General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

CORNELL UNIVERSITY
Center for Radiophysics and Space Research

ITHACA, N. Y.

FINAL TECHNICAL REPORT

NASA Grant NSG-7324

" ^{3}He BOLOMETER SYSTEMS"

Funded

October 1, 1978 through October 31, 1982

Principal Investigator: Prof. James R. Houck

FINAL TECHNICAL REPORT

NASA Grant NSG-7324

^{3}He BOLOMETER SYSTEMS

Funded

October 1, 1978 through October 31, 1982

Principal Investigator: Prof. James R. Houck

ABSTRACT

During the tenure of this grant a ^{3}He cryostat was constructed to cool a germanium bolometer for use as an infrared detector at submillimeter wavelengths. The system had better sensitivity than any other then existing system for these wavelengths; however, it was clear that the system could be greatly improved if better optical coupling could be achieved between the bolometer and the incoming photon stream. Considerable effort was expended to improve this coupling. However, even our best results fell short of an ideal system by a factor of nearly 5 in coupling efficiency.

CRYOSTAT

The cryostat built in this program used an adsorption pump to reduce the vapor pressure over a small bath of ^{3}He. A summary of the system's characteristics is presented in the Table 1.

Table 1 - Cryostat Performance

Liquid N_2 hold time	12 hours
Liquid ^{4}He hold time	14 hours
Pumped ^{3}He hold time	15 hours
Operating temperature	0.37°K
Heat load into the ^{3}He	13 μW
Thermal conductivity of heat switch	45 mW/°K
Volume of ^{3}He pumping system	120 cm^3
Amount of ^{3}He used in dewar	1 liter STP
Volume of ^{4}He bath	0.87 liters
Volume of liquid N_2 bath	0.80 liters

The ^{3}He system consists of three basic parts, a charcoal-filled adsorption pump, a ^{4}He cooled condenser and a small liquid ^{3}He chamber. In operation the system is first cooled to about 2K using conventional ^{4}He techniques. The adsorption pump is heated, forcing the ^{3}He gas out of the charcoal and into the condenser. The gas then condenses and runs by gravity feed into the ^{3}He chamber. The adsorption pump was then activated by closing a heat switch between it and the ^{4}he bath. The ^{3}He was thus pumped back into the charcoal, resulting in a cooling of the remaining liquid. The system had ^{3}He hold-time of 15 hours and could be

recycled in about 20 minutes. It is an ideal system for conducting tests at temperatures between ~0.3 and 0.4K. A schematic view of the system is shown in Figure 1.

THE BOLOMETER

The bolometer was constructed from doped germanium supplied by A. J. Seivers of the Cornell Physics Department. Only very recently has better material been produced using transmutation-doping. The electrical leads to the bolometer chip were soldered on using gallium/indium solder. The leads themselves were fine brass wires. The bolometer chip was epoxied onto the sapphire receiver chip. The sapphire was coated with a semitransparent coating of Nicrome to improve its absorption properties. The electrical properties of the bolometer are shown in the table. A schematic view of the bolometer and its optical system are shown in Figures 2 and 3. Table 2 lists its physical properties.

Table 2

Heat Capacity of Bolometer Elements

Element	Volume	Heat Capacity	0.43°K Heat Capac
Sapphire chip	$0.476 \times 0.476 \times 0.127$ cm^3	3.80×10^{-7} T^{3}J/°K	8.39×10^{-11}J/°K
Ge thermistor	$0.40 \times 0.30 \times 0.10$ cm^3	3.5×10^{-6} T^{3}J/°K	3.22×10^{-11}J/°K
Epoxy	1.6×10^{-5} cm^3	7.00×10^{-4} T^{3}J/°K	8.60×10^{-10}J/°K
Indium solder	1.6×10^{-5} cm^3	1.47×10^{-4} T^{3}J/°K	1.81×10^{-10}J/°K
Brass wires	3.24×10^{-6} cm^3	1.36×10^{-4} T J/°K	2.02×10^{-10}J/°K
NiCr film	1.7×10^{-7} cm^3	1.50×10^{-3} T J/°K	$1.10z10^{-10}$J/°K
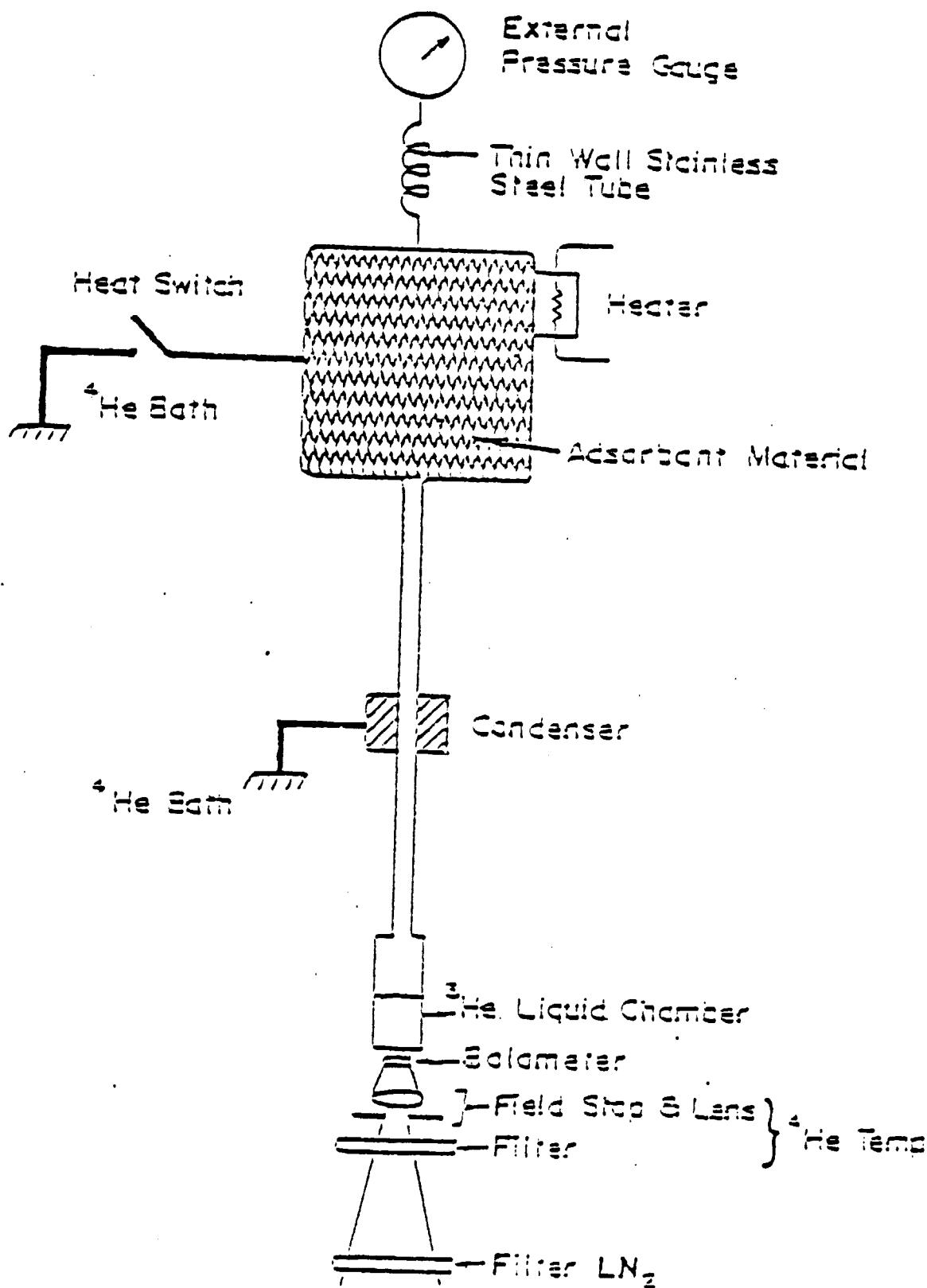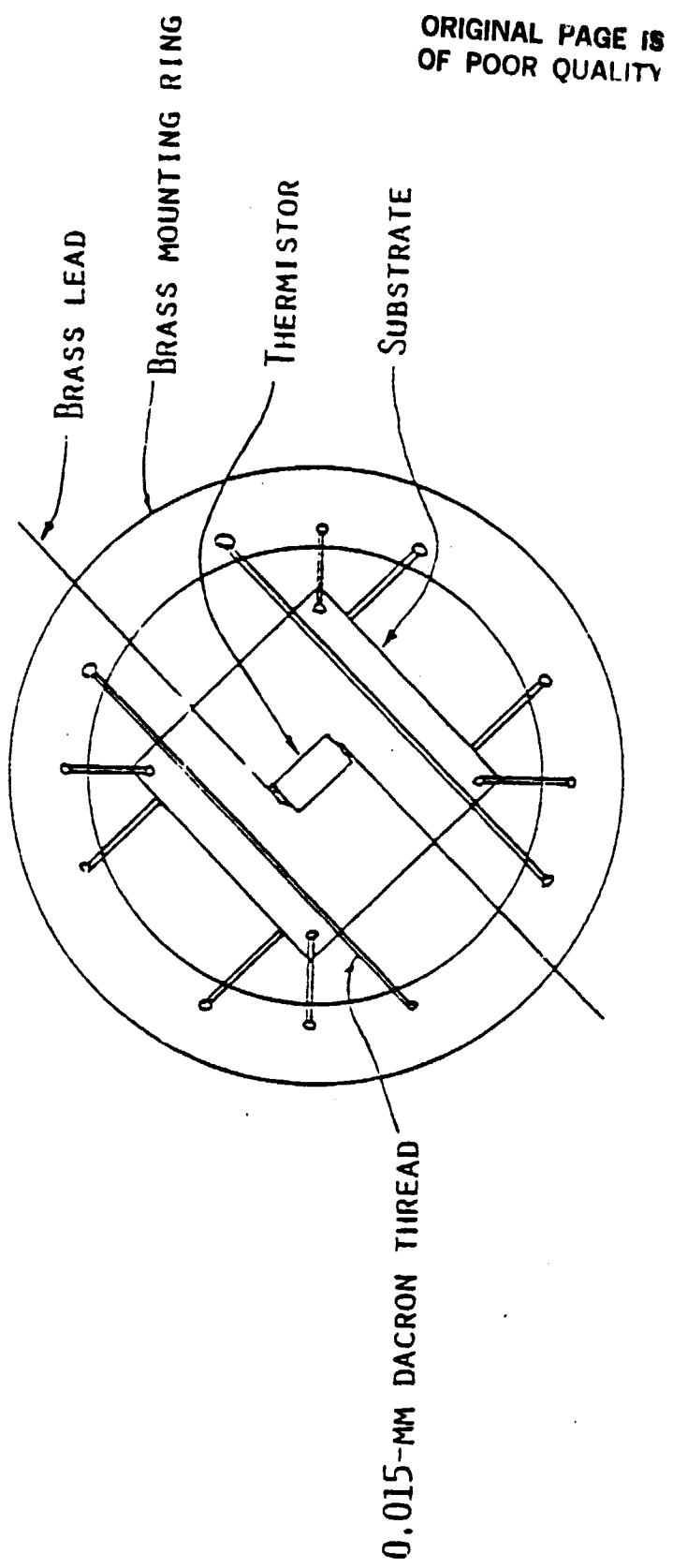
Figure 1

Figure 2 - Composite bolometer used in the ^{3}He dewar.
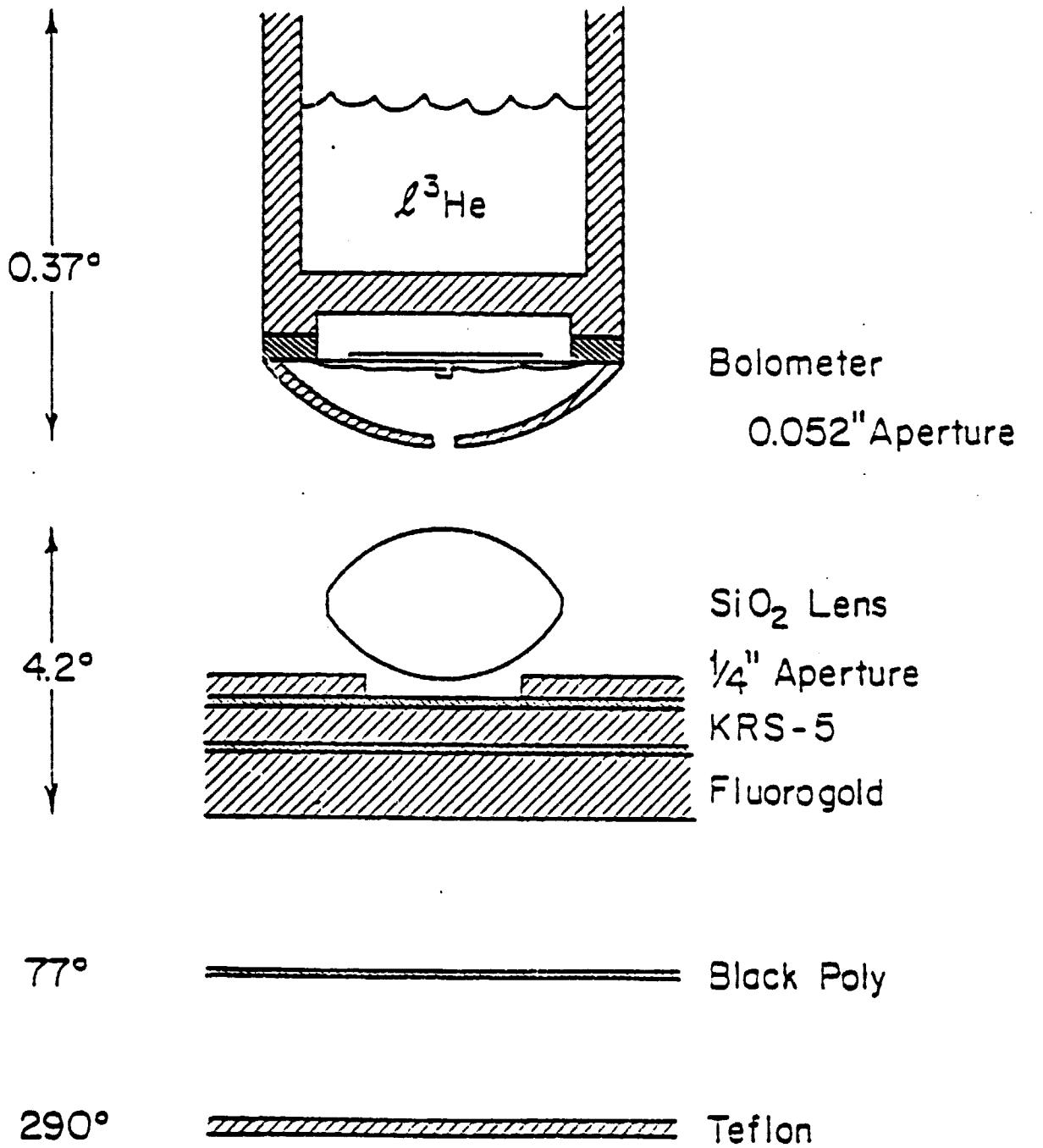
Figure 3

Figure 3

OPTICAL COUPLING

One of the main difficulties of a system of this type is to efficiently couple the radiation to the bolometer. Our first experiments used a quartz field lens to image the exit pupil to the source onto the entrance aperture of the bolometer cavity. In an effort to improve the coupling, a Winston cone was tested. Although superior- to-simple filed lenses, it did not perform better than our best field lens.

ELECTRONICS

Microphonics is one of the continual problems with many bolometer systems. This is because of the relatively small voltage responsivities of these devices. In a system used for routine observations all sorts of measures can be taken to reduce microphonic noise. Unfortunately, these procedures are not feasible in a system intended primarily for testing since they, in general, make rapid assembly and disassembly more difficult. We therefore equipped the system with an internal JFET preamplifier to reduce both the number and lengths of wires coming out of the dewar with low-level signals. The electrical noise sources are listed in Table 3. Table 4 gives a summary of the bolometer's performance.

Table 3
Dewar Noise at 10 Hz, Measured at the Bolometer

Background power noise	5.2 nV√Hz
Thermal fluctuation noise	5.0 nV√Hz
Bolometer Johnson noise	5.6 nV√Hz
Load resistor Johnson noise	3.2 nV√Hz
Excess current noise	4.9 nV√Hz
Preamp voltage noise	4.1 nV√Hz
Preamp current noise	5.4 nV√Hz

Table 4

Measured Bolometer Electrical Performance

Time constant C/C_e = 13.9 msec

Heat capacity C = 1.50 x 10^{-9} J/°k

Effective thermal conductivity G_e = 1.08 x 10^{-7} W/°K

Thermal conductivity G = 0.91 x 10^{-7} W/°K

Operating temperature T_b = 0.43°K

Load resistor R_L = 36.5 MΩ

CONCLUSIONS

We have developed a high-sensitivity ^{3}He cooled system for submilli-
meter astronomy. However, thre are still large gains to be had by
improving the coupling to the bolometer chip. This system was tested in
the field on the Palomar 5-meter telescope and achieved a sensitvity of
5.8 Jy/$(Hz)^{1/2}$. The electrical NEP of the bolometer was considerably
better an 10^{-15}W/$(Hz)^{1/2}$.