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HIGH ALTITUDE INFRARED ROCKET ASTRONOMY

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This report describes the work completed between 15 November 1969 and 10 December 1970, and is divided into five sections:

A) Detectors for the wavelength range 5μ to 30μ,
B) Detectors for the wavelength range 65μ to 1.5 mm,
C) Performance of telescope system,
D) Integration and vibration testing,
E) Rocket flight AO-4.004 -- 2 December 1970.

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A) Detectors for the wavelength range 5μ to 30μ,

B) Detectors for the wavelength range 65μ to 1.5 mm,

C) Performance of telescope system,

D) Integration and vibration testing,

E) Rocket flight AO-4.004 -- 2 December 1970,

F) Personnel and publications.

A) Detectors for the Wavelength Range 5 to 30μ

Work on short wavelength detectors (5-30μ) has been primarily devoted to fabrication and testing of copper doped germanium detectors, with some time spent on the testing of mercury doped germanium detectors obtained from Santa Barbara Research Center (SBRC).

The fabrication technique used closely follows that described by T.M. Quist.[1] Germanium blocks with evaporated copper layers were baked in an 85% argon, 15% hydrogen atmosphere at 745 °C for 18 hours followed by a rapid quench. Various methods of soldering indium contacts to 3 mm cubes cut from the germanium blocks were tried; no method was found to be substantially superior to any other.

The NEP's (Noise Equivalent Power) of the detectors were determined in the standard manner, using a 600 °C blackbody as a reference source, and an interference filter to define the spectral response of the system (12-14 microns). All detectors were tested at 4.2 °K; no attempts to test detectors at other temperatures were made. Results to date indicate the best copper doped detectors have NEP's of 5×10^{-13} watts, and responsivities of .5 - 1.5 amps/watt. These detectors are essentially background photon noise limited. Under low light level conditions, the NEP of the detector was less than 3×10^{-15} watts/$Hz^{1/2}$.

Mercury-doped germanium detectors supplied by SBRC were also tested to determine their NEP's. The best results to date are NEP's of $3\text{-}6 \times 10^{-11}$ watts. The copper-doped germanium detectors markedly

1) Quist, T.M., Proc. IEEE, 56, 1212 (1968).

outperform the commercially manufactured mercury-doped germanium detectors.

B) Detectors for the Wavelength Range 65μ to 1.5 mm

Work on long wavelength detectors has been primarily concerned with fabrication and testing of detectors. The spectral response and the noise-equivalent power (NEP) were measured. Filters, also necessary for the scheduled sounding rocket flight, have been constructed.

1) Gallium Doped Germanium (Ge:Ga)

Gallium-doped germanium detectors were constructed from 3 mm cubes of gallium concentration[1)] $n \sim 7 \times 10^{13}$ cm^{-3} and majority carrier mobility $\mu_{4.2^oK} \sim 2 \times 10^5$ cm^2 $volt^{-1}$ sec^{-1}. After cleaning the cubes in CP-4 etch, two faces of the cube were indium soldered. Leads (copper wire) were then soldered to these two faces of the cube.

For the flight, it was necessary to reject 63μ radiation from the Ge:Ga detector, because atomic oxygen in the atmosphere emits strongly at that wavelength. A Yoshinaga filter has been constructed to accomplish this rejection.

Measurements of the spectral response and NEP of the detectors were made at a detector temperature of 4.2^oK. The spectral response was found by comparing the response of Ge:Ga to a Golay cell using a Perkin Elmer 301 Far Infrared Spectrometer. The NEP of the detector was measured in the flight system using a specially constructed 77^oK blackbody. The NEP of the detector filter system is 4.5×10^{-13} watts $(Hz)^{1/2}$.

2) Gallium Arsenide (GaAs)

The gallium arsenide detector material was supplied by Professor Ballantyne of the Electrical Engineering School, Cornell University.

A high-purity epitaxial layer of GaAs (~ 100μ thick) was grown on a semi-insulating substrate. The donor concentration was $n \sim 6.4 \times 10^{14}$ cm^{-3} and the electron mobility $\mu_{300^oK} \sim 7000$ cm^2 $volt^{-1}$ sec^{-1}.

The detectors were cut to 2-1/2 mm x 4-1/2 mm and leads were attached by two different techniques. In one method[2)], small (10 mil) pellets of high purity tin were alloyed to the detector at 320°C in a hydrogen-hydrogen chloride atmosphere. Leads were then indium soldered to the tin. Professor Ballantyne also supplied one detector with gold leads that were thermal-compression bonded at 300°C and 5,000 psi to Ge-Au-Ni strips that had been evaporated and alloyed to the detector. The NEP and spectral responses obtained for the two different detectors were identical.

In the flight, it was necessary to reject 147μ radiation from the GaAs detector because atomic oxygen emits strongly at that wavelength. A suitable Yoshinaga filter was constructed to accomplish this rejection.

The NEP of the GaAs filter system was measured in the flight system to be 9×10^{-12} $watts/(Hz)^{1/2}$.

3) Rollin Detector (InSb)

A Rollin detector of high resistivity InSb was constructed. The InSb was cut to 3mm x 5mm x 0.3mm, and after a brief etching, leads were indium soldered to the detector. The spectral response of the Rollin detector has been measured with the lamellar grating interferometer.

In the flight system, a cold subminiature audio transformer was used to impedance match the detector to the preamplifier. The secondary was capacitively tuned to 165 Hz, the chopping frequency to maximize the signal-to-noise ratio. An interference filter was used to reject radiation in the wavelength range 1 - 6μ, the range in which InSb has intrinsic response. A wire mesh filter determined the 1.3 mm cut-off for the detector.

References

1) Moore, W.J. and Shenker, H., Infrared Physics 5, 99 (1965).
2) Stillman, G.E., Wolfe, C.M. and Dimmock, J.O., P.I.B. Intl. Symp. on Submillimeter Waves (1970).

C) Performance at the Telescope System

The telescope system was assembled and calibrated using a black body radiation source.[1] The following results were obtained:

Channel Number	Wavelength range	NEP (system)	NEFD
1	5-6μ	2×10^{-14} watts $H_z^{-\frac{1}{2}}$	10^{-16} w/cm^2 $H_z^{-\frac{1}{2}}$
2	12-14	2×10^{-14} " "	10^{-16} " "
3	16-22	2×10^{-14} " "	10^{-16} " "
4	70-130	4.5×10^{-13}	4.5×10^{-15}
5	200-300	9×10^{-12}	4.5×10^{-14}
6	300-1300	2×10^{-12}	10^{-14}

The sensitivity figures listed above are for the entire telescope system. As such they do not include corrections for filter or chopper losses.

1) J.R. Houck and M.O. Harwit, Science 1271, 164 (1969).

D) Integration and Vibration Testing

The payload was trucked to AFCRL for testing during the week of 2 November 1970. The integration tests were performed on 3 November. Only a few minor interference problems were encountered. No RFI (radio frequency interference) was detected. The vibration tests were conducted on 4 November. These tests were followed by a "turn on" to check the functioning of the system after vibration. No problems were detected during the vibration or turn on tests.

The payload and support equipment were shipped directly from AFCRL to White Sands for the flight.

E) <u>Rocket Flight A04.004-3 2 December 1970</u>

The payload was prepared for flight at WSMR between 19 and 24 November. The horizontal check was made on 25 November. The vertical check was made on 30 November.

An Aerobee 170 (SN 174-4) was used to carry the payload to a peak altitude of 118 miles on 2 December 1970. The T-time was 0132 MST.

All parts of the payload functioned as expected. There were no problems with either the cryogenic or vacuum systems.

A problem developed with the altitude control system (ACS) at T+225 seconds (approximately at peak altitude) which caused the system to roll, pitch, and yaw in a more or less unpredictable manner. This anomalous behavior continued for 80 seconds after which time the ACS attempted to stabilize the vehicle. However, there was too little control gas available to enable the ACS to regain control. A Nikon aspect camera was flown as part of the scientific package. The film from the camera has been developed but a determination of the telescope pointing direction after 225 seconds has not been completed. We are rather certain that the telescope looked toward the Earth for at least part of the time after 225 seconds. We expect to have the complete aspect solution within the next month (15 January 1971). The operations or servicing of the ACS system was not the responsibility of Cornell University or any of its subcontractors.

The payload was recovered in good condition on 3 December 1970.

The telescope and its support equipment have been returned to Cornell. The telescope and detectors will be recalibrated during the next few weeks.

F) Personnel and Publications

The following persons were supported at least in part by the contract during the past year.

Name	Function or areas of Responsibility	Support
M.O. Harwit	Project Scientist	Part time
J.R. Houck	Project Scientist	
B.W. Jones	Aspect camera and ACS	
J.L. Pipher	Long wavelength detectors	
B.T. Soifer	Short wavelength detectors	
J. Stasavage	Technician	Part time
V. Neigh	Machinist	Part time

The following papers cited at least partial support by this contract.

Martin O. Harwit, J.R. Houck and Robert V. Wagoner, "Observational Upper Limits to the Electromagnetic Energy Radiated by Normal Galaxies", Nature 228, 451 (1970).

B.W. Jones and J.R. Houck, "A Lamellar Grating for Use with Infrared Spectrophotometers", Applied Optics 9, 2582 (1970).

J.L. Pipher and J.R. Houck, "A Cryogenic Black Paint for the Far Infrared", Applied Optics (in press for March 1971).