MEASUREMENT OF LIGHT SCATTERED FROM A LASER BEAM BY THE ATMOSPHERE

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I. Introduction

This report summarizes the work done under National Aeronautics and Space Administration Grant NsG-710 during the period December 1, 1964 to May 31, 1965, the second 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, the basic receiver and laser transmitter system was completed, a number of minor modifications were made, and a series of backscatter measurements were carried out with a relatively low-power, ten megawatt laser system. This laser could not be adjusted to give single pulse output; in consequence, the observations made cannot be considered definitive. These preliminary results, however, were quite promising and are outlined in the sections to follow.

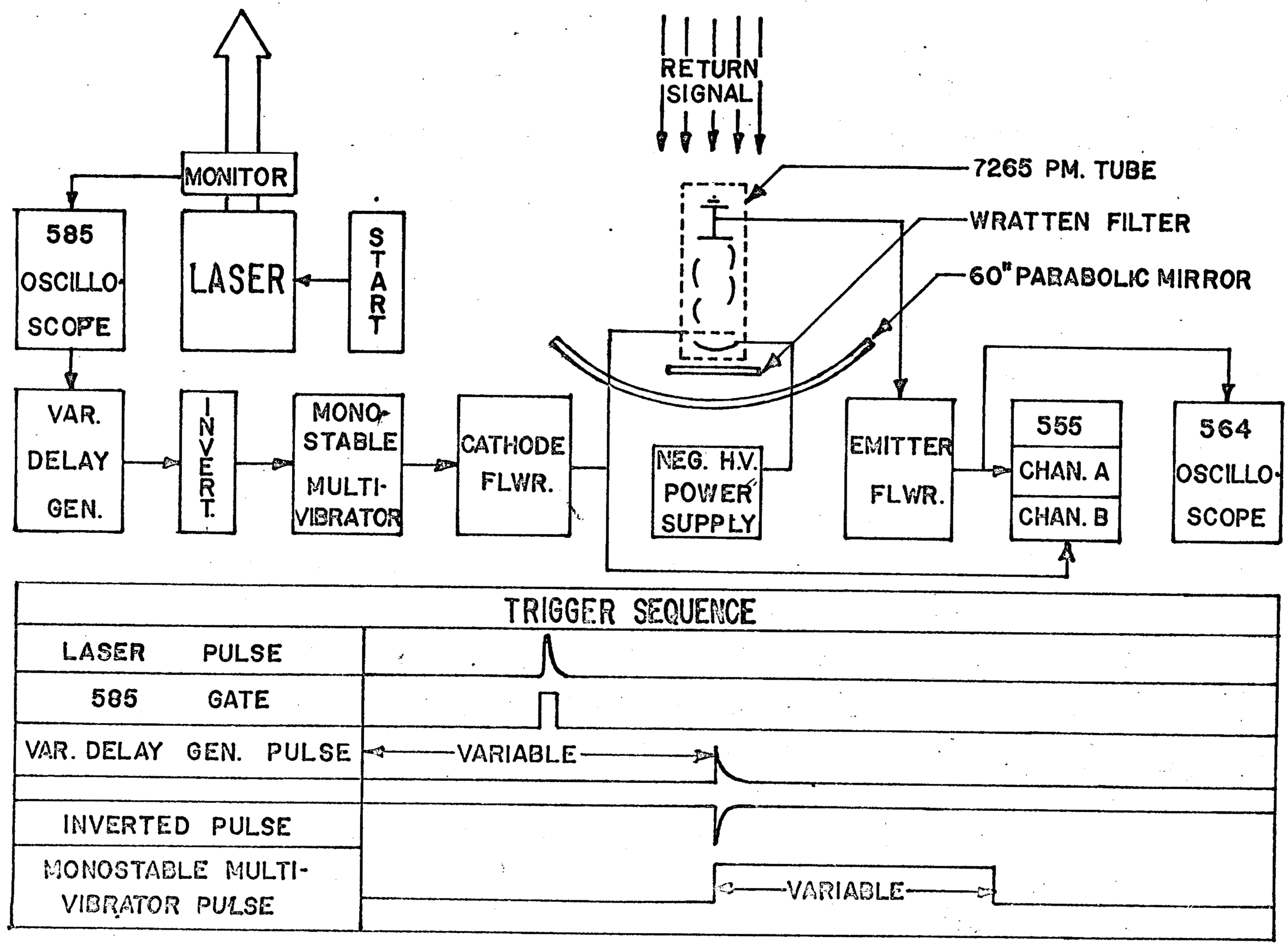
II. Research Activities

A. Laser Transmitter - Receiver System

General:

A schematic diagram of the experimental apparatus is given on page 2 with the trigger sequence indicated in the lower half of the diagram. The apparatus essentially consists of a 60 inch parabolic mirror with a photomultiplier positioned near the focal point and a laser aligned with its transmission axis parallel to the optical axis of the mirror. The operation of the system may be understood by following a monitor pulse through the apparatus: The laser fires through a series of baffles and a collimating lens system and is monitored by a photodiode mounted on the collimator.

SCHEMATIC DIAGRAM OF LASER–RECEIVER SYSTEM



The signal developed by the photodiode is displayed on a fast oscilloscope set to trigger on the giant pulse. A synchronous gate generated by the oscilloscope triggers a variable delay generator whose output is inverted and used to trigger a monostable multivibrator. The multivibrator generates a square wave whose amplitude and width are continuously variable over a wide range. This square wave drives the focus grid-to-photocathode voltage positive thereby focussing the tube and turning it on. In consequence, the photomultiplier used to detect the backscattered radiation collected by the mirror may be "gated on" at any time after the laser has been fired. The multivibrator gate is monitored on one channel of a dual beam oscilloscope and the photomultiplier output on the other. In addition, the backscattered signal as measured by the photomultiplier is stored in a storage oscilloscope for purposes of ready comparison with other shots.

Laser Monitor

In the series of backscatter measurements made in March and April, some difficulty was encountered in adequately monitoring the laser. Various types of photoelectric devices were tried with varying degrees of success. At present an EGG SD-100 photodiode with a specified rise of about four nanoseconds is in the system.

In view of the difficulties encountered in the first series of observations, considerable attention has been paid to the monitoring problem. The response of various photomultipliers to a very low intensity, but extremely fast light pulse from a pulsed hydrogen lamp was studied in considerable detail. The light pulse used for these studies had a rise of less than one nanosecond and was roughly square. The pulse width was variable from about four to twenty nanoseconds depending on the length of the charge line used. Of all the photomultipliers checked, the RCA 931 (a nine stage tube) had the best response. The tube was capable of seeing a 4 nanosecond pulse without undue integration, and its response to a 20 nanosecond pulse (roughly the same as a Q switched laser) was excellent. The SD-100 photodiode is not capable of measuring the low light level of these fast pulses; in consequence, we cannot be certain of its rise. For convenience, we plan to try it; however, a monitor employing an RCA 931 photomultiplier has been built as a back-up system.

Laser Transmitter

A precision steerable table with four degrees of freedom and rigidly attached to the mirror mount has been constructed to serve as a laser mount. This mount is adaptable to any laser head weighing up to about seventy-five pounds. A passively Q-switched laser with a nominal peak power output of 10 megawatts has been used in all of the measurements made to date. Since it could not be made to deliver a single giant pulse, it has not provided satisfactory results. A laser system with a nominal peak power output of 50 megawatts purchased by the College for this project will be available in July, 1965. In addition, a second system with a nominal peak power of 75 megawatts to be purchased from grant funds will be delivered in August, 1965.

Receiver System

A 60 inch parabolic mirror is used to collect the backscattered radiation. The radiation collected by the mirror is focussed on an RCA 7265 photomultiplier mounted on a precision steerable table near the focal point. Provision has been made to include auxiliary optics in order that interference filters may be incorporated in the system.

The problem of photomultiplier gating has received additional attention during the period covered by this report. In order to avoid undesirable differentiation of the photomultiplier output, it is necessary that the anode of the tube be operated at ground potential. In consequence, the photocathode is placed at -2400v; and, in order to defocus the tube, the focus grid is biased at -2440v. Originally, the grid was biased at -2420v; however, the giant laser pulse was evident on the output when the tube was defocussed. The tube was not saturated nor were spurious emissions from the photocathode noted; however, a higher reverse bias seemed in order. The gate generated by the multivibrator drives the focus grid positive with respect to the photocathode and, in consequence, refocusses the tube. The multivibrator gating pulse has the following characteristics:

Rise Time	About 200 nanoseconds
Width	Continuously variable from about 2 microseconds to 4 milliseconds

Of particular interest is the response of the tube to very low-light levels immediately after being driven from an unfocussed to focussed condition. This point was checked by observing scintillations produced in zinc sulfide by a very weak radioactive source (about 9 microcuries of Radium). A study of the pulse height distribution produced by these scintillations indicated that the photomultiplier reached full gain within the rise time of the gating pulse. Further, no transients associated with electrical pick-up were evident, nor were bursts possibly associated with electron build-up at the photocathode in evidence.

B. Results Obtained

During the last two weeks of March and the first two weeks of April, 1965, about fifty backscatter measurements were made with the system outlined in section II A. Minor difficulties were encountered in synchonizing the system with the emission of the giant pulse by the laser; this difficulty has since been resolved. The photomultiplier gating system functioned quite well. The laser system was found to emit a giant pulse about 500μ seconds after the initiation of pump action. In virtually every case, about 200μ seconds later a second smaller giant pulse was emitted followed by sucessive pulses at about 100μ second intervals. The size of these sucessive pulses could be reduced by pumping very near threshold and by very careful temperature control of the ruby rod at about 107°F. Further increases in temperature of the rod would have probably helped, but the manufacturer's specifications would have been exceeded and the overall efficiency of the laser system greatly reduced. Nevertheless, in several instances backscatter was measured up to about 40 km with an excellent signed-to-noise ratio. At that point the laser usually emitted another giant pulse and the record was no longer useful.

This preliminary series of observations did not provide any results suitable for analysis; however, several minor modifications of the system were suggested. Further, the results obtained indicate that the system is quite capable of making measurements to very high altitude when a higher powered laser capable of single pulse operation is incorporated into the system.

C. Data Analysis

Work is proceeding on methods of analyzing atmospheric backscatter data. Computer programs have been written to treat various aspects of the problem. Among these programs are:

1. Program to compute the standard atmosphere
2. Program to compute Rayleigh backscatter as a function of time in terms of the geometry of the experimental system.
3. Program to compute Mie angular scattering functions and extinction coefficients for both real and complex indices of refraction. From these calculations Mie backscatter as a function of time will be computed.
4. Programs to compute angular scattering functions of very large particles based on geometrical optics.
5. Program to compute atmospheric attenuation in terms of surface visibility
6. Time of sunset in the atmosphere as a function of height.

All of these programs have been coded in Fortran II and are subdivided into subroutines and function sub-programs in order to make them compatible with any computer accepting Fortran II. At present all have been run on an IBM 1620 at the Computing Center with the exception of No. 5 which has not been finished.

D. Related Work

1. Measurements of the angular response of several narrow band

interference filters are being made by an undergraduate research assistant associated with another group. These filters will eventually be incorporated into our receiver system.

2. The presence of the OH Meinel Bands in airglow observations has raised the question of possible interaction of ruby laser radiation with an absorption band of this system. A transition of this system is calculated to exist at 6939.6Å; however, this calculation could be in error by several Angstroms. In addition, we have been unable to locate a precise experimental measurement of this transition. In consequence, a student under the direction of another faculty member has undertaken the problem of determining the location of this transition.

III. PERSONNEL

The personnel working on this problem are listed below.

Faculty

Dr. James D. Lawrence, Jr.
Associate Professor of Physics
Principal Investigator

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)
Mrs. Mary Tobin; B. S.	(Department Fellowship)

Technician

Mr. C. B. Hinton, Jr.