AD-758 913

RAMAN SCATTERING DIAGNOSTICS IN THE PRESENCE OF A12O3

Samuel Lederman

Polytechnic Institute of Brooklyn

Prepared for:

Army Research Office-Durham
Advanced Research Projects Agency

December 1972

CONTRACT NO. DAHC04-69-C-0077
ARPA ORDER NO. 1442, AMENDMENT 2
PROGRAM CODE 9E30

RAMAN SCATTERING DIAGNOSTICS IN THE PRESENCE OF Al_2O_3

by

SAMUEL LEDERMAN

POLYTECHNIC INSTITUTE OF BROOKLYN

DEPARTMENT
of
AEROSPACE ENGINEERING
and
APPLIED MECHANICS

DECEMBER 1972

PIBAL REPORT No. 72-39

13

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Polytechnic Institute of Brooklyn Dept. of Aerospace Eng. and Applied Mechanics	2a. REPORT SECURITY CLASSIFICATION Unclassified
	2b. GROUP

3. REPORT TITLE

RAMAN SCATTERING DIAGNOSTICS IN THE PRESENCE OF Al_2O_3

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Research Report

5. AUTHOR(S) (First name, middle initial, last name)

Samuel Lederman

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
December 1972	8	None

8a. CONTRACT OR GRANT NO. DAHC04-69-C-0077	9a. ORIGINATOR'S REPORT NUMBER(S) PIBAL Report No. 72-39
b. PROJECT NO. ARPA Order No. 1442, Amendment 2	
c. Program Code 9E30	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U.S. Army Research Office-Durham Box CM, Duke Station Durham, North Carolina 27706

13. ABSTRACT

An experiment was conducted to determine the effect of Al_2O_3 on the Raman scattering from N_2 and O_2 in the presence of Al_2O_3. It was found that within the experimental accuracy no effect could be determined. Furthermore, the presence of Al_2O_3 could also be ascertained using the Raman effect, although no quantitative results are as yet available.

DD FORM 1 NOV 65 1473

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Raman scattering						
Scattering from Al_2O_3						
Interference effects						

ii

RAMAN SCATTERING DIAGNOSTICS

IN THE PRESENCE OF Al_2O_3

by

Samuel Lederman

This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by the U.S. Army Research Office-Durham, under Contract No. DAHC04-69-C-0077.

POLYTECHNIC INSTITUTE OF BROOKLYN

Department

of

Aerospace Engineering and Applied Mechanics

December 1972

PIBAL Report No. 72-39

RAMAN SCATTERING DIAGNOSTICS IN THE PRESENCE OF Al_2O_3 †

by

Samuel Lederman‡

Polytechnic Institute of Brooklyn
Preston R. Bassett Research Laboratory
Farmingdale, New York

ABSTRACT

An experiment was conducted to determine the effect of Al_2O_3 on the Raman scattering from N_2 and O_2 in the presence of Al_2O_3. It was found that within the experimental accuracy, no effect could be determined. Furthermore, the presence of Al_2O_3 could also be ascertained using the Raman effect, although no quantitative results are as yet available.

---

† This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by the U.S. Army Research Office-Durham, under Contract No. DAHC04-69-C-0077.

This work was accomplished by a cooperative effort of Dr. M.H. Bloom, Dr. P. Khosla, Mr. J. Bornstein and the author, and was prepared for presentation at the "Review and Planning of ARPA Program on Rocket-Plume Diagnostics" held at the Institute for Defense Analyses, December 14, 1972.

‡ Professor of Aerospace Engineering.

I. INTRODUCTION

In the modern rocket engines the exhausts contain large weight-fractions of solid particles. The slip velocity, size distribution, and concentration of solid particles in the exhausts, affect performance. A detailed knowledge of these quantities as a function of position throughout the jet would permit accurate prediction of the amount of degradation and provide clues as to how to reduce it. Such data could show the location of areas of incomplete combustion in jet engine burners and the fuel droplet size distribution during combustion. A complete description of the system would require the measurement not only of the specie concentration and temperature in the combustion chamber, but also the specie concentration temperature, particle size and particle velocity distribution as a function of position in the exhausts of the engine in question. Ideally these measurements should be accomplished without any probes interfering with the combustion process or the exhausts. They can be accomplished possibly by remote means using light scattering. This scattering can take on several forms to accomplish the above simultaneously. Utilizing Mie and Rayleigh scattering of a laser beam, particle size could be determined. Raman scattering from the same beam could provide specie concentration and temperature of the species. Laser Doppler velocity measurements can provide velocity distribution and assist in a more accurate determination of the particle size measured by Mie scattering. There are still difficulties which must be overcome.

II. EXPERIMENTAL PROCEDURE AND RESULTS

As is well-known, among the combustion products appearing at the exhausts of rockets and jet engines, there are particles which may interfere with the remote optical measurements and diagnostics of the flows in question. Among others, aluminum oxide is a particle which does appear in the rocket exhaust and, according to some experts in the field, is capable of interfering with spectral measurements of the constituents of the exhausts. In particular, there is a strong possibility that diagnostics based on the Raman effect might be made impossible by the presence of Al_2O_3.

In order to investigate this problem it was decided to construct a simple experiment to see if indeed there is a strong interference with the Raman lines of other species due to spectral lines attributable to Al_2O_3. Fig. 1 presents the experimental apparatus. As is seen, this is essentially a static calibration setup. Experiments were run utilizing this apparatus. Experiments presetting the spectrograph for the Raman shift of N_2 were run. The scattered intensity from the nitrogen present in the atmosphere was recorded. As a reference in order to normalize the scattered intensities, the incident intensity was also recorded, utilizing a TRG photodiode. Leaving the spectrograph at the same wavelength setting, a test was run with a large number of Al_2O_3 powder mixed in the tested volume. The exact N_2 particle density is at this time unknown. However, a visual inspection indicated that there were a sufficient number of Al_2O_3 particles to alter the light transmission characteristics of the test volume. It appears that the

Raman scattered intensity from N_2 remained unaltered. At least within the accuracy of this experiment, no visible interference could be detected. Some of the results are shown in Table I.

The same kind of tests were conducted, tuning in the spectrograph on the atmospheric oxygen. The results were the same. No detectable effects, within the accuracy of these experiments, could be found.

A close examination of the data did, however, indicate a slight decrease in the Raman intensity in the presence of Al_2O_3. While this apparent effect must be verified by further experiments, it could possibly be explained by the change in light transmittivity of the mixture.

Having performed the above experiments it was decided to detune the spectrograph by approximately 100 Å from the expected Raman line of N_2 and the O_2 in the presence of Al_2O_3 and in the absence of the above. Tests were run under those conditions and no scattered intensity could be recorded. It was then decided to record the Raman intensities resulting from the Al_2O_3 powder.

It turns out that Al_2O_3 is Raman active at a number of frequencies. These are tabulated in Table II, together with the shifted wavelength of a Ruby laser used as the primary illuminator.

It was found that while the Raman scattered intensities did appear, their magnitude was not identical for all lines. The absolute intensities of each frequency is, however, impossible to ascertain with this experiment. This is due in part to the crudeness of the experimental setup and in part to the uncertainty of the number density of the Al_2O_3 in each particular test. Some recordings are seen in Fig. 2.

Another experiment which might be relevant to the problem of particle size and particle detection is being conducted in our laboratory. This experiment is concerned with the application of the Raman scattering technique to multiphase flow diagnostics in a supersonic stream. The objective is to determine the mass concentration of a particular chemical compound and resolve the fraction of the species in liquid and gaseous phase. This is applied to water in particular. It has been established by Bender that vapor H_2O has a Raman shift of 3651.7 cm^{-1}, while liquid H_2O has a Raman line at 1648 cm^{-1} as established by Rao and Koteswaran. Based upon these findings it was decided to look into this problem and find out if indeed it is possible to find the mass concentrations of vapor and liquid H_2O in a multiphase mixture.

To achieve this it was decided as a first step to demonstrate in a controlled static test chamber the technique, since the phase properties of water are well-known and lend themselves easily to controlled experimental techniques. The experimental apparatus is being assembled now. It consists of a cross-shaped scattering chamber within which the desired vapor, liquid phase distribution are created by vaporizing and subsequently condensing the water. When required, additional liquid water is added by spray heads.

TABLE I

WAVELENGTH	REF. PULSE	SCATTERED PULSE	RATIO	POWDER
8283	15.5 mv	280 mv	18.07	NO
8283	15.5 mv	230 mv	14.84	YES
8283	14.0 mv	300 mv	21.43	YES
6600	13.5 mv	0	0	YES
7784	14.0 mv	200 mv	14.29	NO
7784	14.0 mv	205 mv	14.64	YES
7784	14.0 mv	210 mv	15.00	YES

TABLE II

WAVENUMBER	SHIFTED WAVELENGTH FROM 6943 Å
$\nu_1 = 378.7\ cm^{-1}$	7130.48
$\nu_2 = 416.7\ cm^{-1}$	7139.65
$\nu_3 = 429.4\ cm^{-1}$	7156.9
$\nu_4 = 448.1\ cm^{-1}$	7166.
$\nu_5 = 577.1\ cm^{-1}$	7232.8
$\nu_6 = 644.8\ cm^{-1}$	7268.4
$\nu_7 = 746.6\ cm^{-1}$	7322.5

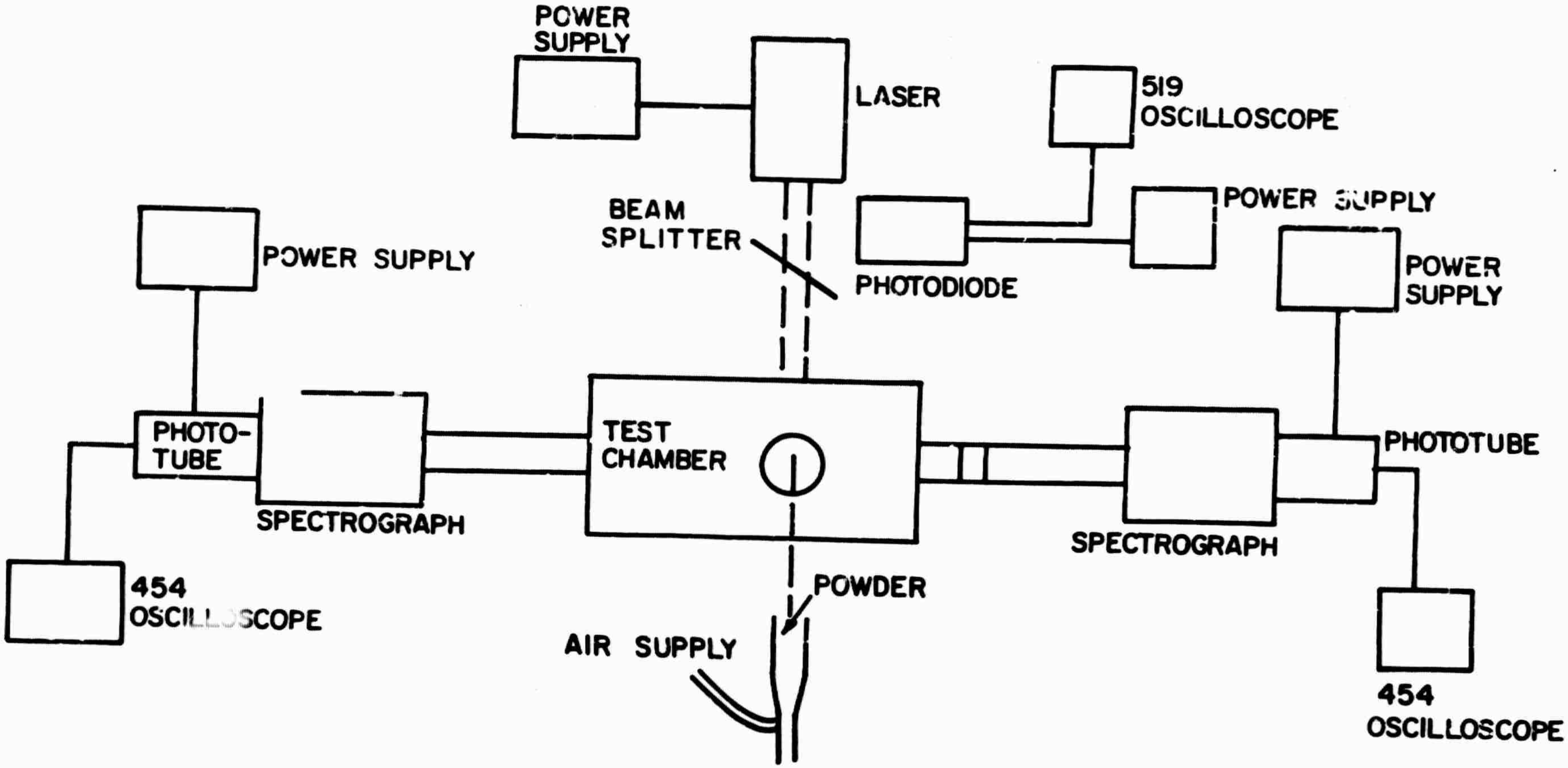
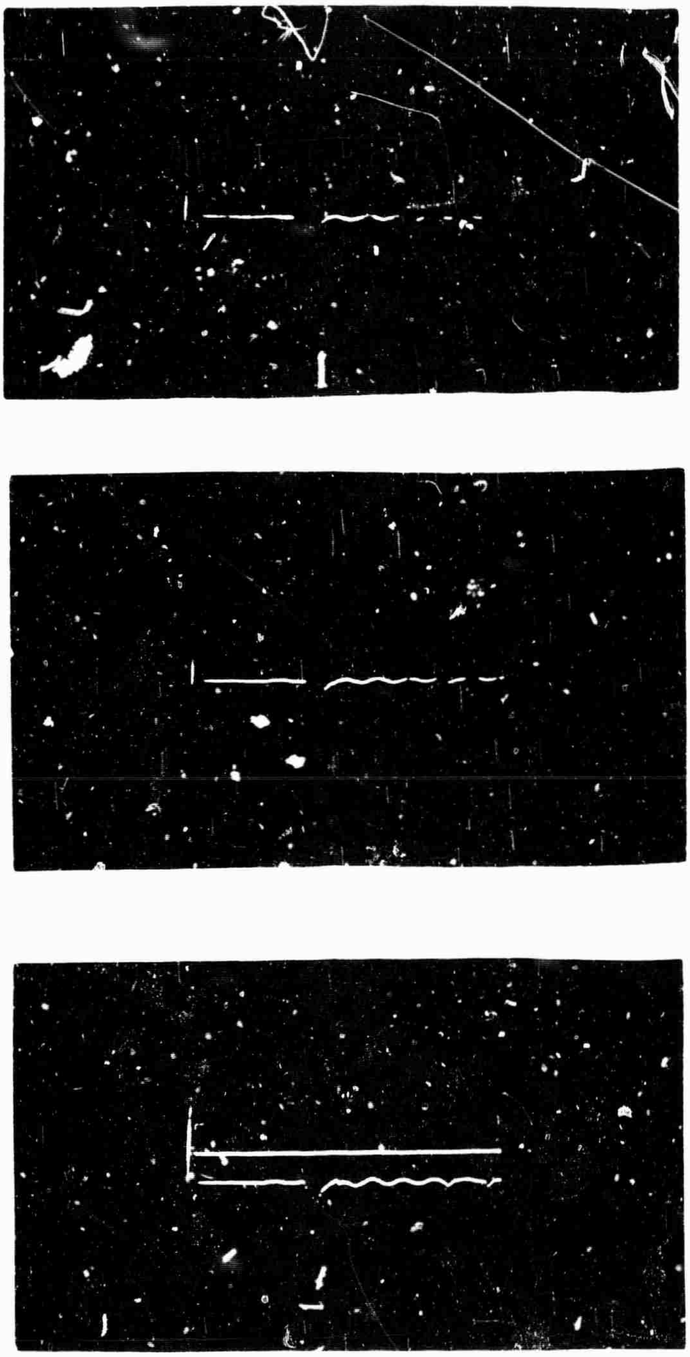


FIG. I EXPERIMENTAL APPARATUS



O_2
7784 Å
100 mv/DIV.

$O_2 + Al_2O_3$
7784 Å
100 mv/DIV.

Al_2O_3
7140 Å
50 mv/DIV.

FIG. 2 OSCILLOSCOPE RECORDINGS