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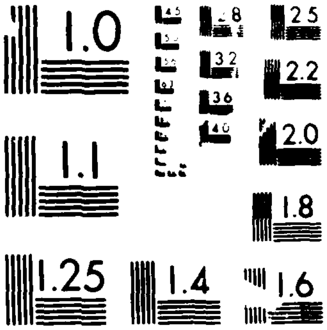

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This report presents the description of the diagnostic equipment purchased, the cost of that equipment, and how the equipment is being utilized to carry out research in the study of plasmas formed from high energy lasers. The program was funded by DoD as part of the University Research Instrumentation Program (URIP). Important results of the thermodynamic and heat transfer associated with laser sustained plasmas are presented.

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SUMMARY OF EQUIPMENT PURCHASED AND DESCRIPTION OF ITS USE: SUPPORT OF RESEARCH IN BEAMED ENERGY PROPULSION

AFOSR Grant No. 84-0291[‡]
(University Research Instrumentation Program: URIP)

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(‡) Dr. Leonard H. Caveny was Program Director AFOSR/NP.
Dr. Julian Tishkoff is now acting Director on this activity.

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(1) Co-Principal Investigators
(2) Ph.D Candidate; ONR Fellow

OVERVIEW

The equipment purchased under Grant AFOSR 84-291 has been used in a series of experiments funded by the Air Force Office of Scientific Research to study a new form of orbit-raising rocket propulsion: laser propulsion. A complete report documenting the progress and results of these experiments has been submitted along with this document (Annual Report UILU ENG 86-4001).

Presented below is a brief summary of the purposes of the experimental program, followed by a discussion of how the purchased equipment has been used, and detailing some of the key results. This is then followed by a summary of the budgeted purchases.

I) Laser Propulsion Research

Laser propulsion is a potentially promising new form of rocket propulsion which makes use of a laser-sustained plasma (LSP) to convert laser energy into the thermal energy of a propellant gas. Complete studies of LSP's is necessary if the feasibility of laser propulsion is to be assessed.

In particular, it is necessary to completely map temperatures within the plasma core. Because of the extreme temperatures encountered (> 10,000 K), spectroscopic techniques are required. The plasma temperature maps can be used to calculate fractional absorption and radiative losses by the plasma, and to study the spectra of the radiative emissions.

It is also important to measure the fraction of the incident laser power that is retained by the gas as thermal energy. Only if a high fraction is retained by the propellant can laser propulsion be practical. These measurements are made by constructing temperature mappings of the downstream flowfield, where temperatures are the 2000-8000 K range.

II) Equipment Uses and Key Results

A) OMA Spectroscopic System

The EG&G OMA III spectroscopic system is used to record two-dimensional temperature mappings of the core of laser-sustained plasmas, at temperatures up to 20,000 K. The system consists of an automated controlling console, a detector controller, a silicon-intensified target detector, a monochromator for fine spectral resolution, fiber optics for remote measurements, and a gated power supply to record transient events.

A sample temperature mapping produced using the OMA is shown in Figure 1. The system has allowed accurate measurements to be made at a variety of laser power and flow conditions, revealing considerable detail concerning the nature and behavior of laser-sustained plasmas. The temperature scans have also permitted comparison with the predictions of a theoretical model currently under development (see Figure 2), allowing us to test the basic assumptions used in the model.

In addition, it is possible to use the measured OMA temperature fields to calculate the percentage of the incident laser power that is absorbed and reradiated by the plasma. Such calculations have been performed, and the results compared to experimental measurements of absorption and thermal efficiency, as shown in Figure 3. The excellent agreement between the results, as well as the modeling predictions, confirm the validity of the independent measurement schemes.

The OMA system is also used to record the fluorescent emissions from seed molecules in the laser-induced fluorescence studies discussed in Section C.

A few related pieces of equipment were purchased along with the OMA III system. These include a Unislide assembly to allow translation of the detector to produce the 2-D maps, spectral calibration lamps to aid in alignment and spectral response of the detector, and gratings and imaging optics for the monochomator.

B) Additional Equipment

A small portion of the equipment budget has been used to purchase some additional equipment needed for fractional absorption measurements at high pressures and flow velocities. This equipment consists of a Polytran laser inlet window, used in tests at pressures up to four atmospheres, and NaCl windows, used in the high flow rate tests. A small storage oven was also purchased in which to store the laser windows to prevent fogging of the crystals in humid air.

Using this equipment, the global absorption data presented in Figure 4 was recorded. The data are important in evaluating what fraction of the laser power can be absorbed by the plasma, and in exploring the dependence of this property on pressure and flow rate.

C) Excimer/Dye Laser System for Planar Laser-Induced Fluorescence

One of the key parameters of the laser-sustained plasma is its ability to retain the absorbed laser energy in the form of thermal energy of the propellant gas. Such measurements have never before been attempted, and are crucial in evaluating the feasibility of laser propulsion.

We are now in the process of conducting such measurements, using laser-induced fluorescence (LIF) techniques. Basically stated, LIF is a process in which an electronic transition of a seed atom is excited by a pulse of laser energy from a tunable dye laser; the intensity of the fluorescent emission from the excited atom can then be used to calculate temperatures and flow velocities, both of which are necessary to measure thermal efficiency.

The excimer/dye laser system makes such measurements possible. The excimer laser is used to pump the dye laser, and the dye laser is used to excite the seed atoms. The wavelength of the dye laser output can be tuned to the transition of interest using the wavelength controller stepper motor. Additional optics for the excimer pump beam make it possible to work at a wider range of emission wavelengths.

To date, no efficiency measurements have as yet been completed. However, the LIF system is fully operational, and is now being tested through temperature and concentration measurements of methane flames. A schematic of the LIF system is presented in Figure 5.

III. Budget

A breakdown of equipment purchases is summarized on the following pages. A few differences between proposed and actual purchases should be noted.

Because the cost of the excimer/dye laser system was greater than expected, portions of the OMA III system were purchased using contract funding. This includes the SIT detector and detector controller. Also, several small components of the OMA system, such as the Unislide device, were not discussed in the proposed equipment purchases.

In addition, the purchase of Additional Equipment was not originally budgeted; these purchases were made after promising new areas of research became apparent during the preliminary stages of the experimental work.

BUDGET/INSTRUMENTATION

A) Optical Multichannel Analyser (EG&G Princeton Applied Research)

Model	Description	Price
1460R	OMA III Console w/Full Memory	$ 12,825.00
1301	Optical Trigger Pickup	1,206.50
K0165	Fiber Optic Kit	1,092.50
SC0059	OMA Interface Cable	356.25
1460/98	Winchester Disk Drive	3,900.00
CE0002	Keyboard	302.87
		$ 19,683.12

Accessories for OMA System

1228	Monochromator (EG&G)	$ 6,175.00
--	Spectral Calibration Lamp Set (Oriel Corp.)	557.19
B4021BJ	Unislide Translation Stage w/Stepper Motor (Velmex, Inc.)	711.15
M092-FD08	Additional Stepper Motor (Graham Electronics)	140.00
--	Additional Electronics (Hamilton/Avnet Electronics)	106.59
4096,4098,4101	Imaging Lenses for Monochromator (Oriel Corp.)	495.00
21998	Grating for Monochromator (Instruments SA, Inc.)	500.00
HR320	Kinematic Mount (Instruments SA, Inc.)	230.00
		$ 8,914.93

Sub-total for (A): $19,683.12 + $8,914.93 = $ 28,598.05

BUDGET/INSTRUMENTATION (Continued)

B) Additional Experimental Equipment

Sodium Chloride Polytran Crystal Laser Window (Harshaw/Filtrol)	$ 2,488.89
10 Sodium Chloride Laser Window Blanks (Harshaw/Filtrol)	1,237.65
Storage Oven for NaCl Windows (American Scientific Products)	581.99
Sub-total	$ 4,308.53

C) Excimer Dye Laser System for Laser-Induced Fluorescence Experiments (Lambda Physik)

Model	Description	Price
EMG 203M	Pulsed Excimer Laser 100W *Maximum* Average Power	$109,800.00
EMG 70-2	Unstable Resonator Optics for EMG 203 (KrF Operation)	2,600.00
FL2002	Dye Laser	18,900.00
FL22XeCl-H	Pumping Kit for Dye Laser	4,310.00
FL512	Stepping Motor Controller for Dye Wavelength Selector	2,250.00
	Less Duty and Discount	- 11,000.00
	Sub-total	$126,860.00

Total Costs: $28,598.05 + $4,308.53 + $126,860.00 =	$159,766.58
Less Cost Sharing by Dept. of Mech. & Ind. Engr.	- 9,766.58
Final Costs	$150,000.00

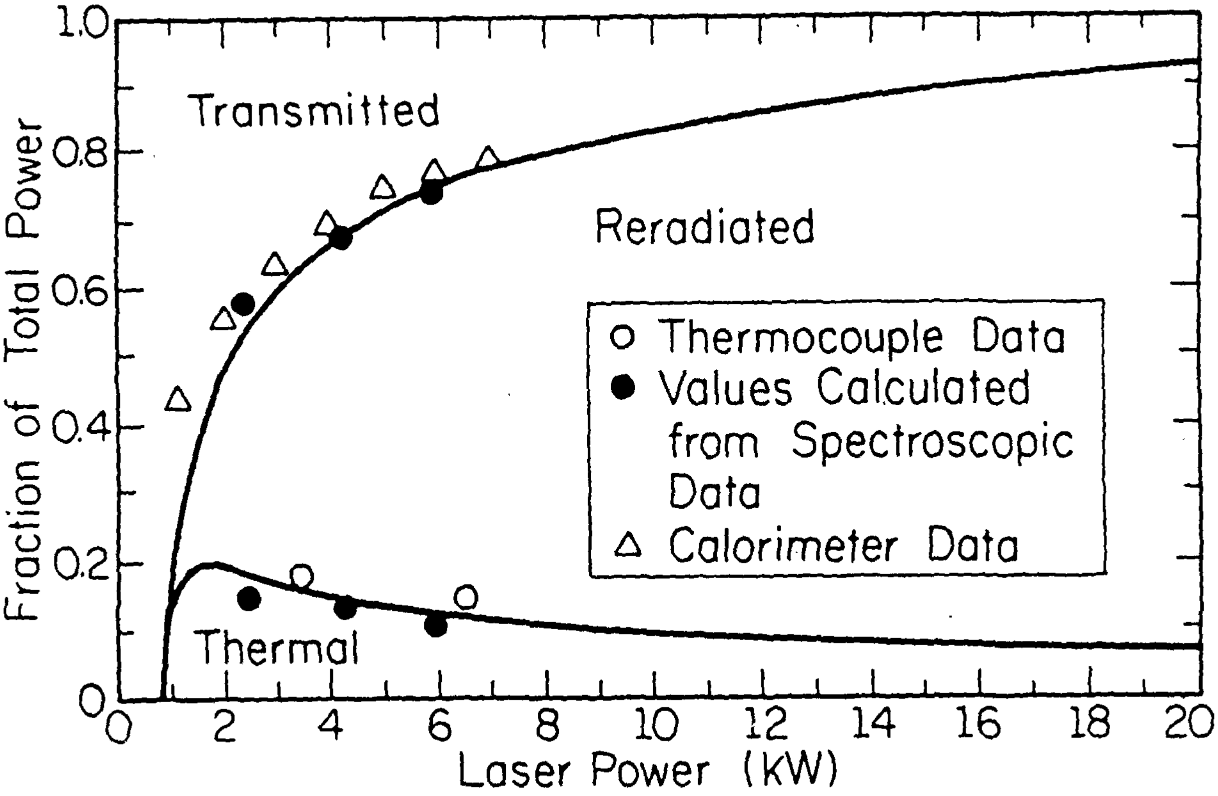

Figure 3 Experimental and Numerical Model Results for Global Absorption and Thermal Efficiency as a Function of Laser Power

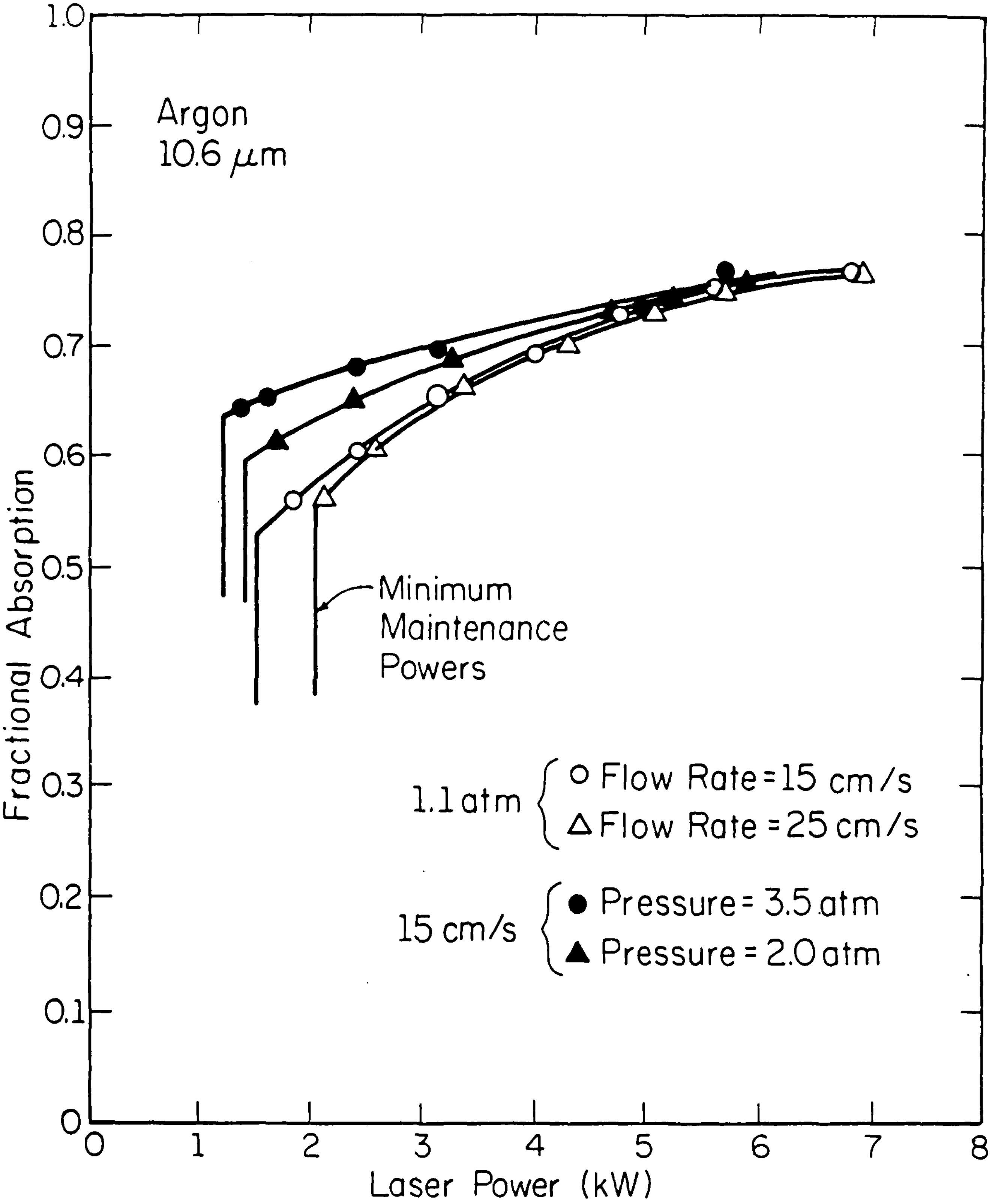

Figure 4 Global Absorption Data Taken at High Gas Pressures and Flow Velocities

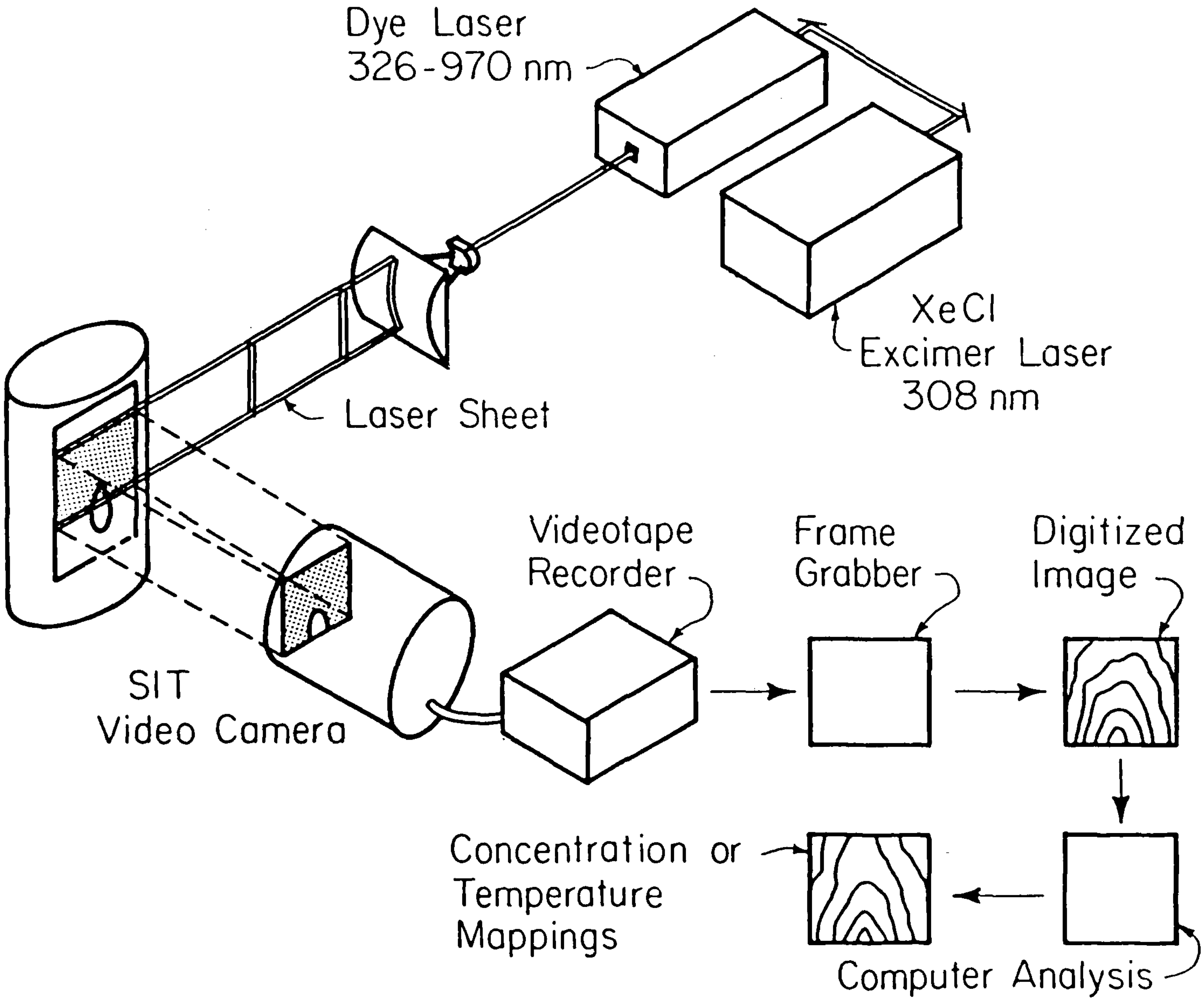

Figure 5 Laser-Induced Fluorescence Diagnostic System. The Videotape/Frame Grabber System Has Been Replaced by the More Versatile OMA System.

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