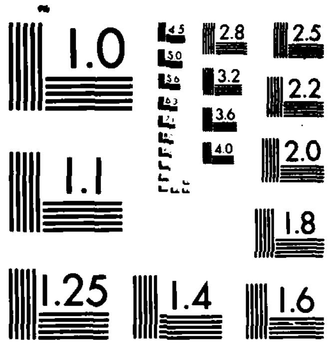
AD-A166 228 LASER THERMAL PROPULSION(U) TENNESSEE UNIV SPACE INST TULLAHOMA D KEEFER 21 MAR 84 AFOSR-TR-86-0086 AFOSR-83-0043 1/1

UNCLASSIFIED F/G 20/9 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

AD-A166 228

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified AD-A166 228	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) AFOSR-TR- 86-0086
6a. NAME OF PERFORMING ORGANIZATION University of Tennessee Space Institute 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State and ZIP Code) Applied Physics Research Group Tullahoma, Tennessee 37388	7b. ADDRESS (City, State and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Air Force Office of Scientific Research 8b. OFFICE SYMBOL (If applicable) NA AFOSR/NA	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER AFOSR-83-0043
8c. ADDRESS (City, State and ZIP Code) Bolling AFB, DC 20332	10. SOURCE OF FUNDING NOS. PROGRAM ELEMENT NO.: 61102F PROJECT NO.: 2308 TASK NO.: K1 WORK UNIT NO.:
11. TITLE (Include Security Classification) Laser Thermal Propulsion	
12. PERSONAL AUTHOR(S) Dennis Keefer	

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
Annual	FROM 1/1/83 TO 1/14/84	1984, March 21	6

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB. GR.	Laser Propulsion, Laser Sustained Plasmas, Plasma Spectroscopy, Argon Plasmas

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

The principal objective of this research investigation is to determine experimentally the effects of a forced convection environment and optical geometry on the stability, fractional power absorption, plasma structure, and fluid mixing in a laser sustained plasma (LSP). A continuous, 1.5 kW, axial flow, carbon dioxide laser was used to create the LSP in a cylindrical quartz flow channel. The convection flowfield surrounding the plasma was controlled by the volume flow through the test chamber, and the optical geometry was determined by the focal length of the lens. Digital images of the plasma in selected narrow wavelength intervals were obtained using a calibrated, CID digital camera and a VICOM digital image processing computer. These images were then Abel inverted to give a spatial plasma emission coefficient which determined the spatial distribution of the plasma temperature. Data were obtained for argon plasmas at a nominal pressure of two atmospheres and four different mean incident flow velocities from 0.4 to 2.9 m/s. The nominal incident laser power was 1 kW. Detailed examination of the complex interactions of the various

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Leonard H. Caveny	22b. TELEPHONE NUMBER (Include Area Code) (202) 767-4937 22c. OFFICE SYMBOL AFOSR/NA

DD FORM 1473, 83 APR EDITION OF 1 JAN 73 IS OBSOLETE.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

DTIC FILE COPY

energy absorption and loss mechanisms will lead to a more complete understanding of the processes which control plasma stability, fractional power absorption and mixing in the laser sustained plasma.

By
Distribution/
Availability Codes

Dist	Avail and/or Special
A-1	

WORK STATEMENT

AFOSR-83-0043

Objective

The principal objective of this research is to determine the effect of a forced convection flow environment on the stability, fractional power absorption, flow structure and mixing in a laser sustained plasma (LSP).

Approach

Experimental measurements of the plasma temperature field and flow field will be compared with existing models for the LSP developed by the Air Force Weapons Lab (AFWL), Physical Sciences, Inc. (PSI), Pennsylvania State University (PSU), and The University of Tennessee Space Institute (UTSI) to elucidate the physical mechanisms which control plasma stability, power absorption, and fluid mixing.

The plasma absorption mechanism, inverse bremsstrahlung, is applicable at all potential laser wavelengths, but the UTSI experiments will utilize a 1.5 kW carbon dioxide laser to take advantage of the long run times, good beam quality, and ease of operation. Argon will be used as the plasma medium since it is easily sustained with moderate laser power and will afford a relatively large range of pressures, and flow rates for the experimental study. Experimental results can be extrapolated to other gases and laser wavelengths through the known relationships between wavelength and absorption coefficient for inverse bremsstrahlung.

The temperature field in the plasma will be measured using narrow bandpass images of the plasma emission acquired with a VICOM digital image processing computer and CID video camera. The resulting temperature fields will permit spatially resolved evaluation of the energy conversion from laser absorption to thermal radiation, thermal conduction, and thermal convection within the plasma. Optical holographic interferometry will be used to measure the density of the lower temperature portions of the flow, and will permit the evaluation of flow field velocity and convective mixing between the high temperature plasma core and the outer buffer flow.

Status of the Research Effort

The surplus carbon dioxide laser obtained from The US Army Ballistic Research Laboratory (BRL) was installed at UTSI and put into operation. The mirrors had been damaged in storage and had to be returned to the manufacturer for refurbishing. An experimental chamber was designed and fabricated and the digital image computer and camera system installed and calibrated. Considerable effort was required to modify existing computer codes for Abel inversion and to develop new computer codes to reduce the digital image data to emission coefficient and then to plasma temperature fields.

Experimental data were obtained for argon plasmas at a nominal input power of 1 kW and a nominal pressure of 2 atmospheres at four different mean flow velocities from 0.44 to 2.85 m/s. These experiments represent the first known measurements of laser sustained plasmas in a controlled, forced convective flow environment. The plasmas were stable for these conditions and could be maintained indefinitely at these conditions. The images of the plasma showed that the peak temperature region of the plasmas moved closer to the focal point of the f/3.5 converging laser beam as the flow velocity was increased. Isophote contours of the plasma emission indicate that as the plasma moves closer to the focal point in response to increasing flow velocity, the peak temperature in the plasma increases and the length of the strongly absorbing region also increases in length. Both of these effects increase the fractional power absorption from the laser beam and suggest that stable, high absorption operation of the LSP can be controlled through the use of forced convection. This effect is shown in Figure 1. A typical three-dimensional representation of the measured temperature field of the plasma is shown in Figure 2. The effect of the "doughnut" beam mode of the unstable oscillator can be seen in the lower temperature near the beam axis in the upstream portion of the plasma which is caused by radiation cooling of the plasma.

List of Publications

1. Dennis Keefer, Rush Elkins, C. E. Peters, and Lee Jones, "Laser Thermal Propulsion," Orbit Raising and Maneuvering Propulsion: Research Status and Needs, Progress in Astronautics and Aeronautics Series, Ed. by L. H. Caveny, to be published, 1984.

2. Dennis Keefer, C. E. Peters, and H. Crowder, "A Reexamination of the Laser-Supported Combustion Wave," accepted for publication in the AIAA Journal, 1984.

3. Dennis Keefer, H. L. Crowder, and R. E. Elkins, "A Two-Dimensional Model of the Hydrogen Plasma for a Laser Powered Rocket," accepted for publication in the AIAA Journal, 1984.

Professional Personnel

1. Dr. Dennis Keefer, Professor of Engineering Science and Mechanics

2. Dr. Carroll Peters, Professor of Aerospace and Mechanical Engineering

3. Herbert Crowder, Engineer

4. Newton Wright, Engineer

Interactions

There is a close and continuing role as advisor and consultant between Drs. Keefer and Peters with the Laser Propulsion project at NASA Marshall Space Flight Center. This interaction involves the diagnostics, ignition, and data analysis for experiments in laser sustained hydrogen plasmas and experimental design and preliminary experimentation on water vapor absorption in carbon dioxide laser beams. The project at NASA/MSFC is Dr. T. Dwayne McCay.

A paper entitled "A Reexamination of the Laser-Supported Combustion Wave" was given by Dr. Keefer at the AIAA Thermophysics Conference at Montreal in June, 1983.

Inventions

None.

Additional Statement

It has become clear that a modification to the chamber must be made in order to separate the transmitted beam power from thermal radiation and convective heating of the gas in order to accurately determine the fractional power absorption of the plasma. This will involve the design and fabrication of a special mirror to close the end of the chamber. Additionally, it appears that the advent of thermoplastic imaging devices make it practical to develop a holographic, real-time interferometer to determine the density of the flow field in the lower temperature portions of the plasma. We propose that we be allowed to undertake the development of this advanced plasma diagnostic technique with AFOSR support through either an expansion of the current contract or initiation of a separate contract.

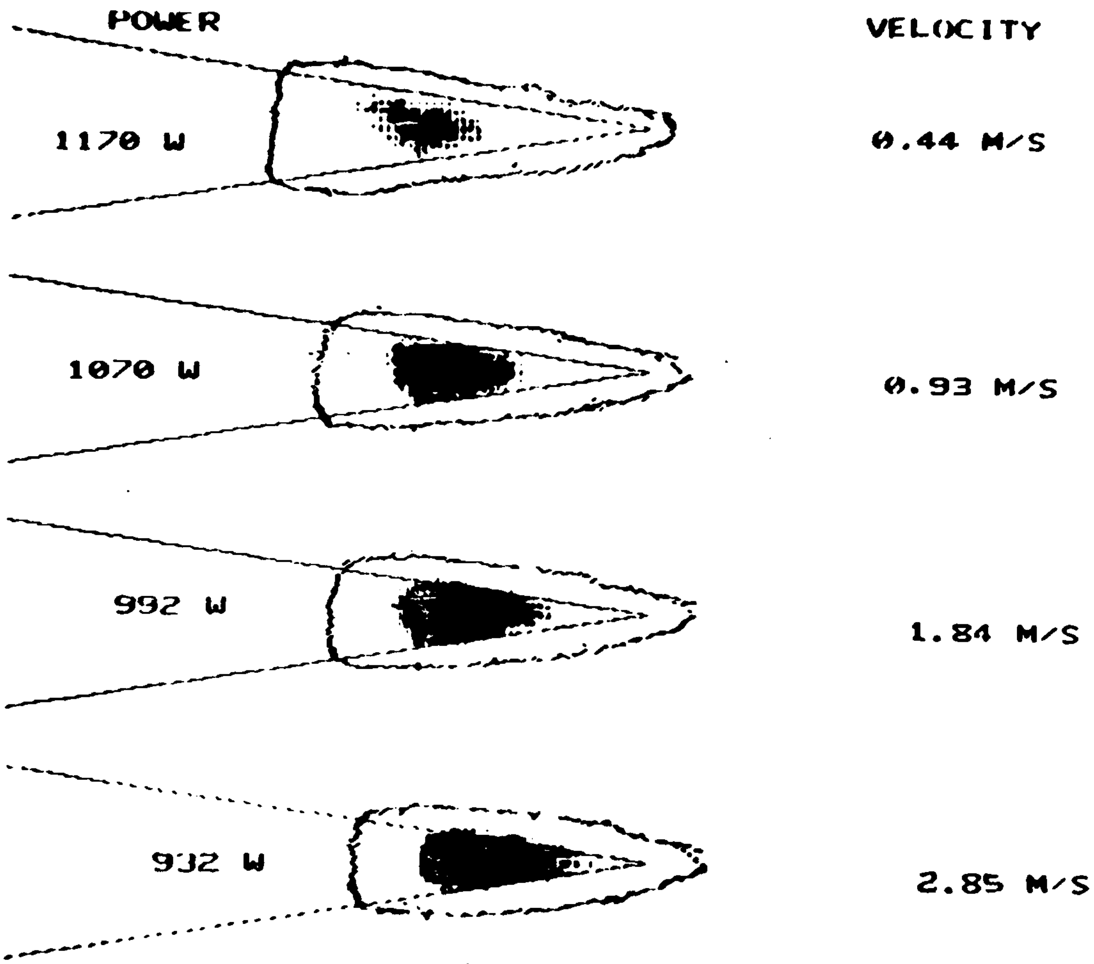


Figure 1. Experimental results for laser sustained argon plasmas at a nominal pressure of two atomospheres. Note that the plasma moves closer to the focal point with increasing flow velocity. The dark area indicates the region of the plasma where most of the laser beam absorption takes place, and these results indicate that a larger fraction of beam power is absorbed as the plasma moves closer to the focal point.

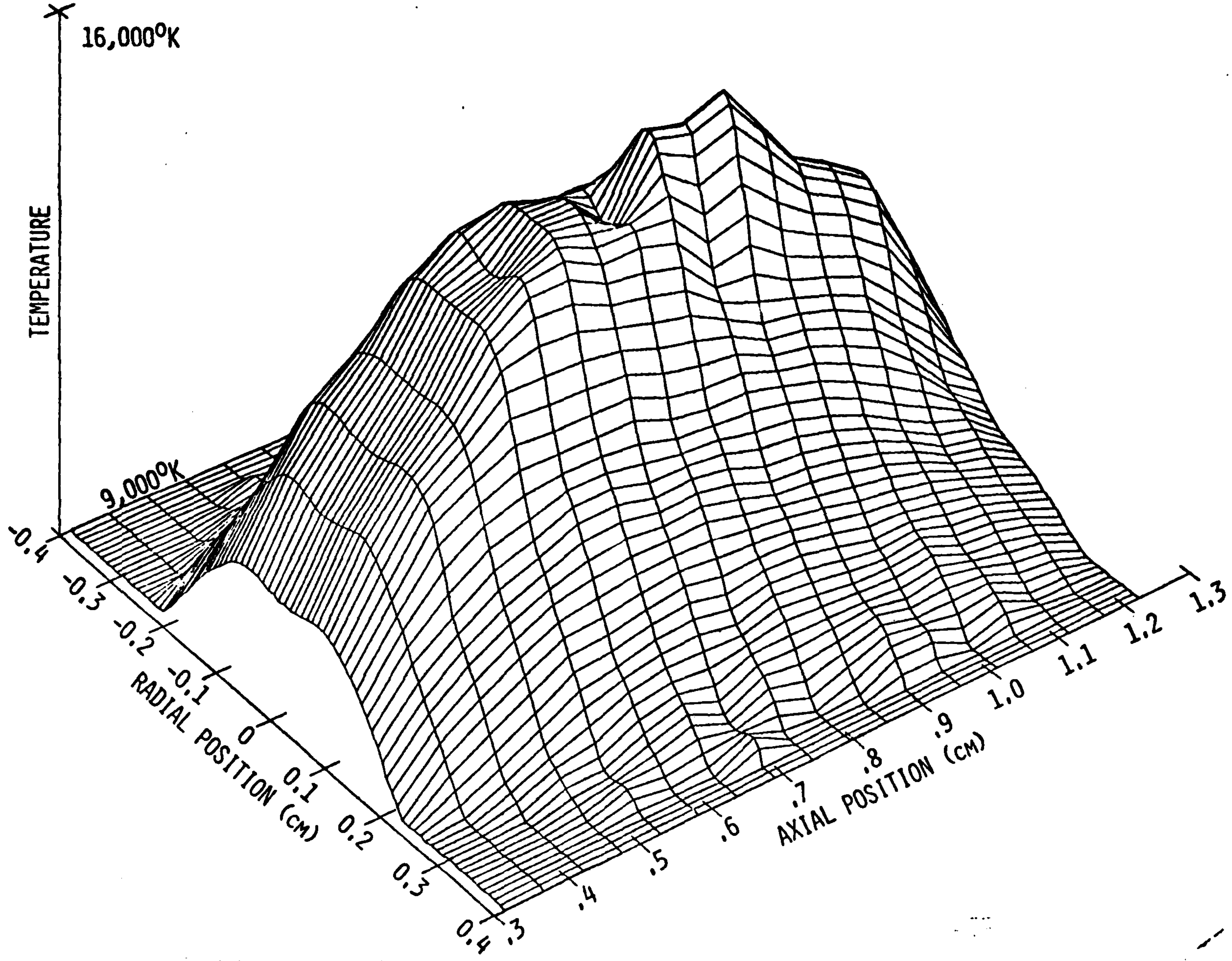


FIGURE 2. TEMPERATURE FIELD FOR ARGON PLASMA EXPERIMENT
2 ATM. PRESSURE, 932 W INCIDENT POWER,
MEAN VELOCITY 2.85 M/s

END

DTIC

5-86