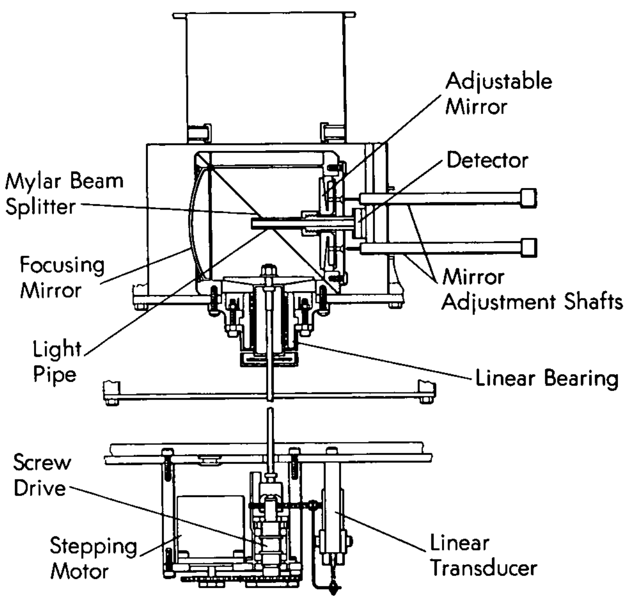
NASA TECH BRIEF

Ames Research Center

Liquid-Helium-Cooled Michelson Interferometer

The problem:

To design a rocket-flight spectrometer for examination of the far infrared emission spectra of astronomical objects; since emissions in this region are exceptionally weak, it is necessary to reduce spectral and thermal contamination from the earth's atmosphere as well as from the spectrometer itself.



The solution:

Construct a liquid-helium-cooled Michelson interferometer.

How it's done:

An interferometer was selected because studies showed that grating instruments suffer primarily from lack of throughput, that is, they have a low value of SΘ (where S is the area of the entrance pupil and Θ is the solid acceptance angle). Moreover, grating instruments occupy large volumes in flight packages and they have severe order-sorting requirements in the spectral regions of interest. In contrast, double beam interferometers (such as the Michelson instrument) and multiple beam interferometers (such as the Fabry-Perot types) are compact and have a large throughput.

The Michelson interferometer was selected for the intended purpose because it can be readily adapted to make spectral scans and can be used as a detector of discrete line emissions. Additional attractive features of this type of interferometer are that beam splitter requirements are not as severe as those for a Fabry-Perot instrument, and that very little predispersing is required. In principle, the Fabry-Perot interferometer has the higher resolution but when the reflectivity of the beam splitter is low, there is little difference between the performances of both types.

Design of the beam splitter for the Michelson instrument posed many severe problems, among which was the selection of a material of construction. Thin dielectric pellicles appeared to offer simplicity of fabrication; moreover, they require no compensating plates and are nearly as efficient as metal meshes. However, complications arise because pellicles have a finite thickness and, in effect, they perform as solid Fabry-Perot interferometers with their own channel spectra. Nevertheless, computations indicated that Mylar (refractive index 1.72) could be used provided large, self-supporting discs would perform at low temperatures.

The results of a program of investigation revealed that Mylar film discs stretched between two optically

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flat metal surfaces exhibited negligible sag (earth's gravity) and remained structurally intact on repeated cooling to 4°K. The sag for a 100-mm diameter film of the order of 0.0254 mm in thickness was found to be about 0.00058 mm; this sag can be tolerated even for an instrument used on the earth's surface.

One of the most severe problems in making a liquid-helium-cooled interferometer is the scan mechanism for the moving mirror. The mirror must move 2 cm with its surface perfectly parallel to the beam splitter. Bearings, and lubricants also constitute a severe problem at these low temperatures; however, these were originally circumvented by using fixed supports, spring strips, rollers, and a tungsten selenide cryogenic lubricant. In fact, the lubricant was found to perform so satisfactorily that it was possible to replace flat-on-flat sliding members with a linear bearing composed of rows of ball bearings retained in a steel cylinder. The efficacy of the arrangement which provided mirror motion was checked by observation of Fizeau fringes resulting from He-Ne laser illumination of the mirror and beam splitter; parallel motion over a 2-cm travel was within 5 fringes per centimeter.

A laboratory prototype of a flight instrument was constructed and tested. The interferometer assembly, its drive mechanism, and detector are shown in the diagram. For laboratory testing, these components were mounted in a nitrogen-jacketed liquid-helium Dewar which had provisions for pumping over the helium space. A flight Dewar with the same interior dimensions which incorporated super insulation in place of the liquid nitrogen was designed but never fabricated.

Note:

Requests for additional information may be directed to:

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Patent status:

No patent action is contemplated by NASA.

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