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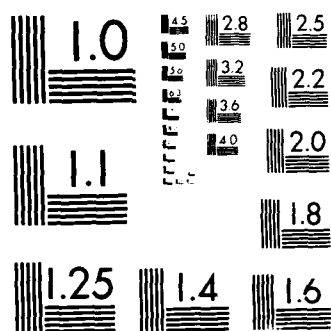
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PROGRAM TO INCREASE THE MEASUREMENT CAPABILITIES OF
THE AFGL FIXED AND MOBILE HIGH ALTITUDE LIDAR SYSTEMS

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31 March 1988

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AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
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This technical report has been reviewed and is approved for publication.

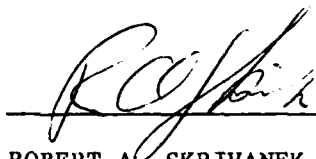


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FOREWORD

This report covers PhotoMetrics' three year effort under Contract F19628-84-C-0085 in support of the AFGL high-altitude ground-based lidar systems. The authors wish to thank Dr. Dwight Sipler (AFGL/LID), the Contract Manager, and Dr. Russell Philbrick (AFGL/LID) for their continued support throughout the program.



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SECTION 1
PROGRAM OBJECTIVES AND EVENTS

The objective of this contractual effort was to upgrade the capabilities of the AFGL fixed (GLEAM) and mobile (GLINT) energetic Nd:YAG lidar systems to include DIAL, Fluorescence and Raman measurement capabilities. The award date of the contract was 25 September 1984, with a total contractual period of 39 months.

Initial tasks under the program included integration of the Lambda Physik Fl2002EC Dye Laser into the Fixed facility, working toward the sodium fluorescence measurement. The laser controller and monitor etalons were acquired during the first quarter of the program. Also, during the first quarter, planning for the expanded capability of the trailer system was initiated while the construction of the trailer was being completed under an earlier contract.

During the second and third quarter work was started on the design of a detector system for the 24 inch telescope. The detector, described elsewhere in this report, was to include a Fabry-Perot etalon to facilitate operation of the system into daylight hours.

During the fourth quarter preparations were made to take the trailer system to Wallops Island, Virginia, and then on to Alaska toward the end of 1985. We assisted in producing the first sodium fluorescence measurements with the GLEAM system at the end of the fourth quarter. Measurements continued into the fifth quarter. The work was done in conjunction with Dr. C. S. Gardner of the University of Illinois. The results appeared in Journal of Geophysics Research (Simultaneous Lidar Measurements of the Sodium Layer at the Air Force Geophysics Laboratory and the University of Illinois, JGR, 91, 12131, 1986). The detector

for the 24 inch telescope was completed during the fifth quarter and tested at Wallops Island in December 1985.

During the sixth quarter (January-March, 1986) the trailer system was air-lifted to Fairbanks, Alaska and the system was installed at the Poker Flat Rocket Research Range. Acquisition of Rayleigh data to altitudes near 80 km was started approximately 1 February and continued to 23 March 1986. PhotoMetrics provided two people in the field during this period. There was an additional acquisition period during April and the system returned to Hanscom in early May. Also during the seventh quarter the Fabry-Perot etalon was added to the 24-inch telescope detector system.

During the eighth quarter testing of the Fabry-Perot system started and work was initiated on its wavelength stabilization system. Also, the trailer was shipped to a subcontractor for additional structural modifications, including installation of a new jack system and the cutting of a large access panel in one side. This new port was necessary to allow future installation of an excimer laser. In August 1986, G. Davidson and W. Moskowitz attended the 13th International Laser Radar conference in Toronto. During September, W. Moskowitz met with Prof. David Rees at University College London to discuss operational aspects of the wavemeter Dr. Rees was constructing for use in the measurement of the sodium temperature.

During the ninth quarter (October-December, 1986) work continued on the modification of the trailer and on reduction and analysis of the Alaska data. During the tenth and eleventh quarters the trailer modification was completed and work was started on an upgraded data acquisition system. The new system, to replace the current LeCroy, uses DSP Technology modules and a Camac crate with an interface to a PC/AT computer for control and data storage.

SECTION 2

TWENTY-FOUR INCH TELESCOPE DETECTOR SYSTEM

PhotoMetrics has designed, constructed, and tested a detector for the 24 inch diameter lidar receiver telescope in the GLINT trailer (known as the "H" detector because of its high altitude measuring capability). The design requirements for the telescope - H detector system were the following:

- Adjustable field of view up to 1 mrad.
- Insertable eyepiece which looks through the same field stop as the photomultiplier tube (PMT).
- Highest practical quantum efficiency.
- Adjustable infinity focus.
- Interchangeable narrow band optical filters - requires temperature control.
- Mechanical shutter to eliminate low altitude return - must be synchronizable with a pre-existing system.
- Upgradeable to permit daytime use.
- Low noise, photon counting detection for high altitude returns - requires cooled PMT.

The design chosen meets the above requirements while minimizing the number of optical surfaces and the blur. Furthermore, the lenses chosen are all standard stock AR coated singlets, facilitating replacement, extension to other wavelength regions, and redesign.

2.1 The Optical Circuit

The optical schematic of the detector appears in figure 2.1. The unfolded, refractive equivalent of the f/15, 24 inch diameter reflective telescope is also shown, in figure 2.2. The conjugate image planes have been traced through each element of the detector so that vignetting limits and filter coupling can be evaluated.

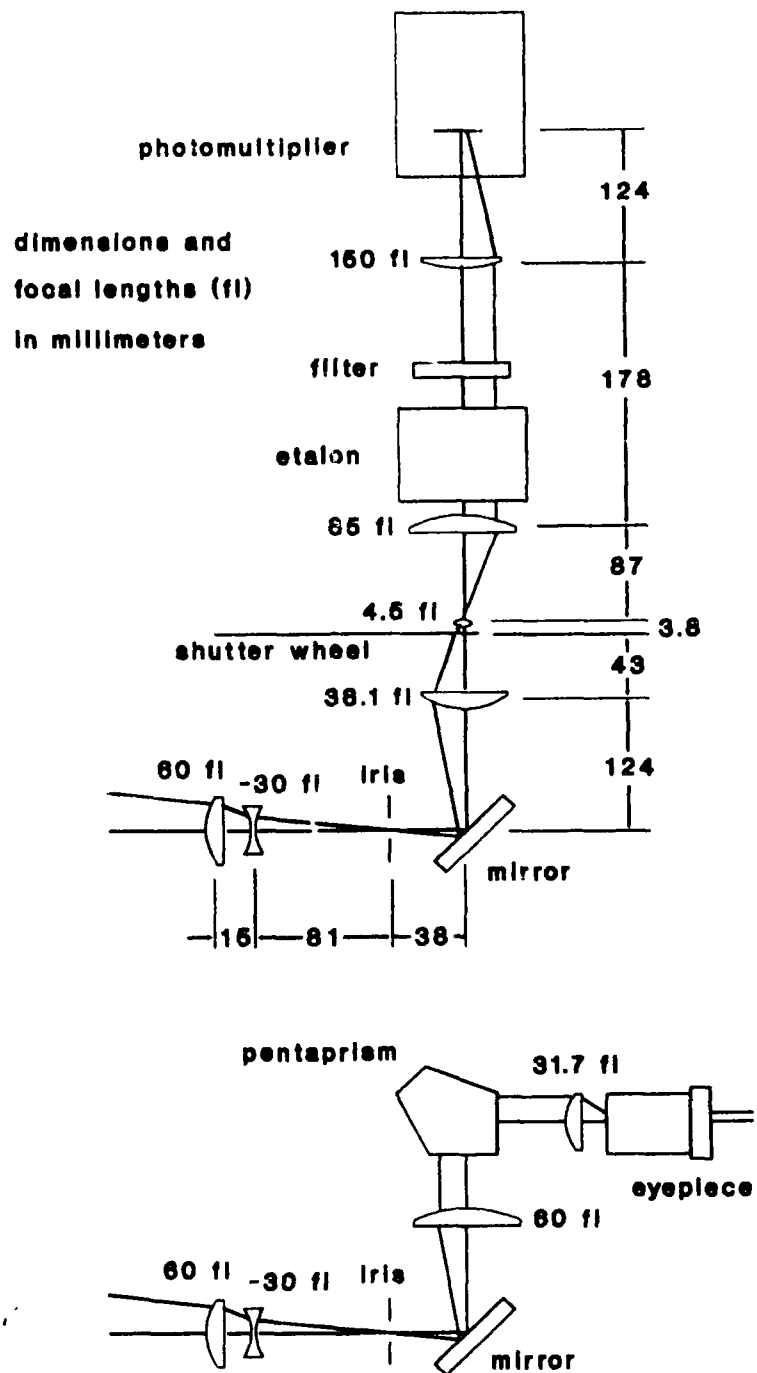


Figure 2.1 H detector optical schematic.

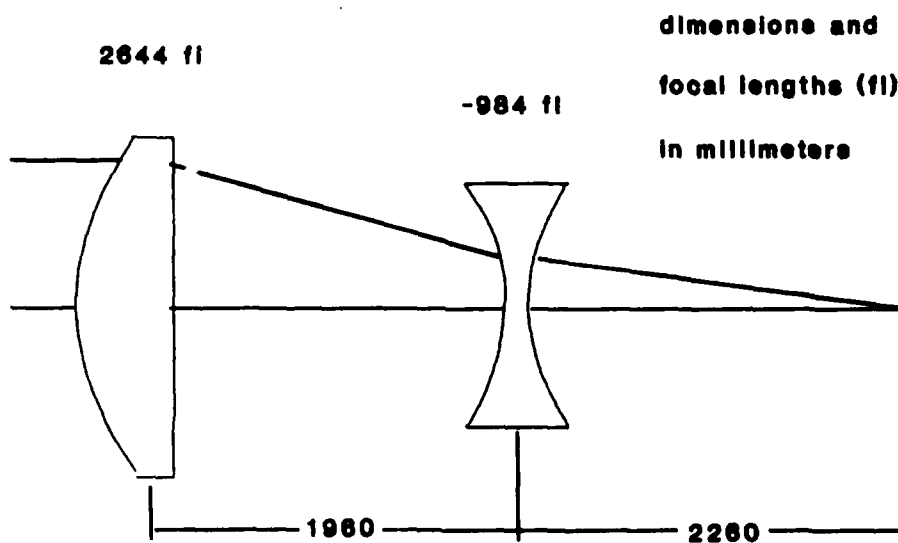


Figure 2.2 Telescope equivalent.

The first lens is externally, axially translatable and together with the negative second lens provides focussing of a star image on the field stop iris.

A folding mirror diverts the optical path upward to afford a compact design. The third lens (shutter lens) images the telescope primary on the shutter. The image is only 1 mm diameter, so the 6 inch diameter shutter rotating at 3600 rpm cuts off the optical path in 40 microseconds. The star field image is also quite small and appears just behind the fourth lens.

The fourth and fifth lenses together form a modified microscope objective to magnify the image at the shutter to a 2.2 cm diameter image 20 cm behind the sixth lens. Stars are imaged at infinity with a net 27X angular magnification. The optical environment between the objective and the sixth or PMT lens is well suited for narrow band filters and etalons.

The PMT lens collects the light into a well blurred spot which slightly underfills the PMT photocathode. Blurring is desirable at the PMT to average over defects in the photocathode.

2.2 Alignment

Adjustments in the optical path have been carefully minimized - too many degrees of freedom usually complicate alignment procedures unnecessarily. The following procedures assume the telescope is properly aligned.

The shutter lens is axially translated, using the focussing handle on its mount, to give a sharp image of the telescope spider (suspension assembly for the secondary mirror) on the shutter. The image at the shutter is easily observed from above by removing the PMT lens plate and sighting through the objective at a piece of translucent scotch tape stuck to the underside of the slot in the shutter wheel. A nylon screw locks the shutter lens mount when the proper focus is obtained.

The objective, as an assembly, is focusable using the handle on its mount. With the PMT lens in place and the scotch tape removed from the shutter wheel, an image of the telescope spider appears 8.5 cm above the PMT lens. A focussing jig has been provided which consists of a blackened aluminum tube of suitable length, an eyeloupe, and an image screen. The jig is placed atop the PMT lens and the objective is focussed for the sharpest spider image. Care should be taken to keep the objective from hitting the shutter wheel. A longer tube is provided with the jig to check the focus of a star image 15 cm above the PMT lens. In practice, it is the iris, closed down to a pinhole, which is imaged using daylight illumination through the telescope. (After the detector is aligned, stars can be brought into focus with the iris using the first, or focussing lens. A knob, external to the detector, adjusts the focussing lens while you observe through the eyepiece.) The objective itself needs alignment if it cannot be positioned to yield adequately sharp images using the focussing jigs.

Internal alignment of the objective is the most tedious of the alignment procedures. The small fourth lens, or nose lens of the objective is held in a conical nosepiece which slides into the objective body. The nosepiece is locked at the proper focus with two setscrews. To gain access to the setscrews, the entire objective should be unscrewed from its mount and lifted out. After adjusting the nosepiece, reinstall the objective and check the foci using the two jigs. The process repeats until both images are suitably sharp. Although the entire process is cumbersome, the threaded collar which secures the objective in its mount permits easy objective removal and preserves alignment upon reinstallation.

The folding mirror is responsible for keeping the optical axis concentric with the lenses. The spider image above the PMT lens is a good indicator of concentricity. Alignment of the folding mirror has no effect on the other

adjustments - if at any point during the alignment of the detector, the image appears poorly centered, the folding mirror should be adjusted.

2.3 Eyeiece

A pentaprism and lens swing into the optical path between the folding mirror and the shutter lens to divert the image to an eyepiece. An external knob controls the insertion of the prism assembly. A back stop screw and locknut assure proper centering of the image in the eyepiece. The eyepiece slides in its barrel to afford a comfortable focus on the iris. As explained earlier, a focussing control on the first lens brings star images into focus with the iris.

2.4 Housing

The detector is housed in a light tight, structurally supportive enclosure. A mechanical layout appears in figure 2.3. The shutter wheel is contained in a "box" formed by the motor mounting plate and filter box floor. The shutter lens and objective mount to this box as well, resulting in a high degree of optical isolation for stray light between the telescope and the PMT. Room lights or even direct lighting on the detector have not been noticeable in the signal. Even the open eyepiece is sufficiently isolated from the PMT to cause no concern during operation - plans to cap the eyepiece when not in use have proven unnecessary. The entire housing and most metal components inside have been bead blasted and anodized to a matte black finish.

2.5 Filters

The 18 cm long collimated beam path between the objective and the PMT lens is contained in a thermally controlled, insulated filter box. A 5 cm diameter dielectric bandpass filter supported in a tilt mount limits the background bandpass to 5 angstroms. Quick release slide

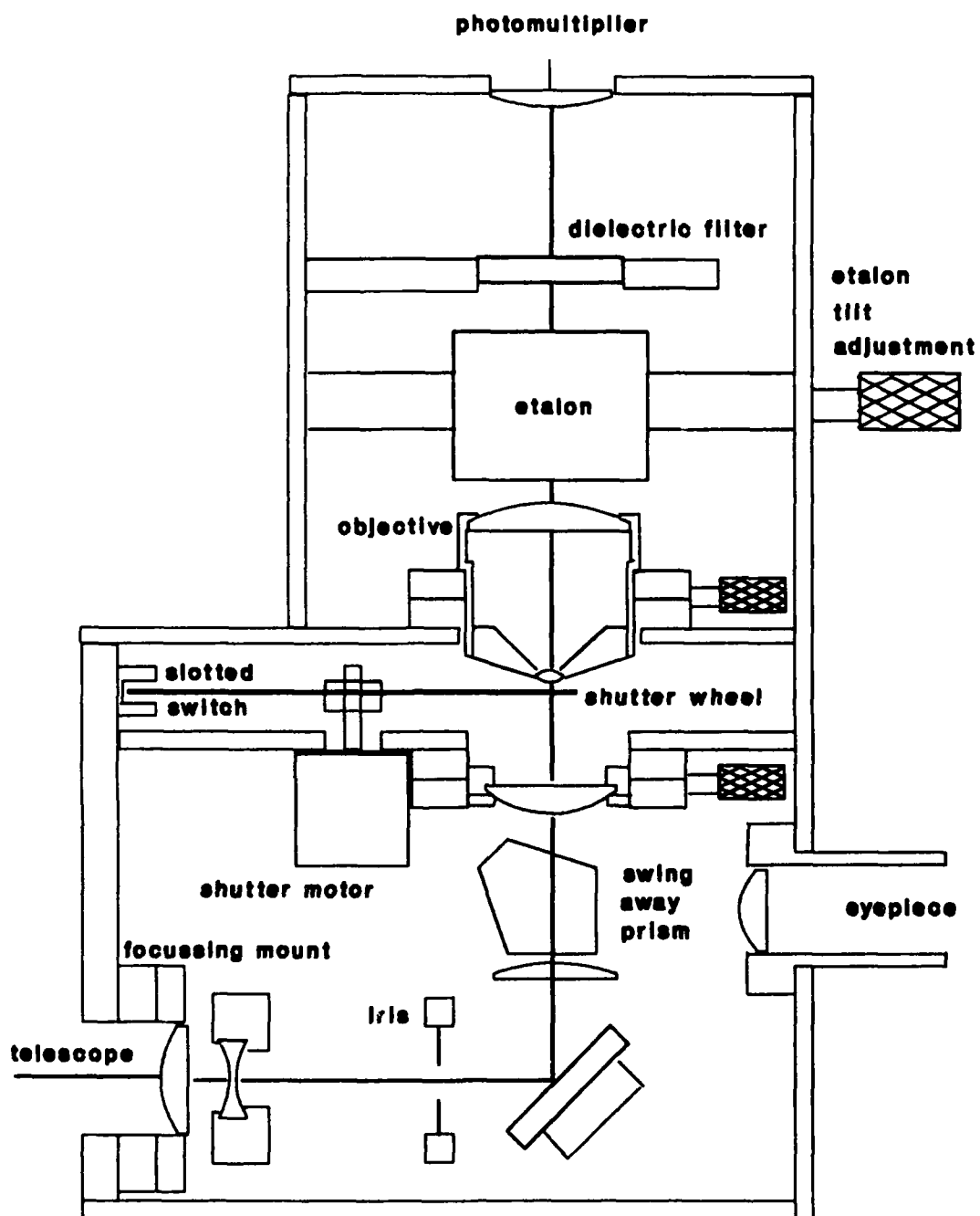


Figure 2.3 H detector mechanical layout.

mounts are being designed to allow rapid changing of different, prealigned filters.

An additional order of magnitude of background rejection is provided by an etalon for daytime lidar measurements. The etalon, supplied by Burleigh Instruments, has a 14 angstrom free spectral range, and a finesse of 70. The spacing and tilt of the etalon's plane reflectors are controlled by piezoelectric elements within the etalon unit.

2.6 Etalon Feedback Control

The thermally controlled filter box provides adequate stability for the 5 angstrom dielectric filter, but the etalon requires active feedback to remain tuned to the laser wavelength. Several units operate together to generate a stabilization reference and feedback error signal for the etalon. The error signal is amplified by a Burleigh high voltage amplifier and applied to the piezoelectric actuators in the etalon.

The error signal is derived by observing electronically the lineshape of a reference lamp during an otherwise unused time period. The hollow cathode reference lamp is contained in an aluminum housing in which a plastic Fresnel lens couples the light out through a 1 mm core optical fiber. A fiber coupling on the H detector enclosure transmits the reference light through focussing optics to a 1 mm spot on the top of the shutter wheel. An angled, reflective ring, machined into the top surface of the shutter wheel, efficiently couples the light upward into the objective assembly, through the filters, and into the photomultiplier. The lamp is only turned on for 2 ms after a 4 ms delay from the start of the data window. The lamp housing contains circuitry which boosts the < 15 volt lamp control pulse to the several hundred volt level required by the hollow cathode lamp.

The etalon control circuit responsible for firing the lamp simultaneously performs two additional tasks: A ramp

and offset voltage is sent to the etalon high voltage amplifier, and a counter circuit monitors the photo-multiplier signal. The offset level and ramp slope are independently controllable - together they cause the etalon to scan rapidly through the reference lamp lineshape while the lamp is on, and then to return to the laser wavelength. The counter circuit counts photon pulses upward during the first half of the ramp, and downward during the remainder of the ramp. The sign of the resulting count is integrated for several seconds while the lamp firing/etalon ramp cycle repeats at 60 Hz. The integrated signal provides the error feedback for the etalon amplifier.

A second counter integrates the total signal during the etalon ramp and regulates the amplitude of the reference lamp control pulses. The reference lamp brightness is thus stabilized.

2.7 Shutter Wheel Synchronization

The shutter wheel is locked to external synchronization pulses. A slotted optical switch detects the shutter opening and produces a pulse for comparison with the external synchronization pulse.

Errors in the rotation of the shutter wheel are detected by a phase-locked-loop, filtered by oscillation damping circuitry, and applied to a voltage controlled oscillator. The oscillator supplies the clock for a shutter wheel position counter, as well as the drive for the two phase synchronous shutter wheel motor. MOSFET output stages and step-up transformers boost the motor drive to 120 volt square waves.

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