A New Electronic System for Detecting Microwave Spectra*

WALTER GORDY AND MYER KESSLER
Department of Physics, Duke University, Durham, North Carolina
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IN an earlier report[1] we described a single-crystal detecting system for microwave spectroscopy which employs a low frequency cut-off filter to eliminate the contour of the oscillator mode and the spurious signals caused by reflections in the microwave line. We have now improved the sensitivity of our system by a modulation technique which allows the signal to be amplified at higher frequencies.

Upon the slowly varying sawtooth voltage used to sweep the microwave oscillator over its mode we superimpose a radiofrequency voltage (≈ 100 kc) of low amplitude which causes the oscillator to be frequency modulated over a small range of frequencies, at a rate determined by the superimposed radiofrequency. An absorption line of a gas then acts as a discriminator to produce intensity modulation of the output radiation at a frequency corresponding to that of the modulating voltage. A single-crystal detector is used with an amplifier tuned to the modulating frequency. After pre-amplification at this frequency a second detector is employed followed by the filter mentioned above and by an audio amplifier. The filter we find effective against reflections. There are sharp, strong signals caused by the abrupt beginning and ending of the mode which are not eliminated by the filter. These are easily identified and are useful as indicators for crystal tuning and as markers to define the limits of tube oscillation.

Using the method described here with a 3.6-meter K-band wave-guide cell we easily detected the stronger lines of $N^{15}H_3$ in its naturally occurring concentrations of 0.3 percent in ordinary NH_3. A photograph of the 3,3 line of $N^{15}H_3$ thus obtained is shown in Fig. 1. The photograph of the 3,3 line of $N^{14}H_3$ in Fig. 2 demonstrates that good resolution can also be obtained. The distortions apparent in these photographs are not caused by the modulation but by the narrow band pass of the receiver used. Objectionable distortions can, of course, be produced by an incorrect modulation, but the adjustment of the modulation voltage is not critical.

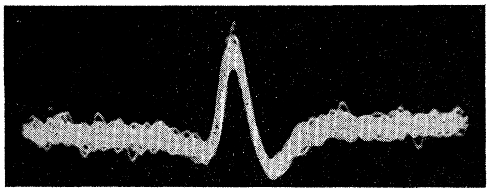

FIG. 1. Cathode-ray scope display of the 3,3 line of $N^{15}H_3$ at natural concentrations of 0.3 percent in normal ammonia. Cell length, 3.6 meters. Pressure, 2×10^{-3} mm of Hg. Modulation frequency 100 kc.

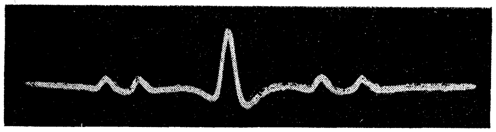

FIG. 2. Cathode-ray scope display of the 3,3 line $N^{14}H_3$ showing satellite structure. Cell length, 3.6 meters. Pressure, 4×10^{-3}. Modulation frequency 100 kc.

No greater sensitivity can be claimed for the system described above than for the Stark-effect modulation method of Hughes and Wilson.[2] In both systems the reception depends upon an intensity modulation produced by a high frequency motion of the signal in time (or components of the signal in the Stark-effect case). The present method has the advantage of being convenient to use with a cell of indefinite length. It is in general easier to modulate the oscillator than the molecules. The Hughes-Wilson method has the advantage of not requiring a filter to eliminate reflections.

A more complete description of the system will be reported elsewhere.

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[1] W. Gordy and M. Kessler, Phys. Rev. **71**, 540 (1947).

[2] R. H. Hughes and E. B. Wilson, Jr., Phys. Rev. **71**, 562 (1947).

New Atomic Lines in the Infra-Red Solar Spectrum

ROBERT R. McMATH, ARTHUR ADEL, LEO GOLDBERG, AND ORREN C. MOHLER
McMath-Hulbert Observatory of the University of Michigan
Lake Angelus, Pontiac, Michigan
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THE infra-red region of the solar spectrum offers a rich and unique field for astrophysical study, for it is here that one is most likely to encounter atomic lines of high excitation potential. Studies of infra-red lines may be expected to yield important information on the extent to which the solar atmosphere departs from thermodynamic equilibrium. They may also serve to provide a check on current theories of the solar continuous absorption coefficient, and can furnish valuable supplementary data for the laboratory analysis of spectra.

During the past two months, a Cashman lead-sulfide photo-conductive cell has been employed in conjunction with the McGregor tower and spectrograph of the McMath-Hulbert Observatory to map the solar spectrum in the region 1 to 2μ. The spectrograph is of the Littrow type, consisting of a 15,000-line plane grating and 25-foot lens collimator, the dispersion being 2.1A/mm in the first order. The spectrum was traced on a Speedomax recorder, the dispersion on the record being 1.63 mm/A. The limiting resolution on the tracings was determined by the widths of the entrance and exit slits, 0.25 mm, which corresponds to about $\frac{1}{2}$A in the focal plane of the spectrograph. The resolution appears adequate to register clearly faint Fraunhofer lines with equivalent widths as low as 0.01A.

The search for atomic lines was hampered by the absence of accurate laboratory wave-length standards beyond the photographic limit at about 13,500A. Approximate standards (within about 2–3A) were first established by the method of overlapping grating orders, with the expectation that the standards would be refined through the use of wave-lengths computed for atomic lines from accurate laboratory term values. Since the FeI atom is the most prolific source of lines in the photographic region of the solar spectrum, a search was first made in the extensive compilation of term values by Russell and Moore,[1] for lines in the region between about 15,000A and 16,500A. In this region only three multiplets permitted by *LS* coupling were found in the tables, the triad $3d^64s(a^6D)5s\,e^5D - 3d^64s(a^6D)5p u^5F^\circ t^5D^\circ u^5P^\circ$. Of the 33 possible lines in these multiplets, nineteen have been identified with practical certainty on tracings of the solar spectrum, while the remaining fourteen are too badly blended, usually with strong telluric lines of water vapor, to permit conclusive identifications.

With the aid of the accurate wave-length calibration established by the identification of the e^5D triad of FeI, many additional atomic lines have been identified, including more than 20 intersystem and interlimit combinations of FeI, 12 lines of SiI, 10 lines of CI, and several faint lines of TiI and VI. Many other lines of CI appear to be present, but the inaccuracies of the calculated wave numbers make the assignments precarious. The SiI identification includes most of the lines of the multiplets $4p\,^1P - 3d\,^1P^\circ$, $4p\,^1D - 4d\,^1D^\circ$, $4p\,^3D - 5s\,^3P^\circ$, and $4p\,^3D - 4d\,^3D^\circ$.

Approximate measures of intensity have been made for the e^5D triad of FeI. The equivalent widths of the strongest lines average about 0.25A, which is surprisingly high, in view of the high excitation potential (5.6 volts) of the e^5D term. A preliminary calculation indicates that the populations of the e^5D levels (as compared with the ground state) are at least 50 times greater than would be expected from a Boltzmann distribution at a temperature of 4800°K.

A full account of the present investigation will appear in the *Astrophysical Journal.*

[1] H. N. Russell and C. E. Moore, Trans. Am. Phil. Soc. 34, Part 2 (1944).

Conversion of Ordinary Sound into Second Sound

WILLIAM M. FAIRBANK, HENRY A. FAIRBANK, AND C. T. LANE
Sloane Physics Laboratory, Yale University, New Haven, Connecticut*

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IN 1938 L. Tisza[1] predicted theoretically that temperature fluctuation in liquid helium *II* should be propagated through the liquid as an undamped wave with a characteristic temperature dependent velocity. V. Peshkov[2] experimentally confirmed this prediction in 1944. He generated the second-sound waves by means of a resistance coil immersed in the fluid whose temperature was made to fluctuate by passing an alternating current of known frequency through it. This method of generating second sound was used in his later measurements[3] and also by us.[4, 5] Up to this time no successful experiments have been reported using other methods of generating second sound. The problem is one of creating a periodic change in the normal and superfluid components of the liquid. For example, a non-porous diaphragm vibrating perpendicular to its plane would not be expected to accomplish this purpose, but a diaphragm vibrating parallel to its plane should accomplish this phase separation, since the normal component has a non-zero viscosity. E. Lifshitz[6] has handled the above cases theoretically and also discussed the second-sound radiation from a surface whose temperature fluctuates periodically in time.

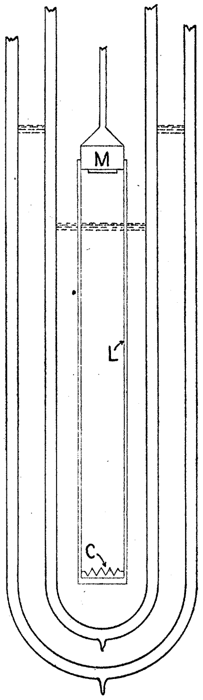

FIG. 1. Schematic diagram of the apparatus.

It occurred to us that it might be possible to generate second sound at a liquid vapor interface by allowing normal sound generated in the vapor to be reflected from the liquid surface. The consequent pressure fluctuations at this surface would be accompanied by corresponding temperature fluctuations giving rise to second-sound waves in the liquid column. Figure 1 is a schematic diagram of the apparatus. In the inner Dewar flask is placed a Lucite tube (*L*) closed at one end by a magnetic-type microphone (*M*) and at the