# TWO DEVICES FACILITATING SPECTROMETRY IN THE FAR INFRARED

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1. *A Balanced Thermocouple.* In spectrometric investigations in the infrared two principal difficulties are the extremely small energy available in the long waves, and the relatively great intensity of the near infrared. This latter is of particular importance in using an echlette grating which reflects the short waves with great intensity in high orders. The arrangement here described was devised to overcome both of these inconveniences.

If one chooses to use a thermopile as radiation sensitive device, practical reasons make the most sensitive form a single junction of the minimum possible surface area. This necessitates the use either of very short spectrometer slits and a spectrometer of great aperture, or of some device for refocussing the slit image, reduced in size, on the thermojunction without any considerable loss of light. This device has been employed in several cases. In the far infrared one is of course limited to the use of mirrors, which have inconvenient aberrations. It was found to be very satisfactory to use a thermocouple with two receivers about 1.5 mm in vertical dimension and 0.5 mm broad, located one above the other and very close together. The image of the emergence slit of the spectrometer, reduced about five times in size, is focussed on this pair of junctions by means of a concave mirror (a gilded plano-concave spectacle lens of —10 diopters), the upper half of the slit focusses on the lower junction and vice versa. The aperture of the spectrometer is F5. If the mirror just mentioned is made sufficiently large to catch all of the light, the reduced image will be diffuse due to aberrations. How this difficulty may be partly avoided may be seen by referring to Fig. 1. In the spectrometer plan, *M* represents a narrow vertical mirror which diverts the beam onto the emergence slit where an image of the primary slit is formed. This mirror is divided horizontally into two equal parts, each of which is slightly tilted from the vertical. The upper part throws the portion of the beam passing through the upper half of the slit slightly downward, and the lower half similarly diverts the rest of the beam upward. Consequently all of the light will fall on a mirror at *C* which is of less aperture than would otherwise be required, and the images on the thermojunctions are thereby sharpened. This device is only permitted by the fact that the mirrors *M* are very close to the emergence slit. Evidently the linear vertical emergence slit must be replaced by two half slits, coinciding at one end but making slight angles with the vertical, as shown in *B* of Fig. 1, which is a representation of the thermocouple arrangement and spectrometer slits in perspective.

For the spectrometer shutter, is used a very thin piece of glass, a plate of rock salt, or some other material which is transparent out to about 4$\mu$, but opaque to radiations between 30 and 100$\mu$. The shutter is placed before the primary slit and closes the upper and lower slit halves alternately. Now the wavelengths shorter than 30$\mu$ are cut

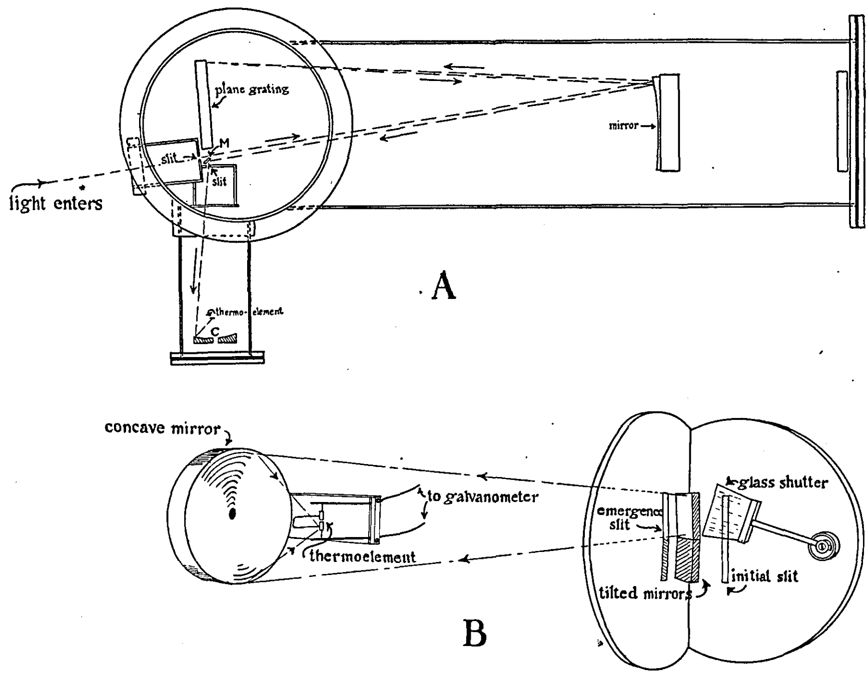


FIG. 1. *A. Plan of spectrometer. B. Thermoelement arrangement in perspective.*

down as much as possible by the use of rough mirrors and soot filters and a quartz window at the slit; but since that radiation which does get through falls about equally on both thermojunctions, the net effect is zero, and even if its intensity fluctuates no galvanometer deflection results. By a motion of the shutter, however, the long infrared rays may be caused to fall either on the upper or lower thermojunction and a double deflection results.

We have found this arrangement much superior to another means of doubling the galvanometer deflection, namely mechanically moving the thermocouple so that the slit image falls first on one and then on the other junction. The symmetry of the device described cuts down drift due to heating or cooling of the apparatus, and such drifts as are observed are usually to be ascribed to thermal potentials in the galvanometer.

This device, together with a d'Arsonval galvanometer of sensitivity $2.4 \times 10^{-9}$ ampere per mm at 1 meter, has been sucessfully used in investigating the absorption spectrum of hydrogen chloride between 70 and $100\mu$.[1]

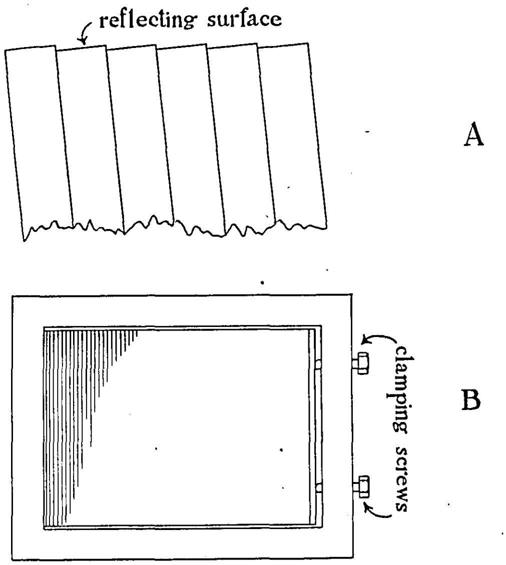


FIG. 2. *A. Section through a part of grating. B. Grating assembled in its frame.*

2. *An ideal echlette grating.* The writer has experimented with several forms of reflecting grating in an attempt to find one which will economically utilize the small intensities available in the far infrared. A form was first tried which has been employed by Witt.[2] This consists of a silvered glass mirror from which half the silver has been removed in equally spaced strips. Unfortunately glass in general reflects the far infrared rather well and the contrast between silvered and unsilvered glass is not nearly so great as is desirable.

The most efficient form of grating is of course that known as the "echlette." We have made some attempts at ruling very coarse gratings

[1] Badger, Pro. Nat. Acad. *13*, p. 408; 1927.
[2] Witt, ZS. f. Phys. *28*, p. 236; 1924.

of this type in brass, but with only moderate success. For a rather coarse grating, however, we have found very convenient and economical of light the device described below, which is an "adjustable echlette" with an ideal groove form. (It has been called to the author's attention that a device similar to the one described was suggested some years ago by Professor A. A. Michelson. The difficulties for the case of ordinary wave lengths, however, will be obvious.)

A considerable number of plane parallel glass plates of equal size and thickness are stacked face to face and clamped in a massive rectangular brass frame. In our case 64 plates of dimensions $0.163 \times 4 \times 8$ cm were used. The stack of plates is then ground and polished as a whole so as to form a massive plane parallel block, of which the plane surfaces are made up of the long edges of the individual plates. One of these surfaces is then coated with a metallic film by sputtering.

The clamping screws in the frame are then loosened just enough so that the plates will slide when moderate pressure is applied, and the stack is then staggered so as to form a stairway. This forms the grating surface. To obtain a regular step interval requires some ingenuity and patience. The best procedure is to place the frame so that the plate edges are vertical, and to push the individual plates from behind until their edges make contact with a very heavy straight edge which is held firmly, making the desired angle with the frame. If the straight edge is illuminated from below, by looking downward along the plate edges one can tell fairly accurately when contact is made. By adjusting the inclination of the straight edge to the frame one can determine the depth of each step, or the angle at which the grating will reflect at greatest intensity.

For best results the glass plates should be reasonably plane-parallel. It was found, however, that it is not really necessary to have them specially ground. Several hundred photographic plates were available, and from these twenty-five of most uniform thickness were chosen and cut into rectangular pieces of the proper size. From these about ten percent were selected as sufficiently perfect to meet the requirements. The grating constructed in this way was used in the investigations on hydrogen chloride mentioned above.

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