595</td>
<td>To compute the time dependent population levels in upper and lower states from rate equations</td>
<td>Plasma Kinetics (Excimers)</td>
<td>U, L</td>
<td>Time-Depend, Discharge Model</td>
</tr>
<tr>
<td>KINETIC</td>
<td>Lawrence Livermore Laboratory</td>
<td>W. Lowell Morgan</td>
<td>(415) 422-6289</td>
<td>To model the basic laser kinetics for E-Beam pumped and discharge lasers</td>
<td>Laser Kinetics (Excimers)</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>KRF</td>
<td>TRW</td>
<td>Jeanette Betts</td>
<td>(213) 516-1453</td>
<td>To model KRF lasers and amplifiers</td>
<td>Laser Kinetics (Krf)</td>
<td>L</td>
<td>P</td>
</tr>
<tr>
<td>LAGAD</td>
<td>Westinghouse R&amp;D Center</td>
<td>Martin J. Pechersky</td>
<td>(412) 256-7353</td>
<td>To compute non-steady gas-dynamics resulting from discharge heating and flow loop heat exchangers in a closed cycle system</td>
<td>System Gas Dynamics</td>
<td>L</td>
<td>P</td>
</tr>
</tbody>
</table>

* T = theory, U = user’s manual, L = listing, RP = related publication, P = proprietary.
** Now at Sandia Laboratory.
<table>
<thead>
<tr>
<th>Code</th>
<th>Residing Organization Key Contact</th>
<th>Principal Purpose of Code</th>
<th>Code Classification</th>
<th>Documentation</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>LASER</td>
<td>Northrop R&amp;T Center</td>
<td>General laser kinetics synthesis and analysis for a broad class of transient, electrically excited laser systems</td>
<td>Laser Kinetics</td>
<td>T, U, L</td>
<td></td>
</tr>
<tr>
<td>LASIM</td>
<td>Westinghouse R&amp;D Center</td>
<td>Simulation of UV initiated self-sustained discharge pumped XeF lasers</td>
<td>Laser Kinetics (XeF)</td>
<td>L, RP</td>
<td></td>
</tr>
<tr>
<td>MOC</td>
<td>U. of Alabama in Huntsville</td>
<td>To compute transient flow associated with sudden energy deposition characteristic of pulsed laser operations</td>
<td>Cavity Gas Dynamics</td>
<td>RP</td>
<td></td>
</tr>
<tr>
<td>NRL LASER</td>
<td>Naval Research Lab.</td>
<td>Modeling of a variety of high power gas lasers. Mostly rare gas halides</td>
<td>Laser Kinetics (Excimers)</td>
<td>T, L, RP</td>
<td></td>
</tr>
<tr>
<td>OPTEX</td>
<td>Westinghouse R&amp;D Center</td>
<td>To predict the laser output for the 10.6 µm P(14) and P(11) lines for a pulsed TEA laser</td>
<td>Laser Kinetics (CO₂)</td>
<td>T</td>
<td>P</td>
</tr>
<tr>
<td>POSEIDON</td>
<td>Poseidon Research Center</td>
<td>To model 1-D flow and acoustic in laser cavity and acoustic attenuation subsystem. (A 2-D version also exists.)</td>
<td>Cavity Gas Dynamics</td>
<td>T, RP</td>
<td></td>
</tr>
<tr>
<td>PSI LASER</td>
<td>Physical Science, Inc.</td>
<td>A series of general kinetics codes for cavity gain and power output calculations</td>
<td>Laser Kinetics (Excimers)</td>
<td>RP</td>
<td></td>
</tr>
<tr>
<td>REDAC</td>
<td>Rocketdyne</td>
<td>To model PEN performance</td>
<td>PEN</td>
<td>U</td>
<td>P</td>
</tr>
<tr>
<td>STAGE</td>
<td>R&amp;D Associates</td>
<td>To model beam duct, cavity acoustics</td>
<td>Cavity Gas Dynamics</td>
<td>T, L</td>
<td></td>
</tr>
<tr>
<td>SUPER-SONIC</td>
<td>Northrop R&amp;T Center</td>
<td>Analysis of an electrically excited supersonic flow CO laser</td>
<td>Laser Kinetics (CO)</td>
<td>T, U, L</td>
<td></td>
</tr>
<tr>
<td>TDFI-EDL</td>
<td>Lockheed-Huntsville</td>
<td>To estimate performance trends of a CW EDL with unstable resonator</td>
<td>Laser Kinetics (CO₂)</td>
<td>T, U</td>
<td>Coupled Optics Kinetics and Gas Dynamics</td>
</tr>
<tr>
<td>TEA</td>
<td>Westinghouse R&amp;D Center</td>
<td>To model the laser kinetics of a pulsed 10.6 µm CO₂ laser and to predict its performance</td>
<td>Laser Kinetics (CO₂)</td>
<td>T, U</td>
<td></td>
</tr>
<tr>
<td>TELSAT</td>
<td>R&amp;D Associates</td>
<td>To study steady state and transient thermodynamic and fluid dynamic system performance</td>
<td>System Gas Dynamics</td>
<td>T, L, RP</td>
<td></td>
</tr>
</tbody>
</table>

* T = theory, U = user's manual, L = listing, RP = related publication, P = proprietary.
<table>
<thead>
<tr>
<th>Code Name</th>
<th>Residing Organization</th>
<th>Key Contact</th>
<th>Principal Purpose of Code</th>
<th>Code Classification</th>
<th>Documentation*</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNSEDLI</td>
<td>AFWL</td>
<td>CPT Ted Salvi (505) 844-0256</td>
<td>Time dependent behavior of CW CO\textsubscript{2} EDL with mode-media instability</td>
<td>Laser Kinetics (CO\textsubscript{2})</td>
<td>T, U, L</td>
<td>Coupled Optics, Kinetics and Gas Dynamics</td>
</tr>
<tr>
<td>UVLZR</td>
<td>Los Alamos Sci. Lab.</td>
<td>Arthur E. Greene (505) 667-7799</td>
<td>To study kinetics of rare gas halide lasers, design more efficient PFNs</td>
<td>Laser Kinetics (Excimer)</td>
<td>RP</td>
<td>Coupled to PFN</td>
</tr>
<tr>
<td>VIBKIN</td>
<td>Boeing Aerospace Co.</td>
<td>Donald J. Nelson (206) 773-1498</td>
<td>To model the kinetics of an electric discharge pumped supersonic CO laser</td>
<td>Laser Kinetics (CO)</td>
<td>T, U, L</td>
<td></td>
</tr>
<tr>
<td>XENON</td>
<td>U. of Illinois</td>
<td>T. DeTemple (217) 333-3094</td>
<td>Synthesis of E-Beam initiated Ar-Xe laser</td>
<td>Laser Kinetics (Excimer)</td>
<td>RP</td>
<td></td>
</tr>
</tbody>
</table>

*T = theory, U = user's manual, L = listing, RP = related publication, P = proprietary.
Table 2
SUMMARY OF LASER KINETICS CODES

This table summarizes the 21 laser kinetics codes surveyed. Listed under each code are information pertaining to: gas systems treated; type of operation; method of initiation treated in each code as well as comments.
<table>
<thead>
<tr>
<th>Code Name</th>
<th>Gas System Treated</th>
<th>Type of Operation</th>
<th>Method(s) of Initiation</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMLASE</td>
<td>CO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Pulsed</td>
<td>Self-Sustained</td>
<td></td>
</tr>
<tr>
<td>COLASE</td>
<td>CO</td>
<td>Pulsed</td>
<td>Self-Sustained</td>
<td></td>
</tr>
<tr>
<td>EBEAM</td>
<td>CO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Pulsed</td>
<td>E-Beam</td>
<td>Discharge Non-Uniformity Treated</td>
</tr>
<tr>
<td>EKLAMP (Lockheed)</td>
<td>CO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Pulsed, CW</td>
<td>E-Beam Controlled</td>
<td>Close Cycle Decontamination Treated</td>
</tr>
<tr>
<td>EDLNOO (AFWL)</td>
<td>CO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Pulsed</td>
<td>E-Beam</td>
<td></td>
</tr>
<tr>
<td>EDLSL (AFWL)</td>
<td>CO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Pulsed</td>
<td>Self-Sustained</td>
<td></td>
</tr>
<tr>
<td>ETRANV (AFIT)</td>
<td>CO&lt;sub&gt;2&lt;/sub&gt;, CO</td>
<td>Pulsed, CW</td>
<td>E-Beam</td>
<td></td>
</tr>
<tr>
<td>KINETIC</td>
<td>Excimers</td>
<td>Pulsed</td>
<td>E-Beam</td>
<td>Boltzmann Solver Included Extensive Graphics</td>
</tr>
<tr>
<td>KRF</td>
<td>KrF</td>
<td>Pulsed</td>
<td>E-Beam</td>
<td></td>
</tr>
<tr>
<td>LASER</td>
<td>Excimers</td>
<td>Pulsed</td>
<td>E-Beam</td>
<td>Boltzmann Solver Included Widely Distributed Code</td>
</tr>
<tr>
<td>LASIM</td>
<td>XeF</td>
<td>Pulsed</td>
<td>Self-Sustained UV-Initiated</td>
<td></td>
</tr>
<tr>
<td>NKL LASER</td>
<td>Excimers</td>
<td>Pulsed, CW</td>
<td>E-Beam</td>
<td>Bolzmann Solver Included Reaction Scheme Specified Using Symbolic Names for Reactants and Products</td>
</tr>
<tr>
<td>OPTEX</td>
<td>CO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Pulsed</td>
<td>E-Beam</td>
<td>10 μm P(14) and P(18) Lasing Output Predicted</td>
</tr>
<tr>
<td>PSI LASER</td>
<td>Excimers</td>
<td>Pulsed, CW</td>
<td>E-Beam</td>
<td>A Series of General Kinetics</td>
</tr>
<tr>
<td>SUPERSONIC</td>
<td>CO</td>
<td>Pulsed, CW</td>
<td>E-Beam</td>
<td>1-D Gas Dynamics</td>
</tr>
<tr>
<td>TEA (Westinghouse)</td>
<td>CO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Pulsed, CW</td>
<td>E-Beam</td>
<td>1-D Gas Dynamics, Physical Optics</td>
</tr>
</tbody>
</table>

(Continued)
<table>
<thead>
<tr>
<th>Code Name (Org.)</th>
<th>Gas System Treated</th>
<th>Type of Operation</th>
<th>Method(s) of Initiation</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNSEDL2 (AFWL)</td>
<td>CO₂</td>
<td>Pulsed, CW</td>
<td>E-Beam</td>
<td>2-D Gas Dynamics, Physical Optics Coupled to PFN</td>
</tr>
<tr>
<td>UVLZR (LASL)</td>
<td>Excimers</td>
<td>Pulsed</td>
<td>UV Preionized Electron Impact Avalanche E-Beam Self-Sustained E-Beam Self-Sustained</td>
<td></td>
</tr>
<tr>
<td>VIBKIN (Boeing)</td>
<td>CO</td>
<td>Pulsed, CW</td>
<td>E-Beam</td>
<td></td>
</tr>
<tr>
<td>XENON (U. of Ill.)</td>
<td>Ar-Xe</td>
<td>Pulsed</td>
<td>E-Beam</td>
<td></td>
</tr>
</tbody>
</table>
Table 3
SUMMARY OF GAS DYNAMICS CODES

This table summarizes the seven gas dynamics codes surveyed. Listed under each code is information pertaining to: level of complexity; type of equations used; coordinate system; flow components treated, and special features.
Table 3
SUMMARY OF GASDYNAMIC CODES

<table>
<thead>
<tr>
<th>Code Name (Org.)</th>
<th>Level of Complexity</th>
<th>Type of Equations Used</th>
<th>Coordinate System</th>
<th>Flow Components Treated</th>
<th>Special Features Modeled</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCUBE (UAH)</td>
<td>Algebraic Model</td>
<td>Viscous Compressible</td>
<td>1-D</td>
<td>Closed Cycle</td>
<td>HX Compressors Treated</td>
</tr>
<tr>
<td>FREESL (RDA)</td>
<td>Finite Difference</td>
<td>Viscous Compressible</td>
<td>2-D</td>
<td>Cavity Flow</td>
<td>Beam Duct Interface Modeled</td>
</tr>
<tr>
<td>LAGAD (Westinghouse)</td>
<td>Algebraic (MOC)</td>
<td>Compressible</td>
<td>1-D + Time</td>
<td>Closed Cycle</td>
<td>Single Pulse Acoustic Treated</td>
</tr>
<tr>
<td>MOC (UAH)</td>
<td>Finite Difference</td>
<td>Viscous Compressible</td>
<td>1-D + Time</td>
<td>Cavity Flow</td>
<td>Single Pulse Acoustic Treated</td>
</tr>
<tr>
<td>POSEIDON (Poseidon)</td>
<td>Finite Difference</td>
<td>Compressible</td>
<td>2-D + Time</td>
<td>Cavity Flow</td>
<td>Repetitive Pulse Acoustic for an Open System Can Be Treated</td>
</tr>
<tr>
<td>STROBE (RDA)</td>
<td>Finite Difference</td>
<td>Compressible</td>
<td>3-D + Time</td>
<td>Cavity, Beam Duct</td>
<td>Single Pulse Acoustic Treated</td>
</tr>
<tr>
<td>TELSAT (RDA)</td>
<td>Finite Difference</td>
<td>Compressible</td>
<td>1-D + Time</td>
<td>Closed Cycle</td>
<td>HX, Compressors Treated</td>
</tr>
</tbody>
</table>
4. DETAILED RETURN OF SURVEY QUESTIONNAIRES

This section presents in alphabetical order returned questionnaires of the 42 codes surveyed. The questionnaire for each code is organized in the order of GENERAL INFORMATION, KINETICS, GASDYNAMICS, and OPTICS. The information stated herein follows as close as possible to those provided. Since no technical information was provided on ELENDIF and REDAC, only general information is reported on these codes.
CODE NAME: BACPR  

TECHNICAL AREA(S):  Electron Kinetics

DEVICE COMPONENTS TREATED:

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: To predict electron transport, excitation and ionization coefficients from cross-section data.

ASSESSMENT OF CAPABILITIES: A thoroughly tested code used by many laboratories. Useful for mean electron energy from about twice thermal up to values at which energy loss to ionization is about 10% of input. Thoroughly documented.

ASSESSMENT OF LIMITATIONS: Not accurate when inelastic cross-sections are comparable with elastic cross-section or when energy input to ionization is comparable with total input.

OTHER UNIQUE FEATURES:

ORIGINATOR/KEY CONTACT:
Name: A. V. Phelps
Organization: Joint Institute for Laboratory Astrophysics
Address: U. of Colorado, Boulder, CO 80309
Phone: (303) 492-7850

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RF = Related Publication):


STATUS:
Operational Currently?: X
Under Modification?:
Purpose(s): Some modifications have been made since Luft's report.

Ownership?:
Proprietary?:

MACHINE/OPERATING SYSTEM (on which installed): CDC 7600 & CDC 6400

TRANSPORTABLE?: X
Machine Dependent Restrictions:

SELF-CONTAINED?:
Other Codes Required (name, purpose): None

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

<table>
<thead>
<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Job:</td>
<td></td>
</tr>
<tr>
<td>Typical Job:</td>
<td></td>
</tr>
<tr>
<td>Large Job:</td>
<td></td>
</tr>
<tr>
<td>Approximate Number of FORTRAN Lines:</td>
<td></td>
</tr>
</tbody>
</table>

COMMENTS:
# KINETICS CODE

**CODE NAME:** BACPR

## 1. CODE STRUCTURE

<table>
<thead>
<tr>
<th>COORDINATE SYSTEM (✓):</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>inspace:</td>
<td>Expanding:</td>
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</table>

<table>
<thead>
<tr>
<th>KINETICS GRID DIMENSIONALITY (✓):</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1-D:</td>
<td>2-D:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GAIN REGION SYMMETRY RESTRICTIONS:</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain Vary Along Optical Axis:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NUMERICAL SCHEME USED IN RATE CALCULATION (✓):</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Explicit:</td>
<td>Implicit:</td>
</tr>
<tr>
<td>Others (specify): backwar prolongation</td>
<td></td>
</tr>
</tbody>
</table>

**REFERENCE OF METHOD USED:**

Sherman

## 2. PLASMA KINETICS MODEL

<table>
<thead>
<tr>
<th>NUMBER OF SPECIES TREATED (specify):</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Positive Species:</td>
<td>0</td>
</tr>
<tr>
<td>Number of Negative Species:</td>
<td>1</td>
</tr>
<tr>
<td>Number of Neutral Species:</td>
<td>≤ 3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>REACTION MECHANISM MODELED (✓):</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Ionization:</td>
<td>(Reference)</td>
</tr>
<tr>
<td>E-Beam:</td>
<td>Self-Sustained:</td>
</tr>
<tr>
<td>UV-Initiated:</td>
<td>Others (specify):</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Secondary Ionization (specify):</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Attachment:</td>
<td>Detachment:</td>
</tr>
<tr>
<td>Ion-Ion Recombination:</td>
<td>Charge Transfer:</td>
</tr>
<tr>
<td>Dissociation/Recombination:</td>
<td>Others (specify):</td>
</tr>
</tbody>
</table>

**DISCHARGE POWER INPUT MODELED (✓):**

<table>
<thead>
<tr>
<th>Uniform:</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-Field:</td>
<td>✓</td>
</tr>
</tbody>
</table>

**REFERENCES FOR REACTION MECHANISM AND RATES:**

Other Unique Features:

## 3. LASING KINETICS MODEL

**GENERAL (specify):**

<table>
<thead>
<tr>
<th>Lasing Species:</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Species:</td>
<td>1 electrons</td>
</tr>
<tr>
<td>Number of Reactions:</td>
<td></td>
</tr>
<tr>
<td>Other Major Species Considered:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IMPACT EXCITATION MODELED (✓):</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibrational:</td>
<td>Electric:</td>
</tr>
<tr>
<td>Others (specify):</td>
<td>rotation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ENERGY TRANSFER MODES MODELED (✓):</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>V→T:</td>
<td>NA</td>
</tr>
<tr>
<td>V→R:</td>
<td></td>
</tr>
<tr>
<td>V→V:</td>
<td></td>
</tr>
<tr>
<td>Others (specify):</td>
<td></td>
</tr>
</tbody>
</table>

| Lasing Transition: | P-Branch: |
|--------------------| E-Branch: |
| Single Line Model (✓): |
| Multi-Line Model (✓): |
| Assumed Rotational Population Distribution State (✓): |
| Equilibrium: | Nonequilibrium: |
| Number of Laser Lines Modeled: | |

Source of Rate Coefficients Used in Code:

**LINE PROFILE MODELS (✓):**

Doppler Broadening: NA

Collisional Broadening:

**REFERENCES FOR REACTION MECHANISM AND RATES:**

## 4. RECIRCULATION CONTAMINANTS MODELED (✓):**

<table>
<thead>
<tr>
<th>Cx:</th>
<th>OHx:</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx:</td>
<td>HNOx:</td>
</tr>
</tbody>
</table>

Others (specify):

REFERENCE FOR REACTION MECHANISM AND RATES:

OTHER UNIQUE FEATURES:
**CODE NAME:** BMLASE  
**TECHNICAL AREA(S):** Kinetics  
**DEVICE COMPONENTS TREATED:** Laser Cavity  
**PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE:** To model the laser kinetics of a pulsed 14 μm or 16 μm CO₂ laser and to predict the performance of the laser.  

**ASSESSMENT OF CAPABILITIES:** Can handle gas mixtures of CO₂: N₂: He: H₂O: H₂ at any temperature and pressure, and for any pulse length.  

**ASSESSMENT OF LIMITATIONS:** Is one-dimensional, stable resonators, and assumes that the rotational and kinetic temperatures are the same.  

**OTHER UNIQUE FEATURES:** The lowest eight vibrational levels are treated exactly, and the population of the rotational level involved in the lasing is not assumed to be in equilibrium with the other rotational level populations.  

**ORIGINATOR/KEY CONTACT:**  
**Name:** Lyle Taylor  
**Organization:** Westinghouse Electric Corporation  
**Address:** 1310 Beulah Rd., Pittsburgh, PA 15266  
**Phone:** 412-327-5833  

**AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):**  

**STATUS:**  
Operational Currently? Yes  
Under Modification? No  

**OWNERSHIP:** Westinghouse  
**Proprietary:** Yes  

**MACHINE/OPERATING SYSTEM (on which installed):** U-1106  
**TRANSPORTABLE:** Yes  
**Self-Contained:** Yes  
**Machine Dependent Restrictions:** none  
**OTHER CODES REQUIRED (NAME, PURPOSE):** 

**ESTIMATE OF RESOURCES REQUIRED FOR RUNS:**  
<table>
<thead>
<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Job:</td>
<td>51400</td>
</tr>
<tr>
<td>Large Job:</td>
<td>2080</td>
</tr>
</tbody>
</table>

**COMMENTS:**  
Fabry-Perot Cavity modeled using geometric optics and floating gain.
KINETICS CODE

1. CODE STRUCTURE
   COORDINATE SYSTEM (✓):
   - Cartesian: ✓
   - Expanding: ✓
   KINETICS GRID DIMENSIONALITY (✓):
   - 1-D: ✓
   - 2-D: ___
   - 3-D:  
   GAIN REGION SYMMETRY RESTRICTIONS:
   - Gain Vary Along Optical Axis: No
   - Flow Direction: No
   KINETICS MODELED:
   - Pulsed: ___
   - CW: ___
   NUMERICAL SCHEME USED IN RATE CALCULATION (✓):
   - Explicit: ___
   - Implicit: ___
   - Others (specify): Hamming


2. PLASMA KINETICS MODEL
   NUMBER OF SPECIES TREATED (specify):
   - Number of Positive Species: ___
   - Number of Negative Species: ___
   - Number of Neutral Species: ___
   REACTION MECHANISM MODELED (✓):
   - Primary Ionization: (Reference)
     - E-Beam: ✓
     - Self-Sustained: ✓
     - UV-Initiated: ✓
     - Others (specify): ___
   - Secondary Ionization: (Reference)
     - Attachment: ✓
     - Detachment: ✓
     - Ion-Ion Recombination: ✓
     - Charge Transfer: ___
     - Dissociation/Recombination: ___
     - Others (specify): ___
   - Source of Rate Coefficients Used: ___

3. LASING KINETICS MODEL
   GENERAL (specify):
   - Lasing Species: CO₂
   - Number of Species: 5
   - Number of Reactions: 58
   - Other Major Species Considered: N₂, He, H₂O, H₂
   IMPACT EXCITATION MODELED (✓):
   - Vibrational: ✓
   - Electronic: ✓
   - Others (specify): ___
   ENERGY TRANSFER MODES MODELED (✓):
   - V-T: ✓
   - V-R: ✓
   - V-E: ✓
   - Others (specify): ___
   - Lasing Transition: P-Branch: ✓
     - R-Branch: ✓
   - Single Line Model (✓)
   - Multi-Line Model (✓)
   - Assumed Rotational Population Distribution State (✓):
     - Equilibrium: ___
     - Nonequilibrium: ✓
   - Number of Laser Lines Modeled: 4
   - Source of Rate Coefficients Used in Code: ___
   LINE PROFILE MODELS (✓):
   - Doppler Broadening: ✓
   - Collisional Broadening: ✓
   - Others (specify): Voigt Profiles are used.

4. RECIRCULATION CONTAMINANTS MODELED (✓): none
   - O₃: ___
   - NO₂: ___
   - HNO₃: ___
   - Others (specify): ___

REFERENCE FOR REACTION MECHANISM AND RATES:

OTHER UNIQUE FEATURES:

24
TECHNICAL AREA(S): Electron Kinetics

DEVICE COMPONENTS TREATED: Overall System Characteristics

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: Given a homogeneous isotropic gas mixture with a uniform applied DC field, code calculated the electron distribution function and thus the forward/reverse excitation pumping rates and the fractional power transfer for each process as well as transport properties. These rates can be used in a kinetics code to determine the time-varying population distribution.

ASSESSMENT OF CAPABILITIES: Given E/N, and a set of cross-sections, BOLTZ calculates all the above quantities. Code has a variable number of bins for integrating, can include variable number of gases, super-elastic and electron-electron collisions.

ASSESSMENT OF LIMITATIONS: Number of energy bins & inelastic processes are limited by computer storage. Physical model is valid for fractional ionization up to 10^{-2} and fractional power into ionization and dissociation ≤10%. Convergence is difficult for superelastic-dominated cases.

OTHER UNIQUE FEATURES:

ORIGINATOR/KEY CONTACT:
Name: CPT Gary L. Duke
Organization: AFWAL/POOC-3
Address: Wright-Patterson AFB, Dayton, OH
Phone: (513) 255-2923

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and R.P. = Related Publication): Code is well documented with comment cards (U);

STATUS:
Operational Currently?: yes
Under Modification?: no
 Purpose(s): 

Ownership?: AFWAL/POOC
Proprietary?: no

MACHINE/OPERATING SYSTEM (on which installed): CYBER 175 and CYBER 74

TRANSPORTABLE?: Probably
Machine Dependent Restrictions: Programmed in Fortran IV

SELF-CONTAINED?: yes
Other Codes Required (name, purpose): none

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

<table>
<thead>
<tr>
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<tbody>
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<td>Small Job: 50K</td>
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<tr>
<td>Typical Job: 100K</td>
<td>20 sec (10 diff E/N's input)</td>
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<tr>
<td>Large Job: 150K</td>
<td>9 sec (3 diff E/N's input)</td>
</tr>
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</table>

Approximate Number of FORTRAN Lines: 2500

COMMENTS: Note: BOLTZ is an electron kinetics code, not a gas kinetics code. As yet it is not linked to any other kinetic or chemistry type code.
KINETICS CODE

CODE NAME: BOLTZ

1. CODE STRUCTURE
COORDINATE SYSTEM: [ ] Cartesian; [ ] Expanding;

KINETICS GRID DIMENSIONALITY: [ ] 1-D; [ ] 2-D; [ ] 3-D;

GAIN REGION SYMMETRY RESTRICTIONS:
Gain Vary Along Optical Axis: [ ]
Flow Direction: [ ]

KINETICS MODELED: [ ] Pulsed; [ ] CW;

NUMERICAL SCHEME USED IN RATE CALCULATION: [ ] Explicit; [ ] Implicit; [ ] Others (specify);

REFERENCE OF METHOD USED: [ ] Simpson Integration

2. PLASMA KINETICS MODEL
NUMBER OF SPECIES TREATED (specify):
Number of Positive Species: [ ]
Number of Negative Species: [ ]
Number of Neutral Species: [ ]

REACTION MECHANISM MODELED: [ ] Primary Ionization; (Reference)
E-Beam;
Self-Sustained;
UV-Initiated;
Others (specify);

Secondary Ionization: [ ] Attachment; (Reference)
Detachment;
Ion-Ion Recombination;
Charge Transfer;
Dissociation/Recombination;
Others (specify);

DISCHARGE POWER INPUT MODELED: [ ] Uniform; [ ] Non-Uniform;
E-Field; [ ] E/N input
Others (specify);

3. LASING KINETICS MODEL
GENERAL (specify):
Lasing Species:
Number of Species:
Number of Reactions:
Other Major Species Considered: Rotational, attachment, dissociation, ionization (all impact)

IMPACT EXCITATION MODELED: [ ]

ENERGY TRANSFER MODES MODELED: [ ]

LINE PROFILE MODELS: [ ] Doppler Broadening;
Collisional Broadening;
Others (specify);

4. RECIRCULATION CONTAMINANTS MODELED: [ ] none
O3: [ ]; OH: [ ]; NO2: [ ]; HNO2: [ ];
Others (specify);

REFERENCE FOR REACTION MECHANISM AND RATES:

OTHER UNIQUE FEATURES:
**CODE NAME:** CCUBE  
**TECHNICAL AREA(S):** Gas Dynamics  
**DEVICE COMPONENTS TREATED:** Cavity, Diffuser, Heat Exchangers, Compressor  
**PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE:** Computes the flow properties throughout a closed circulator for a steady state cw laser.

**ASSESSMENT OF CAPABILITIES:** Temperature dependent gas properties are modeled.

**ASSESSMENT OF LIMITATIONS:**

**OTHER UNIQUE FEATURES:** Can be used to investigate various design configurations.

**ORIGINATOR/KEY CONTACT:**
- **Name:** G. R. Karr and C. C. Shih  
- **Organization:** Mech. Eng. Dept., Univ. of Ala. in Huntsville  
- **Address:** Huntsville, AL 35809  
- **Phone:** (205) 895-6330, (205) 895-6075, or (205) 895-6145

**AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User’s Manual, L = Listing, and RP = Related Publication):**

**STATUS:**
- Operational Currently?: yes  
- Under Modification?: yes  
- Purpose(s): Continuous changing code used to investigate designs of current interest.

**Ownership:** UAH  
**Proprietary:**

**MACHINE/OPERATING SYSTEM (on which installed):** UNIVAC 1108

**TRANSPORTABLE:** yes  
**Machine Dependent Restrictions:** none

**SELF-CONTAINED:** yes  
**Other Codes Required (name, purpose):** none

**ESTIMATE OF RESOURCES REQUIRED FOR RUNS:**

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<tr>
<th>Core Size (Octal Words)</th>
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<td>Small Job:</td>
<td>order of 100 sec.</td>
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<td>Typical Job:</td>
<td></td>
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<tr>
<td>Large Job:</td>
<td></td>
</tr>
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</table>

**Approximate Number of FORTRAN Lines:** 1 box cards

**COMMENTS:**

---

27
### GAS DYNAMICS CODE

**CODE NAME:** CCUBE

---

#### 1. CODE STRUCTURE

**COORDINATE SYSTEM** (√):
- Cartesian: √
- Expanding: 

**FLUID GRID DIMENSIONALITY** (√):
- 1-D: √
- 2-D: 
- 3-D: 

**FLOW FIELD MODELED** (√):
- Compressible Flow: √
- Incompressible: 
- Viscous Flow: √
- No Flow: 

**BASIC MODELING APPROACH** (√):
- Algebraic: 
- Integral Method: 
- Finite Difference: 
- Others (specify): 

**REFERENCE FOR APPROACH USED:**

---

#### 2. GAS DYNAMICS MODEL FEATURES:

**GAS SUPPLY MODELED** (√):
- Mixture Preparation: √
- Mixture Injection: 
- Nozzles: 
- Flow Plates: 
- Others (specify): 

**CAVITY INITIAL CONDITION DETERMINED BY** (specify): Calculated as steady state.

---

#### 3. EXHAUST RECIRCULATION MODEL

**GENERAL SYSTEM MODELED** (√):
- Open System: 
- Closed System: 
- Closed Cycle: √

**EXHAUST SYSTEM FEATURES** (√):
- Pressure Recovery: 
- Ejector System: 
- Compressor/Tan: 
- Heat Exchanger: √
- Gas Make-Up: 
- Others (specify): 

---

#### 4. ACOUSTIC ATTENUATION MODEL

**GENERAL FEATURES MODELED** (√):
- Single Pulse: 
- Repetitive Pulse: 

**DIMENSIONALITY TREATED** (√):
- 1-D: 
- 2-D: 
- 3-D: 

**DISTURBANCE MODELED** (√):
- Pressure Wave: 
- Entropy Wave: 
- Others (specify): 

**WAVE PROPAGATION TREATMENT** (√):
- Linear Wave: 
- Nonlinear Wave: 
- Others (specify): 

**THEORETICAL BASIS:** (Reference)

**NUMERICAL METHODOLOGY:** (Reference)

**ACOUSTIC ATTENUATORS CONSIDERED** (√):
- Muffler: 
- Heat Exchanger: 
- Horn: 
- Porous Wall: 
- Others (specify): 

---

#### 5. MODEL EFFECTS ON OPTICAL MODES DUE TO

**INDEX OF REFRACTION VARIATION** (√):

**OTHER UNIQUE FEATURES:**

---

28
CODE NAME: COLASE  
TECHNICAL AREA(S): Kinetics

DEVICE COMPONENTS TREATED: Laser Cavity

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: To model the laser kinetics of a pulsed, electric discharge CO laser and to predict the performance of the laser. This code is a modification of the code developed for CW lasers by William B. Lacina of the Northrop Corporation.

ASSESSMENT OF CAPABILITIES: Can handle gas mixtures of CO: N\textsubscript{2}: Ar: He: Xe: O\textsubscript{2} at any temperature and pressure and excited by an electric discharge.

ASSESSMENT OF LIMITATIONS: The model is one-dimensional, can only model stable resonators, and assumes the same temperature for rotational and kinetic energies.

OTHER UNIQUE FEATURES: Includes superelastic collisions and discharge kinetics, and has sophisticated output formats.

ORIGINATOR/KEY CONTACT:
Name: Lyle Taylor
Organization: Westinghouse Electric Corporation
Address: 1310 Beulah Rd., Pittsburgh, PA 15668
Phone: 412-256-5833

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User’s Manual, L = Listing, and RP = Related Publication):

STATUS:
Operational Currently?: no
Under Modification?: no

Ownership?: U.S. Government
Proprietary?: no

MACHINE/OPERATING SYSTEM (on which installed): U-1106 and CDC-7600

TRANSPORTABLE?: no

Machine Dependent Restrictions:

SELF-CONTAINED?: yes

Other Codes Required (name, purpose):

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

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<td>60 sec, CDC-7600</td>
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<td>Typical Job</td>
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<tr>
<td>Large Job</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

COMMENTS:

Fabry-Perot cavity model using floating gain, geometric optics.
KINETICS CODE

CODE NAME: COLASE

1. CODE STRUCTURE

COORDINATE SYSTEM (✓):
- Cartesian: ✓
- Expanding: ➥

KINETICS GRID DIMENSIONALITY (✓):
- 1-D: ✓
- 2-D: __
- 3-D: __

GAIN REGION SYMMETRY RESTRICTIONS:
- Gain Vary Along Optical Axis: No
- Flow Direction: __

KINETICS MODELED: Pulsed; ✓ CW: ______

NUMERICAL SCHEME USED IN RATE CALCULATION (✓):
- Explicit: __
- Implicit: __
- Others (specify): Simpson's Rule

REFERENCE OF METHOD USED: ______

2. PLASMA KINETICS MODEL

NUMBER OF SPECIES TREATED (specify):
- Number of Positive Species: 6
- Number of Negative Species: 6
- Number of Neutral Species: 6

REACTION MECHANISM MODELED (✓):
- Primary Ionization: (Reference)
  - E-Beam: __
  - Self-Sustained: ✓
  - UV-Initiated: ✓
  - Others (specify): ______

- Secondary Ionization (Reference)
  - Attachment: ✓
  - Detachment: __
  - Ion-Ion Recombination: __
  - Charge Transfer: __
  - Dissociation/Recombination: __
  - Others (specify): ______

Source of Rate Coefficients Used: ______

DISCHARGE POWER INPUT MODELED (✓):
- Uniform: ✓
- Non-Uniform: __
- E-Field: __
- Others (specify): ______

3. LASING KINETICS MODEL

GENERAL (specify):
- Lasing Species: CO
- Number of Species: 6
- Number of Reactions: 10
- Other Major Species Considered: N₂, Ar, He, Xe, O₂

IMPACT EXCITATION MODELED (✓):
- Vibrational: __
- Electronic: ✓
- Others (specify): ______

ENERGY TRANSFER MODES MODELED (✓):
- V-T: ✓
- V-R: __
- V-V: ✓
- Others (specify): ______

- Lasing Transition: P-Branch: ✓
- R-Branch: __
- Single Line Model (✓): ______
- Multi-Line Model (✓): ______
- Assumed Rotational Population Distribution State (✓): __
- Equilibrium: __
- Nonequilibrium: __

- Number of Laser Lines Modeled: 40

Source of Rate Coefficients Used in Code: ______

LINE PROFILE MODELS (✓):
- Doppler Broadening: __
- Collisional Broadening: ✓
- Others (specify): ______

4. RECIRCULATION CONTAMINANTS MODELED (✓):
- None: ______
- O₂: ___
- OH: ___
- NO: ___
- HNO: ___
- Others (specify): ______

REFERENCE FOR REACTION MECHANISM AND RATES: ______

OTHER UNIQUE FEATURES: ______

30
**CODE NAME:** DENSITY  
**TECHNICAL AREA(S):** Kinetics

**DEVICE COMPONENTS TREATED:** None, other than a simple RLC circuit

**PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE:** Determine the time dependent species concentrations, voltage, and current in XeCl laser plasma. Program is centered around a subroutine DGEAR from the International Mathematics and Science Library (IMSL) for CDC 6600 computers. DGEAR is a subroutine for solving stiff differential equations.

**ASSESSMENT OF CAPABILITIES:** Currently tracks 7 species, plus voltage and current. Requires 110K of storage, 32K of which is a plotting routine. It takes about 7 sec. to calculate 500 time increments. This really depends upon how stiff the equations are.

**ASSESSMENT OF LIMITATIONS:** Code is presently awkward to change the number of equations. Code requires data bank of rates.

**OTHER UNIQUE FEATURES:** The electron kinetic rates are generally calculated by a separate code called BOLTZ which is not yet linked to DENSITY. These rates are interpolated using a SPLINE fit.

**ORIGINATOR/KEY CONTACT:**
- **Name:** CPT Gary L. Duke
- **Organization:** AFWAL/POOC-3
- **Address:** Wright-Patterson APB, OH 45433
- **Phone:** (513) 255-2923 or (513) 255-3835

**AVAILABLE DOCUMENTATION** (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):
- DGEAR is described in the IMSL description or in:

**STATUS:**
- Operational Currently?: yes
- Under Modification?: yes
- Purpose(s): To increase the number of species, update rates, and link to BOLTZ code. Also want to make the code have a variable time step dependent upon the voltage change.
- Ownership?: U.S. Government
- Proprietary?:

**MACHINE/OPERATING SYSTEM (on which installed):** CDC 6600 in FORTRAN

**TRANSPORTABLE?:** yes, if IMSL is available.

**SELF-CONTAINED?:**
- Other Codes Required (name, purpose): DGEAR involves stiff differential equations.

**ESTIMATE OF RESOURCES REQUIRED FOR RUNS:**

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<th>Core Size (Octal Words)</th>
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<tr>
<td>Typical Job:</td>
<td>110K</td>
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<tr>
<td>Large Job:</td>
<td>110K</td>
</tr>
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</table>

**Approximate Number of FORTRAN Lines:** 450 excluding DGEAR

**COMMENTS:**
**KINETICS CODE**

**CODE NAME: DENSITY**

### 1. CODE STRUCTURE

- **COORDINATE SYSTEM** (√):
  - Cartesian: ✗
  - Expanding: ✓

- **KINETICS GRID DIMENSIONALITY** (√):
  - 1-D: ✗
  - 2-D: ✓
  - 3-D: ✗

- **GAIN REGION SYMMETRY RESTRICTIONS**:
  - Flow Direction:
    - KINETICS MODELED: Pulsed: ✓ CW: ✗

- **NUMERICAL SCHEME USED IN RATE CALCULATION** (√):
  - Explicit: ✗
  - Implicit: ✓
  - Others (specify): DGEAR

- **REFERENCE OF METHOD USED**:
  - See description in Available Documentation

### 2. PLASMA KINETICS MODEL

- **NUMBER OF SPECIES TREATED** (specify):
  - Number of Positive Species: 2
  - Number of Negative Species: 2
  - Number of Neutral Species: 3

- **REACTION MECHANISM MODELED** (√):
  - Primary Ionization: (Reference)
    - E-Beam: ✓
    - Self-Sustained: ✓ Only Townsend Ionization
    - UV-Initiated: ✗
    - Others (specify): ✗

  Secondary Ionization: (Reference)
  - Attachment: ✓
  - Detachment: ✗
  - Ion-Ion Recombination: ✓
  - Charge Transfer: ✗
  - Dissociation/Recombination: ✓
  - Others (specify): ✗

- **Source of Rate Coefficients Used**:
  - Current literature

- **DISCHARGE POWER INPUT MODELED** (√):
  - Uniform: ✗
  - Non-Uniform: ✓
  - E-Field: ✓
  - Others (specify): LRC circuit

### 3. LASING KINETICS MODEL

- **GENERAL** (specify):
  - Lasing Species: XeCl
  - Number of Species: 3
  - Number of Reactions: 2
  - Other Major Species Considered: Xe*, Xe+, Xe2, Cl-, HCl (✓)

- **IMPACT EXCITATION MODELED** (✓):
  - (Reference)
    - Vibrational: ✓ HCl
    - Electronic: ✓ Xe
    - Others (specify): ✓

- **ENERGY TRANSFER MODES MODELED** (✓):
  - (Reference)
    - V-T: ✓ Collisional relaxation rate
      - Const.
      - V-R: ✓
      - V-X: ✓
  - Others (specify): ✓
    - Lasing Transition: P-Branch:
    - R-Branch:

    Single Line Model (✓)
    - Multi-Line Model (✓)
      - Assumed Rotational Population Distribution State (✓)
        - Equilibrium:
        - Nonequilibrium:
      - Number of Laser Lines: ✓ 1
      - Source of Rate Coefficients Used in Code:

    SOURCE LINE PROFILE MODELS (✓):
    - Doppler Broadening:
    - Collisional Broadening:
    - Others (specify):

### 4. RECIRCULATION CONTAMINANTS MODELED (✓): none
- O3: ✗
- OH: ✗
- NO: ✗
- N2O: ✗
- HNO3: ✗
- Others (specify): ✗

- **REFERENCE FOR REACTION MECHANISM AND RATES**:

- **OTHER UNIQUE FEATURES**:

---

32
CODE NAME: E-Beam Transport  TECHNICAL AREA(S): Kinetics

DEVICE COMPONENTS TREATED: Discharge gap including the foil, cathode, and the anode

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: The code is developed to model the E-beam transport in the 2-D discharge gap of an EDL under prescribed E-field and B-field. It computes the E-beam energy deposition distribution. When it is coupled to the PLASMA TRANSPORT CODE, accurate E-field and ionization distributions can be obtained.

ASSESSMENT OF CAPABILITIES: Although this code was written for the beam-electron energies between 5 to 500 keV, the energy range can be extended by adding more loss mechanisms and changing the cross sections. Discharge geometry can also be altered.

ASSESSMENT OF LIMITATIONS: At the present time, discharge cavities with dielectric flow plate and E-beam shield cannot be handled; field penetration in the region between the foil and the cathode is ignored.

OTHER UNIQUE FEATURES: Semi-analytical and semi-empirical formulas will be used to speed up the computation. Provision will be made for estimating the space charge arising from thermalization of the backscattered E-beam.

ORIGINATOR/KEY CONTACT:

Name: T.K. Tip
Organization: P & D Associated
Address: P.O. Box 9695, Marina del Rey, CA 90291
Phone: (213) 822-1715 ext. 448

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and N = Related Publication): Permission from AFWL is required to obtain the following documents.

1. EDL Discharge Modeling Status Report (T)
2. LASL Monte-Carlo Electron Transport Codes, Pts. 1 & II (Flow Charts)
3. Using the LASL Monte-Carlo Electron Transport Codes (U,L)

STATUS:
Operational Currently?: not ready
Under Modification?: yes
Purpose(s): To speed up the code by incorporating semi-analytic and semi-empirical formulas; to sample the space charges arising from the backscattered E-beam.
Ownership?: RDA
Proprietary?: Permission from AFWL is required.

MACHINE/OPERATING SYSTEM (on which installed): CRAY-I

TRANSPORTABLE?: yes
Machine Dependent Restrictions: Core size, FORTRAN Language

SELF-CONTAINED?:
Other Codes Required (name, purpose): Poisson equation solver is required to iterate for the E-field.

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

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<thead>
<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
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</thead>
<tbody>
<tr>
<td>Small Job: 200,000</td>
<td>250 (for 1,000 particles)</td>
</tr>
<tr>
<td>Typical Job: 200,000</td>
<td>1,250 (for 5,000 particles)</td>
</tr>
<tr>
<td>Large Job: 200,000</td>
<td>2,500 (for 10,000 particles)</td>
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<tr>
<td>Approximate Number of FORTRAN Lines:</td>
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</tr>
</tbody>
</table>

COMMENTS:
## 1. CODE STRUCTURE

**COORDINATE SYSTEM** (✓):
- Cartesian: ✓ Expanding: 

**KINETICS GRID DIMENSIONALITY** (✓):
- 1-D: 
- 2-D: ✓ 
- 3-D: 

**GAIN REGION SYMMETRY RESTRICTIONS:**
- Gain Var. Along Optical Axis: 
- Flow Direction: 

**KINETICS MODELED:**
- Pulsed: 
- CW: 

**NUMERICAL SCHEME USED IN RATE CALCULATION** (✓):
- Explicit: 
- Implicit: 
- Others (specify): 

**REFERENCE OF METHOD USED:** 

## 2. PLASMA KINETICS MODEL

**NUMBER OF SPECIES TREATED** (specify):
- Number of Positive Species: 
- Number of Negative Species: 
- Number of Neutral Species: 

**REACTION MECHANISM MODELED** (✓):
- Primary Ionization: (Reference)
  - E-Beam: ✓ Self-Sustained: 
  - UV-Initiated: 
  - Others (specify): 

- Secondary Ionization: (Reference)
  - Attachments: 
  - Detachments: 
  - Ion-Ion Recombination: 
  - Charge Transfer: 
  - Dissociation/Recombination: ✓ 
  - Others (specify): 

**Source of Rate Coefficients Used:**
- AERL’s experimental values 

**DISCHARGE POWER INPUT MODELED** (✓):
- Uniform: 
- Non-Uniform: ✓ 
- E-Field: ✓ 
- Others (specify): 

## 3. LASING KINETICS MODEL

**GENERAL** (specify):
- Lasering Species: 
- Number of Species: 
- Number of Reactions: 
- Other Major Species Considered: 

**IMPACT EXCITATION MODELED** (✓): (Reference)
- Vibrational: 
- Electronic: 
- Others (specify): 

**ENERGY TRANSFER MODES MODELED** (✓): (Reference)
- V-T: 
- V-R: 
- V-V: 
- Others (specify): 
- Lasing Transition: P-Branch: 
  - R-Branch: 
- Single Line Model (✓): 
- Multi-Line Model (✓): 
  - Assumed Rotational Population Distribution State (✓):
    - Equilibrium: 
    - Non-equilibrium: 
- Number of Laser Lines Modeled: 
- Source of Rate Lines Used in Code: 

**LINE PROFILE MODELS** (✓):
- Doppler Broadening: 
- Collisional Broadening: 
- Others (specify): 

## 4. RECIRCULATION CONTAMINANTS MODELED** (✓):
- O<sub>3</sub>: 
- OH: 
- NO: 
- HNO<sub>3</sub>: 
- Others (specify): 

**REFERENCE FOR REACTION MECHANISM AND RATES:** 

**OTHER UNIQUE FEATURES:** 

---

**KINETICS CODE**

**CODE NAME:** E-Beam Transport
CODE NAME: EBEAM  TECHNICAL AREA(S): Kinetics
DEVICE COMPONENTS TREATED: Laser Cavity, Lasing Gas, Electrical Power
PRINCIPAL PURPOSES/APPLICATIONS OF CODE: Compute time history of electric laser output power output for EBEAM or axial lasers. Input requires electric power input, laser cavity specifications, and gas species and densities.

ASSESSMENT OF CAPABILITIES: The code is compact and fast. Output values compare favorably with experimental values.

ASSESSMENT OF LIMITATIONS: Kinetics are approximated to speed the computations. Therefore, gas species limited to CO₂, He, N₂, and water vapor.

OTHER UNIQUE FEATURES: Gain spike values are computed.

ORIGINATOR/KEY CONTACT:
Name: Arthur Werkheiser
Organization: U. S. Army Missile Command
Address: DRSMI-RHA Directed Energy Directorate, Redstone Arsenal, AL 35898
Phone: (205) 876-8161

AVAILABLE DOCUMENTATION: Formal documentation being assembled. Informally, there is available listing and user's manual.

STATUS:
Operational Currently?: yes
Under Modification?: yes
Purposes: Attempting a two-dimensional representation of the output.

Ownership?: U. S. Army
Proprietary?: No

MACHINE/OPERATING SYSTEM: CDC 6600

TRANSPORTABLE?: yes

SELF-CONTAINED?:

Other Codes Required (name, purpose): No

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

<table>
<thead>
<tr>
<th>Type of Job</th>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Job</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical Job</td>
<td>30K</td>
<td>10 sec</td>
</tr>
<tr>
<td>Large Job</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Approximate Number of FORTRAN Lines: 500

COMMENTS:
# KINETICS CODE

## CODE NAME: EBEAM

### 1. CODE STRUCTURE

<table>
<thead>
<tr>
<th>COORDINATE SYSTEM (✓):</th>
<th>Cartesian; Expanding;</th>
</tr>
</thead>
<tbody>
<tr>
<td>KINETICS GRID DIMENSIONALITY (✓):</td>
<td>1-D: ✓ 2-D: 3-D:</td>
</tr>
<tr>
<td>GAIN REGION SYMMETRY RESTRICTIONS:</td>
<td>Gain Vary Along Optical Axis:</td>
</tr>
<tr>
<td>KINETICS MODELED:</td>
<td>Pulsed; CW:</td>
</tr>
<tr>
<td>NUMERICAL SCHEME USED IN RATE CALCULATION (✓):</td>
<td>Explicit; Implicit;</td>
</tr>
<tr>
<td>REFERENCE OF METHOD USED:</td>
<td></td>
</tr>
</tbody>
</table>

### 2. PLASMA KINETICS MODEL

<table>
<thead>
<tr>
<th>NUMBER OF SPECIES TREATED (specify):</th>
<th>Number of Positive Species:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Negative Species:</td>
<td></td>
</tr>
<tr>
<td>Number of Neutral Species:</td>
<td></td>
</tr>
<tr>
<td>REACTION MECHANISM MODELED (✓):</td>
<td>Primary Ionization: (Reference)</td>
</tr>
<tr>
<td>Secondary Ionization (Reference):</td>
<td>Attachment;</td>
</tr>
<tr>
<td>Detachment;</td>
<td></td>
</tr>
<tr>
<td>Ion-Ion Recombination;</td>
<td>Charge Transfer;</td>
</tr>
<tr>
<td>Dissociation/Recombination;</td>
<td></td>
</tr>
<tr>
<td>Source of Rate Coefficients Used:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DISCHARGE POWER INPUT MODELED (✓):</th>
<th>Uniform; Non-Uniform; E-Field;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Others (specify): all three can be selected.</td>
<td></td>
</tr>
</tbody>
</table>

### 3. LASING KINETICS MODEL

<table>
<thead>
<tr>
<th>GENERAL (specify):</th>
<th>Lasing Species: CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Species:</td>
<td>3</td>
</tr>
<tr>
<td>Number of Reactions:</td>
<td></td>
</tr>
<tr>
<td>IMPACT EXCITATION MODELED (✓):</td>
<td>Vibrational: (Reference)</td>
</tr>
<tr>
<td>Electronic:</td>
<td></td>
</tr>
<tr>
<td>Others (specify): not explicitly defined</td>
<td></td>
</tr>
<tr>
<td>ENERGY TRANSFER MODELS MODELED (✓):</td>
<td>V-T:</td>
</tr>
<tr>
<td>V-R: ✓</td>
<td></td>
</tr>
<tr>
<td>V-V: ✓</td>
<td></td>
</tr>
<tr>
<td>Others (specify): not explicitly defined</td>
<td></td>
</tr>
<tr>
<td>Lasing Transition: P-Branch; R-Branch;</td>
<td></td>
</tr>
<tr>
<td>Single Line Model (✓): ✓</td>
<td></td>
</tr>
<tr>
<td>Multi-Line Model (✓):</td>
<td></td>
</tr>
<tr>
<td>Assumed Rotational Population Distribution State (✓): Equilibrium;</td>
<td></td>
</tr>
<tr>
<td>Nonequilibrium; ✓</td>
<td></td>
</tr>
<tr>
<td>Number of Laser Lines Modeled: 1</td>
<td></td>
</tr>
<tr>
<td>Source of Rate Coefficients Used in Code:</td>
<td></td>
</tr>
</tbody>
</table>

| LINE PROFILE MODELS (✓): | Doppler Broadening; |
| Collisional Broadening: | |
| Others (specify): | |

### 4. RECIRCULATION CONTAMINANTS MODELED (✓): | O₂; OH; |
| NO; HNO: | not specified |
| Others (specify): | |

| REFERENCE FOR REACTION MECHANISM AND RATES: | |

| OTHER UNIQUE FEATURES: | |

---

36
CODE NAME: EBEAM2  TEHNCICAL AREA(S): Kinetics

DEVICE COMPONENTS TREATED: Power Supply

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: Given power supply specifications for an E-Beam laser, computes the E-Beam gun and sustainer voltage and current time history. Gas species and densities are also inputted.

ASSESSMENT OF CAPABILITIES: Provides a graphical display of current and voltage for each of the two electrical systems in a pulsed E-beam laser.

ASSESSMENT OF LIMITATIONS: Restricted to CO₂, N₂, and HE Gas Systems. Laser outputted not computed.

OTHER UNIQUE FEATURES: was used in a comparison between theory and experiment. Easily showed gas rate coefficient dependencies.

ORIGINATOR/KEY CONTACT:
Name: Arthur Werkheiser
Organization: US Army Missile Command
Address: DRSMI-RHA, Directed Energy Directorate, Redstone Arsenal, AL 35898
Phone: (205) 876-8161


STATUS:
Operational Currently?: yes
Under Modification?: no

Ownership?: US Army
Proprietary?: No

MACHINE/OPERATING SYSTEM (on which installed): DEC PDP 11/34

TRANSPORTABLE?: No
Machine Dependent Restrictions: Requires a Tektronics 4012 terminal

SELF-CONTAINED?:
Other Codes Required (name, purpose): Requires Tektronics Plot 10 Software

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

<table>
<thead>
<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Job:</td>
<td>Typical Job: 25K</td>
</tr>
<tr>
<td>Large Job:</td>
<td></td>
</tr>
</tbody>
</table>

Approximate Number of FORTRAN Lines: 300

COMMENTS:
1. CODE STRUCTURE
   CODE NAME: EBEAM2
   COORDINATE SYSTEM (✓)
   Cartesian: Expanding:
   KINETICS GRID DIMENSIONALITY (✓)
   1-D:
   2-D:
   3-D:
   GAIN REGION SYMMETRY RESTRICTIONS:
   Gain vary Along Optical Axis:
   Flow Direction:
   KINETICS MODELED: Pulsed: CW:
   NUMERICAL SCHEME USED IN RATE CALCULATION (✓)
   Explicit:
   Implicit:
   Others (specify):
   REFERENCE OF METHOD USED:

2. PLASMA KINETICS MODEL
   NUMBER OF SPECIES TREATED (specify)
   Number of Positive Species:
   Number of Negative Species:
   Number of Neutral Species:
   REACTION MECHANISM MODELED (✓)
   Primary Ionization: (Reference)
   E-Beam:
   Self-Sustained:
   UV-Initiated:
   Others (specify):
   Secondary Ionization (Reference)
   Attachment:
   Detachment:
   Ion-Ion Recombination:
   Charge Transfer:
   Dissociation/Recombination:
   Others (specify):
   Source of Rate Coefficients Used:
   DISCHARGE POWER INPUT MODELED (✓)
   Uniform:
   E-Field:
   Others (specify):

3. LASING KINETICS MODEL
   GENERAL (specify)
   Lasing Species:
   Number of Species:
   Number of Reactions:
   Other Major Species Considered:
   IMPACT EXCITATION MODELED (✓)
   Vibrational:
   Electronic:
   Others (specify):
   ENERGY TRANSFER MODELS MODELED (✓)
   V-T:
   V-R:
   Others (specify):
   Lasing Transition:
   P-Branch:
   R-Branch:
   Single Line Model (✓)
   Multi-Line Model (✓)
   Assumed Rotational Population Distribution State (✓)
   Equilibrium:
   Nonequilibrium:
   Number of Laser Lines Modeled:
   Source of Rate Coefficients Used in Code:

4. RECIRCULATION CONTAMINANTS MODELED (✓)
   none
   O₂:
   OH:
   NO:
   HNO₃:
   Others (specify):
   REFERENCE FOR REACTION MECHANISM AND RATES:
   OTHER UNIQUE FEATURES:
CODE NAME: **EBM2D**
TECHNICAL AREA(S): Kinetics
DEVICE COMPONENTS TREATED: Laser Cavity, Gas

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: **EBM2D** Computes a 2-dimensional distribution of electron density, electric field, and power deposited within a laser cavity for a given potential difference and current density for electric lasers.


ASSESSMENT OF LIMITATIONS: Reiterates 6 times in computing one distribution. Does not give a time history. Restricted to a few species.

OTHER UNIQUE FEATURES: Makes use of cavity symmetry. Includes several empirical approximations to speed the calculations. Presupposes an EBEAM laser.

ORIGINATOR/KEY CONTACT:
Name: Arthur Werkheiser
Organization: U.S. Army Missile Command
Address: DRSMI-RHA Directed Energy Directorate, Redstone Arsenal, AL 35898
Phone: (205) 876-8161


STATUS:
Operational Currently?: yes
Under Modification?: yes
Purpose(s): Combining this with EBEAM to produce a two-dimensional time history.
Ownership?: US Army
Proprietary?: no

MACHINE/OPERATING SYSTEM (on which installed): CDC 6600
TRANSPORTABLE?: yes
Machine Dependent Restrictions: no

SELF-CONTAINED?:
Other Codes Required (name, purpose):

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

<table>
<thead>
<tr>
<th></th>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Job:</td>
<td>30K</td>
<td>15 sec</td>
</tr>
<tr>
<td>Typical Job:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large Job:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Approximate Number of FORTRAN Lines: 400

COMMENTS:
KINETICS CODE

1. CODE STRUCTURE
COORDINATE SYSTEM (✓):
Cartesian: ✓ Expanding:

KINETICS GRID DIMENSIONALITY (✓):
1-D: ___ 2-D: ✓ 3-D: ___

GAIN REGION SYMMETRY RESTRICTIONS:
Gain Vary Along Optical Axis: ___

Flow Direction:
KINETICS MODELED: Pulsed: ___ CW: ___

NUMERICAL SCHEME USED IN RATE CALCULATION (✓):
Explicit: ✓ Implicit: ✓
Others (specify): ___

REFERENCE OF METHOD USED:

2. PLASMA KINETICS MODEL
NUMBER OF SPECIES TREATED (specify):
Number of Positive Species: ___
Number of Negative Species: ___
Number of Neutral Species: ___

REACTION MECHANISM MODELED (✓):
Primary Ionization: (Reference)
E-Beam: ✓
Self-Sustained: ___
UV-Initiated: ___
Others (specify): ___

Secondary Ionization (Reference)
Attachment: ✓
Detachment: ✓
Ion-Ion Recombination: ✓
Charge Transfer: ✓
Disassociation/Recombination: ✓
Others (specify): ___

Source of Rate Coefficients Used:

DISCHARGE POWER INPUT MODELED (✓):
Uniform: ✓ Non-Uniform: ___
E-Field: ___
Others (specify): ___

3. LASING KINETICS MODEL
GENERAL (specify):
Lasing Species: CO
Number of Species: ___
Number of Reactions: ___
Other Major Species Considered: ___

IMPACT EXCITATION MODELED (✓):
Vibrational: ___ Electronic: ___
Others (specify): ___

ENERGY TRANSFER MODES MODELED (✓):
V-T: ___ V-R: ___ V-V: ___
Others (specify): ___

Lasing Transition:
P-Branch: ___ R-Branch: ___
Single Line Model (✓): ✓
Multi-Line Model (✓): ✓
Assumed Rotational Population Distribution State (✓): ✓
Equilibrium: ✓ Nonequilibrium: ___
Number of Laser Lines Modeled: ___
Source of Rate Coefficients Used in Code:

LINE PROFILE MODELS (✓):
Doppler Broadening: ___
Collisional Broadening: ___
Others (specify): ___

4. RECIRCULATION CONTAMINANTS MODELED (✓): none
O: ___ OH: ___
NO: ___ HNO: ___
Others (specify): ___

REFERENCE FOR REACTION MECHANISM AND RATES:

OTHER UNIQUE FEATURES:
CODE NAME: EDLAMP
TECHNICAL AREA(S): Kinetics, Gas Dynamics

DEVICE COMPONENTS TREATED: Cavity

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE:
- Cavity Performance

ASSESSMENT OF CAPABILITIES:
- Suited for any E-Beam controlled EDL

ASSESSMENT OF LIMITATIONS:
- One-D Only (Flow distance for CW applications, time for pulsed application)

OTHER UNIQUE FEATURES:
- Detailed Plasma Kinetics; code can model kinetics effects due to recirculation on performance.

ORIGINATOR/KEY CONTACT:
Name: Jürgen Thoenes
Organization: Lockheed-Huntsville Research & Engineering Center
Address: P. O. Box 1103, Huntsville, AL 35807
Phone: (205) 837-1800, ext. 416

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):

STATUS:
- Operational Currently?: yes
- Under Modification?:

Ownership?: Lockheed & U.S. Army, MICOM
Proprietary?: No

MACHINE/OPERATING SYSTEM (on which installed):
- CDC 6600 (MICOM), CYBER 176 (AFWL)

TRANSPORTABLE?: yes
- Machine Dependent Restrictions: none for CDC Computers

SELF-CONTAINED?:
- Other Codes Required (name, purpose): Boltzmann Electron Kinetics Code

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:
- Core Size (Octal Words) | Execution Time (sec, CDC 7600)
  Small Job: |
  Typical Job: 145K | 60
  Large Job: |
  Approximate Number of FORTRAN Lines: 5000

COMMENTS:
- Fabry-Perot cavity modeled using geometric optics.
## KINETICS CODE

### 1. CODE STRUCTURE

**COORDINATE SYSTEM:**

<table>
<thead>
<tr>
<th>Cartesian</th>
<th>Expanding</th>
</tr>
</thead>
</table>

**KINETICS GRID DIMENSIONALITY:**

<table>
<thead>
<tr>
<th>1-D</th>
<th>2-D</th>
</tr>
</thead>
</table>

**GAIN REGION SYMMETRY RESTRICTIONS:**

- Gain Vary Along Optical Axis: □
- Flow Direction: □

**KINETICS MODELED:**

- Pulsed: □
- CW: □

**NUMERICAL SCHEME USED IN RATE CALCULATION:**

- Explicit: □
- Implicit: □

**REFERENCE OF METHOD USED:**


### 2. PLASMA KINETICS MODEL

**NUMBER OF SPECIES TREATED:**

- Number of Positive Species: □
- Number of Negative Species: □
- Number of Neutral Species: □

**REACTION MECHANISM MODELED:**

- Primary Ionization: □
- E-Beam: □
- Self-Sustained: □
- UV-Initiated: □

**SECONDARY IONIZATION:**

- Attachment: □
- Detachment: □
- Ion-Ion Recombination: □
- Charge Transfer: □
- Dissociation/Recombination: □

**DISCHARGE POWER INPUT MODELED:**

- Uniform: □
- E-Field: □

**REFERENCE FOR REACTION MECHANISM AND RATES:**


### 3. LASING KINETICS MODEL

**GENERAL:**

- Number of Species: □
- Number of Reactions: □
- Other Major Species Considered: □

**IMPACT EXCITATION MODELED:**

- Vibration: □
- Electronic: □
- Others: □

**ENERGY TRANSFER MODES MODELED:**

- V-T: □
- V-R: □
- V-V: □

**SOURCE OF RATE COEFFICIENTS USED:**


### 4. RECIRCULATION CONTAMINANTS MODELED

- O: □
- OH: □
- NO: □
- HNO: □

**REFERENCE FOR REACTION MECHANISM AND RATES:**


### OTHER UNIQUE FEATURES:

- □
**GAS DYNAMICS CODE**

**CODE NAME:** EDLAMP

### 1. CODE STRUCTURE

**COORDINATE SYSTEM:** 
- Cartesian: 
- Expanding: 

**FLUID GRID DIMENSIONALITY:**
- 1-D: **✓**
- 2-D: 
- 3-D: 
- Time Dependent: 

**FLOW FIELD MODELED:**
- Compressible Flow: **✓**
- Incompressible: 
- Viscous Flow: 
- No Flow: 

**BASIC MODELING APPROACH:**
- Algebraic: 
- Integral Method: 
- Finite Difference: **✓**
- Others (specify): 

**DECONTAMINATION METHOD TREATED:**
- Scrubber: **✓**
- Shower: 
- Catalytic Reactor: **✓**
- Others (specify): Scrubber/Catalytic reactor modeled by adjusting mixture composition.

### 4. ACOUSTIC ATTENUATION MODEL

**GENERAL FEATURES MODELED:**
- Single Pulse: 
- Repetitive Pulse: 

**DIMENSIONALITY TREATED:**
- 1-D: 
- 2-D: 
- 3-D: 
- Time Dependent: 

**DISTURBANCE MODELED:**
- Pressure Wave: 
- Entropy Wave: 
- Others (specify): 

**WAVE PROPAGATION TREATMENT:**
- Linear Wave: 
- Nonlinear Wave: 
- Others (specify): 

**THEORETICAL BASIS:** (Reference) 

**NUMERICAL METHODOLOGY:** (Reference) 

**ACOUSTIC ATTENUATORS CONSIDERED:**
- Muffler: 
- Heat Exchanger: 
- Horn: 
- Porous Wall: 
- Others (specify): 

### 2. GAS DYNAMICS MODEL FEATURES

**GAS SUPPLY MODELED:**
- Mixture Preparation: 
- Mixture Injection: 
- Nozzles: 
- Flow Plates: 
- Others (specify): 

**CAVITY INITIAL CONDITION DETERMINED BY:**
- given P, T, U, Equil. concentrations 

### 3. EXHAUST RECIRCULATION MODEL

**GENERAL SYSTEM MODELED:**
- Open System: **✓**
- Closed System: 
- Closed Cycle: **✓**

**EXHAUST SYSTEM FEATURES:**
- Pressure Recovery: 
- Ejector System: 
- Compressor/Fan: 
- Heat Exchanger: **✓**
- Gas Make-Up: **✓**
- Others (specify): Heat exchanger modeled via specified drop in T. Make-up modeled by adjusting mixture composition.

### 5. MODEL EFFECTS ON OPTICAL MODES DUE TO

**INDEX OF REFRACTION VARIATION:**
- Other (specify): 

**OTHER UNIQUE FEATURES:**

---

43
CODE NAME: EDLNOD  TECHNICAL AREA(s): Kinetics

DEVICE COMPONENTS TREATED: Cavity

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: Small signal gain and energy extraction for CO$_2$ EDL's.

ASSESSMENT OF CAPABILITIES: Both versions of this code have demonstrated good agreement with experimental data from Humdinger, ABEL, and the AFWL Pulsar Device.

ASSESSMENT OF LIMITATIONS: The energy extraction routine is not based on physical optics principles, so predictions are of limited utility. The code assumes uniform electric field and electron density.

OTHER UNIQUE FEATURES:

ORIGINATOR/KEY CONTACT:
Name: CPT Robert F. Walter
Organization: AFWL/AREP
Address: Kirtland AFB, NM 87117
Phone: 505-844-1786

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):
L RP: AFWL TR-74-216
J. Appl. Phys. 46, 3566, Aug. 1975

STATUS:
Operational Currently?: yes
Under Modification?: yes
Purpose(s): Provide voltage and current input waveforms of arbitrary temporal profile.

Ownership?: US AirForce
Proprietary?: no

MACHINE/OPERATING SYSTEM (on which installed): CRAY-1, CDC 6600

TRANSPORTABLE?: yes

Machine Dependent Restrictions:

SELF-CONTAINED?:

Other Codes Required (name, purpose): IDHANK - Boltzmann Equation Code required to calculate electron excitation rates.

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

<table>
<thead>
<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Job:</td>
<td></td>
</tr>
<tr>
<td>Typical Job:</td>
<td>(200,000)</td>
</tr>
<tr>
<td>Large Job:</td>
<td></td>
</tr>
</tbody>
</table>

COMMENTS:
KINETICS CODE

CODE NAME: EDLNOD

1. CODE STRUCTURE

COORDINATE SYSTEM (✓):
- Cartesian: Expanding:

KINETICS GRID DIMENSIONALITY (✓):
- 1-D: ✓
- 3-D: 

GAIN REGION SYMMETRY RESTRICTIONS:
- Gain Vary Along Optical Axis:
  - Flow Direction:

KINETICS MODELED: Pulsed: ✓ CW:

NUMERICAL SCHEME USED IN RATE CALCULATION (✓):
- Explicit: ✓
- Implicit: 
- Others (specify):


2. PLASMA KINETICS MODEL

NUMBER OF SPECIES TREATED (specify):
- Number of Positive Species: 0
- Number of Negative Species: 1
- Number of Neutral Species: 4

REACTION MECHANISM MODELED (✓):
- Primary Ionization: ✓ (Reference)
- E-Beam:
- Self-Sustained:
- UV-Initiated:
- Others (specify):

SECONDARY IONIZATION (Reference)
- Attachment:
- Detachment:
- Ion-Ion Recombination:
- Charge Transfer:
- Dissociation/Recombination:
- Others (specify):

Source of Rate Coefficients Used:

DISCHARGE POWER INPUT MODELED (✓):
- Uniform: ✓
- Non-Uniform:
- E-Field:
- Others (specify):

3. LASING KINETICS MODEL

GENERAL (specify):
- Lasing Species: 1
- Number of Species: 4
- Number of Reactions:
- Other Major Species Considered:

IMPACT EXCITATION MODELED (✓):
- Vibrational: ✓
- Electronic: 
- Others (specify):

ENERGY TRANSFER MODELS MODELED (✓):
- Reference
- V-V: ✓
- V-R:
- V-I:
- Others (specify):
- Lasing Transition: P-Branch: ✓
- R-Branch:
- Single-Line Model (✓): ✓
- Multi-Line Model (✓): ✓
- Assumed Rotational Population Distribution State (✓): ✓
- Equilibrium:
- Nonequilibrium:
- Number of Laser Lines Modeled: 1
- Source of Rate Coefficients Used in Code: AFWL TR-74-216

LINE PROFILE MODELS (✓):
- Doppler Broadening: ✓
- Collisional Broadening: ✓
- Others (specify):

4. RECYCLATION CONTAMINANTS MODELED (✓): none
- O₂: 
- OH: 
- NO₂: 
- HNO₃: 
- Others (specify):

REFERENCE FOR REACTION MECHANISM AND RATES:

OTHER UNIQUE FEATURES:

45
CODE NAME: EDLSL

TECHNICAL AREA(S): Kinetics

DEVICE COMPONENTS TREATED: CO/H, or He/H, EDL Cavity Kinetics

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: Models the kinetics of photon production by a glow discharge in an EDL cavity containing CO, N, and He or He using the 6-temperature model of AVCO written by Dr. A.T. Gavrielides of the AFWL.

ASSESSMENT OF CAPABILITIES: A fast and simple algorithm which does not account for E-beam spreading, has no optics in it, and assumes a constant average Ne which is an input.

ASSESSMENT OF LIMITATIONS: Has been anchored to other codes such as that of Lockheed and has shown agreement within 10-15%.

OTHER UNIQUE FEATURES:

ORIGINATOR/KEY CONTACT:
Name: A. T. Gavrielides
Organization: AFWL/LRE
Address: Kirtland AFB, N.M. 87106
Phone: (505) 844-4691

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):
none

This is an "in-house" code used by a limited number of people.

STATUS:
Operational Currently?: yes
Under Modification?:
Purpose(s):

Ownership?: AFWL/LRE
Proprietary?: NO

MACHINE/OPERATING SYSTEM (on which installed): CDC 6600/ CYBER 176

TRANSPORTABLE?: marginally
Machine Dependent Restrictions: Was written for CDC and is not in ANSll Fortran

SELF-CONTAINED?:
Other Codes Required (name, purpose): Requires DISSPLA package and a library differential equation solver.

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:
Small Job:
Typical Job: 4992  20 sec
Large Job:
Approximate Number of FORTRAN Lines: 150

COMMENTS:

46
KINETICS CODE

CODE NAME: EDLSL

1. CODE STRUCTURE

COORDINATE SYSTEM (√):
- Cartesian: Expanding:

KINETICS GRID DIMENSIONALITY (√):
- 1-D: 2-D: 3-D:

GAIN REGION SYMMETRY RESTRICTIONS:
- Gain Vary Along Optical Axis:

KINETICS MODELED: Pulsed: CW:

NUMERICAL SCHEME USED IN RATE CALCULATION (√):
- Explicit: Implicit: Others (specify):

REFERENCE OF METHOD USED: AVCO 6-temp model programmed by Dr. A.T. Cavielie of the AFRL.

2. PLASMA KINETICS MODEL

NUMBER OF SPECIES TREATED (specify):
- Number of Positive Species:
- Number of Negative Species:
- Number of Neutral Species:

REACTION MECHANISM MODELED (√):
- Primary Ionization: (Reference)
- E-Beam:
- Self-Sustained: √ AEPL Kinetics Handbook
- UV-Initiated:
- Others (specify):

Secondary Ionization (Reference)
- Attachment:
- Detachment:
- Ion-Ion Recombination:
- Charge Transfer:
- Dissociation/Recombination:
- Others (specify):

Source of Rate Coefficients Used:

DISCHARGE POWER INPUT MODELED (√):
- Uniform: √ Non-uniform:
- E-Field:
- Others (specify):

3. LASING KINETICS MODEL

GENERAL (specify):
- Lasing Species: √ CO2
- Number of Species:
- Number of Reactions:
- Other Major Species Considered:

IMPACT EXCITATION MODELED (√):
- Vibrational:
- Electronic:
- Others (specify):

ENERGY TRANSFER MODES MODELED (√):
- V-T:
- V-R:
- V-V:

REFERENCE FOR REACTION MECHANISM AND RATES:

OTHER UNIQUE FEATURES: Gain switch spike computed.

LINE PROFILE MODELS (√):
- Doppler Broadening:
- Collisional Broadening:
- Others (specify):

4. RECIRCULATION CONTAMINANTS MODELED (√): none
- O3:
- OH:
- NO:
- HNO:
- Others (specify):

REFERENCE FOR REACTION MECHANISM AND RATES:

OTHER UNIQUE FEATURES: Gain switch spike computed.

plotting capability.
CODE NAME: EED, also called BOLT
TECHNICAL AREA(S): Electron Kinetics

DEVICE COMPONENTS TREATED: NA

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: EED solves for the steady-state electron distribution function using the Boltzmann Equation. Elastics, inelastic and super-elastic interactions are considered, as well as electron-electron interactions.

ASSESSMENT OF CAPABILITIES: Very general. It will consider any gas as long as cross-section data for that gas are available. If no super-elastics or electron-electron interactions are included, the code is very fast.

ASSESSMENT OF LIMITATIONS: The electron-electron interactions are somewhat untested and it's not clear if the formulation is correct. If superelastics are included, the method is slow. Also, if superelastics are included, a lot of core memory is required.

OTHER UNIQUE FEATURES: Very easy to use, clear output, very little machine-dependent features. Input is checked for consistency and validity.

ORIGINATOR/KEY CONTACT:
Name: Henry Happ
Organization: Tetra Corp.
Address: 1325 San Mateo, SE, Albuquerque, NM 87108
Phone: (505) 256-3595

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):
Boltz: A code to solve the Boltzmann Electron Transport Equation, Tetra TR-78-001 (T, U)
Listings are available upon request.

STATUS:
Operational Currently: yes
Under Modification: no
Purpose(s): 

Ownership: U. S. Government
Proprietary: No

MACHINE/OPERATING SYSTEM (on which installed): CDC 6600 or 176, CRAY-1

TRANSPORTABLE?: Almost
Machine Dependent Restrictions: How the machine orders its display code. Problem only occurs in one or two lines of code. Also, write statements use A8 formats.

SELF-CONTAINED?: Finally, NAMELIST is used.
Other Codes Required (name, purpose): none

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

<table>
<thead>
<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Job: 32533 *</td>
<td></td>
</tr>
<tr>
<td>Typical Job: 232433</td>
<td></td>
</tr>
<tr>
<td>Large Job: 232533</td>
<td></td>
</tr>
</tbody>
</table>

Approximate Number of FORTRAN Lines: 2400

COMMENTS: * If superelastics are to be included, a large array of size (256,256) is used. References to this array can be removed if superelastics are not used.
## KINETICS CODE

### CODE NAME: EED

### 1. CODE STRUCTURE

**COORDINATE SYSTEM (✓):**
- Cartesian: ✓
- Expanding: ❌

**KINETICS GRID DIMENSIONALITY (✓):**
- 1-D: ✓
- 2-D: ❌
- 3-D: ❌

**GAIN REGION SYMMETRY RESTRICTIONS:**
- Symmetry: ❌
- Flow Direction: ❌

**KINETICS MODELED:**
- Pulsed: ❌
- CW: ✓

**NUMERICAL SCHEME USED IN RATE CALCULATION (✓):**
- Explicit: ✓
- Implicit: ❌
- Others (specify): ❌

**REFERENCE OF METHOD USED:**

### 2. PLASMA KINETICS MODEL

**NUMBER OF SPECIES TREATED (specify):**
- Number of Positive Species: ❌
- Number of Negative Species: ❌
- Number of Neutral Species: ❌

**REACTION MECHANISM MODELED (✓):**
- Primary Ionization: (Reference)
- E-Beam: ❌
- Self-Sustained: ❌
- UV-Initiated: ❌
- Others (specify): ❌

- Secondary Ionization: (Reference)
- Attachment: ❌
- Detachment: ❌
- Ion-Ion Recombination: ❌
- Charge Transfer: ❌
- Dissociation/Recombination: ❌
- Others (specify): ❌

**DISCHARGE POWER INPUT MODELED (✓):**
- Uniform: ❌
- Non-Uniform: ❌
- E-Field: ✓
- Others (specify): ❌

**REFERENCE FOR REACTION MECHANISM AND RATES:**

### 3. LASING KINETICS MODEL

**GENERAL (specify):**
- Lasing Species: ❌
- Number of Species: ❌
- Number of Reactions: ❌
- Other Major Species Considered: ❌

**IMPACT EXCITATION MODELED (✓):**
- Vibrational: ❌
- Electronic: ❌
- Others (specify): ❌

**ENERGY TRANSFER MODES MODELED (✓):**
- V-T: ❌
- V-R: ❌
- V-V: ❌
- Others (specify): ❌

### 4. REGICIRCULATION CONTAMINANTS MODELED (✓):

- Source of Rate Coefficients Used: ❌

**REFERENCE FOR REACTION MECHANISM AND RATES:**

**OTHER UNIQUE FEATURES:**

49
CODE NAME: ELECT
TECHNICAL AREA(S): Electron Kinetics

DEVICE COMPONENTS TREATED: Laser cavity; electrical excitation

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: To provide an analysis of electron kinetics for an arbitrary gas mixture (possibly including excited species) as a function of electric field by numerical solution of the Boltzmann equation.

ASSESSMENT OF CAPABILITIES: Code provides for electron-molecule, momentum transfer, superelastic, and electron-electron collisions; quasisteady state approximation retains \( \frac{dn}{dt} \) term for electron creation or loss from external ionization, secondary ionization, attachment, recombination, etc.

ASSESSMENT OF LIMITATIONS: No significant limitations.

OTHER UNIQUE FEATURES: Code is more general than most, inasmuch as there are few limitations on scattering processes, electron-electron collisions are included, superelastic collisions are included, and the analysis can be generated for an arbitrary number of species or reaction. User-oriented, flexible input/output characteristics.

ORIGINATOR/KEY CONTACT:
Name: William B. Lacina
Organization: Northrop Research and Technology Center
Address: One Research Park, Palos Verdes Peninsula, CA 90274
Phone: (213) 377-4811 Ext. 362

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):

STATUS:
Operational Currently?: yes
Under Modification?: no
Purpose(s):

Ownership?: Northrop Research & Tech./William B. Lacina
Proprietary?: No. Public Domain

MACHINE/OPERATING SYSTEM (on which installed): CDC 6600

TRANSPORTABLE?: yes
Machine Dependent Restrictions: yes (word size)

SELF-CONTAINED?: yes
Other Codes Required (name, purpose):

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

<table>
<thead>
<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Job</td>
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</tr>
<tr>
<td>Typical Job</td>
<td></td>
</tr>
<tr>
<td>Large Job</td>
<td></td>
</tr>
</tbody>
</table>

Approximate Number of FORTRAN Lines: 4,000

COMMENTS:
NOTE: The actual Boltzmann subroutines (without the main program ELECT and miscellaneous I/O routines) are shorter, and could be easily extracted from this code for usage elsewhere.
1. CODE STRUCTURE
COORDINATE SYSTEM (✓)
- Cartesian
- Expanding
KINETICS GRID DIMENSIONALITY (✓)
- 1-D
- 2-D
- 3-D
GAIN REGION SYMMETRY RESTRICTIONS
- Gain Vary Along Optical Axis
Flow Direction
KINETICS MODELED
- Pulsed
- CW
NUMERICAL SCHEME USED IN RATE CALCULATION (✓)
- Explicit
- Implicit
- Others (specify)
REFERENCE OF METHOD USED

2. PLASMA KINETICS MODEL
NUMBER OF SPECIES TREATED (specify)
- Number of Positive Species: Arbitrary
- Number of Negative Species:
- Number of Neutral Species:
REACTION MECHANISM MODELED (✓)
- Primary Ionization (Reference)
  - E-Beam:
  - Self-Sustained:
  - UV-Initiated:
- Others (specify)
- Secondary Ionization (Reference)
  - Attachment:
  - Detachment:
  - Ion-Ion Recombination:
  - Charge Transfer:
  - Dissociation/Recombination:
- Others (specify)
- Source of Rate Coefficients Used:
  - Miscellaneous
DISCHARGE POWER INPUT MODELED (✓)
- Uniform: ✓
- Non-Uniform:
- E-Field: ✓
- Others (specify): E-beam or other

3. LASING KINETICS MODEL
GENERAL (specify): N.A.
- Lasing Species:
- Number of Species:
- Number of Reactions:
- Other Major Species Considered:
IMPACT EXCITATION MODELED (✓)
- Vibrational (Reference)
- Electronic:
- Others (specify)
ENERGY TRANSFER MODELS MODELED (✓)
- V-T:
- V-R:
- V-V:
- Others (specify)
- Lasing Transition:
  - P-Branch:
  - R-Branch:
- Single Line Model (✓)
- Multi-Line Model (✓)
  - Assumed Rotational Population Distribution State (✓)
    - Equilibrium:
    - Nonequilibrium:
    - Number of Laser Lines Modeled:
    - Source of Rate Coefficients Used in Code:
LINE PROFILE MODELS (✓)
- Doppler Broadening:
- Collisional Broadening:
- Others (specify)

4. RECIRCULATION CONTAMINANTS MODELED (✓)
- None
- O₃:
- OH:
- NO₂:
- HNO₃:
- Others (specify)
REFERENCE FOR REACTION MECHANISM AND RATES:
OTHER UNIQUE FEATURES:
CODE NAME: ELENDIF

TECHNICAL AREA(S): Electron Kinetics

DEVICE COMPONENTS TREATED:

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: Time Dependent Boltzmann Code

ASSESSMENT OF CAPABILITIES: (1) Backward prolongation (using a multi-step, variable stepsize integration algorithm); (2) Matrix solution of the steady-state Boltzmann equation including superelastic processes; (3) Time dependent relaxation calculation of the distribution function.

ASSESSMENT OF LIMITATIONS:

OTHER UNIQUE FEATURES: In addition to computing the electron energy distribution function, the code computes mean electron energy, drift velocity, characteristic energy, inelastic and superelastic rate coefficients, and energy flow rates for the processes being included in the calculation.

ORIGINATOR/KEY CONTACT:
Name: CPT Gary L. Duke
Organization: AFWAL/POOC-3
Address: Wright-Patterson AFB, Dayton, OH
Phone: (513) 255-2923


STATUS:
Operational Currently?: Yes
Under Modification?: No
Purpose(s):

Ownership?:
Proprietary?: No

MACHINE/OPERATING SYSTEM (on which installed):

TRANSPORTABLE?: Yes
Machine Dependent Restrictions: Programmed in Fortran IV

SELF-CONTAINED?:
Other Codes Required (name, purpose): none

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

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<tr>
<th>Core Size (Octal Words)</th>
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</tr>
<tr>
<td>Typical Job:</td>
<td>120K</td>
</tr>
<tr>
<td>Large Job:</td>
<td>15 Sec</td>
</tr>
<tr>
<td>Approximate Number of FORTRAN Lines:</td>
<td>1200</td>
</tr>
</tbody>
</table>

COMMENTS:
NOTE: ELENDIF was brought to us by MAJ R.D. Franklin from Lawrence Lab. He has since moved on and although the code is operational it is not currently being used.
CODE NAME: ETRANV  TECHNICAL AREA(S): Kinetics

DEVICE COMPONENTS TREATED: 

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: Time dependent solution of master equation for vibrational energy exchange. Used in modeling of vibrational-rotational laser systems (CO₂, CO, HF, DF).

ASSESSMENT OF CAPABILITIES: Time dependent or steady state solutions of state populations (200), with capability to treat five (5) different molecular species. Capable of being linked to solution of collisional Boltzmann equation

ASSESSMENT OF LIMITATIONS: Uncertainty in rate (V-V and V-T) scaling with respect to vibrational state and translational temperature.

OTHER UNIQUE FEATURES:

ORIGINATOR/KEY CONTACT:
Name: Wm. F. Bailey
Organization: AFIT/ENP A.F. Institute of Technology, Physics Dept.
Address: Bldg. 640, Area B, Wright-Patterson AFB, Ohio 45433
Phone: 513-255-2012

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):
"Collision Induced Dissociation of Diatomic Molecules", AFAPL-TR-78-105, Nov. 1978 (RP)

STATUS:
Operational Currently: X
Under Modification: 
Purpose(s): 

Ownership: U.S.A.F.
Proprietary: 

MACHINE/OPERATING SYSTEM (on which installed): CDC 6600

TRANSPORTABLE: X
Machine Dependent Restrictions:

SELF-CONTAINED: X
Other Codes Required (name, purpose):

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

<table>
<thead>
<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
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</thead>
<tbody>
<tr>
<td>Small Job:</td>
<td></td>
</tr>
<tr>
<td>Typical Job:</td>
<td></td>
</tr>
<tr>
<td>Large Job:</td>
<td></td>
</tr>
</tbody>
</table>

Approximate Number of FORTRAN Lines: 

COMMENTS: 53
1. CODE STRUCTURE
COORDINATE SYSTEM ( ):
Cartesian: Expanding;
KINETICS GRID DIMENSIONALITY ( ):
1-D: ; 2-D: ; 3-D: ;
GAIN REGION SYMMETRY RESTRICTIONS:
Gain Vary Along Optical Axis: ;
Flow Direction: ;
KINETICS MODELED: Pulsed: ; CW: ;
NUMERICAL SCHEME USED IN RATE CALCULATION ( ):
Explicit: ; Implicit: ; Others (specify): ;
REFERENCE OF METHOD USED: ;

2. PLASMA KINETICS MODEL
NUMBER OF SPECIES TREATED (specify):
Number of Positive Species: ;
Number of Negative Species: ;
Number of Neutral Species: ;
REACTION MECHANISM MODELED ( ):
Primary Ionization: (Reference)
E-Beam: ; Self-Sustained: ; UV-initiated: ; Others (specify): ;
Secondary Ionization (Reference)
Attachment: ; Detachment: ;
Ion-Ion Recombination: ; Charge Transfer: ;
Dissociation/Recombination: ; Others (specify): ;
Source of Rate Coefficients Used: ;
DISCHARGE POWER INPUT MODELED ( ):
Uniform: ; Non-Uniform: ; E-Field: ; Others (specify): ;
REFERENCE OF METHOD USED: ;

3. LASING KINETICS MODEL
GENERAL (specify):
Lasing Species: ; Number of Species: ; Number of Reactions: ; Other Major Species Considered: ;
IMPACT EXCITATION MODELED ( ):
Vibrational: ; Electronic: ; Others (specify): ;
ENERGY TRANSFER MODES MODELED ( ):
V-T: ; V-R: ; V-V: ; Others (specify): ;
Lasing Transition: P-Branch: ; R-Branch: ;
Assumed Rotational Population Distribution State ( ):
Equilibrium: ; Nonequilibrium: ; Number of Laser Lines Modeled: Variable
Source of Rate Coefficients Used in Code: SSH
LINE PROFILE MODELS ( ):
Doppler Broadening: ; Collisional Broadening: ; Others (specify): ;
REFERENCE FOR REACTION MECHANISM AND RATES:
OTHER UNIQUE FEATURES:

4. RECIRCULATION CONTAMINANTS MODELED ( ):
none
O: ; OH: ; NO: ; HNO: ; Others (specify): ;
REFERENCE FOR REACTION MECHANISM AND RATES:
OTHER UNIQUE FEATURES:
CODE NAME: FREESL  
TECHNICAL AREA(S): Gas Dynamics  

DEVICE COMPONENTS TREATED: Cavity-Beam Duct Interface  

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: Compute development of free shear layer at interface of primary cavity flow and secondary injected beam duct flow, in a confined channel.  

ASSESSMENT OF CAPABILITIES: Determines penetration of beam duct gas into cavity - diffusion of CO2 into beam duct - velocity and species concentration profiles across shear layer and optical path difference.  

ASSESSMENT OF LIMITATIONS: Determination of streamwise velocity at lower boundary requires solution of elliptic problem and is unknown within the context of the parabolic shear layer equations - both zero shear and zero velocity boundary conditions used to bound problem.  

OTHER UNIQUE FEATURES: Shear layer edge conditions determined through influence of shear layer displacement thickness on inviscid cavity flow. Unequal diffusion coefficients used in conjunction with binary diffusion approximation.  

ORIGINATOR/KEY CONTACT:  
Name: Peter Crowell  
Organization: RDA  
Address: ATO 9377 Int. Airport, Albuquerque, NM 87119  
Phone: 505-884-3011  

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):  
T, L, RDA Report No. 80-A/K-21-0.1143  

STATUS:  
Operational Currently?: yes  
Under Modification?: yes  
Purpose(s): Improved turbulence model (2 eq. model) current version uses eddy viscosity model.  

Ownership?: RDA  
Proprietary?: No  

MACHINE/OPERATING SYSTEM (on which installed): CRAY-I  

TRANSPORTABLE?: Yes  
Machine Dependent Restrictions: None  

SELF-CONTAINED?:  
Other Codes Required (name, purpose): None  

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:  

<table>
<thead>
<tr>
<th>Small Job</th>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Job</td>
<td>500-600 sec on cray using 150 mesh points and 200 marching steps</td>
<td></td>
</tr>
<tr>
<td>Large Job</td>
<td>Approximate Number of FORTRAN Lines</td>
<td></td>
</tr>
</tbody>
</table>

COMMENTS:  

55
GAS DYNAMICS CODE

1. CODE STRUCTURE
   COORDINATE SYSTEM (✓):
     Cartesian:    Expanding: ✓
   FLUID GRID DIMENSIONALITY (✓):
     1-D:  
     2-D: ✓
     3-D:  
   Time Dependent:  
   FLOW FIELD MODELED (✓):
     Compressible Flow: ✓
     Incompressible:  
     Viscous Flow: ✓
     No Flow:       
   BASIC MODELING APPROACH (✓):
     Algebraic:  
     Integral Method: 
     Finite Difference: ✓
     Others (specify): 
   DECONTAMINATION METHOD TREATED (✓):
     Scrubber:  
     Shower:     
     Catalytic Reactor: none
     Others (specify): 

2. GAS DYNAMICS MODEL FEATURES:
   GAS SUPPLY MODELED (✓):
     Mixture Preparation: N₂, CO₂, He
     Mixture Injection: N₂  
     Nozzles:       
     Flow Plates:  
     Others (specify): Beam duct injection into cavity is N₂
   CAVITY INITIAL CONDITION DETERMINED BY (specify): assumed initial profiles

3. EXHAUST/RECIRCULATION MODEL
   GENERAL SYSTEM MODELED (✓):
     Open System:   
     Closed System: 
     Closed Cycle:  
   EXHAUST SYSTEM FEATURES (✓):
     Pressure Recovery: 
     Ejector System:    
     Compressor/Fan:   
     Heat Exchanger:  
     Gas Make-Up:     
     Others (specify): 

4. ACOUSTIC ATTENUATION MODEL
   GENERAL FEATURES MODELED (✓):
     Single Pulse:  
     Repetitive Pulse:  
   DIMENSIONALITY TREATED (✓):
     1-D:  
     2-D:  
     3-D:  
     Time-Dependent:  
   DISTURBANCE MODELED (✓):
     Pressure Wave: 
     Entropy Wave:   
     Others (specify): 
   WAVE PROPAGATION TREATMENT (✓):
     Linear Wave:  
     Nonlinear Wave:  
     Others (specify): 
   THEORETICAL BASIS: (Reference)
   NUMERICAL METHODOLOGY: (Reference)

5. MODEL EFFECTS ON OPTICAL MODES DUE TO (✓):
   Index of Refraction Variation?: yes
   Other (specify): Optical path difference computed across shear layer

OTHER UNIQUE FEATURES:
CODE NAME: GALERK  
TECHNICAL AREA(S): Electron Kinetics

DEVICE COMPONENTS TREATED:

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: To predict electron transport and excitation-ionization coefficients from cross-section data.

ASSESSMENT OF CAPABILITIES: For the first time provides practical means of taking into account properly the effects of large inelastic cross-sections, such as that for vibrational excitation of N₂ or CO.

ASSESSMENT OF LIMITATIONS: Requires large computer, e.g., used only on CRAY I so far; requires user to adjust grid and to iterate solutions in presence of ionization.

OTHER UNIQUE FEATURES:

ORIGINATOR/KEY CONTACT:

Name: L.C. Pitchford (originator)
Organization: Joint Institute of Laboratory Astrophysics
Address: University of Colorado, Boulder, CO 80309
Phone: (303) 492-8255

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):


STATUS:

Operational Currently?: X
Under Modification?: X
Purpose(s): To allow operation on CDC 7600 using external memory.

Ownership?: Joint Institute of Laboratory Astrophysics under support from AFAPL.
Proprietary?:

MACHINE/OPERATING SYSTEM (on which installed): CRAY I

TRANSPORTABLE?: to other CRAY I's
Machine Dependent Restrictions:

SELF-CONTAINED?:
Other Codes Required (name, purpose):

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

<table>
<thead>
<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
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</thead>
<tbody>
<tr>
<td>Small Job:</td>
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</tr>
<tr>
<td>Typical Job:</td>
<td>5 sec. on CRAY I</td>
</tr>
<tr>
<td>Large Job:</td>
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</tbody>
</table>

COMMENTS:

57
KINETICS CODE

1. CODE STRUCTURE
   COORDINATE SYSTEM: (✓) NA
      Cartesian: Expanding:
   KINETICS GRID DIMENSIONALITY: (✓) 3-D:
      1-D: 2-D:
   GAIN REGION SYMMETRY RESTRICTIONS:
      Gain Vary Along Optical Axis:
   KINETICS MODELED: Pulsed: CW: (✓)
   NUMERICAL SCHEME USED IN RATE CALCULATION: (✓)
      Explicit:
      Implicit:
      Others (specify): Matrix inversion

   REFERENCE OF METHOD USED: Pitchford et al

2. PLASMA KINETICS MODEL
   NUMBER OF SPECIES TREATED: (specify)
      Number of Positive Species: 0
      Number of Negative Species: 1 electrons
      Number of Neutral Species: ≤ 3
   REACTION MECHANISM MODELED: (✓)
      Primary Ionization: (Reference)
      E-Beam: Self-Sustained: (✓)
      (UV-Initiated:)
      Others (specify):
      Secondary Ionization: (Reference)
      Attachment:
      Detachment:
      Ion-Ion Recombination:
      Charge Transfer:
      Dissociation/Recombination:
      Others (specify): Collisional
      Ionization
   Source of Rate Coefficients Used:
   Crosssections from Phelps (unpublished)
   DISCHARGE POWER INPUT MODELED: (✓)
      Uniform: (✓) Non-Uniform:
      E-Field: (✓)
      Others (specify):

3. LASING KINETICS MODEL
   GENERAL: (specify)
      Lasing Species:
      Number of Species: 1 electrons
      Number of Reactions:
      Other Major Species Considered:
   IMPACT EXCITATION MODELED: (✓)
      Vibrational:
      Electronic:
      Others (specify): Rotation
   ENERGY TRANSFER MODELS MODELED: (✓) 1-D:
      V-T: V-R: V-V:
      Others (specify):
      Lasing Transition: P-Branch: R-Branch:
      Single Line Model (✓)
      Multi-Line Model (✓)
      Assumed Rotational Population Distribution State (✓)
      Equilibrium:
      Nonequilibrium:
      Number of Laser Lines Modeled:
      Source of Rate Coefficients Used in Code:

   LINE PROFILE MODELS: (✓) 1-D:
      Doppler Broadening:
      Collisional Broadening:
      Others (specify):

4. RECIRCULATION CONTAMINANTS
   MODELED: (✓) NA
      O3: OH:
      NOx:
      Others (specify):
   REFERENCE FOR REACTION MECHANISM AND RATES:

   OTHER UNIQUE FEATURES:

58
CODE NAME: HGX80            TECHNICAL AREA(S): Kinetics

DEVICE COMPONENTS TREATED: laser/discharge cavity

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: Computation of laser/discharge properties in electrically excited rare-gas halide and mercury-halide lasers.

ASSESSMENT OF CAPABILITIES: Capable of quantitative calculation of excited state and ion densities and electric discharge properties.

ASSESSMENT OF LIMITATIONS: Restricted to spatially uniform, volume-dominated media.

OTHER UNIQUE FEATURES:

ORIGINATOR/KEY CONTACT:
Name: William L. Nighan
Organization: United Technologies Research Center MS 90
Address: East Hartford, CT 06108
Phone: (203) 727-7596


STATUS:
Operational Currently?: X
Under Modification?: 

Ownership?: UTRC
Proprietary?: yes

MACHINE/OPERATING SYSTEM (on which installed): UNIVAC 1100/81A

TRANSPORTABLE?: yes, FORTRAN
Machine Dependent Restrictions: none

SELF-CONTAINED?: no
Other Codes Required (name, purpose):

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

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<thead>
<tr>
<th></th>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
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</thead>
<tbody>
<tr>
<td>Small Job</td>
<td>55K</td>
<td>approximately 10 sec</td>
</tr>
<tr>
<td>Typical Job</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large Job</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Approximate Number of FORTRAN Lines: 1800

COMMENTS: * HGX80 requires Runge-Kutta routine from Sperry's MATHPACK, UTRC interpolation routines (TEBAR, SPLEVEL and SPLINE), and UTRC code FU79 for the computation of electron distribution functions and electron rate coefficients.
1. CODE STRUCTURE

**COORDINATE SYSTEM** (√):
- Cartesian: √
- Expanding: 

**KINETICS GRID DIMENSIONALITY** (√):
- 1-D: √
- 2-D: 
- 3-D: 

**GAIN REGION SYMMETRY RESTRICTIONS:**
- Gain Vary Along Optical Axis: 

**KINETICS MODELED:**
- Pulsed: √
- CW: 

**NUMERICAL SCHEME USED IN RATE CALCULATION** (√):
- Explicit: 
- Implicit: √
- Others (specify): 


2. PLASMA KINETICS MODEL

**NUMBER OF SPECIES TREATED** (specify):
- Number of Positive Species: 6
- Number of Negative Species: 2
- Number of Neutral Species: 9

**REACTION MECHANISM MODELED** (√):
- Primary Ionization: (Reference)
- E-Beam: √
- Self-Sustained: √
- LV-Initiated: 
- Others (specify): 
- Secondary Ionization (Reference)
- Attachment: √
- Detachment: 
- Ion-Ion Recombination: √
- Charge Transfer: 
- Dissociation/Recombination: √
- Others (specify): 

**DISCHARGE POWER INPUT MODELED** (√):
- Uniform: √
- Non-Uniform: 
- E-Field: √
- Others (specify): 

3. LASING KINETICS MODEL

**GENERAL** (specify):
- Lasing Species: rare gas/mercury halide
- Number of Species: 
- Number of Reactions: 
- Other Major Species Considered: 

**IMPACT EXCITATION MODELED** (√):
- Vibrational: 
- Electronic: 
- Others (specify): 

**ENERGY TRANSFER MODES MODELED** (√):
- V-T: 
- V-R: 
- V-V: 
- Others (specify): 

**REFERENCE FOR REACTION MECHANISM AND RATES:** 

**OTHER UNIQUE FEATURES:** 

4. RECIRCULATION CONTAMINANTS MODELED (√)
- None
- Others (specify): 

**REFERENCE FOR REACTION MECHANISM AND RATES:** 

**OTHER UNIQUE FEATURES:** 

---
CODE NAME: ILLOPT

TECHNICAL AREA(S): Optics

DEVICE COMPONENTS TREATED: Optical Systems

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE:
Illumination evaluation and optimization.

ASSESSMENT OF CAPABILITIES:
Evaluates intensity patterns of very general optical systems.

ASSESSMENT OF LIMITATIONS:
Geometrical optics only, ray-tracing, no diffraction.

OTHER UNIQUE FEATURES:

ORIGINATOR/KEY CONTACT:
Name: Johanna Schruben
Organization: Westinghouse R&D Center
Address: Pittsburgh, PA 15235
Phone: 412-256-3611

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):

STATUS:
Operational Currently: Yes
Under Modification: No

Ownership: Westinghouse
Proprietary: Yes

MACHINE/OPERATING SYSTEM (on which installed):
UNIVAC 1108

TRANSPORTABLE: No
Machine Dependent Restrictions: Yes

SELF-CONTAINED: Yes

Other Codes Required (name, purpose):

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

<table>
<thead>
<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600) (UNIVAC)</th>
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</thead>
<tbody>
<tr>
<td>Small Job: 90,000K</td>
<td>60</td>
</tr>
<tr>
<td>Typical Job:</td>
<td>120</td>
</tr>
<tr>
<td>Large Job:</td>
<td>3600</td>
</tr>
</tbody>
</table>

Approximate Number of FORTRAN Lines: 61

COMMENTS:
1. CODE STRUCTURE

BASIC TYPE (✓):
- Physical Optics:
- Geometrical:
- Constant Gain:
  - Floating Gain:

FIELD (POLARIZATION) REPRESENTATION (✓):
- Scalar:
- Vector:

COORDINATE SYSTEM (✓):
- Cartesian:
- Expanding (specify): ✓

TRANSVERSE GRID DIMENSIONALITY (specify):
- One-Dimensional:
- Two-Dimensional: ✓

FIELD SYMMETRY RESTRICTIONS:*:

MIRROR SHAPE(S) ALLOWED (✓):
- Square:
- Rectangular:
- Circular:
- Elliptical:
- Strip:
- Arbitrary: ✓

CONFIGURATION FLEXIBILITY (✓):
- Fixed, Single Resonator Geometry:
- Fixed, Multiple Resonator Geometries:
- Modular, Multiple Resonator Geometries:
- Others (describe): Arbitrary

2. PROPAGATION TECHNIQUE (✓) (All that apply):
- Fresnel Integral Algorithms:
  - With Kernel Averaging:
  - Gaussian Quadrature:
  - Fast Fourier Transform (FFT):
  - Fast Hankel Transform (FHT):
  - Gardener-Fresnel-Kirchhoff (GFK):
    - Ray Trace
  - Others (specify):
- Finite Difference Algorithms
  - Method (specify):

3. RESONATOR MODELING FEATURES

GENERAL CAPABILITIES:
- Stability (✓):
  - Stable Resonators:
  - Unstable Resonators:
- Type (✓):
  - Standing Wave:
  - Traveling Wave (Ring):
  - Reverse Traveling Wave:
  - Branch (✓):
    - Positive:
    - Negative:
- Optical Element Models Included (✓):
  - Flat Mirrors:
  - Spherical Mirrors:
  - Cylindrical Mirrors:
  - Telescopes:
  - Scraper Mirrors:
  - Deformable Mirrors:
  - Spatial Filters:
  - Gratings (specify type):
  - Other Elements (specify):

PRINCIPAL RESONATOR GEOMETRIES MODELED (Please List):
OPTICS CODE
(Concluded)

CODE NAME: ILOOPT

GAIN MODELS (✓):
- Bare Cavity Only:
- Simple Saturated Gain:
- Detailed Model (See Section 3 in Kinetics Code)

BARE CAVITY FIELD MODIFIER MODELS (✓):
- Mirror Tilt:
- Mirror Decentration:
- Aberrations/Thermal Distortion:
  - Arbitrary:
  - Selected (specify):
- Reflectivity Loss:
- Output Coupler Edges:
  - Rolled:
  - Serrated:
  - Other:

LOADED CAVITY FIELD MODIFIER MODELS (✓):
- Refractive Index Variation:
- Gas Absorption:
- Overlapped Beams (for flux updating):
  - Number of Overlaps Allowed:
  - Others:

FAR FIELD MODELS (✓):
- Beam Steering Removal:
- Optimal Focal Search:
- Beam Quality:
- Atmospheric Propagation Effects:
- Others:

BEAM CONTROL SYSTEM MODELED (✓):
- Pointer/Tracker Subsystem:
- Beam Jitter:
- Autonomous:
- Target Model:
  - Motion Effects:

OTHER UNIQUE FEATURES (e.g., Beam/Mode Rotation, Extra-Cavity Adaptive Optics, Multipath/Parasitic Effect, Beam Director Elements, etc.):
CODE NAME: KINBOLTZ  TECHNICAL AREA(S): Kinetics

DEVICE COMPONENTS TREATED: NA

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: Given a set of reactions and reaction rates, the code will compute the time-dependent population levels in upper and lower states. A Boltzmann code is used to compute the reaction rates. Although it is set for Mercury-Xenon, it is constructed in a general fashion to allow for other elements.

ASSESSMENT OF CAPABILITIES: Very general and very modular. If the desired reactions are included, and cross-sections for the gases are available, the code will calculate the time-dependent population levels.

ASSESSMENT OF LIMITATIONS: NAMELIST is used for input, though this could be changed. It is fairly fast. For power out calculations, the user must supply the equations. The code is basically a linear diff. eqn. system solver.

OTHER UNIQUE FEATURES: Very modular. The Boltzmann code package and the integration package can be changed with a minimum of code changes. Input is checked for consistency and validity. Output is very clear.

ORIGINATOR/KEY CONTACT:
Name: Henry Happ
Organization: Tetra Corp.
Address: 1325 San Mateo, SE, Albuquerque, NM 87108
Phone: (505) 256-3595

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):
Kinboltz: A Mercury-Xenon Kinetics Code (U)
Listings are available upon request.

STATUS:
Operational Currently?: yes
Under Modification?:
Purpose(s):

Ownership?: U. S. Government
Proprietary?: No

MACHINE/OPERATING SYSTEM (on which installed): CDC 6600 or 176

TRANSPORTABLE?: Almost
Machine Dependent Restrictions: Formats are A8 or A10 for Hollerith Characters. NAMELIST is used.

SELF-CONTAINED?: Other Codes Required (name, purpose): Runge-Kutta Integrator. Can be supplied with the package.

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

<table>
<thead>
<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
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</thead>
<tbody>
<tr>
<td>Small Job</td>
<td>45000</td>
</tr>
<tr>
<td>Typical Job</td>
<td></td>
</tr>
<tr>
<td>Large Job</td>
<td></td>
</tr>
</tbody>
</table>

Approximate Number of FORTRAN Lines: 1000 Kinetics + 2400 Boltz = 3500 lines

COMMENTS:
12 K Kinetics Code + 32 K Boltz
KINETICS CODE

CODE NAME: KINBOLTZ

1. CODE STRUCTURE

COORDINATE SYSTEM (✓):
- Cartesian: ✓
- Expanding: 

KINETICS GRID DIMENSIONALITY (✓):
- 1-D: ✓
- 2-D: 
- 3-D: 

GAIN REGION SYMMETRY RESTRICTIONS:
- Gain Vary Along Optical Axis: 
- Flow Direction: 
- KINETICS MODELED: Pulsed: ✓ CW: 

NUMERICAL SCHEME USED IN RATE CALCULATION (✓):
- Explicit: ✓
- Implicit: 
- Others (specify): 


2. PLASMA KINETICS MODEL

NUMBER OF SPECIES TREATED (specify):
- Number of Positive Species: user-defined
- Number of Negative Species: user-defined
- Number of Neutral Species: user-defined

REACTION MECHANISM MODELED (✓):
- Primary Ionization: (Reference)
  - E-Beam: ✓ User-defined
  - Self-Sustained: ✓
  - UV-initiated: 
- Others (specify): 

Secondary Ionization (Reference)

Attachment: User-defined

Detachment: 

Ion-Ion Recombination:

Charge Transfer:

Dissociation/Recombination:

Others (specify): 

Source of Rate Coefficients Used: The user is responsible for providing the coefficients.

REFERENCE FOR REACTION MECHANISM AND RATES:

OTHER UNIQUE FEATURES:

3. LASING KINETICS MODEL

GENERAL (specify):
- Lasing Species: User-defined
- Number of Species: user-defined
- Number of Reactions: User-defined
- Other Major Species Considered: 

IMPACT EXCITATION MODELED (✓):
- Vibrational: ✓ user-defined
- Electronic: ✓
- Others (specify): 

ENERGY TRANSFER MODES MODELED (✓):
- V-T: ✓ user-defined
- V-R: ✓
- V-V: ✓
- Others (specify): 

SOURCE OF RATE COEFFICIENTS USED IN CODE:

LINE PROFILE MODELS (✓):
- Doppler Broadening: 
- Collisional Broadening: 
- Others (specify): 

4. RECIRCULATION CONTAMINANTS MODELED (✓):
- O₂: 
- OH: 
- NO₂: 
- HNO₃: 
- Others (specify): 

DISCHARGE POWER INPUT MODELED (✓):
- Uniform: ✓
- Non-Uniform: 
- E-Field: 
- Others (specify): 

OTHER UNIQUE FEATURES:
CODE NAME: KINETIC TECHNICAL AREA(S): Kinetics

DEVICE COMPONENTS TREATED: None

PRINCIPAL PURPOSES/APPLICATION(S) OF CODE: This code is used for basic laser
kinecics calculations for e-beam pumped lasers (it can treat discharge
lasers also).

ASSESSMENT OF CAPABILITIES: It performs kinetics calculations using either a
Maxwellian electron distribution (Te computed internally) or with an electron
distribution computed by a subroutine that solves the Boltzmann equation.
It will also perform amplifier calculations.

ASSESSMENT OF LIMITATIONS:

OTHER UNIQUE FEATURES: The code has very extensive graphics (some of which
can be interactive) output

ORIGINATOR/KEY CONTACT:
Name: W. Lowell Morgan
Organization: Lawrence Livermore Laboratory
Address: Box 808, L-472, Livermore, CA 94505
Phone: (415) 522-0289

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and
RP = Related Publication): In general, none. I'll provide a listing

The Boltzmann solver is documented as JILA Information Center Report
#19, Univ. of Colorado, Boulder, CO.

STATUS:
Operational Currently?: yes
Under Modification?: less so as time goes on

Ownership?:
Proprietary?:

MACHINE/OPERATING SYSTEM (on which installed): CRAY 1A

TRANSPORTABLE?: perhaps
Machine Dependent Restrictions: core size and run time, as the code is optimized
for vector calculations on the CRAY

SELF-CONTAINED?:
Other Codes Required (name, purpose): MAXRATE - uses cross-section data to create
a table of rates vs. electron temperature.

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

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<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
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<tr>
<td>Small Job:</td>
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<tr>
<td>120K decimal</td>
<td>14 sec CRAY x 30 sec 7600*</td>
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<tr>
<td>Typical Job:</td>
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<tr>
<td>250K decimal</td>
<td>60 sec CRAY x 12 min 7600**</td>
</tr>
<tr>
<td>Large Job:</td>
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</tr>
</tbody>
</table>

Approximate Number of FORTRAN Lines: 2500

COMMENTS: * The kinetics only takes a few seconds, the remainder is graphics
(this is the Maxwellian version) ** This is the version that includes solution
of the Boltzmann equation for electrons.
**KINETICS CODE**

**CODE NAME:** KINETIC

### 1. CODE STRUCTURE

- **COORDINATE SYSTEM:**
  - Cartesian: Expanding
  - **KINETICS GRID DIMENSIONALITY:**
    - 1-D: \( \checkmark \)
    - 2-D: 
    - 3-D: 

- **GAIN REGION SYMMETRY RESTRICTIONS:**
  - Gain Vary: Along Optical Axis
  - Flow Direction
- **KINETICS MODELED:**
  - Pulsed: \( \checkmark \)
  - CW: 
- **NUMERICAL SCHEME USED IN RATE CALCULATION:**
  - Explicit: 
  - Implicit: \( \checkmark \)
  - Others (specify): 

**REFERENCE OF METHOD USED:** Gear

### 2. PLASMA KINETICS MODEL

- **NUMBER OF SPECIES TREATED** (specify):
  - Number of Positive Species: Arbitrary
  - Number of Negative Species: 
  - Number of Neutral Species: 10
- **REACTION MECHANISM MODELED:**
  - Primary Ionization: \( \checkmark \)
  - (Reference)
  - E-Beam: 
  - Self-Sustained: \( \checkmark \)
  - UV-Initiated: \( \checkmark \)
  - Others (specify): fission fragments
- **Secondary Ionization** (Reference)
  - Attachment: 
  - Detachment: 
  - Ion-Ion Recombination: 
  - Charge Transfer: \( \checkmark \)
  - Dissociation/Recombination: 
  - Others (specify): 

**Source of Rate Coefficients Used:** cross sections

**DISCHARGE POWER INPUT MODELED:**
- Uniform: \( \checkmark \)
- Non-Uniform: 
- E-Field: \( \checkmark \)
- Others (specify): 

### 3. LASING KINETICS MODEL

- **GENERAL** (specify):
  - Lasing Species: anything: Xe*, KrF, ArF
  - Number of Species: 30
  - Number of Reactions: 100
  - Other Major Species Considered: 
- **IMPACT EXCITATION MODELED:**
  - Vibrational: \( \checkmark \)
  - Electronic: 
  - Others (specify): 
- **ENERGY TRANSFER MODES MODELED:**
  - V-T: \( \checkmark \)
  - V-R: 
  - V-V: \( \checkmark \)
  - Others (specify): 
  - Lasing Transition: P-Branch: 
  - F-Branch: 
  - Single Line Model \( \checkmark \): 
  - Multi-Line Model \( \checkmark \): 
  - Assumed Rotational Population Distribution State \( \checkmark \): Equilibrium 
  - Nonequilibrium: 
  - Number of Laser Lines Modeled: 
  - Source of Rate Coefficients Used in Code: 

**LINE PROFILE MODELS:**
- Doppler Broadening: 
- Collisional Broadening: 
- Others (specify): 

### 4. RECIRCULATION CONTAMINANTS MODELED:

- none: 
  - \( O_3 \):
  - \( OH \):
  - \( NO_3 \):
  - \( HNO_3 \):
  - Others (specify): 

**REFERENCE FOR REACTION MECHANISM AND RATES:**

**OTHER UNIQUE FEATURES:** The code is very general, all information concerning specific problems is in the data set.
**CODE NAME:** KRF  
**TECHNICAL AREA(S):** Kinetics

**DEVICE COMPONENTS TREATED:**

**PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE:** Modeling KRF lasers and amplifiers.

**ASSESSMENT OF CAPABILITIES:** Handles gas deposition, kinetics, absorption, lasing in Fabry-Perot cavity.

**ASSESSMENT OF LIMITATIONS:** Specific code for KRF

**OTHER UNIQUE FEATURES:**

**ORIGINATOR/KEY CONTACT:**
- **Name:** Jeanette Betts
- **Organization:** TRW DSSG
- **Address:** 1 Space Park, Redondo Beach, CA 90278
- **Phone:** 213-536-1453

**AVAILABLE DOCUMENTATION** (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):

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<th>STATUS</th>
<th>Operational Currently?</th>
<th>Under Modification?</th>
<th>Purpose(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>yes</td>
<td>yes</td>
<td></td>
</tr>
</tbody>
</table>

**MACHINE/OPERATING SYSTEM** (on which installed): CDC Cyber 174

**TRANSPORTABLE?** yes

**SELF-CONTAINED?** yes

**ESTIMATE OF RESOURCES REQUIRED FOR RUNS:**
- **Small Job:** 1 FL-50500  42 sec Cyber 174
- **Typical Job:**
- **Large Job:**

**COMMENTS:**

68
KINETICS CODE

CODE NAME: KRF

1. CODE STRUCTURE
COORDINATE SYSTEM (✓):
Cartesian: Expanding:
KINETICS GRID DIMENSIONALITY (✓):
1-D: ✓ 2-D: 3-D: ___
GAIN REGION SYMMETRY RESTRICTIONS:
Gain Vary Along Optical Axis: ✓
KINETICS MODELED: Pulsed: ✓ CW: ___
NUMERICAL SCHEME USED IN RATE CALCULATION (✓):
Explicit: ___ Implicit: ___ Others (specify): ___
REFERENCE OF METHOD USED:
Modified Trainor

2. PLASMA KINETICS MODEL
NUMBER OF SPECIES TREATED (specify):
Number of Positive Species: 6
Number of Negative Species: 1
Number of Neutral Species: 17
REACTION MECHANISM MODELED (✓):
Primary Ionization: (Reference)
E-Beam: __ Self-Sustained: ___ UV-Initiated: ___ Others (specify): ___
Secondary Ionization (Reference)
Attachment: ___ Detachment: ___ Ion-Ion Recombination: ___
Charge Transfer: ___ Dissociation/Recombination: ___ Others (specify): ___
Source of Rate Coefficients Used:
literature-several sources
DISCHARGE POWER INPUT MODELED (✓):
Uniform: ___ Non-Uniform: ___ E-Field: ___ Others (specify): ___

3. LASING KINETICS MODEL
GENERAL (specify):
Lasing Species: KrF
Number of Species: 24
Number of Reactions: 92
Other Major Species Considered: Ar^+, ArF^-, Ar^*, Ke^*, F^-  ___
IMPACT EXCITATION MODELED (✓):
Vibrational: ___ Electronic: ✓ Others (specify): ___
ENERGY TRANSFER MODES MODELED (✓):
V-T: ___ V-R: ___ V-V: ___ Others (specify): ___
L*stng Transition:
P-Bran< h:
R-Pain :
Single-Line Model (✓):
Multi-Line Model (✓):
Assumed Rotational Population Distribution State (✓):
Equilibrium: ___ Nnonequilibrium: ___
Number of Laser Lines Modeled: ___
Source of Rate Coefficients Used in Code: ___
LINE PROFILE MODELS (✓):
Doppler Broadening: ___ Collisional Broadening: ___ Others (specify): ___

4. RECIRCULATION CONTAMINANTS MODELED (✓):
O_2: ___ OH: ___ NO: ___ HNO: ___ Others (specify): ___
REFERENCE FOR REACTION MECHANISM AND RATES:
OTHER UNIQUE FEATURES:

69
<table>
<thead>
<tr>
<th>CODE NAME:</th>
<th>LAGAD</th>
<th>TECHNICAL AREA(S):</th>
<th>Gas Dynamics</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEVICE COMPONENTS TREATED:</td>
<td>Laser Cavity &amp; Flow Loop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE:</td>
<td>Compute non-steady gas dynamics resulting from discharge heating &amp; flow loop heat exchanger &amp; blower requirements.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASSESSMENT OF LIMITATIONS:</td>
<td>Constant gas properties, i.e. $C_p$, $C_v$, $\gamma$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OTHER UNIQUE FEATURES:</td>
<td>Calcomp Plot of Wave Diagram</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ORIGINAL/KEY CONTACT:**

- **Name:** Martin J. Pechersky
- **Organization:** Westinghouse R&D Center
- **Address:** 1310 Beulah Road, Pgh, PA 15235
- **Phone:** 412-256-7353

**AVAILABLE DOCUMENTATION:**

- Please specify, use T = Theory, U = User's Manual, L = Listing, and R = Related Publications:
- Listing is proprietary, no other documentation

**STATUS:**

- Operational Currently?: Yes
- Under Modification?:
- Purpose?:

- Ownership?: Westinghouse
- Proprietary?: Yes

**MACHINE/OPERATING SYSTEM (on which installed):**

- UNIVAC-1108

**TRANSPORTABLE:** Yes

**SELF-CONTAINED:** Yes

**ESTIMATE OF RESOURCES REQUIRED FOR RUNS:**

<table>
<thead>
<tr>
<th>Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
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<tbody>
<tr>
<td>Small Job:</td>
<td></td>
</tr>
<tr>
<td>Typical Job:</td>
<td>22411</td>
</tr>
<tr>
<td>Large Job:</td>
<td>17 sec - UNIVAC-1108</td>
</tr>
</tbody>
</table>

**COMMENTS:**

800
1. CODE STRUCTURE
   COORDINATE SYSTEM (✓)
     Cartesian: ✓ Expanding:
   FLUID GRID DIMENSIONALITY (✓)
     1-D: ✓
     2-D: 
     3-D: 
     Time Dependent:
   FLOW FIELD MODELED (✓)
     Compressible Flow:
     Incompressible:
     Viscous Flow:
     No Flow:
   BASIC MODELING APPROACH (✓)
     Algebraic: 
     Integral Method:
     Finite Difference:
     Others (specify): Method of Characteristics
   REFERENCE FOR APPROACH USED:
     Text's of Shapiro & Rudinger

2. GAS DYNAMICS MODEL FEATURES:
   GAS SUPPLY MODELED (✓)
     Mixture Preparation:
     Mixture Injection:
     Nozzles:
     Flow Plates:
     Others (specify):
   CAVITY INITIAL CONDITION DETERMINED BY (specify): Code

3. EXHAUST/RECIRCULATION MODEL
   GENERAL SYSTEM MODELED (✓)
     Open System: 
     Closed System: ✓
     Closed Cycle: ✓
   EXHAUST SYSTEM FEATURES (✓)
     Pressure Recovery:
     Ejector System:
     Compressor/Fan: ✓
     Heat Exchanger:
     Gas Make-Up:
     Others (specify):

4. ACOUSTIC ATTENUATION MODEL
   GENERAL FEATURES MODELED (✓)
     Single Pulse: ✓ Repetitive Pulse:
   DIMENSIONALITY TREATED (✓)
     1-D: ✓ 2-D: 
     3-D: 
     Time-Dependent:
   DISTURBANCE MODELED (✓)
     Pressure Wave: ✓ Entropy Wave:
     Others (specify): Hot gas clearing*
   WAVE PROPAGATION TREATMENT (✓)
     Linear Wave:
     Nonlinear Wave: ✓
     Others (specify):
   THEORETICAL BASIS: (Reference)
   NUMERICAL METHODOLOGY: (Reference)
   ACOUSTIC ATTENUATORS CONSIDERED (✓)
     Muffler:
     Heat Exchanger:
     Horn:
     Porous Wall:
     Others (specify):
   MODEL EFFECTS ON OPTICAL MODES DUE TO (✓)
     Index of Refraction Variation:
     Other (specify):
   OTHER UNIQUE FEATURES:
     *Auxiliary code to compute in flow acoustic damping

DECONTAMINATION METHOD TREATED (✓)
  Scrubber:
  Shower:
  Catalytic Reactor:
  Others (specify):

71
CODE NAME: LASER  
TECHNICAL AREA(S): Kinetics

DEVICE COMPONENTS TREATED: Laser Cavity

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: General laser kinetics synthesis and analysis. Coupled system of molecular kinetics, plasma kinetics, external discharge circuit, and optical radiative extraction for a spatially homogeneous medium. Applicable to a broad class of transient, electrically excited laser systems. User-oriented, flexible input/output structure, well documented.

ASSESSMENT OF CAPABILITIES: This code synthesizes, from an arbitrary list of molecular kinetics reactions and species, a completely coupled laser kinetics analysis. Molecular kinetics subroutines for an arbitrary reaction scheme are translated automatically into FORTRAN source code and coupled to plasma kinetics, electron kinetics, and optical radiative extraction for a spatially homogeneous medium. Applicable to a broad class of transient, electrically excited laser systems. Developed in connection with rare gas halide excimer lasers (e.g. KrF). Capability is quite comprehensive and general.

OTHER UNIQUE FEATURES: Program automatically synthesizes its own molecular kinetics source code for execution. Secondary electron collisions are automatically linked to electron kinetics analysis provided by numerical solution of Boltzmann equation. Boltzmann analysis contains superelastic/electron-electron/inelastic/mom.transfer.

ORIGINATOR/KEY CONTACT:
Name: William B. Lacina
Organization: Northrop Research & Technology Center
Address: One Research Park, Palos Verdes Peninsula, CA 90274
Phone: (213) 377-4811 ext. 362


STATUS:
Operational Currently?: yes
Under Modification?: no
Purpose(s): Modifications by other users may be in progress.

Ownership?: Northrop Research & Tech./William B. Lacina
Proprietary?: Public Domain

MACHINE/OPERATING SYSTEM (on which installed): CDC 6600

TRANSPORTABLE?: yes
Machine Dependent Restrictions: Yes (CDC word size)

SELF-CONTAINED?: yes
Other Codes Required (name, purpose):

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

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<th>Core Size (Octal Words)</th>
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<td>Typical Job:</td>
<td>200,000</td>
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<td>Large Job:</td>
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Approximate Number of FORTRAN Lines: 6,000

COMMENTS:
1. CODE STRUCTURE
COORDINATE SYSTEM (✓):
   Cartesian: NA
   Expanding: ✓

KINETICS GRID DIMENSIONALITY (✓):
   1-D: ✓
   2-D: __
   3-D: __

GAIN REGION SYMMETRY RESTRICTIONS:
   Gain Vary Along Optical Axis: NO
   Flow Direction: __

KINETICS MODELED:
   Pulsed: ✓
   CW: __

NUMERICAL SCHEME USED IN RATE CALCULATION (✓):
   Explicit: ✓
   Implicit: __
   Others (specify): rate constants from input, and from Boltzmann plasma calculations.

REFERENCE OF METHOD USED: ____________

2. PLASMA KINETICS MODEL
NUMBER OF SPECIES TREATED (specify):
   Number of Positive Species: arb.
   Number of Negative Species: arb.
   Number of Neutral Species: arb.

REACTION MECHANISM MODELED (✓):
   Primary Ionization: ✓ (Reference)
   E-Beam: ✓
   Self-Sustained: ✓
   UV-Initiated: ✓
   Others (specify): reasonably arbitrary.

Secondary Ionization (Reference):
   Attachment: ✓
   Detachment: ✓
   Ion-Ion Recombination: ✓
   Charge Transfer: ✓
   Dissociation/Recombination: ✓
   Others (specify): ____________

Source of Rate Coefficients Used:
   Miscellaneous: ____________

3. LASING KINETICS MODEL
GENERAL (specify):
   Lasing Species: ONE
   Number of Species: arbitrary
   Number of Reactions: arbitrary
   Other Major Species Considered: ____________

IMPACT EXCITATION MODELED (✓):
   Vibrational: ✓
   Electronic: ✓
   Others (specify): ____________

ENERGY TRANSFER MODES MODELED (✓):
   (Reference)
   V→T: ____________
   V→R: ____________
   V→V: ____________
   Others (specify): ____________

4. REIRRADIATION CONTAMINANTS MODELED (✓):
   None

REFERENCE FOR REACTION MECHANISM AND RATES:
   ____________

OTHER UNIQUE FEATURES:
   ____________
CODE NAME: LASIM  TECHNICAL AREA(S): Kinetics

DEVICE COMPONENTS TREATED:

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE:
Simulation of UV initiated, self-sustained discharge - pumped XeF lasers.

ASSESSMENT OF CAPABILITIES:
Predicts discharge & laser operation - physical description of experimental system is used. Circuit - discharge interaction is modeled.

ASSESSMENT OF LIMITATIONS:
Spatially uniform plasma/laser model.

OTHER UNIQUE FEATURES:

ORIGINATOR/KEY CONTACT:
Name: L.E. Kline
Organization: Westinghouse R&D
Address: 1310 Beulah Road, Pittsburgh, PA 15235
Phone: 412-256-7552

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RF = Related Publication):


STATUS:
Operational Currently?: Yes
Under Modification?:

Purpose(s):

Ownership?: Gov't contract
Proprietary?: No

MACHINE/OPERATING SYSTEM (on which installed):
UNIVAC-1100

TRANSPORTABLE?: Yes
Machine Dependent Restrictions:

SELF-CONTAINED:
Other Codes Required (name, purpose): Boltzman Solver is required to calculate electron excitation rates vs. E/P

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

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<td>Large Job:</td>
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Approximate Number of FORTRAN Lines: 600

COMMENTS:
KINETICS CODE

CODE NAME: LASIM

1. CODE STRUCTURE

COORDINATE SYSTEM (✓):
- Cartesian: ✓ Expanding

KINETICS GRID DIMENSIONALITY (✓):
- 1-D:
- 2-D:
- 3-D:
- 0-D X

GAIN REGION SYMMETRY RESTRICTIONS:
- Gain Vary Along Optical Axis: No

KINETICS MODELED: Pulsed; ✓ CW;

NUMERICAL SCHEME USED IN RATE CALCULATION (✓):
- Explicit:
- Implicit:
- Others (specify):

REFERENCE OF METHOD USED:

2. PLASMA KINETICS MODEL

NUMBER OF SPECIES TREATED (specify):
- Number of Positive Species: 2
- Number of Negative Species: 2
- Number of Neutral Species: 5

REACTION MECHANISM MODELED (✓):
- Primary Ionization: (Reference)
- E-Beam:
- Self-Sustained: ✓
- UV-Initiated:
- Others (specify):
- Secondary Ionization: (Reference)
- Attachment:
- Detachment:
- Ion-Ion Recombination:
- Charge Transfer:
- Dissociation/Recombination:
- Others (specify):

Source of Rate Coefficients Used:

DISCHARGE POWER INPUT MODELED (✓):
- Uniform:
- E-Field:
- Others (specify):

3. LASING KINETICS MODEL

GENERAL (specify):
- Lasing Species: 1
- Number of Species: 9
- Number of Reactions: 20
- Other Major Species Considered:

IMPACT EXCITATION MODELED (✓):
- Vibrational:
- Electronic:
- Others (specify):

ENERGY TRANSFER MODES MODELED (✓):
- V-T:
- V-R:
- V-V:
- Others (specify):
- Lasing Transition: P-Branch:
- R-Branch:
- Single Line Model (✓):
- Multi-Line Model (✓):
- Assumed Rotational Population Distribution State (✓):
- Equilibrium:
- Nonequilibrium:
- Number of Laser Lines Modeled:
- Source of Rate Coefficients Used in Code:

LINE PROFILE MODELS (✓):
- Doppler Broadening:
- Collisional Broadening:
- Others (specify):

4. RECIRCULATION CONTAMINANTS MODELED (✓): None
- C₂:
- OH:
- NO:
- HNO₂:
- Others (specify):

REFERENCE FOR REACTION MECHANISM AND RATES: Kline et al., Proc Laser '78

OTHER UNIQUE FEATURES:

75
CODE NAME: MOC  
TECHNICAL AREA(S): Gas Dynamics  
DEVICE COMPONENTS TREATED: Cavity

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: Computes the transient flow associated with sudden energy deposition that is characteristic of pulsed laser operation.

ASSESSMENT OF CAPABILITIES:

ASSESSMENT OF LIMITATIONS: Shock wave interaction with solid boundaries not modeled.

OTHER UNIQUE FEATURES:

ORIGINATOR/KEY CONTACT:
Name: C. C. Shih and G. R. Karr
Organization: Mech. Eng. Dept., Univ. of Ala. in Huntsville
Address: Huntsville, AL 35809
Phone: (205) 895-6330, (205) 895-6075


STATUS:
Operational Currently?: X
Under Modification?: X
Intend to look at wave interaction with acoustic attenuators

Ownership?: UAH
Proprietary?:

MACHINE/OPERATING SYSTEM (on which installed): UNIVAC 1108

TRANSPORTABLE?: YES
Machine Dependent Restrictions: none

SELF-CONTAINED?: YES
Other Codes Required (name, purpose):

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:
Core Size (Octal Words) Execution Time (sec, CDC 7600)
Small Job: 
Typical Job: order of 100 sec.
Large Job: 
Approximate Number of FORTRAN Lines:

COMMENTS:  

76
1. CODE STRUCTURE
COORDINATE SYSTEM (✓):
- Cartesian: ✓
- Expanding: 
FLUID GRID DIMENSIONALITY (✓):
- 1-D: ✓
- 2-D: 
- 3-D: ✓
- Time Dependent: ✓
FLOW FIELD MODELED (✓):
- Compressible Flow: ✓
- Incompressible: 
- Viscous Flow: ✓
- No Flow: 
BASIC MODELING APPROACH (✓):
- Algebraic: ✓
- Integral Method: 
- Finite Difference: ✓
- Others (specify): 
REFERENCE FOR APPROACH USED:
Method of Characteristics

2. GAS DYNAMICS MODEL FEATURES:
GAS SUPPLY MODELED (✓):
- Mixture Preparation: ✓
- Mixture Injection: 
- Nozzles: 
- Flow Plates: 
- Others (specify): 
CAVITY INITIAL CONDITION DETERMINED
BY (specify): given

3. EXHAUST RECIRCULATION MODEL
GENERAL SYSTEM MODELED (✓):
- Open System: ✓
- Closed System: 
EXHAUST SYSTEM FEATURES (✓):
- Pressure Recovery: ✓
- Ejector System: 
- Compressor Tam: 
- Heat Exchanger: 
- Gas Make-Up: 
- Others (specify): 

4. ACOUSTIC ATTENUATION MODEL
GENERAL FEATURES MODELED (✓):
- Single Pulse: ✓
- Repetitive Pulse: 
DIMENSIONALITY TREATED (✓):
- 1-D: ✓
- 2-D: ✓
- 3-D: ✓
- Time-Dependent: ✓
DISTURBANCE MODELED (✓):
- Pressure Wave: ✓
- Entropy Wave: ✓
- Others (specify): 
WAVE PROPAGATION TREATMENT (✓):
- Linear Wave: ✓
- Nonlinear Wave: ✓
- Others (specify): 
THEORETICAL BASIS: (Reference)
Method of Characteristics
NUMERICAL METHODOLOGY: (Reference)
Finite Difference
ACOUSTIC ATTENUATORS CONSIDERED (✓):
- Muffler: 
- Heat Exchanger: 
- Horn: 
- Porous Wall: 
- Others (specify): none

5. MODEL EFFECTS ON OPTICAL MODES DUE TO (✓):
- Index of Refraction Variation: 
- Other (specify): Fractional density gradient (∂ρ/ρ)
OTHER UNIQUE FEATURES:

77
NRL Laser Kinetics

CODE NAME: Code (Unofficial)  TECHNICAL AREA(S): Kinetics

DEVICE COMPONENTS TREATED: Laser Cavity; Chemical Kinetics electrical circuit;

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: Modeling of a variety of high power gas lasers. Mostly rare gas halides. Some non-lasing applications such as modeling of absorption in pure rare gases and isotope separation kinetics.

ASSESSMENT OF CAPABILITIES: Highly flexible; Has been easily adapted to a wide variety of physical systems. Easily portable from one computer to another. No convergence problems with chemical kinetics integrator. Coupled external circuit.

ASSESSMENT OF LIMITATIONS: Spatially homogeneous (zero-dimensional) approximation for kinetics. E-beam ionization rate provided as external waveform. Secondary electron kinetics (time-dependent).

OTHER UNIQUE FEATURES: Reaction scheme specified using symbolic names for reactants and products. Output provides detailed and useful description of kinetics and lasing.

ORIGINATOR/KEY CONTACT:

Name: Louis J. Palumbo
Organization: Laser Physics Branch, Code 6540
Address: Naval Research Laboratory, Washington, DC 20375
Phone: (202) 767-2255

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):


(L): Originator supplies listings and tape copies on request. (Listing is well commented) (SEE ATTACHED SHEET)

STATUS:

Operational Currently?: Yes (several versions)
Under Modification?: yes

Purposes: Modifications are underway to make code more user oriented and to make more efficient use of computer memory.

Ownership?: No (developed on U.S. Gov't time-available to public)
Proprietary?: No (earlier versions have been sent to private industrial labs

MACHINE/OPERATING SYSTEM (on which installed): Texas Instruments - Advanced Scientific Computer (ASC). Also was successfully adapted to IBM-170.

TRANSPORTABLE?: Reasonably
Machine Dependent Restrictions: Some versions contain ENCODE/DECODE statements, these are currently being replaced. Code is more efficient on a vectorizing

SELF-CONTAINED?: Yes
/ Fortran compiler.

Other Codes Required (name, purpose): None

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

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<td>Typical Job:</td>
<td>150,000</td>
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<td>Large Job:</td>
<td>~250,000</td>
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Approximate Number of FORTRAN lines: 6000

COMMENTS: Very simple time-dependent lasing computation for a Fabry-Perot cavity using constant gain, geometric optics.
AVAILABLE DOCUMENTATION con't:

CODE NAME: NRL Laser Kinetics Code


KINETICS CODE

CODE NAME: NRL LASER

1. CODE STRUCTURE

COORDINATE SYSTEM (✓)
Cartesian; Expanding;

KINETICS GRID DIMENSIONALITY (✓)
1-D; ✓ 2-D;
3-D; Spatially homogeneous (Zero-D)

GAIN REGION SYMMETRY RESTRICTIONS:
Gain: Varying Along Optical Axis; (sometimes)
Flow Direction: no flow

KINETICS MODELED:
Pulsed; ✓ CW; ✓

NUMERICAL SCHEME USED IN RATE CALCULATION (✓)
Explicit; ✓ Implicit;
Others (specify): Runge-Kutta-Treanor Method for stiff diff. eqs

REFERENCE OF METHOD USED: C.E. Treanor

2. PLASMA KINETICS MODEL

NUMBER OF SPECIES TREATED (specify):
Number of Positive Species: 0-15 typical
Number of Negative Species: 0-5 typical
Number of Neutral Species: 5-50 typical

REACTION MECHANISM MODELED (✓)
Primary Ionization:
E-Beam: ✓
Self-Sustained:
UV-Initiated:
Others (specify): E-beam sustained as well as pure e-beam pumped.

Secondary Ionization (Reference)
Attachment: ✓
Detachment: ✓
Ion-Ion Recombination:
Charge Transfer:
Disassociation/Recombination:
Others (specify):

Source of Rate Coefficients Used:
mostly open literature

DISCHARGE POWER INPUT MODELED (✓)
Uniform: ✓ Non-Uniform;
E-Field: ✓
Others (specify): external circuit coupled to kinetics.

Electron kinetics are modeled either by solving the steady state Boltzmann transport equation or by a time-dependent but greatly simplified rate-equation method.

3. LASING KINETICS MODEL

GENERAL (specify):
Lasing Species: ✓
Number of Species: 10-50 typical
Number of Reactions: 10-200 typical
Other Major Species Considered:

IMPACT EXCITATION MODEL (✓)

V-T: ✓ V-R: ✓ V+V: ✓
Others (specify):

ENERGY TRANSFER MODELS MODELED (✓)
V-V: ✓
V-T:
V-R:
Others (specify):

REFERENCE FOR REACTION MECHANISM AND RATES:

OTHER UNIQUE FEATURES:

4. RECIRCULATION CONTAMINANTS MODELED (✓)

O₂: ✓ OH: ✓
NO: ✓ HNO: ✓
Others (specify):

REFERENCE FOR REACTION MECHANISM AND RATES:

OTHER UNIQUE FEATURES:
CODE NAME: OPTEX
TECHNICAL AREA(S): Kinetics

DEVICE COMPONENTS TREATED: Laser Cavity

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: The lasing outputs for the 10.5 μm P(14) and P(18) lines are predicted as a function of the individual cavity lengths for a pulsed TEA laser.

ASSSESSMENT OF CAPABILITIES: The ratio of energies contained in the two transitions was verified experimentally.

ASSSESSMENT OF LIMITATIONS: The predicted pulse shapes are questionable.

OTHER UNIQUE FEATURES: A Gaussian mode pattern was used instead of a plane wave.

ORIGINATOR/KEY CONTACT:
Name: Dennis Suhre
Organization: Westinghouse Research
Address: 1310 Beulah Road, Pittsburgh, PA 15235
Phone: 412-256-7353

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User’s Manual, L = Listing, and R.P. = Related Publication):

STATUS:
Operational Currently?: No
Under Modification?: No
Purpose(s):

Ownership?: Westinghouse
Proprietary?: Yes

MACHINE/OPERATING SYSTEM (on which installed): UNIVAC 1100

TRANSPORTABLE?: Yes
Machine Dependent Restrictions:

SELF-CONTAINED?:
Other Codes Required (name, purpose): None

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

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<td>reasonable</td>
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COMMENTS:
KINETICS CODE

CODE NAME: OPTEX

1. CODE STRUCTURE
COORDINATE SYSTEM (✓):
Cartesian; Expanding: ✓

KINETICS GRID DIMENSIONALITY (✓):
1-D: ✓ 2-D: ✓ 3-D: 

GAIN REGION SYMMETRY RESTRICTIONS:
Gain Vary Along Optical Axis:
Flow Direction:
KINETICS MODELED: Pulsed; ✓ CW: 

NUMERICAL SCHEME USED IN RATE CALCULATION (✓):
Explicit: ✓ Implicit: 
Others (specify):

REFERENCE OF METHOD USED: IEEE J. Quant. Electron. QE-9, 139 (1973)

2. PLASMA KINETICS MODEL
NUMBER OF SPECIES TREATED (specify):
Number of Positive Species:
0
Number of Negative Species:
0
Number of Neutral Species:
3

REACTION MECHANISM MODELED (✓):
Primary Ionization: (Reference)
E-Beam:
Self-Sustained:
UV-Initiated:
Others (specify):

Secondary Ionization (Reference)
Attachment:
Detachment:
Ion-Ion Recombination:
Charge Transfer:
Dissociation/Recombination:
Others (specify):

Source of Rate Coefficients Used:

DISCHARGE POWER INPUT MODELED (✓):
Uniform: ✓ Non-Uniform: 
E-Field: 
Others (specify):

3. LASING KINETICS MODEL
GENERAL (specify):
Lasing Species:
CO₂
Number of Species: 3 (CO₂, N₂, He)
Number of Reactions:
Other Major Species Considered:

IMPACT EXCITATION MODELED (✓):
Vibrational: ✓ Electronic: 
Others (specify):

ENERGY TRANSFER MODELS MODELED (✓):
V-T: ✓ V-R: 
(Reference)
V-V: ✓ IEEE J. Quant. Electron. QE-9, 139 (1973)
Others (specify):

Assumed Rotational Population Distribution State (✓):
Equilibrium: ✓ Nonequilibrium:
Number of Laser Lines Modeled:
Source of Rate Coefficients Used in Code:
Rev. Mod. Phys. 41, 26 (1969)

4. RECIRCULATION CONTAMINANTS MODELED (✓):
None
O₂: 
OH: 
NO: 
HNO₃:
Others (specify):

REFERENCE FOR REACTION MECHANISM AND RATES:

OTHER UNIQUE FEATURES:
CODE NAME: POSSEIDON*  TECHNICAL AREA(S): Gas Dynamics

DEVICE COMPONENTS TREATED: Laser Cavity; Acoustic Attenuation Subsystem

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: The code is used to model one-dimensional flow and acoustics in the laser cavity and the acoustic attenuation subsystem. This is used to predict recovery time of the medium within the laser cavity to a specified homogeneity. A two-dimensional version also exists.

ASSESSMENT OF CAPABILITIES: The code has demonstrated stable and accurate numerical solutions to unsteady flow problems characterized by both strong shock waves and weak acoustic level waves with extremely small numerical diffusion (no artificial viscosity is required).

ASSESSMENT OF LIMITATIONS: Boundary layer phenomena are not simulated and two-dimensional version has high noise floor.

OTHER UNIQUE FEATURES: Any type of gas at any temperature may be employed. Any number of repetitive pulses may be specified. System geometry may be altered at will. The code incorporates: compressibility, nonlinearity, heat transfer, bulk resistance, and mass transport through the side walls. Reflections off of a sudden expansion downstream of the laser cavity incorporate two-dimensional gas dynamics to account for the shape of

ORIGINATOR/KEY CONTACT: James W. Morris
Organization: Poseidon Research
Address: 9550 Owensmouth Avenue, Chatsworth, CA 91311
Phone: (213) 341-9172


STATUS:
Operational Currently?: yes
Under Modification?: no

Ownership?: Poseidon Research
Proprietary?: no

MACHINE/OPERATING SYSTEM (on which installed): CRAY I

TRANSPORTABLE?: yes
Machine Dependent Restrictions: none

SELF-CONTAINED?: yes
Other Codes Required (name, purpose):

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

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<tr>
<td>Typical Job</td>
<td>200,000</td>
<td>20 sec, CRAY I</td>
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<td>Large Job</td>
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Approximate Number of FORTRAN Lines: 2000

COMMENTS: *Name generated for identification purposes.
1. CODE STRUCTURE
COORDINATE SYSTEM (✓):
  - Cartesian:
  - Expanding:
FLUID GRID DIMENSIONALITY (✓):
  - 1-D: ✓
  - 2-D: ✓
  - 3-D: ✓
  - Time Dependent:
FLOW FIELD MODELED (✓):
  - Compressible Flow: ✓
  - Incompressible:
  - Viscous Flow:
  - No Flow:
BASIC MODELING APPROACH (✓):
  - Algebraic: ___
  - Finite Difference: ✓
  - Integral Method: ___
  - Others (specify): ___
REFERENCE APPROACH USED:
  - SHASTA Algorithm
  - Boris & Book, J. Comp. Physiccs II, 38-69

2. GAS DYNAMICS MODEL FEATURES:
GAS SUPPLY MODELED (✓):
  - Mixture Preparation: ✓
  - Mixture Injection:
  - Nozzles:
  - Flow Plates:
  - Others (specify): ___
CAVITY INITIAL CONDITION DETERMINED
BY (specify): §. Isentropic flow relations and initial over-temperature distribution

3. EXHAUST RECIRCULATION MODEL
GENERAL SYSTEM MODELED (✓):
  - Open System: ✓
  - Closed System:
  - Closed Cycle:
EXHAUST SYSTEM FEATURES (✓):
  - Pressure Recovery:
  - Ejector System:
  - Compressor/Fan:
  - Heat Exchanger:
  - Gas Make-Up:
  - Others (specify):
    - 1D: Sudden expansion boundary condition
    - 2D: Open

4. ACOUSTIC ATTENUATION MODEL
GENERAL FEATURES MODELED (✓):
  - Single Pulse: ✓
  - Repetitive Pulse: ✓
DIMENSIONALITY TREATED (✓):
  - 1-D: ✓
  - 2-D: ✓
  - 3-D: ✓
  - Time-Dependent:
DISTURBANCE MODELED (✓):
  - Pressure Wave: ✓
  - Entropy Wave:
  - Others (specify): ___
WAVE PROPAGATION TREATMENT (✓):
  - Linear Wave:
  - Nonlinear Wave: ✓
  - Others (specify): ___
THEORETICAL BASIS: (Reference)
  - Poseidon Research Report No. 16
NUMERICAL METHODOLOGY: (Reference)
ACOUSTIC ATTENUATORS CONSIDERED (✓):
  - Muffler: ✓
  - Heat Exchanger: ✓
  - Horn: ✓
  - Porous Wall: ✓
  - Others (specify):

5. MODEL EFFECTS ON OPTICAL MODES DUE TO (✓):
  - Index of Refraction Variation: ✓
  - Other (specify):
OTHER UNIQUE FEATURES:

84
CODE NAME: PSI LASER

TECHNICAL AREA(S): Kinetics

DEVICE COMPONENTS TREATED: Laser Cavity

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: A series of codes for general kinetic calculations, D/HCl, Kr, Xe, Xe, KrF, CO etc.
Calculate cavity gain and powerout for a Fabry-Perot Resonator

ASSESSMENT OF CAPABILITIES: One-dimensional in time, and one-dimensional in space.

ASSESSMENT OF LIMITATIONS:

OTHER UNIQUE FEATURES: Fluid Dynamics can be modeled separately. Has been used for CDL and Chemical lasers. Output can be used for amplification calculations.

ORIGINATOR/KEY CONTACT:
Name: Paul Lewis or Ray L. Taylor
Address: 30 Commerce Way, Woburn, MA 01801 6 Frank St., Rockport, MA 01966
Phone: (617) 933-8500 (617) 546-7798

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):
RP: PSI TR 19
PSI TR 182

STATUS:
Operational Currently?: X
Under Modification?: Purpose(s):

Ownership?: PSI, RLT
Proprietary?:

MACHINE/OPERATING SYSTEM (on which installed): Prime 400 easily adaptable to IBM, CDC

TRANSPORTABLE?:
Machine Dependent Restrictions: none known

SELF-CONTAINED?:
Other Codes Required (name, purpose): Boltzmann Code, E-Beam source code

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

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<td>Typical Job:</td>
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COMMENTS:

* Name generated for identification purpose.
KINETICS CODE

1. CODE STRUCTURE
COORDINATE SYSTEM (✓):
- Cartesian: ✓ Expanding:
KINETICS GRID DIMENSIONALITY (✓):
- 1-D: ✓ 2-D: ___ 3-D: ___
GAIN REGION SYMMETRY RESTRICTIONS:
- Gain Vary Along Optical Axis: ___
KINETICS MODELED: Pulsed: ✓ CW: ___
NUMERICAL SCHEME USED IN RATE CALCULATION (✓):
- Explicit: ___ Implicit: ✓ Others (specify): ___
REFERENCE OF METHOD USED: ___

2. PLASMA KINETICS MODEL
NUMBER OF SPECIES TREATED (specify):
- Number of Positive Species: ___
- Number of Negative Species: ___
- Number of Neutral Species: ___
REACTION MECHANISM MODELED (✓):
- Primary Ionization: (Reference) ✓
  - E-Beam: ___ Self-Sustained: ✓ UV-Initiated: ___
  Others (specify): ___
- Secondary Ionization: (Reference) ✓
  - Attachment: ___ Detachment: ✓
  - Ion-Ion Recombination: ✓ Charge Transfer: ✓
  - Dissociation/Recombination: ✓
  Others (specify): ___
  Penning Ionization: ___
  Source of Rate Coefficients Used: Literature
DISCHARGE POWER INPUT MODELED (✓): (time only)
- Uniform: ✓ Non-Uniform: ✓
  E-Field: ✓
  Others (specify): ___
REFERENCE OF METHOD USED: ___

3. LASING KINETICS MODEL
GENERAL (specify):
- Lasing Species: Arbitrary
- Number of Species: Arbitrary, typically<
  Number of Reactions: Arbitrary
- Other Major Species Considered: Impurities discharge lasers.
IMPACT EXCITATION MODELED (✓):
- Vibrational: (Reference) ✓
  Electronic: ___
  Others (specify): Rotational
ENERGY TRANSFER MODES MODELED (✓):
- V-T: ✓ V-R: ___ V-V: ___
  Others (specify): ___
  Excitation: P-Branch: ✓ E-Branch: ___
  Single Line Model (✓): ✓ Multi-Line Model (✓): ✓
  Assumed Rotational Population Distribution State (✓): ✓
  Equilibrium: Non-equilibrium: ___
  Number of Laser Lines Modeled: Arbitrary
  Source of Rate Coefficients Used in Code: Literature TR-182
LINE PROFILE MODELS (✓):
- Doppler Broadening: ✓ Collisonal Broadening: ✓
  Others (specify): Voigt
REFERENCE FOR REACTION MECHANISM AND RATES: ___
OTHER UNIQUE FEATURES: ___

4. RECIRCULATION CONTAMINANTS MODELED (✓):
  - none
  - CH: ___ HNO: ___
  - Others (specify): ___
REFERENCE FOR REACTION MECHANISM AND RATES: ___
OTHER UNIQUE FEATURES: ___

CODE NAME: PSI LASER

86
CODE NAME: REDAC

TECHNICAL AREA(S):

DEVICE COMPONENTS TREATED: Pulsed Electrical Power

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: model PFN's performance.

This is a general purpose circuit analysis code.

ASSESSMENT OF CAPABILITIES: excellent

ASSESSMENT OF LIMITATIONS: as good as input

OTHER UNIQUE FEATURES:

ORIGINATOR/KEY CONTACT:
Name: E. Wheatley
Organization: Rocketdyne Division of Rockwell, M.S. FA-28
Address: 6633 Canoga Ave., Canoga Pk 91304
Phone: 213-709-7136

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User’s Manual, L = Listing, and RP = Related Publication):

STATUS:
Operational Currently?: X
Under Modification?:
Purpose(s):

Ownership?: Rockwell
Proprietary?: YES

MACHINE/OPERATING SYSTEM (on which installed): CDC

TRANSPORTABLE?: YES

Self-Contained Restrictions:

Other Codes Required (name, purpose):

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

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<tr>
<td>Typical Job</td>
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Approximate Number of FORTRAN Lines:

COMMENTS:

87
CODE NAME: STROBE

TECHNICAL AREA(S): Gas Dynamics

DEVICE COMPONENTS TREATED: Cavity, Beam Ducts, Flow Plate

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: Beam Duct, Cavity Acoustics

ASSESSMENT OF CAPABILITIES: Multidimensional acoustics caused by non-ideal channels, i.e. beam ducts, standoff distance.

ASSESSMENT OF LIMITATIONS: Incomplete boundary condition formulation at open end, uses constant pressure which is not accurate.

OTHER UNIQUE FEATURES:

ORIGINATOR/KEY CONTACT:
Name: B. Masson
Organization: RDA
Address: ATO Box 9377, International Airport, Alb, NM 87119
Phone: (505) 243-5609

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication): T, L

STATUS:
Operational Currently?: yes
Under Modification?: yes
Purpose(s): Beam Duct Model being improved

Ownership?: RDA
Proprietary?: No

MACHINE/OPERATING SYSTEM (on which installed): CRAY I

TRANSPORTABLE?: Yes
Transportable Restrictions: None

SELF-CONTAINED?:
Other Codes Required (name, purpose): r Plotter

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:
Core Size (Octal Words) | Execution Time (sec, CDC 7600)
------------------------|-------------------------
Small Job:              |
Typical Job:            |
Large Job:              |

Approximate Number of FORTRAN Lines:

GAS DYNAMICS CODE

CODE NAME: **STROBE**

### 1. CODE STRUCTURE

**COORDINATE SYSTEM (✓):**
- Cartesian: __________ Expanding: **✓**

**FLUID GRID DIMENSIONALITY (✓):**
- 1-D: __________
- 2-D: __________
- 3-D: **✓**
- Time Dependent: **✓**

**FLOW FIELD MODELED (✓):**
- Compressible Flow: **✓**
- Incompressible: __________
- Viscous Flow: __________
- No Flow: __________

**BASIC MODELING APPROACH (✓):**
- Algebraic: __________
- Integral Method: __________
- Finite Difference: **✓**
- Others (specify): __________

**REFERENCE FOR APPROACH USED:**
- MacCormack

### 2. GAS DYNAMICS MODEL FEATURES:

**GAS SUPPLY MODELED (✓):**
- Mixture Preparation: __________
- Mixture Injection: __________
- Nozzles: __________
- Flow Plates: **✓**
- Others (specify): __________

**CAVITY INITIAL CONDITION DETERMINED**
- By (specify): __________

### 3. EXHAUST RECIRCULATION MODEL

**GENERAL SYSTEM MODELED (✓):**
- Open System: __________
- Closed System: **✓**
- Closed Cycle: __________

**EXHAUST SYSTEM FEATURES (✓):**
- Pressure Recovery: __________
- Ejector System: __________
- Compressor: Fan: __________
- Heat Exchanger: __________
- Gas Make-Up: __________
- Others (specify): Absorbers

### 4. ACOUSTIC ATTENUATION MODEL

**GENERAL FEATURES MODELED (✓):**
- Single Pulse: __________
- Repetitive Pulse: **✓**
- Time Dependent: __________

**DISTURBANCE MODELED (✓):**
- Pressure Wave: __________
- Entropy Wave: **✓**
- Others (specify): __________

**WAVE PROPAGATION TREATMENT (✓):**
- Linear Wave: __________
- Nonlinear Wave: **✓**
- Others (specify): __________

**THEORETICAL BASIS:** (Reference)

**NUMERICAL METHODOLOGY:** (Reference)

**ACOUSTIC ATTENUATORS CONSIDERED (✓):**
- Muffler: **✓**
- Heat Exchanger: __________
- Horn: __________
- Porous Wall: __________
- Others (specify): __________

### 5. MODEL EFFECTS ON OPTICAL MODES DUE TO (✓):

- Index of Refraction Variation: **✓**
- Other (specify): __________

**OTHER UNIQUE FEATURES:**

- __________
- __________
- __________
**CODE NAME:** SUPersonic  
**TECHNICAL AREA(S):** Kinetics

**DEVICE COMPONENTS TREATED:** Laser cavity

**PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE:** Analysis of an electrically excited supersonic flow CO laser.

**ASSESSMENT OF CAPABILITIES:** Analysis of an electrically excited supersonic CO laser, with coupled molecular kinetics, plasma kinetics, gas dynamics, and optical extraction. (Simple one-dimensional models for gas dynamics and resonator.)

**ASSESSMENT OF LIMITATIONS:** Simplified treatment of gas dynamics and optical resonator.

**OTHER UNIQUE FEATURES:** Provides for multiple lasing transitions, and includes the effects of resonant self-absorption from overlapping transitions in a high pressure gas system. Plasma kinetics are provided by Boltzmann equation, completely coupled to molecular kinetics and optical extraction.

**ORIGINATOR/KEY CONTACT:**

<table>
<thead>
<tr>
<th>Name</th>
<th>William B. Lacina</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization</td>
<td>Northrop Research and Technology Center</td>
</tr>
<tr>
<td>Address</td>
<td>One Research Park, Palos Verdes Estates, CA 90274</td>
</tr>
<tr>
<td>Phone</td>
<td>(213) 377-4811 ext. 362</td>
</tr>
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</table>

**AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and R = Related Publication):**


**STATUS:**

- Operational Currently?: yes
- Under Modification?: no

**Ownership:** Northrop Research & Tech./ William B. Lacina

**Proprietary:** No. Public Domain

**MACHINE/OPERATING SYSTEM (on which installed):** CDC 7600

**TRANSPORTABLE:** yes

**SELF-CONTAINED:** yes

**ESTIMATE OF RESOURCES REQUIRED FOR RUNS:**

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<tr>
<td>Typical Job</td>
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<tr>
<td>Large Job</td>
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**OTHER CODES REQUIRED:**

**COMMENTS:**

90
KINETICS CODE

CODE NAME: SUPersonic

1. CODE STRUCTURE
   COORDINATE SYSTEM (✓):
   - Cartesian;
   - Expanding;
   - Expanding:
   - J-D: ______
   - J-D: ______

   KINETICS GRID DIMENSIONALITY (✓):
   - 1-D: ✓
   - 2-D: ______
   - 3-D: ______

   GAIN REGION SYMMETRY RESTRICTIONS:
   - Gain Vary Along Optical Axis:
   - Flow Direction:
   - KINETICS MODELED: Pulse;
   - CW: ✓

   NUMERICAL SCHEME USED IN RATE CALCULATION (✓):
   - Explicit: ______
   - Implicit: ______
   - Others (specify): ______

   REFERENCE OF METHOD USED:

2. PLASMA KINETICS MODEL
   NUMBER OF SPECIES TREATED (specify):
   - Number of Positive Species:
   - Number of Negative Species:
   - Number of Neutral Species:

   REACTION MECHANISM MODELED (✓):
   - Primary Ionization: (Reference)
   - E-Beam:
   - Self-Sustained:
   - UV-Initiated:
   - Others (specify):

   Secondary Ionization (Reference)
   - Attachment:
   - Detachment:
   - Ion-Ion Recombination:
   - Charge Transfer:
   - Dissociation:
   - Recombination:
   - Others (specify):

   Source of Rate Coefficients Used:

   DISCHARGE POWER INPUT MODELED (✓):
   - Uniform: ✓
   - Non-Uniform:
   - Electric Field: ✓
   - Others (specify):

3. LASING KINETICS MODEL
   GENERAL (specify):
   - Lasing Species: CO/N2/•••X
   - Number of Species: •••
   - Number of Reactions: ______
   - Other Major Species Considered:

   IMPACT EXCITATION MODELED (✓):
   - Vibrational: ✓
   - Electronic: ______
   - Others (specify):

   ENERGY TRANSFER MODES MODELED (✓):
   - V-T: ✓
   - V-R: ✓
   - V-V: ✓
   - Others (specify):

   Lasing Transition: P-Branch: ✓
   - R-Branch:

   Single Line Model (✓):
   - Multi-Line Model (✓): ✓
   - Assumed Rotational Population Distribution State: ✓
   - Equilibrium:
   - Nonequilibrium:
   - Number of Laser Lines Modeled:

   Source of Rate Coefficients Used in Code:
   - Misc.

4. LINE PROFILE MODELS (✓):
   - Doppler Broadening:
   - Collisional Broadening: ✓
   - Others (specify):

5. RECIRCULATION CONTAMINANTS MODELED (✓):
   - none
   - Others (specify):

6. OTHER UNIQUE FEATURES:

   REFERENCE FOR REACTION MECHANISM AND RATES:

   OTHER UNIQUE FEATURES:
**CODE NAME:** TDFI-EDL  
**TECHNICAL AREA(S):** Optics, Kinetics, Gas Dynamics

**DEVICE COMPONENTS TREATED:** Cavity

**PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE:** Estimate performance trends of CV EDL with unstable resonator.

**ASSESSMENT OF CAPABILITIES:** Two-Dimensional Fresnel integral (cylindrical optics) code coupled to detailed EDL plasma kinetics code including E-Beam and discharge model.

**ASSESSMENT OF LIMITATIONS:** Cavity analysis restricted to cylindrical mirror configurations.

**OTHER UNIQUE FEATURES:** Fully coupled kinetics and wave optics code.

**ORIGINATOR/KEY CONTACT:**

Name: Jürgen Thoenes  
Organization: Lockheed-Huntsville Research & Engineering Center  
Address: 4800 Bradford Dr., Huntsville, AL 35807  
Phone: (205) 837-1800 ext. 416

**AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):**


**STATUS:**

Operational Currently?: yes

Under Modification?: Requires updating; not used for several years.

Ownership?: Lockheed-Huntsville

Proprietary?: No

**MACHINE/OPERATING SYSTEM (on which installed):**

**TRANSPORTABLE?:** yes

Machine Dependent Restrictions: CDC 6600/7600

**SELF-CONTAINED?:**

Other Codes Required (name, purpose): Electron Kinetics

**ESTIMATE OF RESOURCES REQUIRED FOR RUNS:**

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<td>Typical Job:</td>
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<td>Large Job:</td>
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**COMMENTS:**
1. CODE STRUCTURE

COORDINATE SYSTEM: Cartesian; Expanding: 

KINETICS GRID DIMENSIONALITY: 1-D; 2-D; 3-D: 

GAIN REGION SYMMETRY RESTRICTIONS: Flow Direction: 

KINETICS MODELED: Pulsed; CW: 

NUMERICAL SCHEME USED IN RATE CALCULATION: Explicit: (flow field) Implicit: (kinetics) Others (specify): 

REFERENCE OF METHOD USED: 

2. PLASMA KINETICS MODEL

NUMBER OF SPECIES TREATED (specify): 
Number of Positive Species: Input 
Number of Negative Species: Input 
Number of Neutral Species: Input 

REACTION MECHANISM MODELED: 
Primary Ionization: (Reference) 
E-Beam: 
Self-Sustained: 
UV-Initiated: 
Others (specify): 

Secondary Ionization: (Reference) 
Attachment: same 
Detachment: 
 Ion-Ion Recombination: 
Charge Transfer: 
Dissociation/Recombination: 
Others (specify): 

Source of Rate Coefficients Used: 

DISCHARGE POWER INPUT MODELED: Uniform; Non-Uniform: 
E-Field: 
Others (specify): 

3. LASING KINETICS MODEL

GENERAL (specify): 

Lasing Species: CO: Input 
Number of Species: Input 
Number of Reactions: Input 

Other Major Species Considered: N_2, He, H_2, O_2 

IMPACT EXCITATION MODELED: 
Vibrational: same 
Electronic: same 
Others (specify): Ionization 

ENERGY TRANSFER MODES MODELED: 

V-T: same 
V-R: 
V-V: same 
Others (specify): 
Lasing Transition: P-Branch: 
R-Branch: 
Single Line Model: 
Multi-Line Model: 

Assumed Rotational Population Distribution State: Equilibrium: Non-equilibrium: 
Number of Laser Lines Modeled: 1 
Source of Rate Coefficients Used in Code: same 

LINE PROFILE MODELS: 
Doppler Broadening: same 
Collisional Broadening: 
Others (specify): Voigt Function 

4. RECIRCULATION CONTAMINANTS MODELED: 
O_2: OH: NO: HNO: 
Others (specify): 

REFERENCE FOR REACTION MECHANISM AND RATES: same 

OTHER UNIQUE FEATURES: 

KINETICS CODE

CODE NAME: EDL (TDPI-EDL)
1. CODE STRUCTURE

COORDINATE SYSTEM (✓):
- Cartesian:
- Expanding:

FLUID GRID DIMENSIONALITY (✓):
- 1-D: ✓
- 2-D: 
- 3-D: 

Flow Field Modeled (✓):
- Compressible Flow:
- Incompressible:
- Viscous Flow:
- No Flow:

BASIC MODELING APPROACH (✓):
- Algebraic:
- Integral Method:
- Finite Difference:
- Others (specify):

REFERENCE FOR APPROACH USED:
Euler integration

2. GAS DYNAMICS MODEL FEATURES:

GAS SUPPLY MODELED (✓):
- Mixture Preparation:
- Mixture Injection:
- Nozzles:
- Flow Plates:
- Others (specify):

CAVITY INITIAL CONDITION DETERMINED BY (specify): Specified (input)

3. EXHAUST/RECIRCULATION MODEL

GENERAL SYSTEM MODELED (✓):
- Open System: 
- Closed System: ✓
- Closed Cycle:

EXHAUST SYSTEM FEATURES (✓):
- Pressure Recovery:
- Ejector System:
- Compressor/Fan:
- Heat Exchanger:
- Gas Make-Up:
- Others (specify):

Circulator analysis requires specification of temp. and flow velocity as function of time around loop.

4. ACOUSTIC ATTENUATION MODEL

GENERAL FEATURES MODELED (✓):
- Single Pulse:
- Repetitive Pulse:

DIMENSIONALITY TREATED (✓):
- 1-D:
- 2-D:
- 3-D:

DISTURBANCE MODELED (✓):
- Pressure Wave:
- Entropy Wave:
- Others (specify):

WAVE PROPAGATION TREATMENT (✓):
- Linear Wave:
- Nonlinear Wave:
- Others (specify):

THEORETICAL BASIS: (Reference)

NUMERICAL METHODOLOGY: (Reference)

ACOUSTIC ATTENUATORS CONSIDERED (✓):
- Muffler:
- Heat Exchanger:
- Horn:
- Porous Wall:
- Others (specify):

5. MODEL EFFECTS ON OPTICAL MODES DUE TO (✓):
- Index of Refraction Variation:
- Other (specify): Random noise

6. UNIQUE FEATURES:

CODE NAME: EDL
(TDFI-EDL)

DECONTAMINATION METHOD TREATED (✓):
- Scrubber:
- Shower:
- Catalytic Reactor:
- Others (specify):

Specified by adjusting mix composition

94
OPTICS CODE

CODE NAME: FICP

CONVERGENCE (✓):
Technique:
- Power Comparison: ✓
- Field Comparison: ✓
- Others (specify):

MULTIPLE EIGENVALUE/EIGENVECTOR EXTRACTOR ALGORITHMS (✓):
- Prony:
- Others (specify):

3. RESONATOR MODELING FEATURES

GENERAL CAPABILITIES:

Stability (✓):
- Stable Resonators: ✓
- Unstable Resonators: ✓

Type (✓):
- Standing Wave:
- Traveling Wave
- Ring:
- Reverse
- Traveling Wave:
- Branch (✓):
  - Positive:
  - Negative:

Optical Element Models Included (✓):
- Flat Mirrors:
- Spherical Mirrors:
- Cylindrical Mirrors:
- Telescopes:
- Scraper Mirrors:
- Deformable Mirrors:
- Spatial Filters:
- Gratings (specify type):
- Other Elements (specify):

Focusing output mirror

PRINCIPAL RESONATOR GEOMETRIES MODELED (Please List):
- Unstable resonator with focused oblique output beam.

(Continued)
### OPTICS CODE

**CODE NAME**

**OPTICS CODE**

(Concluded)

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<td>Simple Saturated Gain:</td>
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<td>Detailed Model (See Section 3 in Kinetics Code)</td>
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<td>Reflectivity Loss:</td>
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<td>Output Coupler Edges Rolled:</td>
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<td>Serrated:</td>
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<td>Number of Overlaps Allowed:</td>
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<td>Others: Random noise option and starter</td>
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<td>Optimal Focal Search:</td>
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</tr>
<tr>
<td>Beam Quality:</td>
<td></td>
</tr>
<tr>
<td>Atmospheric Propagation Effects:</td>
<td></td>
</tr>
<tr>
<td>Others: Non-Amplified oblique focused output beam</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BEAM CONTROL SYSTEM MODELED (✓):</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pointer/Tracker Subsystem:</td>
<td></td>
</tr>
<tr>
<td>Beam Jitter:</td>
<td></td>
</tr>
<tr>
<td>Autoalignment:</td>
<td></td>
</tr>
<tr>
<td>Target Model Motion: Effects:</td>
<td></td>
</tr>
</tbody>
</table>

| OTHER UNIQUE FEATURES (e.g., Beam/Mode Rotation, Extra-Cavity Adaptive Optics, Multipath/Parasitic Effects, Beam Director Elements, etc.): |  |

---

96
**CODE NAME:** TEA Laser Kinetics  
**Program:** Laser Kinetics  
**TECHNICAL AREA(S):** Kinetics  
**DEVICE COMPONENTS TREATED:** Laser Cavity  
**PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE:** To model the laser kinetics of a pulsed 10.6 μm CO₂ laser and to predict the performance of the laser.

**ASSESSMENT OF CAPABILITIES:** Can handle gas mixtures of CO₂: N₂: He: H₂O: H₂ at any temperature and pressure, and pulse lengths from one to twenty microseconds.

**ASSESSMENT OF LIMITATIONS:** Is one-dimensional, can only model stable resonators, cannot handle very short pulses in which Boltzmann equilibrium for the vibrational modes is not a good approximation, and the rotational and kinetic temperatures are the same.

**OTHER UNIQUE FEATURES:** A six-temperature kinetic model is used which includes E/N-dependent electrical excitation and 29 temperature-dependent collisional relaxation rates.

**ORIGINATOR/KEY CONTACT:**  
Name: Lyle Taylor  
Organization: Westinghouse Electric Corporation  
Address: 1310 Beulah Rd., Pittsburgh, PA 15668  
Phone: 412-256-5833

**AVAILABLE DOCUMENTATION (Please specify, use T - Theory, U = User's Manual, L = Listing, and R = Related Publication):**  

**STATUS:**  
Operational Currently?: Yes  
Under Modification?: No  
Purpose(s):  
Ownership?: U.S. Government  
Proprietary?: No

**MACHINE/OPERATING SYSTEM (on which installed):** U-1106 and CDC-7600

**TRANSPORTABLE?:** Yes  
Machine Dependent Restrictions: FORTRAN IV

**SELF-CONTAINED?:** Yes  
Other Codes Required (name, purpose):

**ESTIMATE OF RESOURCES REQUIRED FOR RUNS:**  
<table>
<thead>
<tr>
<th>Small Job:</th>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Job:</td>
<td>14301</td>
<td>7 sec, CDC-7600</td>
</tr>
</tbody>
</table>

**COMMENTS:** Fabry-Perot Cavity modeled using geometric optics with floating gain.
KINETICS CODE

1. CODE STRUCTURE
COORDINATE SYSTEM (✓):
- Cartesian: ✓
- Expanding: ___

COORDINATE SYSTEM (✓):
- Cartesian: ✓
- Expanding: ___

KINETICS GRID DIMENSIONALITY (✓):
- 1-D: ✓
- 2-D: ___
- 3-D: ___

GAIN REGION SYMMETRY RESTRICTIONS:
- Gain Vary Along Optical Axis: no
- Flow Direction: ___

KINETICS MODELED: Pulsed: ✓
- CW: ___

NUMERICAL SCHEME USED IN RATE CALCULATION (✓):
- Explicit: ___
- Implicit: ___
- Others (specify): Hamming


2. PLASMA KINETICS MODEL
NUMBER OF SPECIES TREATED (specify):
- Number of Positive Species: ___
- Number of Negative Species: ___
- Number of Neutral Species: ___

REACTION MECHANISM MODELED (✓):
- Primary Ionization: (Reference)
  - E-Beam: ✓
  - Self-Sustained: ✓
  - UV-Initiated: ✓
  - Others (specify): ___

- Secondary Ionization (Reference)
  - Attachment: ✓
  - Detachment: ✓
  - Ion-Ion Recombination: ___
  - Charge Transfer: ___
  - Dissociation/Recombination: ___
  - Others (specify): ___

Source of Rate Coefficients Used:

DISCHARGE POWER INPUT MODELED (✓):
- Uniform: ✓
- Non-Uniform: ___
- E-Field: ___
- Others (specify):

3. LASING KINETICS MODEL
GENERAL (specify):
- Lasing Species: CO2
- Number of Species: 5
- Number of Reactions: 29
- Other Major Species Considered: He, N2, H2O, H2

IMPACT EXCITATION MODELED (✓):
- Vibrational: ___
- Electronic: ___
- Others (specify): ___

ENERGY TRANSFER MODES MODELED (✓):
- V-T: ✓
- V-R: ___
- V-V: ✓
- Others (specify):

Source of Rate Coefficients Used in Code:
- Westinghouse Paper 78-1C2-ADLAS-P2 (1976)

LINE PROFILE MODELS (✓):
- Doppler Broadening: ✓
- Collisional Broadening: ✓
- Others (specify):

4. RECIPIRICATION CONTAMINANTS MODELED (✓):
- None
- N2: ___
- OH: ___
- NO: ___
- HNO: ___
- Others (specify):

REFERENCE FOR REACTION MECHANISM AND RATES:

OTHER UNIQUE FEATURES:


**CODE NAME:** TELSAT  
**TECHNICAL AREA(S):** Gas Dynamics  
**DEVICE COMPONENTS TREATED:** Overall System Characteristics  
**PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE:** Study steady state and transient Thermodynamic and Fluid Dynamic System Performance.

---

**ASSESSMENT OF CAPABILITIES:** 1-D time dependent assessment of thermodynamic and fluid dynamic performance of laser components and their interactions within the laser system.

**ASSESSMENT OF LIMITATIONS:** limited to 1-D problems.

---

**OTHER UNIQUE FEATURES:** Developed in "building block" format and easily adaptable to different systems (i.e. closed or open loop) can also be used to model non-EDL systems.

---

**ORIGINATOR/KEY CONTACT:**
- **Name:** Earl White
- **Organization:** R&D Associates
- **Address:** ATO 9377 International Airport Albuquerque, NM 87119
- **Phone:** (505) 844-8446

**AVAILABLE DOCUMENTATION** (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication): T, L, RP

---

**STATUS:**
- Operational Currently? yes
- Under Modification? no
- Purpose(s): 

**Ownership:** R&D Associates
- Proprietary? No

**MACHINE/OPERATING SYSTEM (on which installed):** CRAY-1

**TRANSPORTABLE?** yes
- Machine Dependent Restrictions: none

**SELF-CONTAINED?**
- Other Codes Required (name, purpose): none

**ESTIMATE OF RESOURCES REQUIRED FOR RUNS:**

<table>
<thead>
<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
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<tbody>
<tr>
<td><strong>Small Job:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Typical Job:</strong></td>
<td>68096 (Version 1) 44 sec</td>
</tr>
<tr>
<td><strong>Large Job:</strong></td>
<td>118272 (Version 2) 154 sec</td>
</tr>
</tbody>
</table>

**COMMENTS:**
GAS DYNAMICS CODE

1. CODE STRUCTURE

COORDINATE SYSTEM (√):
- Cartesian: √
- Expanding:
FLUID GRID DIMENSIONALITY (√):
- 1-D: √
- 2-D:
- 3-D:
- Time Dependent:
FLOW FIELD MODELED (√):
- Compressible Flow: √
- Incompressible:
- Viscous Flow:
- No Flow:
BASIC MODELING APPROACH (√):
- Algebraic:
- Integral Method:
- Finite Difference: √
- Others (specify):

REFERENCE FOR APPROACH USED:
- Blackburn—Fluid Power Control

2. GAS DYNAMICS MODEL FEATURES:

GAS SUPPLY MODELED (√):
- Mixture Preparation: √
- Mixture Injection:
- Nozzles:
- Flow Plates:
- Others (specify):

CAVITY INITIAL CONDITION DETERMINED BY (specify):
- Input

3. EXHAUST/RECIRCULATION MODEL

GENERAL SYSTEM MODELED (√):
- Open System:
- Closed System: √
CLOSED CYCLE:
- Pressure Recovery:
- Ejector System:
- Compressor/Fan:
- Heat Exchanger: √
- Gas Make-Up: √
- Others (specify): Nozzles, ducting turbine

DECONTAMINATION METHOD TREATED (√):
- Scrubber:
- Shower:
- Catalytic Reactor:
- Others (specify):

ACOUSTIC ATTENUATION MODEL

GENERAL FEATURES MODELED (√):
- Single Pulse:
- Repetitive Pulse:
DIMENSIONALITY TREATED (√):
- 1-D:
- 2-D:
- 3-D:
- Time Dependent:
DISTURBANCE MODELED (√):
- Pressure Wave:
- Entropy Wave:
- Others (specify):

WAVE PROPAGATION TREATMENT (√):
- Linear Wave:
- Nonlinear Wave:
- Others (specify):

THEORETICAL BASE: (Reference)

NUMERICAL METHODOLOGY: (Reference)

ACOUSTIC ATTENUATORS CONSIDERED (√):
- Muffler:
- Heat Exchanger:
- Horn:
- Porous Wall:
- Others (specify):

5. MODEL EFFECTS ON OPTICAL MODES DUE TO...

INDEX OF REFRACTION VARIATION:
- Other (specify):
- Others (specify):

OTHER UNIQUE FEATURES:
CODE NAME: UNSEDL2  

TECHNICAL AREA(S): Optics/Kinetics/Gas Dynamics

DEVICE COMPONENTS TREATED: $CO_2$ EDL

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: Time dependent behavior of CW $CO_2$ EDL with mode media instability.

ASSESSMENT OF CAPABILITIES: 2-D flow + kinetics; FFT optics

ASSESSMENT OF LIMITATIONS: Very expensive to run

OTHER UNIQUE FEATURES: Dynamic Dimensioning

ORIGINATOR/KEY CONTACT:

Name: Ted Salvi
Organization: AFML/ARAO
Address: Kirtland AFB, NM 87117
Phone: 505-844-0256

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):


STATUS:

Operational Currently?: yes
Under Modification?: no
Purpose(s): Not currently being used

Ownership?: USAF
Proprietary?: no

MACHINE/OPERATING SYSTEM (on which installed): CDC 7600 (Cyber 176)

TRANSPORTABLE?: no
Machine Dependent Restrictions: TO; Assembly language FFT

SELF-CONTAINED?

Other Codes Required (name, purpose):

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

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<thead>
<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
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<tr>
<td>Small Job:</td>
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<tr>
<td>Typical Job:</td>
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<tr>
<td>Large Job:</td>
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</tr>
</tbody>
</table>

Approximate Number of FORTRAN Lines: 10,000

COMMENTS:
KINETICS CODE

CODE NAME: UNSEDL2

1. CODE STRUCTURE
   COORDINATE SYSTEM: Cartesian: ✔ Expanding: 
   KINETICS GRID DIMENSIONALITY: 1-D: ✔ 2-D: ✔ 3-D: 
   GAIN REGION SYMMETRY RESTRICTIONS: Gain Vary Along Optical Axis: Multiple sheet Flow Direction: ✔
   KINETICS MODELED: Pulsed: ✔ CW: ✔ (Time Dep)
   NUMERICAL SCHEME USED IN RATE CALCULATION: Explicit: ✔ Implicit: 
   Others (specify): 

   REFERENCE OF METHOD USED: MacCormack's Fluid Dynamic, extended to kinetics

2. PLASMA KINETICS MODEL
   Energy levels: E_UPPER E_LOWER E_N2
   NUMBER OF SPECIES TREATED (specify): Number of Positive Species: Number of Negative Species: Number of Neutral Species: 
   REACTION MECHANISM MODELED: ✔
      Primary Ionization: ✔ (Reference)
         E-Beam: ✔
         Self-Sustained: 
         UV-Initiated: 
         Others (specify): 
      Secondary Ionization: ✔ (Reference)
         Attachment: 
         Detachment: 
         Ion-Ion Recombination: 
         Charge Transfer: 
         Dissociation/Recombination: ✔
         Others (specify): 
   Source of Rate Coefficients Used: 

   DISCHARGE POWER INPUT MODELED: ✔
      Uniform: 
      E-Field: ✔
      Others (specify): 

3. LASING KINETICS MODEL
   GENERAL (specify):
      Lasing Species: CO2 (001)
      Number of Species: 3
      Number of Reactions: 6
      Other Major Species Considered: 

   IMPACT EXCITATION MODELED: ✔
      Vibrational: ✔
      Electronic: 
      Others (specify): 

   ENERGY TRANSFER MODES MODELED: ✔
      V-T: ✔ V-R: ✔ V-V: ✔ (Reference)
      Others (specify): 

   LINE PROFILE MODELS: ✔
      Doppler Broadening: ✔
      Collisional Broadening: 
      Others (specify): 

4. RECIRCULATION CONTAMINANTS MODELED: ✔
   None
   CO: 
   OH: 
   NO: HNO: 
   Others (specify): 

   REFERENCE FOR REACTION MECHANISM AND RATES: Various

OTHER UNIQUE FEATURES: 

102
1. CODE STRUCTURE
COORDINATE SYSTEM:  
Cartesian:  ✓ Expanding:

FLUID GRID DIMENSIONALITY:  
1-D:  
2-D:  ✓  
3-D:  
Time Dependent:

FLOW FIELD MODELED:  
Compressible Flow:  ✓  
Incompressible:  
Viscous Flow:  
No Flow:  

BASIC MODELING APPROACH:  
Algebraic:  
Finite Difference:  ✓  
Others (specify):  actually finite element

REFERENCE FOR APPROACH USED:  
MacCormack

2. GAS DYNAMICS MODEL FEATURES:  
GAS SUPPLY MODELED:  
Mixture Preparation:
Mixture Injection:
Nozzles:  Variable Geometry
Flow Plates:  Choked or face plate
Others (specify):

CAVITY INITIAL CONDITION DETERMINED BY (specify):  solution of time dependent equations, no energy input.

3. EXHAUST, RECIRCULATION MODEL  
GENERAL SYSTEM MODELED:  
Open System:  ✓  Closed System:  
Closed Cycle:  

EXHAUST SYSTEM FEATURES:  
Pressure Recovery:  ✓
Ejector System:  
Compressor/Fan:  
Heat Exchanger:  
Gas Make-Up:  
Others (specify):  A recovery pressure is specified.

4. ACOUSTIC ATTENUATION MODEL  
GENERAL FEATURES MODELED:  
Single Pulse:  
Repetitive Pulse:  

DIMENSIONALITY TREATED:  
1-D:  
2-D:  
3-D:  
Time Dependent:

DISTURBANCE MODELED:  
Pressure Wave:  
Entropy Wave:  
Others (specify):  disturbance propagated by "hydro code" time dependent equations.

WAVE PROPAGATION TREATMENT:  
Linear Wave:  
Nonlinear Wave:  
Others (specify):

THEORETICAL BASIS:  (Reference)

NUMERICAL METHODOLOGY:  (Reference)

ACOUSTIC ATTENUATORS CONSIDERED:  
Muffler:  
Heat Exchanger:  
Horn:  
Porous Wall:  
Others (specify):  no

5. MODEL EFFECTS ON OPTICAL MODES DUE TO:  
Index of Refraction Variation:  ✓  
Other (specify):  gain variation

OTHER UNIQUE FEATURES:  

103
1. CODE STRUCTURE

BASIC TYPE (✓):  
- Physical Optics: ✓
- Geometrical:
- Constant Gain; Floating Gain: ✓

FIELD (POLARIZATION) REPRESENTATION (✓):  
- Scalar: ✓
- Vector:

COORDINATE SYSTEM (✓):  
- Cartesian: ✓
- Expanding (specify): ✓

TRANSVERSE GRID DIMENSIONALITY (specify):  
- One-Dimensional: ✓
- Two-Dimensional: ✓

FIELD SYMMETRY RESTRICTIONS? NO

MIRROR SHAPE(S) ALLOWED (✓):  
- Square: ✓
- Rectangular: ✓
- Circular:
- Elliptical:
- Strip: ✓
- Arbitrary:

CONFIGURATION FLEXIBILITY (✓):  
- Fixed, Single Resonator Geometry:
- Fixed, Multiple Resonator Geometries:
- Modular, Multiple Resonator Geometries: ✓
- Others (describe):

2. PROPAGATION TECHNIQUE (✓ all that apply):  
- Fresnel Integral Algorithms: ✓
- With Kernel Averaging:
- Gaussian Quadrature:
- Fast Fourier Transform (FFT): ✓
- Fast Hankel Transform (FHT): ✓
- Gardener-Fresnel-Kirchhoff (GFK):
- Others (specify):

Finite Difference Algorithms  
- Method (specify):

CONVERGENCE (✓):  
- Technique:
  - Power Comparison:
  - Field Comparison: ✓
  - Others (specify):
- Acceleration Algorithms Used?: No
  - Technique:
- MULTIPLE EIGENVALUE/EIGENVECTOR EXTRACTOR ALGORITHMS (✓):  
  - Prony:
  - Others (specify):

3. RESONATOR MODELING FEATURES

GENERAL CAPABILITIES:  
- Stability (✓):  
  - Stable Resonators: ✓
  - Unstable Resonators:
- Type (✓):  
  - Standing Wave:
  - Traveling Wave (Ring):
  - Reverse Traveling Wave:
  - Branch (✓):
    - Positive: ✓
    - Negative:
- Optical Element Models Included (✓):  
  - Flat Mirrors:
  - Spherical Mirrors: ✓
  - Cylindrical Mirrors:
  - Telescopes:
  - Scraper Mirrors:
  - Deformable Mirrors:
  - Spatial Filters:
  - Gratings (specify type):
  - Other Elements (specify):

PRINCIPAL RESONATOR GEOMETRIES MODELED (Please List):  
- Sets up confocal automatically;
  - other resonators can be set up with some additional minor difficulty.

104 (Continued)
GAIN MODELS (✓)
- Bare Cavity Only:
- Simple Saturated Gain:
- Detailed Model (see Section 3 in Kinetics Code) ✓

BASE CAVITY FIELD MODIFIER MODELS (✓)
- Mirror Tilt:
- Mirror Degradation:
- Aberrations/Thermal Distortion:
- Arbitrary:
  - Selected (specify): ✓
  - Reflectivity Loss:
  - Output Coupler Edges:
  - Rolled:
  - Serrated:
  - Other:

LOADED CAVITY FIELD MODIFIER MODELS (✓)
- Refractive Index Variation:
- Gas Absorption:
- Overlapped Beams (or Flux Spilting):
  - Number of Overlaps Allowed:
  - can be easily set up
- Other:

4) FAR FIELD MODELS (✓)
- Beam Steering Removal:
- Optimal Focal Search:
- Beam Quality:
- Atmospheric Propagation Effects:
- Others:

BEAM CONTROL SYSTEM MODELED (✓)
- Pointer/Tracker Subsystem:
- Beam Jitter:
- Autosalignment:
- Target Model:
  - Motion Effects:

OTHER UNIQUE FEATURES (e.g., Beam/Mode Rotation, Extra-Cavity Adaptive Optics, Multipath/Parasitic Effect, Beam Director Elements, etc.):

105
**CODE NAME:** UVLZR  
**TECHNICAL AREA(s):** Kinetics

**DEVICE COMPONENTS TREATED:** Laser Discharge, PFN

**PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE:** Study kinetics of rare gas halide lasers, design more efficient PFN's.

**ASSESSMENT OF CAPABILITIES:** Code does quite well at describing the electrical characteristics (voltage, current, impedance) of RgH-discharge systems. In general code also predicts lasing onset well.

**ASSESSMENT OF LIMITATIONS:** Code assumes uniform gain and flux and this is bad. Therefore it does not accurately predict output energy. Code requires separate electro-kinetics code.

**OTHER UNIQUE FEATURES:** One version of the code has been modified to provide a gas-phase resistance in code SUPER SCEPTRE. This then permits modelling of nearly any PFN.

**ORIGINATOR/KEY CONTACT:**

- **Name:** Arthur E. Greene
- **Organization:** T-12, LASL
- **Address:** MS-569, Los Alamos Scientific Laboratory, Los Alamos, NM 87545
- **Phone:** 505-667-7799

**AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and R = Related Publication):**

- **RP:** A. E. Greene & C.A. Brau, IEEE J.Q.E. 14, 951, 1978
- **RP:** A. E. Greene, C.R. Tallman, W.L. Willis, & C.A. Brau, Proceedings of International Conference on Lasers 1979, 211.

**STATUS:**

- Operational Currently?: X
- Under Modification?: X
- Purpose(s): Work underway on moving from KrF to XeCl

**Ownership:** LASL is funded by DOE

**Proprietary:** No

**MACHINE/OPERATING SYSTEM (on which installed):** CDC-7600/LTSS

**TRANSPORTABLE:** Yes

**Machine Dependent Restrictions:**

**SELF-CONTAINED:** No

**Other Codes Required (name, purpose):** NOMAD - solves Boltzmann equation to find electron impact pumping rates.

**ESTIMATE OF RESOURCES REQUIRED FOR RUNS:**

<table>
<thead>
<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
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</thead>
<tbody>
<tr>
<td>Small Job</td>
<td></td>
</tr>
<tr>
<td>Typical Job</td>
<td>637</td>
</tr>
<tr>
<td>Large Job</td>
<td></td>
</tr>
</tbody>
</table>

**COMMENTS:**

- Core Size (Octal Words) | Execution Time (sec, CDC 7600)
- Small Job
- Typical Job
- Large Job
- Approximate Number of FORTRAN Lines: 600
# KINETICS CODE

**CODE NAME:** UVLZ

## 1. CODE STRUCTURE

**COORDINATE SYSTEM:**
- Cartesian: Yes
- Expanding

**KINETICS GRID DIMENSIONALITY:**
- 1-D: Yes
- 2-D: 
- 3-D: 

**GAIN REGION SYMMETRY RESTRICTIONS:**
- Gain Vary Along Optical Axis: 

**KINETICS MODELED:**
- Pulsed: Yes
- CW: Yes

**NUMERICAL SCHEME USED IN RATE CALCULATION:**
- Explicit: 
- Implicit: Yes
- Others (specify): 

**REFERENCE OF METHOD USED:** Gear

## 2. PLASMA KINETICS MODEL

**NUMBER OF SPECIES TREATED:**
- Number of Positive Species: 2
- Number of Negative Species: 2
- Number of Neutral Species: 4

**REACTION MECHANISM MODELED:**
- Primary Ionization: E-Beam
- Self-Sustained: 
- UV-Initiated: 
- Others (specify): Electron impact avalanche

**SECONDARY IONIZATION:**
- Attachment: Yes
- Detachment: Yes
- Ion-Ion Recombination: Yes
- Charge Transfer: 
- Dissociation/Recombination: Yes
- Others (specify): 

**SOURCE OF RATE COEFFICIENTS USED:** see RP on page 1

**DISCHARGE POWER INPUT MODELED:**
- Uniform: Yes
- Non-Uniform: 
- E-Field: Yes
- Others (specify): time varying

## 3. LASING KINETICS MODEL

**GENERAL:**
- Lasing Species: KrF* or RgH*
- Number of Species: 5
- Number of Reactions: 2
- Other Major Species Considered: diluent Ne or He (or both), F₂ or halogen donor

**IMPACT EXCITATION MODELED:**
- Vibrational: Yes
- Electronic: 
- Others (specify): 

**ENERGY TRANSFER MODELS MODELED:**
- V-T: 
- V-R: 
- V-V: 
- Others (specify): 

**REFERENCE FOR REACTION MECHANISM AND RATES:**

OTHER UNIQUE FEATURES: Numerous self absorption terms included.

## 4. RECIRCULATION CONTAMINANTS

**MODELED:** none
- O₂: 
- OH: 
- NO₃: 
- HNO₃: 
- Others (specify):
CODE NAME: VIBKIN
TECHNICAL AREA(S): Kinetics
DEVICE COMPONENTS TREATED: Laser Cavity

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: To model the kinetics of the vibration levels of carbon monoxide mixed with helium and argon cooled by supersonic expansion pumped by an electric discharge and unpumped by lasing.

ASSESSMENT OF CAPABILITIES: The model predicts the time histories of the lasing lines which are in very good agreement with pulsed and cw experiments in both small and large scale devices.

ASSESSMENT OF LIMITATIONS: About $50 cost per case to run.

Name: Donald John Nelson, MS 88-46 /Includes CO R-branch resonance effects.
Organization: The Boeing Aerospace Company
Address: P.O. Box 3999 Seattle, WA 98124
Phone: (206) 773-1498


STATUS:
Operational Currently?: yes
Under Modification?: only slowly
Purpose(s): to continue improving the performance

Ownership?: AFWL and Boeing
Proprietary?:

MACHINE/OPERATING SYSTEM (on which installed): IBM 360/370/3032 at Boeing, CDC 6600 at AFWL
TRANSPORTABLE?: yes
Machine Dependent Restrictions: A few statements were changed when transferring between IBM and CDC machines.

SELF-CONTAINED?: yes
Other Codes Required (name, purpose):

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

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<thead>
<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
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<tbody>
<tr>
<td>Small Job:</td>
<td>G 50 CPUSEC for 30 sec pulse</td>
</tr>
<tr>
<td>Typical Job:</td>
<td>C100K, L200K, G160K C 20 CPUSEC G 90 CPUSEC for 60 sec pulse</td>
</tr>
<tr>
<td>Large Job:</td>
<td>G 330 CPUSEC for 250 sec pulse</td>
</tr>
</tbody>
</table>

Approximate Number of FORTRAN Lines: 2200

COMMENTS:
**KINETICS CODE**

**CODE NAME:** VIBKIN

### 1. CODE STRUCTURE
- **COORDINATE SYSTEM (✓):**
  - Cartesian: ✓
  - Expanding: 

- **KINETICS GRID DIMENSIONALITY (✓):**
  - 1-D: ✓
  - 2-D: 
  - 3-D: 

- **GAIN REGION SYMMETRY RESTRICTIONS:**
  - Gain Vary Along Optical Axis: 
  - Flow Direction: ✓

- **KINETICS MODELED:**
  - Pulsed: ✓
  - CW: ✓

- **NUMERICAL SCHEME USED IN RATE CALCULATION (✓):**
  - Explicit: 
  - Implicit: 
  - Other (specify): 

- **REFERENCE OF METHOD USED:**

### 2. PLASMA KINETICS MODEL
- **NUMBER OF SPECIES TREATED (specify):**
  - Number of Positive Species: 
  - Number of Negative Species: 
  - Number of Neutral Species: 

- **REACTION MECHANISM MODELED (✓):**
  - Primary Ionization: (Reference)
  - E-Beam:
  - Self-Sustained:
  - CV-Initiated:
  - Others (specify): 

- **SECONDARY IONIZATION (specify):**
  - Attachment: 
  - Detachment: 
  - Ion-Ion Reaction:
  - Charge Transfer: 
  - Dissociation/Recombination:
  - Others (specify): 

- **Source of Rate Coefficients Used:**

### 3. LASING KINETICS MODEL
- **GENERAL (specify):**
  - Lasing Species: Carbon Monoxide
  - Number of Species: 3
  - Number of Reactions: 
  - Other Major Species Considered: Helium and Argon

- **IMPACT EXCITATION MODELED (✓):**
  - Vibrational: ✓ 7, 23, 30, 32
  - Electronic: 
  - Optical (specify): 

- **ENERGY TRANSFER MODELS MODELED (✓):**
  - Reference:

- **LINE PROFILE MODELS (✓):**
  - Doppler Broadening: 
  - Collisional Broadening: 
  - Others (specify): Voigt

- **SOURCE OF RATE COEFFICIENTS USED:**

### 4. RECIRCULATION CONTAMINANTS MODELED (✓)
- None
- O₃: 
- NO: 
- HNO: 
- Others (specify): 

- **REFERENCE FOR REACTION MECHANISM AND RATES:**

- **OTHER UNIQUE FEATURES:**
  - *See reference on AFWL-TR-75-256

---

*Note: The text contains a table with some columns filled in, indicating the presence and type of information for various aspects of the kinetics code.*
CODE NAME: XENON

TECHNICAL AREA(S): Kinetics

DEVICE COMPONENTS TREATED:

PRINCIPAL PURPOSE(S)/APPLICATION(S) OF CODE: Synthesis of E-Beam initiated A -X e laser.

ASSESSMENT OF CAPABILITIES: Calculates saturated power density for an E-Beam initiated discharge pumped Ar-Xe laser using 10-20 rate equations

ASSESSMENT OF LIMITATIONS: Boltzman code needed to calculate rate constants.

OTHER UNIQUE FEATURES: Collision effect on excited states treated implicitly.

ORIGINATOR/KEY CONTACT:
Name: T. DeTemple
Organization: U. of Ill.
Address: 200 EERL, Urbana, ILL 61801
Phone: 217-333-3094

AVAILABLE DOCUMENTATION (Please specify, use T = Theory, U = User's Manual, L = Listing, and RP = Related Publication):
S. Lawton and T.A. DeTemple, "Near Infrared Gas Lasers" AFAPL-TR-78-107 (RP)

STATUS:
Operational Currently?: no
Under Modification?:
Purpose(s):

Ownership?:
Proprietary?: no

MACHINE/OPERATING SYSTEM (on which installed): CYBER 175

TRANSPORTABLE?: Yes
Machine Dependent Restrictions:

SELF-CONTAINED?:
Other Codes Required (name, purpose): CALCOMP

ESTIMATE OF RESOURCES REQUIRED FOR RUNS:

<table>
<thead>
<tr>
<th>Core Size (Octal Words)</th>
<th>Execution Time (sec, CDC 7600)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Job:</td>
<td>X</td>
</tr>
<tr>
<td>Typical Job:</td>
<td>X</td>
</tr>
<tr>
<td>Large Job:</td>
<td>X</td>
</tr>
</tbody>
</table>

Approximate Number of FORTRAN Lines: Few 1000

COMMENTS:
1. CODE STRUCTURE
COORDINATE SYSTEM (✓): Cartesian; ✓ Expanding:

KINETICS GRID DIMENSIONALITY (✓):
1-D: ✓ 2-D: ✓ 3-D: 

GAIN REGION SYMMETRY RESTRICTIONS:
Gain Vary Along Optical Axis: 

FLOW DIRECTION:
KINETICS MODELED: Pulsed: ✓ CW: 

NUMERICAL SCHEME USED IN RATE CALCULATION (✓):
Explicit: ✓ Implicit: ✓ Others (specify):

REFERENCE OF METHOD USED: Gear Method

2. PLASMA KINETICS MODEL
NUMBER OF SPECIES TREATED (specify):
Number of Positive Species: 5
Number of Negative Species: 1
Number of Neutral Species: 4

REACTION MECHANISM MODELED (✓):
Primary Ionization: (Reference)
E-Beam: ✓ Self-Sustained: ✓ (UV-Initiated): 
Others (specify):

Secondary Ionization (Reference):
Attachment: ✓ Detachment: 
Ion-Ion Recombination: 
Charge Transfer: Dissociation/Recombination: ✓ 
Others (specify):

Source of Rate Coefficients Used: 

VARIOUS

DISCHARGE POWER INPUT MODELED (✓):
Uniform: ✓ Non-Uniform: 
E-Field: 
Others (specify):

3. LASING KINETICS MODEL
GENERAL (specify):
Lasing Species: Xe
Number of Species: 2
Number of Reactions: 40
Other Major Species Considered: Molecular Ions, R.C. Molecules

IMPACT EXCITATION MODELED (✓):
Vibrational: ✓ Electronic: ✓ Others (specify): Excited State

ENERGY TRANSFER MODES MODELED (✓):
V-T: ✓ V-R: ✓ V-V: ✓ Others (specify): Electronic

Lasing Transition: P-Branch:
Single Line Model (✓): ✓ Multi-Line Model (✓): ✓
Assumed Rotational Population Distribution State (✓): 
Equilibrium: ✓ Nonequilibrium: 
Number of Laser Lines Modeled: 1
Source of Rate Coefficients Used in Code: Various

LINE PROFILE MODELS (✓):
Doppler Broadening: ✓ Collisional Broadening: 
Others (specify):

4. RECIRCULATION CONTAMINANTS MODELED (✓): none
O₂: OH: 
NO: HNO₃: 
Others (specify):

REFERENCE FOR REACTION MECHANISM AND RATES:

OTHER UNIQUE FEATURES: Corrects for excited state dependence on electron distribution function.
5. REFERENCES


6. SELECTED BIBLIOGRAPHY


1. AFVAL/AANA-1  
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