MEASUREMENT OF LIGHT

SCATTERED FROM A LASER BEAM

BY THE ATMOSPHERE

Semi-Annual Status Report No. 3

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I. INTRODUCTION

This report summarizes the work done under National Aeronautics and Space Administration Grant NsG-710 during the period 1 June 1965 through 30 November 1965, the third six-month period of the project.

The purpose of the research is an investigation of properties of the earth's atmosphere by laser backscatter techniques. During the six-month period covered by this report, a workable laser system was delivered, and a number of backscatter measurements made. The observations made to date have been made with the laser system operating at about 20% efficiency and with neutral density filters (attenuation factor: about 100) ahead of the receiving optics. Even so excellent backscatter observations of the lower atmosphere to about 30 km have been made and clearly indicate the aerosol structure of the lower atmosphere. Several examples of these measurements are included in this report. Within the next few weeks, a narrow band interference filter will be included in the receiver system, and observations to greater altitudes will be made. In addition, theoretical analysis of the problem is proceeding.

II. RESEARCH ACTIVITIES

A. Laser Transmitter Receiver System

In October, 1965, two workable laser systems became available for these experiments. The rated characteristics of these two systems are as follows:

	Korad K1Q (System Purchased from Grant Funds)	Lear Siegler H140Q (System Purchased from Physics Department Funds)
Energy	1.0 joule	1.0 joule
Peak Power	100 megawatts	50-75 megawatts

In operation, it has been found possible to exceed these ratings. The Korad K1Q system has been aligned such that approximately 2 joules have been Q-switched giving a peak power of about 180 megawatts. The present experiments have been using an energy of 0.5 joule and a peak power of about 40 megawatts. The Lear Siegler System has been operated above 100 megawatts.

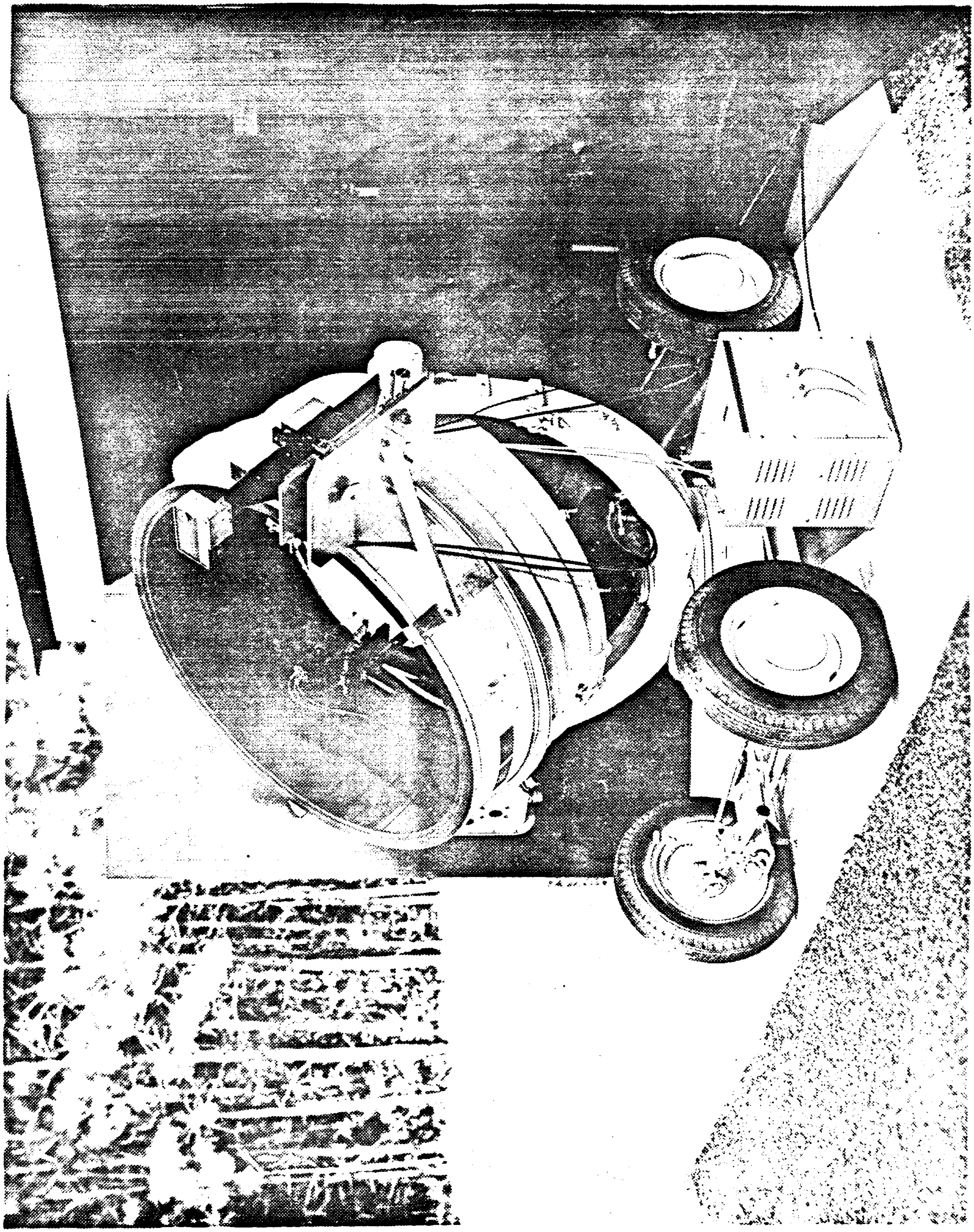
Some changes have been made in the apparatus as described in Progress Report No. 2. An energy monitor has been incorporated in the laser transmitter which provides a measure from shot-to-shot of the emitted energy, the peak power, and the pulse shape. The laser beam is sampled by a beam splitter. The sampled radiation impinges on a second beam splitter and the reflected radiation focussed on a photodiode by a spherical white diffuser. This monitor provides beam energy measurements within 10% of commercially available calorimeters, but has the advantage of not seriously attenuating the laser transmission. The output of the monitor also provides a trigger pulse for gating the receiving system.

At the request of the Langley Research Center, increased emphasis has been placed on making daylight measurements. In order to accomplish these measurements, an interference filter has been incorporated ahead of the photomultiplier. The interference filter has a bandwidth at half maximum of 20 Å and the wavelength of peak transmission is 6943 Å $\pm$ 1 Å. Measurements indicate that the wavelength of peak transmission is shifted so that 6943 Å radiation is well out of the band pass of the filter when the incident radiation deviates more than about 4° from normal incidence. In order to render the radiation reflected from the 60 inch mirror and incident on the filter as parallel as possible, several types of lens systems have been tried and consideration is being given to a Cassegrainian configuration. The aforementioned lens configurations are currently being studied by means of a computer ray trace program. In addition, arrangements have been made to borrow a 12 inch Cassegrainian telescope from Langley Research Center in order to make daylight measurements. An interference filter and our present photomultiplier detector system can easily be incorporated with this telescope. A mount for the telescope and laser system is presently under construction.

A logarithmic amplifier with a range of four decades is also ready to be incorporated in the recording system. Logarithmic amplification of the detector output is desirable in order to extend the height range over which measurements can be made from a given laser transmission.

It is, of course, our intention to make observations to as great an altitude as possible. In order to achieve the ultimate limit of a system of this type, photon counting must be resorted to. The Physics Department of the College is planning to purchase for general laboratory use a multi-scaling system very suitable for use as a photon counting system. It is estimated that the above mentioned system will be available to this project prior to June, 1966.

A photograph of the apparatus is given en the following page.



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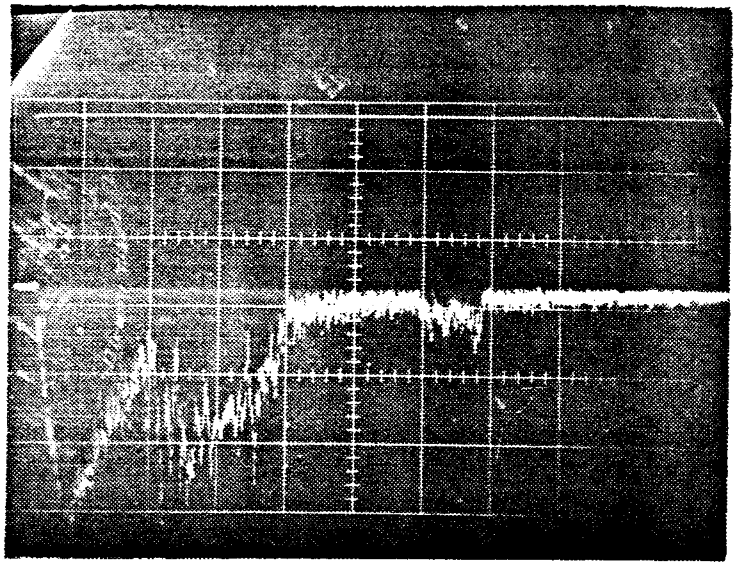
B. Results Obtained

During the month of November and early December, a number of backscatter observations were made operating the laser at reduced power and using neutral density filters ahead of the receiving optics to avoid possible saturation of the photomultiplier. The purpose of these preliminary experiments was to obtain backscatter from the lower atmosphere which could be interpreted without having to take into consideration the behavior of the photomultiplier detector after saturation. Regions of high aerosol concentration in the lower atmosphere in effect provide discrete "targets". Backscatter from such regions provides a useful check of the alignment of the laser-receiver system, and the repeatability of results.

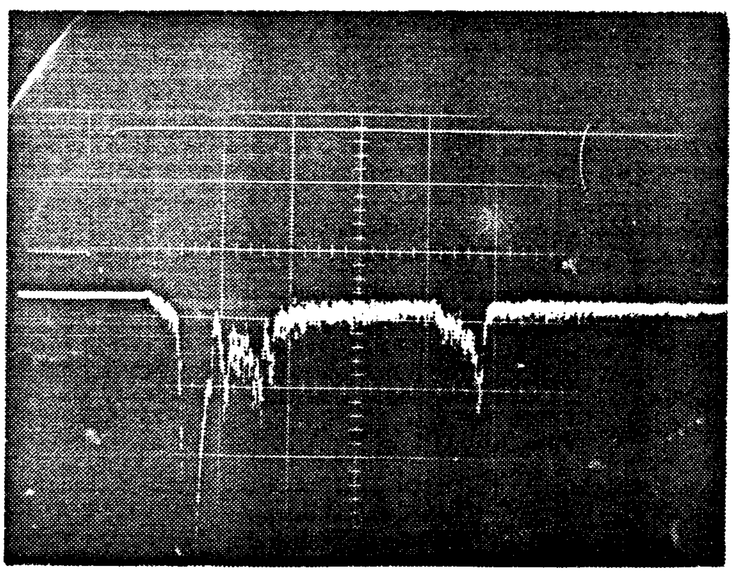
Five typical examples of the results obtained are given on Pages 7-9. In each case the upper trace represents the gating pulse applied to the focus grid of the photomultiplier and the lower trace, the backscattered signal. The laser was delivering about 0.5 joules/pulse with a peak power of about 35 megawatts. The two observations shown in Figures 1 and 2 were made about 90 seconds apart. In Figure 1 the photomultiplier was gated on 5μsec after the laser Q switched and in Figure 2, 20μsec after the laser Q switched. Both observations clearly indicate backscatter from an aerosol region at approximately 10 km. Figure 3 shows the backscatter from three successive laser pulses approximately 65 μsec apart, and is a good example of the repeatability of the results.

The data in Figures 4 and 5 were obtained on a very clear night and no regions of high aerosol concentration were evident. In Figure 4, the photomultiplier gating pulse was 60 μsec wide and delayed 20 μsec after the laser pulse. The middle trace indicates the background radiation, and the lower trace represents the backscattered signal. In Figure 5, the photomultiplier was gated on about 30 μsec after the laser Q-switched and backscattered signal is evident up to a height of approximately 30 km. It is possible, however, that the signal evident near the very end of the record represents "after glow" of the ruby rod. The effect of such afterglow is currently being investigated.



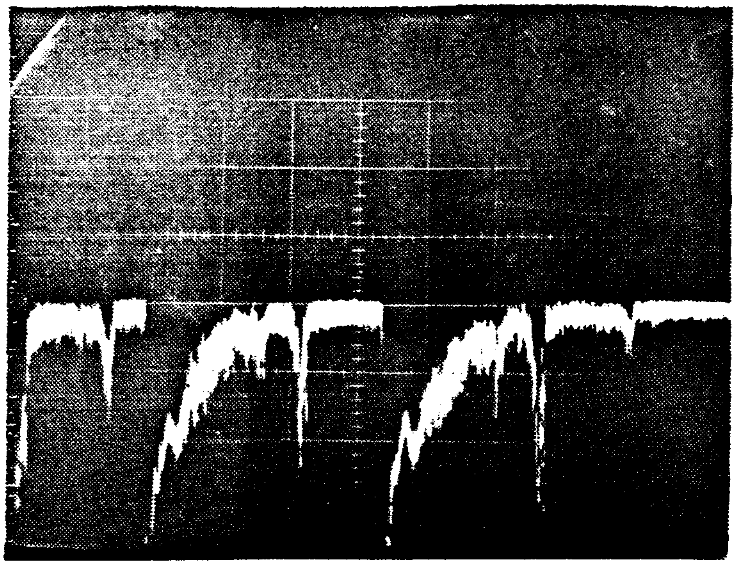
Upper Trace	Photomultiplier Gate 100 v/cm 50 μsec/cm
Lower Trace	Backscatter 0.2 v/cm 10 μsec/cm
Number 70	Wratten Filter
Number 2	Neutral Density Filter
Delay	5 μsec

Figure 1



Upper Trace	Photomultiplier Gate 100 v/cm 20 μsec/cm
Lower Trace	Backscatter 0.2 v/cm 10 μsec/cm
Number 70	Wratten Filter
Number 2	Neutral Density Filter
Delay	20 μsec

Figure 2



Backscatter from 3 laser pulses
0.2 v/cm
20 μsec/cm

Delay from initiation of flashlamp trigger
950 μsec

Number 70	Wratten Filter
Number 2	Neutral Density Filter

Figure 3

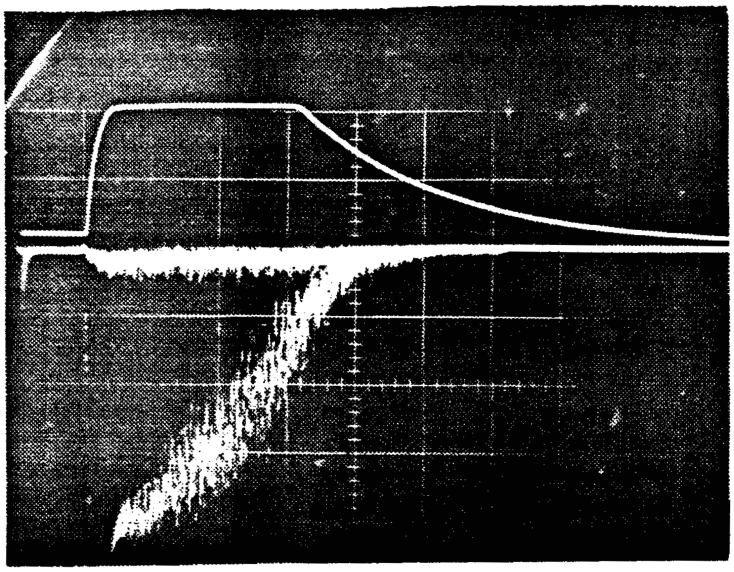


Figure 4

Upper Trace	Photomultiplier Gate 100 v/cm 20 μsec/cm
Middle Trace	Background 0.1 v/cm 20 μsec/cm
Lower Trace	Backscatter 0.1 v/cm 20 μsec/cm
Number 70	Wratten Filter
Number 1	Neutral Density Filter
Delay	20 μsec

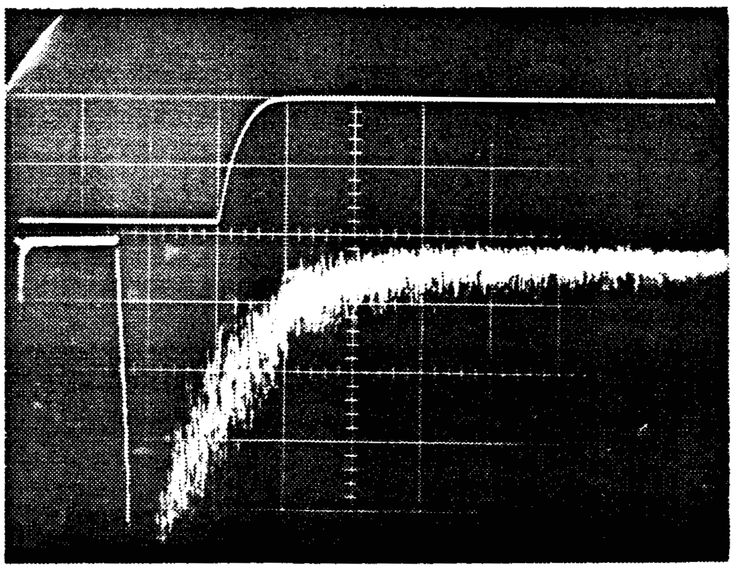


Figure 5

Upper Trace	Photomultiplier Gate 100 v/cm 10 μsec/cm
Lower Trace	Backscatter 0.1 v/cm 20 μsec/cm
Number 70	Wratten Filter
Number 1	Neutral Density Filter
Delay	30 μsec

C. Related Work

1. Measurements have been completed of the angular response of the narrow band interference filter being used in the experiments. The results will be incorporated in a later report.

2. Efforts to observe the calculated 6939.9 Å transition of CH have thus far been unsuccessful. A graduate student under the direction of another faculty member is now devoting full-time to the problem.

3. Mie scatter calculations for $n = 1.33$ and 1.50 for size parameters from 1 to 30 (in increments of .1) have been completed. As soon as computer time is available, these computations will be extended to size parameters up to 200. In addition, angular scattering calculations for Cu and Fe for size parameter from 1 to 30 have been done at the request of the Langley Research Center. The Fortran program used for these calculations and an abridged table of the values computed will be submitted as a contractor's report in the near future.

III. PERSONNEL

The personnel working on this problem are listed below.

Faculty

Dr. James D. Lawrence, Jr.

Associate Professor of Physics

Principal Investigator

Dr. Frederic R. Crownfield, Jr.

Associate Professor of Physics

Graduate Students (Supported by scholarship where indicated)

Mr. M. P. McCormick; B.S., M.A.	(Research Assistantship)
Mr. D. P. Woodman; B.S.	(Research Assistantship)
Mr. L. D. Owen; B.S.	(Research Assistantship)

Technician

Mr. C. B. Hinton, Jr.