NATIONAL RADIO ASTRONOMY OBSERVATORY
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Report of Visit to Texas Instruments, Inc., in Connection with the Germanium Bolometer.

On February 1, I visited the Central Research Laboratories of Texas Instruments, Inc., in Dallas, to see if it would be possible to arrange the procurement of the low temperature germanium bolometer developed there. Conversations were held primarily with F. J. Low, the inventor, and J. R. MacDonald, head of the Physics section. It appears that this will be possible, and that we might obtain by April one of the bolometers complete with a dewar containing an appropriate window for millimeter waves, and a low noise audio amplifier that has been developed for use with the bolometer.

The characteristics of this system are as follows: the bolometer is a thin wafer of gallium-doped germanium, which, when reduced to liquid helium temperature, can detect a minimum power of about 10^{-14} watts with a one second time constant, and any bandwidth. It is installed in a cylindrical aluminum dewar consisting of an outer shield, an inner radiation shield, and inside this a liquid helium container of about one liter capacity. The bolometer is in a recess in one end of this helium container, and is exposed through a window of a suitably transparent material. The interior of the dewar is evacuated. No liquid nitrogen shield is used, helium vapor performing the task usually performed by liquid nitrogen. It requires about two liters of helium to fill the dewar, starting with the dewar at ambient temperature. It requires about one-half hour for thermal equilibrium to be reached, after which the helium holding time is about 24 hours (one liter of helium used). A special low noise audio amplifier must be used because of the low useful signal levels coming from the bolometer. A chopping frequency of about 35 cycles per second is being used as a design figure.

In utilizing the bolometer in observations, the greatest problems presently appear (and we are very naive now) to be not the attainment of high sensitivity, but rather the restriction of bandwidth to a desired band, calibration of intensities, and rejection of unwanted radiation. Very little technology exists in these areas, and what does exist is a combination of radio and optical techniques. The most desirable band at present appears to be the excellent window at about 1.3 mm wavelength, which permits about a 30% bandwidth (10^{11} cps). Windows at 2.2 and 3.1 mm should also be used. It is desirable to limit the bandwidth with a low temperature filter, to eliminate atmospheric radiation from the nearly opaque water vapor lines bounding the windows. This will be difficult. Geometric optics approaches are preferred at these wavelengths. At present, low pass filters are available at these frequencies, but the high-pass configuration required to produce, in total effect, a band pass filter will have to be developed.

Calibration is very difficult, particularly since filters and reflectors of unknown attenuation are necessarily in the optical train. A judicious use of black body radiators is probably called for.

The very strong rejection of unwanted radiations is quite important, since the bolometer responds well to radiation at frequencies from 0 to at least 10^{15} cycles per second, over which band there is strong thermal radiation from the earth, the atmosphere, and most celestial objects. Radiation on most frequencies is much stronger than in the band of interest to us. Therefore, attenuations of the order of 60 db and more over this broad band must be present if leakages at these frequencies are not to dominate the signal and noise in the system. These will have to be obtained by careful design of the optical system, and the use of excellent cold filters.

Antennas will have to have surface tolerances of the order of 0.1 mm, or 0.004 inches. These may be best obtained, probably, through use of surfaces which give good specular optical reflections, and using standard optical testing and figuring techniques to obtain a surface of the required accuracy. It probably would be worthwhile to attempt to generate the proper surfaces by spin casting epoxy resins on a back-up structure, since the successful development of this technique would lead to great savings in time and money in the procurement of collecting area. It is possible to obtain epoxy resin which has the same thermal coefficient of expansion as aluminum, making aluminum the preferred back-up structure, for this as well as other reasons. The major obstacle in spin casting is to overcome the effects of shrinkage (a fraction of a percent) of the epoxy resin during curing. This can almost certainly be overcome by cleaving the surface into many segments with expandable separators before curing, but perhaps there is a better way.

It is proposed that development of millimeter wave observing facilities be commenced following roughly this path:

1) Immediate procurement of the bolometer system as proposed by Texas Instruments.

2) Immediate procurement of the test equipment that would be useful in this project.

3) Immediate experiments with spin casting of epoxy resins, as well as inquiries to D. S. Kennedy to see what might be provided by them.

4) As soon as possible, the construction of a 3-foot antenna on an equatorial mount, for use in preliminary observations from the roof of Jansky Laboratory. This instrument alone will give signal/noise ratios with a one-second time constant of 3000 on Venus at inferior conjunction to 90 at superior conjunction, 500 on Jupiter, down to about 1 on Neptune or a typical comet. Some radio sources will be visible. The beamwidth would be 5'.

5) As experience allows, the construction of a 10 foot antenna for use at Jansky Lab or perhaps on Bald Knob or Buffalo Ridge (for reference, the amount of water vapor in a path to free space, taking 1 unit as the sea level value with a given humidity, is about .53 at Jansky Lab, about .32 at the altitude of Bald Knob or Buffalo Ridge, and about .12 at 9000 feet).

6) Eventually the construction of at least a 30-foot antenna at a very high, dry, site. Perhaps the proposed University of Arizona telescope will be available for this use.

I have said little about the astronomical applications here. There are quite many, including observations of all the planets, many satellites, several asteroids, comets, and other solar system objects. Many cosmic radio sources will be visible, extending spectra some three octaves. High resolution studies will be possible. Beamwidths of 0'.5 will be available with the 30 foot dish, and even higher resolutions with interferometer techniques that should not be too difficult. One might imagine the use of a 300 foot baseline, for instance, which would give a resolution of about 1".5 -- a resolution strictly comparable with optical resolutions.

F. D. Drake
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