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A SCANNING REFLECTION AND TRANSMISSION PHOTOMETER FOR LARGE HIGH POWER LASER OPTICS

BY

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ABSTRACT

The Nova Laser Fusion program at Lawrence Livermore National Laboratory requires the use of large optics up to 109 cm diameter and 380 kg weight. The optical coatings for these optics consist of anti-reflection, high reflector, polarizing beamsplitter and partial transmitter coatings. The absolute reflectance, overall transmittance and uniformity of these coatings are measured with a specialized scanning photometer.

The Nova OTR (overall transmittance/reflectance) photometer operates at 1.064 nm, 528 nm, or 351 nm in order to closely simulate 1st, 2nd and 3rd harmonic frequencies of the Nova fusion laser. The optic is scanned on a large XY carriage while reflectance or transmittance data is taken "on-the-fly". The system is controlled by an LSI 11/23 computer which processes the data and prints out the results in hard copy form, or stores data on a memory disk. The detectors are temperature controlled to within ± 0.01°C which aids in achieving of an absolute accuracy of ± 0.1% to ± 0.5% of full scale, depending on the operating point. The photometer is capable of scanning a large optic (1 meter in diameter) in 20-30 minutes.

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Introduction

The Nova OTR photometer consists of an XY carriage, optical head, electronics and digital processing system. The instrument was designed to measure either reflectance or transmittance of a coated optic while the optic is scanned in a raster pattern. The instrument circumvents the usual approach which is to perform measurements on witness pieces which are coated simultaneously with the large optic during a coating run.

The large masses and coated surface areas of Nova optics requires that the measurements be taken with the optic in horizontal motion. A large number of data points are taken, averaged and stored in the computer memory for later retrival.

The primary features of the instrument are:

1. Photometric accuracies from ± 0.1% to ± 0.5% of full scale.
2. Automatic raster scanning and mapping of R or T on optic.
3. Temperature-controlled photodiodes.
4. Digital processing of data.
5. Angle of incidence range 0-65^{o}, with S or P polarization.

The instrument operates at 1064 nm by virtue of a neodymium-YAG CW laser. This wavelength capability is presently being expanded to 528 nm and 351 nm by virtue of a CW argon-ion laser. These wavelengths closely simulate the 1st, 2nd and 3rd harmonics of the Nova laser (1053 nm, 527 nm and 351 nm, respectively).

XY Carriage

The X-Y carriage was designed to transport a large, heavy optic either horizontally or vertically in front of the optical head. The carriage moves horizontally on rails as shown in Figure 1. The horizontal motion is achieved by a stepping motor which drives a pinion gear on a stationary rack. The carriage moves vertically on two shafts with linear ball bushings. It is driven by a ball lead screw and stepping motor.

The optic to be tested is held rigidly on the carriage in its coating fixture or suitable brackets. The optic can be tilted slightly about the vertical or horizontal axes to assure that the optic will move in directions parallel to its surface.

The stepping motor control system is open-loop in both axes, however, an optical encoder is mounted to the horizontal stepping motor for incremental position verification. When the computer commands the carriage to move horizontally "X cm", the encoder must verify it, or else, the operator is notified of an error in position. The data acquisition, typically, is done during a horizontal scan, only.

The X-Y position accuracy is ±2 mm absolute and position repeatiblity is ±1 mm. The maximum raster scan range is 120 cm and 100 cm for the horizontal and vertical axes, respectively. The nominal X-Y scan rate is 5.0 cm/sec and 0.5 cm/sec for the horizontal and vertical axes, respectively. The maximum horizontal travel is 243 cm and the maximum vertical travel is 101 cm.

1064 nm Optical Head

The 1064 nm optical head is shown in Figure 2. It is mounted to a large protractor and free to move 0-65° angle of incidence. The detector head is shown mounted in front of the optical head for reflectance measurements, and is free to move on the protractor 0-65° in the opposite direction as the optical head.

The 1064 optical head layout is shown in Figure 3. The head contains a Neodymium-YAG laser and a HeNe laser which are aligned coxially to facilitate visual alignment of the beam and the detectors[1].

The 1064 nm laser beam is folded by mirrors and directed to a spatial filter consisting of a pinhole and two lenses (spatial filter lens and optical lens) in an afocal arrangement. A light chopper, near the spatial filter pinhole, chops the beam at 510 hz. The unpolarized beam is linearly polarized with a Glan Thompson calcite polarizer.

The 1064 nm laser beam is split into equal parts and combined coaxially with the visible HeNe laser beam by means of the beam combiner and splitter. Half of the 1064 nm laser beam is transmitted to a reference detector head, and the other half is transmitted to the test optic.

Additional alignment mirrors are provided to enable the HeNe laser beam to be directed through the back of Nd-YAG laser to facilitate coaxial alignment of the two beams.

The optical system can be used to measure either R or T, depending on which side of the test optic the signal detector head is placed. In addition, both R^2 and T^2 can be measured by replacing the signal detector head with a plane mirror and moving the signal detector head to the position shown in Figure 3. The operational modes are listed below:

Operational Mode	Measured Parameter
Single bounce	R
Double bounce	R^2
Single pass	T
Double pass	T^2

The output lens is provided with mutually-orthogonal translation screws as shown in Figure 4. This enables the beam to be deviated during alignment with the detector heads. A polarization selector knob is provided to rotate the polarizer for S or P polarization.

1064 nm Detector Head

The detector head consists of a diffuser assembly, thermo-electrically cooled silicon photodiode and analog preamplifier.

The photometric accuracy depends on the detector head output being linear with the incident laser beam power. This is achieved by means of the diffusers and temperature-controlled photodiode. The 1064 nm detector head is shown in Figure 5.

The diffusers consists of white acrylic plastic which breaks up the coherence of the laser beam and reduces speckle. One diffuser element is shaped into a positive lens which is thicker in the center than near the edge. The radially-varying thickness compensates for the variation in sensitivity of the detector to on-axis and off-axis rays. The shaped diffuser diffuses the incident laser beam while focussing the beam on the detector. A flat response for detector output versus the radial position of the laser beam can be achieved by proper positioning of the diffuser adjustment ring. The detector head is designed to have less than ± 0.1% output variation when the incident laser beam is displaced ± 2 mm from the center position. This compensates for beam wander when an optic is scanned.

The photometric accuracy also depends on the photodiode responsivity being constant in time. The silicon photodiodes (EGG YAG 100) are mounted on a Peltier cooler which maintains the temperature approximately 10°C below ambient to within ± 0.01°C for long periods. The temperature of the photodiode is sensed by a thermistor. A magnified view of the photodiode and Peltier cooler is shown in Figure 6.

The use of shaped diffusers and temperature-controlled photodiodes has contributed significantly to the photometric accuracy of the Nova OTR photometer.

Electronics

The YAG 100 photodiodes are used in the photoconductive mode. A heavy bias (-180 volts) is used to increase the depth of the depletion region so that more electron-hole pairs are created in the junction at 1064 nm. A simplified block diagram of the electronics is shown in Figure 7. The photodiode outputs from the reference and signal detector heads are amplified with an analog preamplifier board, then synchronously- demodulated to reduce noise.

The signal is digitized with an AD converter to an accuracy of 14 bits. This provides ± 0.1% resolution of full scale.

The system is calibrated by moving the optic out of the laser beam and the signal detector head into the beam as shown in Figure 8. The ratio between the outputs from the signal and reference detector heads is determined. The optic is moved into the beam and the detector head is shifted to compensate for beam translation in the case of transmission measurements, or moved to the optical head side of the optic in the case of reflection measurements. After alignment, the optic is scanned while the ratio of the signal and reference detector head outputs is determined. The ratio of the ratios before and after calibration gives the reflectance or transmittance.

It takes approximately 50 milliseconds to make a measurement. Each measurement consists of 285 samples which are averaged as the optic is scanned at 5 cm/sec, nominally. Approximately 15 measurements can be made per second. A maximum of 101 measurement points per horizontal scan line is possible.

The user interface is shown in Figure 9. The CPU is a LSI 11/23 computer with 64 K words of RAM memory. The data is processed after the optic is scanned and can be stored on floppy disk for archival storage. The user has access to a graphics terminal, hard-copy unit, dual floppy disks and remote control which allows manual control of the X-Y carriage. Limit switches are used to prevent the carriage from exceeding its mechanical limits.

Data

Figure 10 shows the results of one horizontal scan of an anti-reflection coated optic such as appears in Figure 1. The length of the scan is 72 cm comprising 37 measurement points. Each measurement point is an average of 285 data points taken at a sample rate of 25 kiloHertz. The 285 data points occur with a beam diameter.

The data contains anomolous values at X = 12.0 cm and X = 16.0 cm. When these points were re-scanned, scattering from dust particles was detected with the visible HeNe beam.

The software can also provide a map of data points that occur inside or outside of a specified R or T range.

528 nm/351 nm Optical Head

At the present time, the OTR photometer is being fitted with an additional optical head, which operates at 528 nm or 351 nm (Argon ion). The main difference between this head and the 1064 nm head is the polarization rotator which replaces the Glan-Thompson polarizer. The polarization rotator rotates the plane of polarization of the laser beam by means of reflection from either two or three mirrors. Detector heads are designed to work at both 528 nm and 351 nm.

Conclusion

The Nova OTR photometer was designed and built to scan large coated optics for the Nova Laser Fusion Program at Lawrence Livermore National Laboratory. It provides a photometric accuracy given below:

R or T Range	Photometric Accuracy
95 - 100%	± 0.1%
75 - 95%	± 0.25%
25 - 75%	± 0.5%
5 - 25%	± 0.25%
0 - 5%	± 0.1%

This instrument can scan a 1 meter diameter optic in 20-30 minutes and provide a map of data points occuring inside or outside of a specified range of R or T. The photometer operates at 1064 nm, 528 nm and 351 nm, and provides data on the uniformity of R and T for large area coatings on flat optics.

Acknowledgements

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References

1. Anthon, E., "Transmission and Reflection Measurements of Large Optical Components for High-Power Lasers", SPIE, Vol. 140, Optical Coatings- Application and Utilization II (1978).

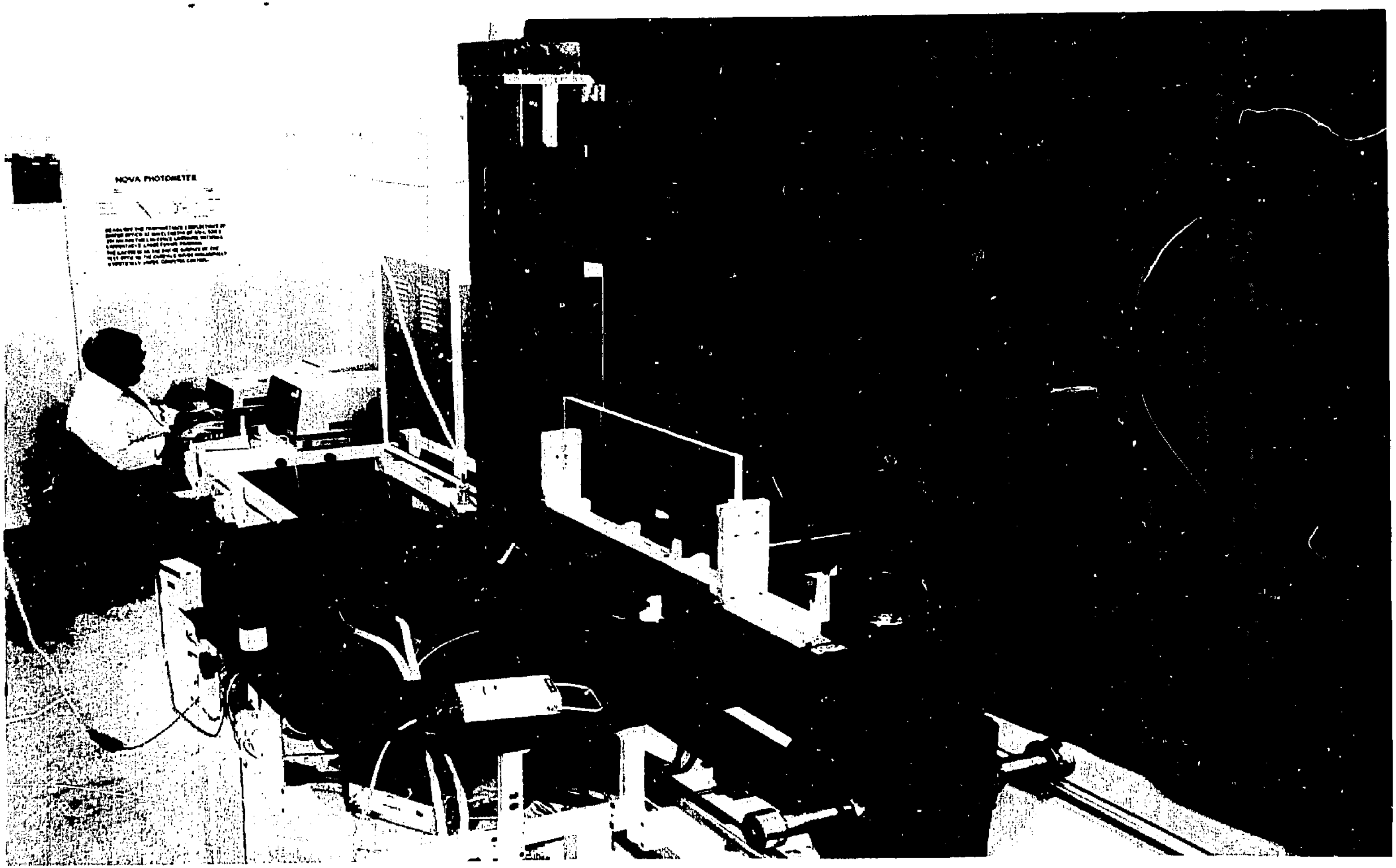

Fig. 1 Nova OTR Photometer.

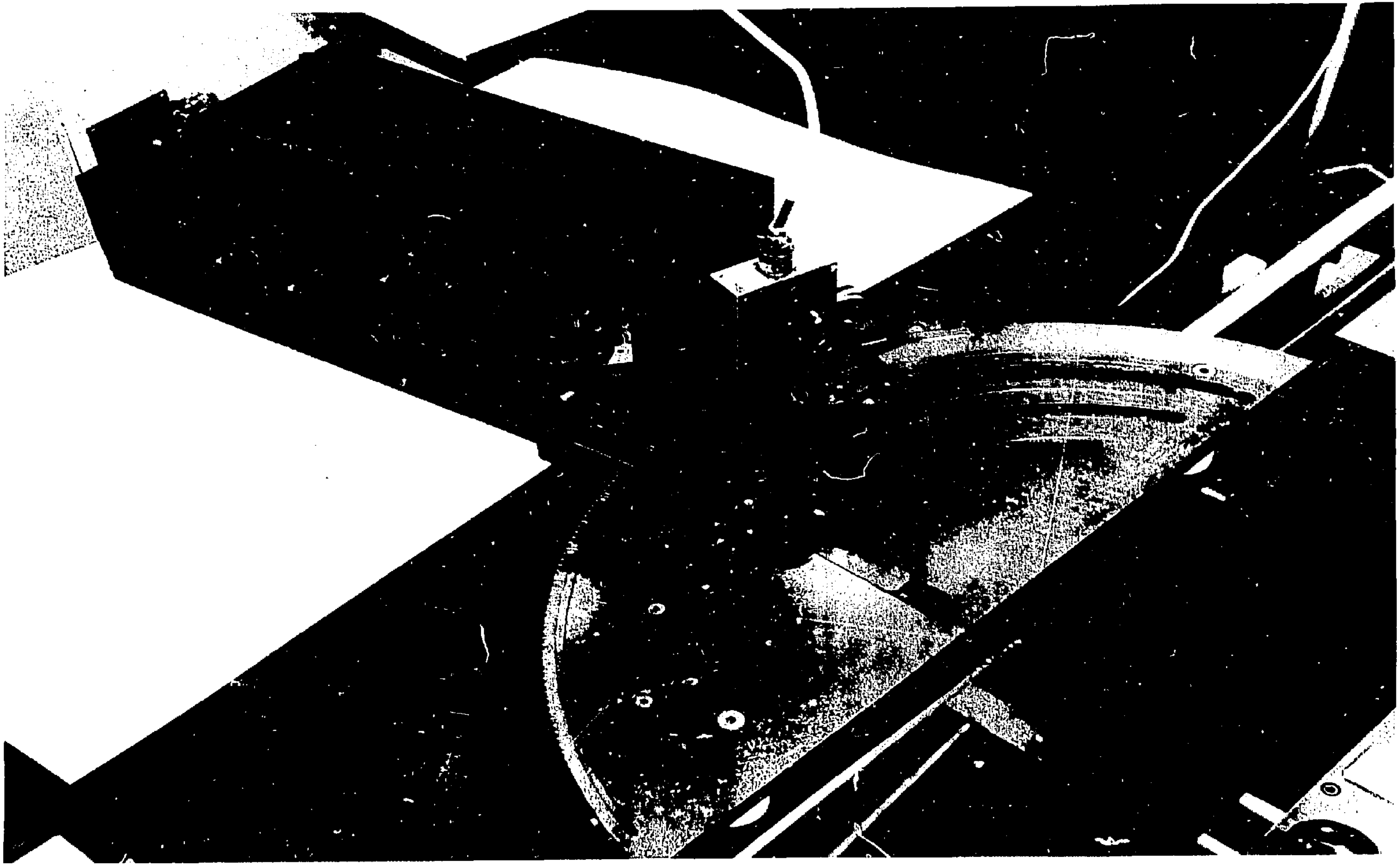

Fig. 2   1064 nm Optical Head.

Fig. 3 **1064 nm OPTICAL HEAD — TOP VIEW**

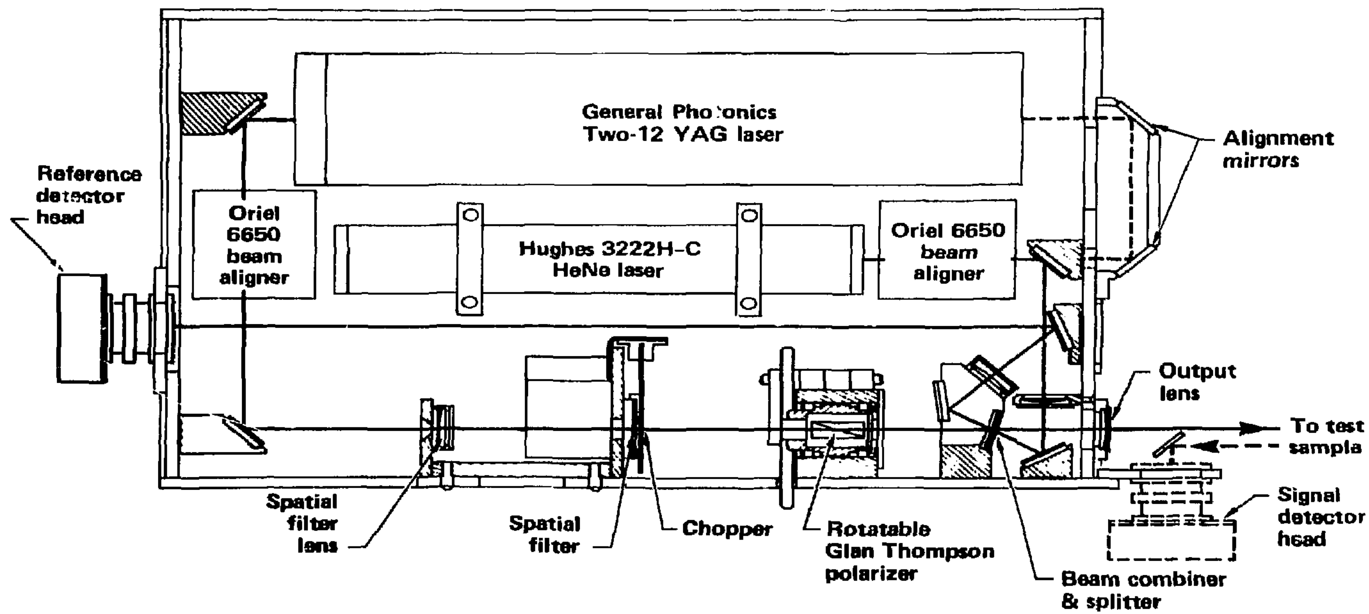

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Fig. 4 **1064 nm OPTICAL HEAD — FRONT VIEW**

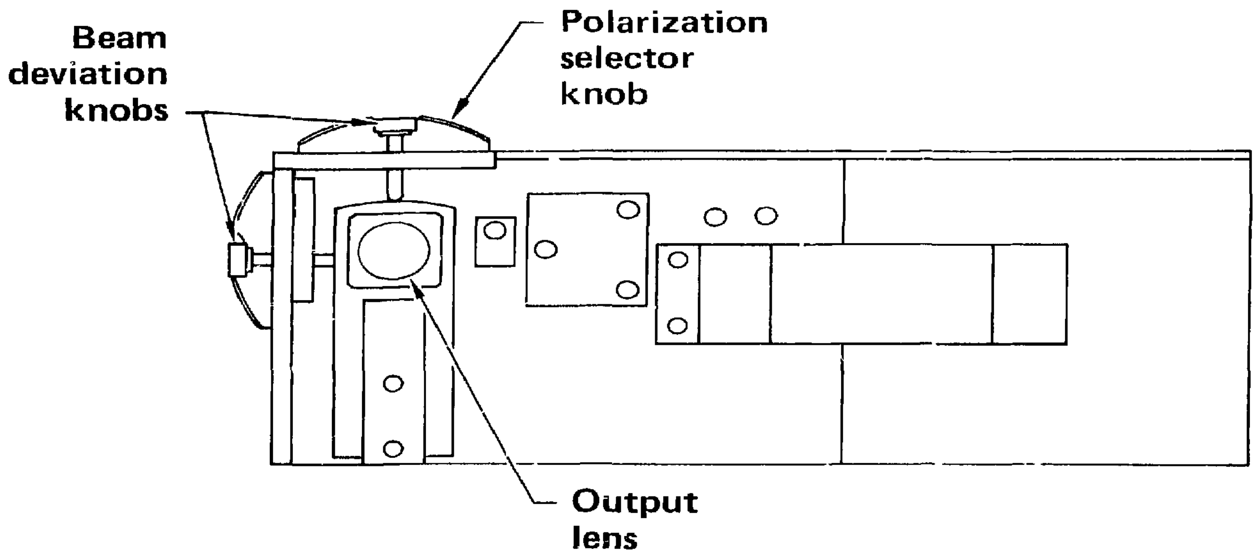

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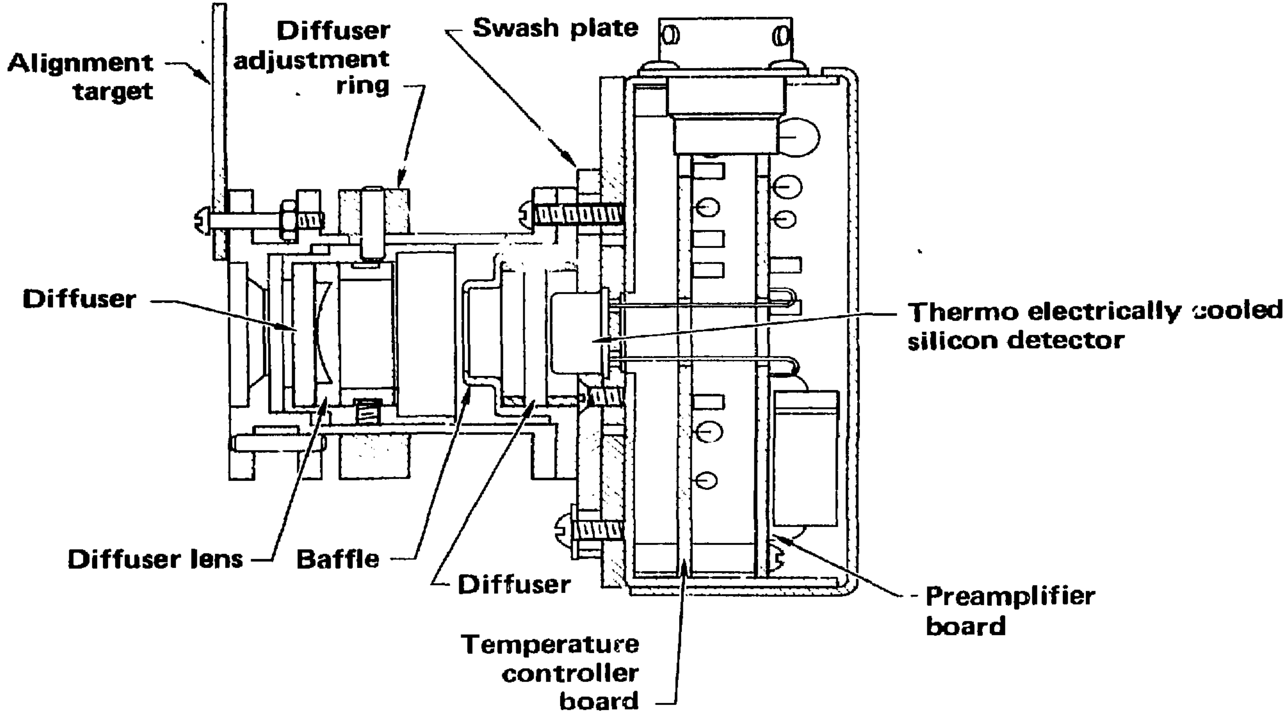
Fig. 5 **1064 nm DETECTOR HEAD**



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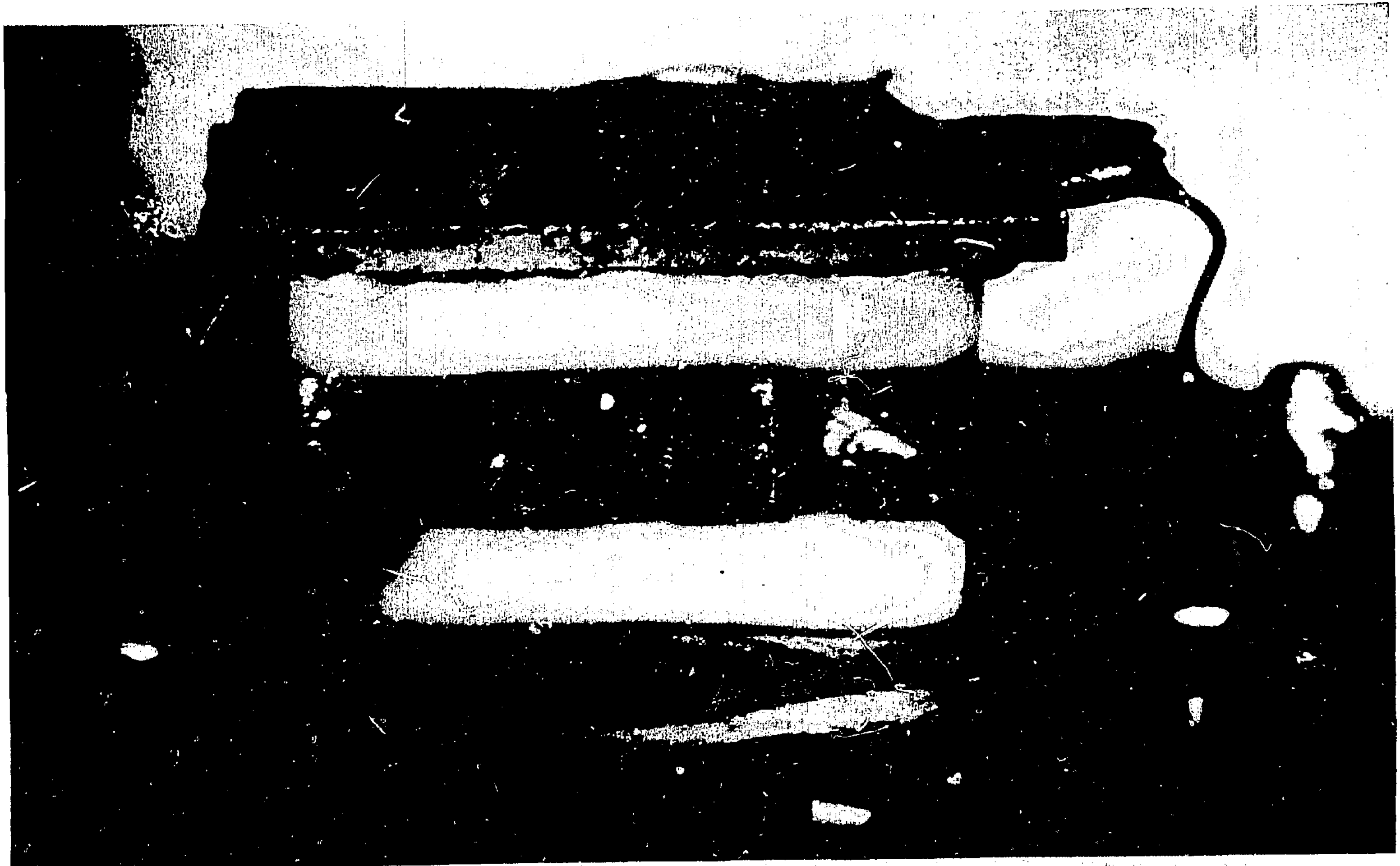
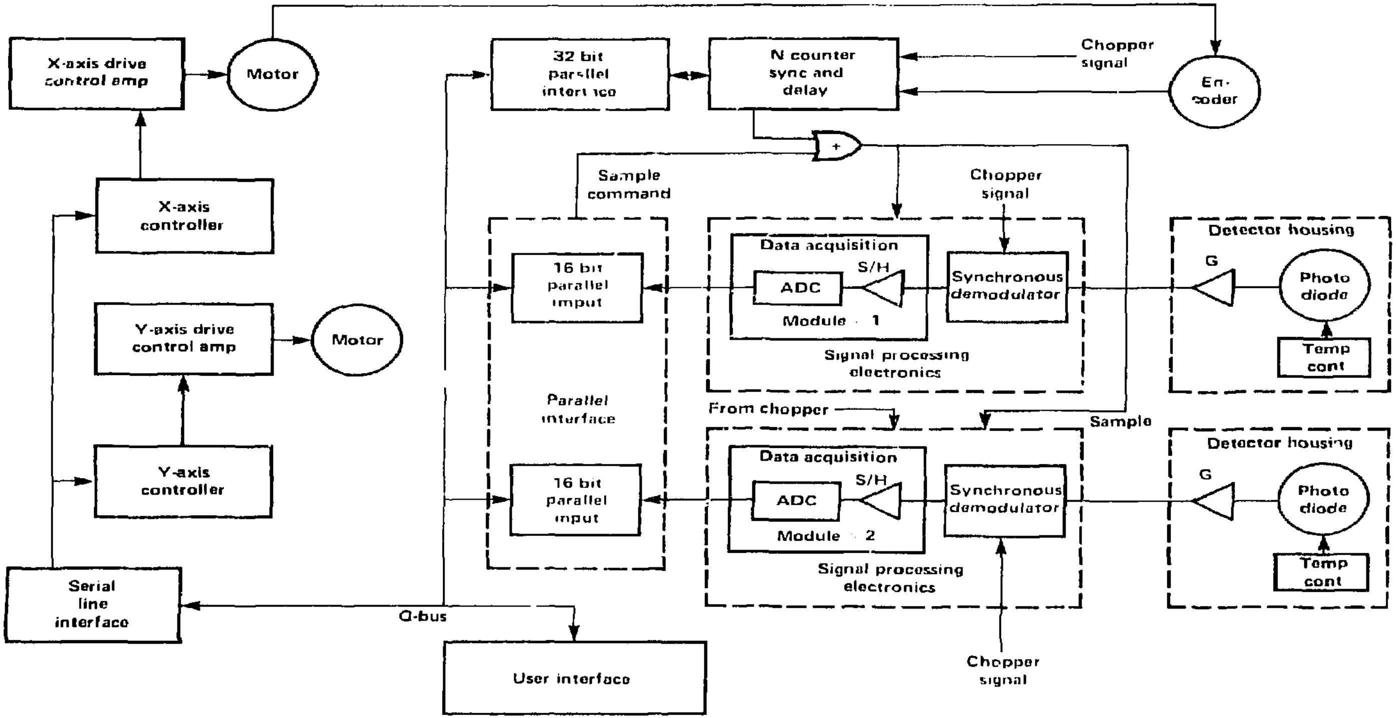


Fig. 6 Thermoelectrically-Cooled Photodiode.

Fig. 7 OTR ELECTRONIC SYSTEM INTERFACE



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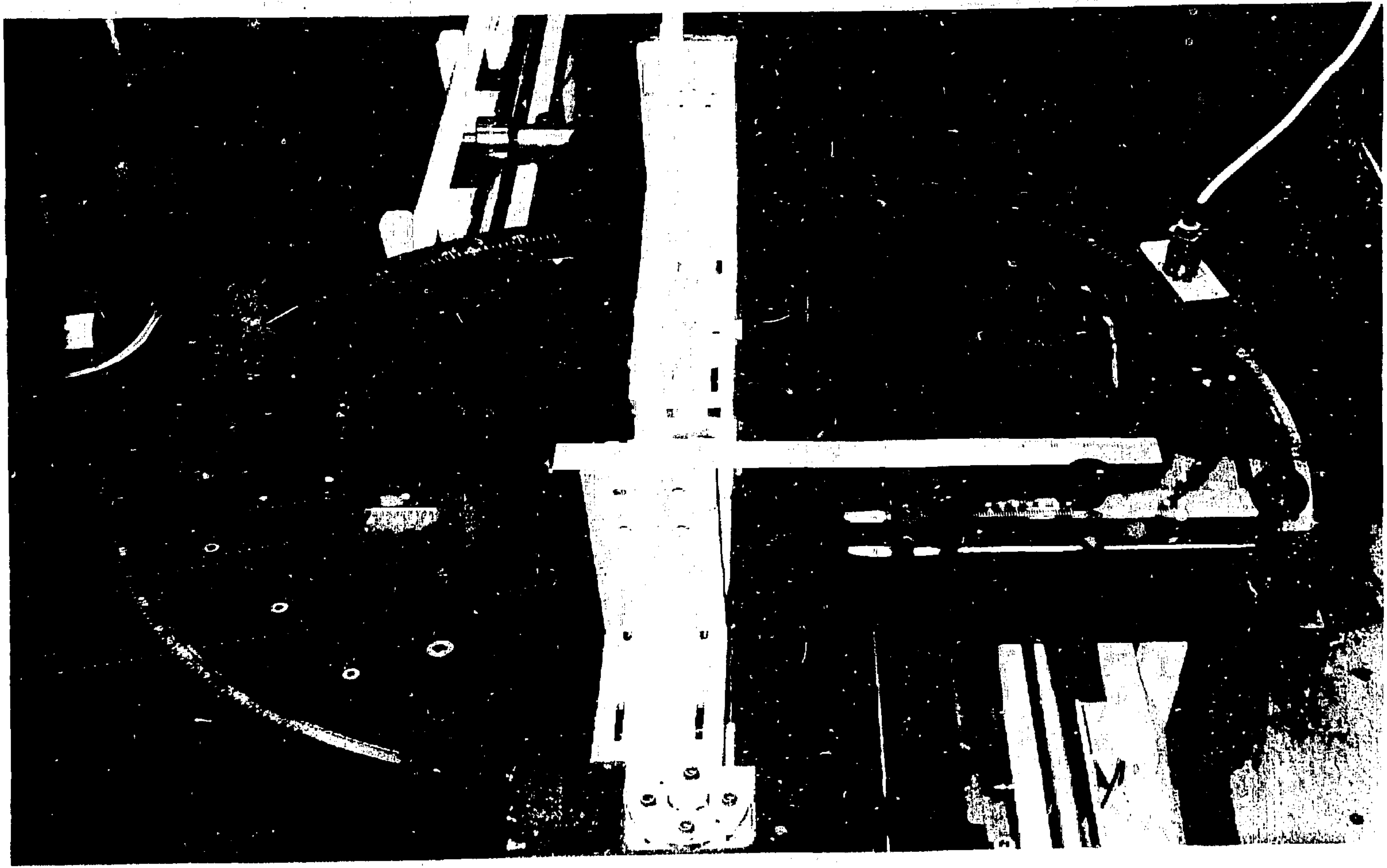

Fig. 8 Calibration With Optic Out Of Beam.

Fig. 9 **OTR PHOTOMETER ELECTRONICS – USER INTERFACE**

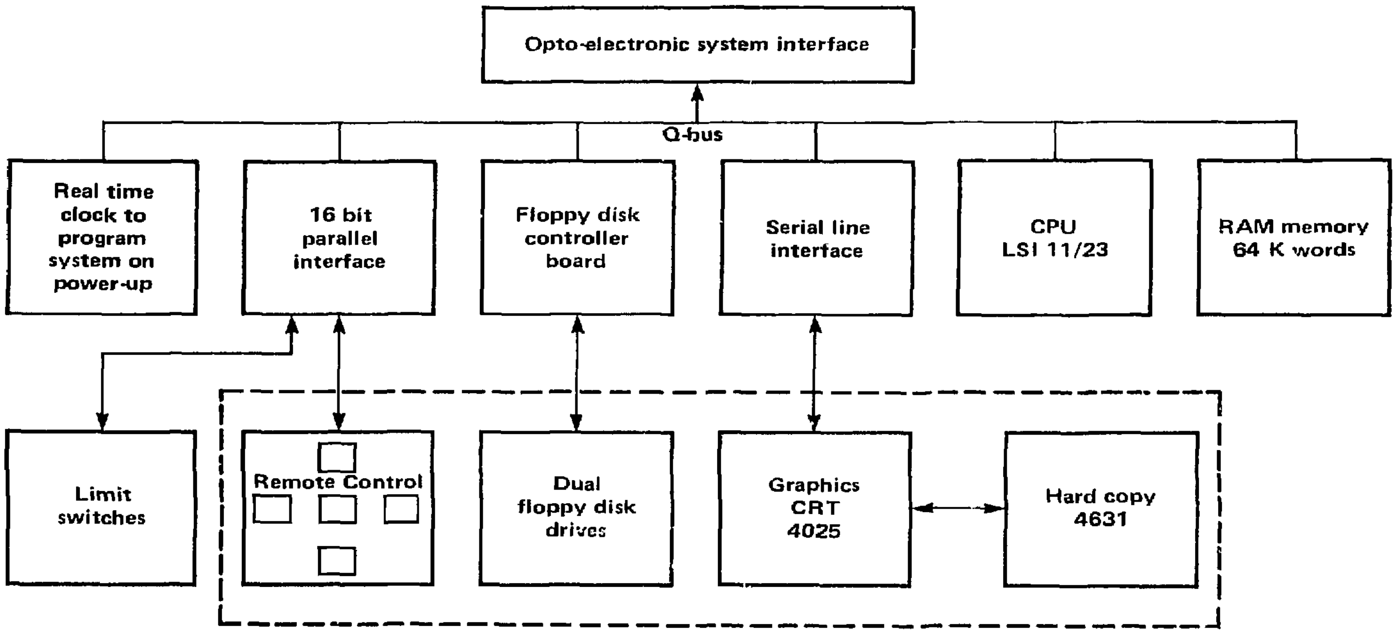

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Fig. 10 REFLECTANCE SCAN
Part ID 1018-084 24-SEP 81 09:36:23
Scan number 3 Y-Coordinate = -8.0

X-COORDINATE	PERCENT	X-COORDINATE	PERCENT
		0.0	0.22
-36.0	0.55	2.0	0.14
-34.0	0.19	4.0	0.14
-32.0	0.16	6.0	0.13
-30.0	0.15	8.0	0.14
-28.0	0.14	10.0	0.15
-26.0	0.14	12.0	0.88
-24.0	0.13	14.0	0.17
-22.0	0 14	16.0	1.67
-20.0	0.13	18.0	0.17
-18.0	0.12	20.0	0.16
-16.0	0.13	22.0	0.18
-14.0	0.12	24.0	0.27
-12.0	0.12	26.0	0.18
-10.0	0.11	28.0	0.18
- 8.0	0.12	30.0	0.18
- 6.0	0.13	32.0	0.21
- 4.0	0.14	34.0	0.23
- 2.0	0.13	36.0	0.19