V. RADIO-FREQUENCY SPECTROSCOPY

A. MOLECULAR-BEAM RESEARCH

Prof. J. R. Zacharias	Dr. G. Knight
Prof. B. T. Feld	Dr. H. Lew
Dr. D. E. Nagle	Dr. J. Levinson
Dr. L. Davis, Jr.	Dr. C. W. Zabel

T. M. Hahn, Jr.

1. Hyperfine Structures and Nuclear Quadrupole Moments of the Halogens

Work has been continuing on this project. No results can be reported at this time because of troubles encountered in converting the atoms of the beam into ions for the analyzing mass spectrometer. During the tuning of the apparatus with beams of potassium atoms, the Zeemann effect of the ground state has been observed at 0.5 gauss, the field of the earth. These lines have a half-width of 1 per cent of the Zeemann frequency. A Technical Report is being prepared, as well as a paper for submission to the Physical Review.

Prof. J. R. Zacharias, Dr. D. E. Nagle, Dr. C. W. Zabel

2. The Hyperfine Structure and Quadrupole Moment of Al^{27}

A Technical Report and a paper are being prepared to summarize this work.

Dr. Hin Lew

3. Third Molecular-Beam Apparatus

Progress is being made in the construction of the third molecular-beam apparatus. The location of leaks in the vacuum system is not completed yet. The construction of deflecting magnets in the machine shop is continuing.

Dr. Hin Lew

4. Theory of Nuclear Effects in Microwave Spectra

The theory of the effects of nuclear electric quadrupole moments on the rotational spectra of slightly asymmetric rotor molecules (see previous progress reports) has been applied to the results of Prof. E. B. Wilson and co-workers of Harvard on vinyl chloride. The agreement between theory and experiment is excellent. Publication of the results of this comparison is being postponed until the experimental results of the Harvard group have been published.

Prof. B. T. Feld, Dr. G. Knight

5. Theory of Nuclear Electric Quadrupole Moments

Work continues, along the lines outlined in the last progress report.

Prof. B. T. Feld

6. The Nuclear Spin and Magnetic Moment of Na^{22}, Cs^{137}

A paper is in preparation on the spins and moments of Na^{22} and Cs^{137}.

Prof. J. R. Zacharias, Dr. L. Davis, Jr.

7. The Nuclear Spin and Magnetic Moment of Cs^{137}

Search is being conducted for Cs^{135} to determine spin and moments.

Prof. J. R. Zacharias, Dr. L. Davis, Jr.

8. The Fourth Atomic-Beam Apparatus

Design considerations have been completed for a short atomic-beam apparatus. This apparatus is designed so as to possess a large solid angle at the detector. The apparatus is intended primarily for use with radioactive substances which are available only in small concentrations.

Machine work on the main vacuum system is now in progress.

T. M. Hahn, Jr.

B. MAGNETIC NUCLEAR RESONANCE

Prof. F. Bitter	W. Dickinson
N. I. Adams, Jr.	T. Wimett

1. Nuclear Resonances at Low Temperatures

The liquid-air-cooled magnet is now in successful operation. The design of a Dewar to be used in the measurement of nuclear magnetic moments at helium temperatures in conjunction with this magnet has been completed. The essential feature of the Dewar is that both the r-f coil containing the sample and a dummy coil to balance the steady signal are wound in the evacuated space on the inner tube of the Dewar. In this way it is hoped that an increased signal and an increased stability of r-f balance with respect to temperature drifts can be obtained. N. I. Adams, Jr.

Two other circuits have been operated in liquid helium. One, a 30-Mc circuit, has been used in a water-cooled air-core solenoid capable of being operated up to 60,000 gauss. The field of this solenoid is so inhomogeneous that its usefulness for resonance experiments is limited to the investigation of very broad resonances.

Very good resonances have been found in ordinary copper and aluminum powders. Oxide layers effectively insulate the particles. Resonances in copper powders have been observed from liquid helium to room temperatures in a 4.6-Mc circuit. The entire resonant circuit in which the sample is placed is in the refrigerated region of the cryostat. The observed signal-to-noise ratio varied approximately as the inverse absolute temperature.

W. Dickinson

2. The Optical Detection of R-F Resonance

Radio-frequency resonance between adjacent levels (usually Zeemann levels) in an atom or molecule has been observed either by noting a change in the response of the r-f circuit, as in nuclear-induction experiments, or in observing a change in the stage of the atomic system, as in atomic or molecular-beam experiments. A third possibility is to observe a change in the radiation emitted by an atom in the presence of an r-f field producing resonance in one of the two states involved in the radiation process.

A theoretical investigation (1) of the frequency, intensity, and polarization of the light emitted by a one-optical electron atom in a ^2P - ^2S transition has been completed. It is to be expected, quite generally, that the optical radiation of an atom will be affected by the presence of an r-f field in resonance with the levels in either the upper or lower state involved in the transition.

The interest in this approach to the problem lies in the fact that optical experiments can be performed with relatively few atoms confined in a sealed-off vessel, and that the obtainable precision is determined by the width of the levels used in the experiment, rather than by the observed width of the radiated line. The method may, therefore, be applicable to the measurement of hyperfine structures of isotopes available in only small quantities.

The difficulty of the method lies in the fact that, with available optical resolving powers, the components of the line being studied will not be resolved. There will, however, be a difference in the state of polarization of various parts of a line, and resonance would have to be detected by a change in this resonance structure. It is pointed out that very small changes in the polarization structure of a line can be observed by the usual method of modulating the change at a frequency which can be selectively amplified.

F. Bitter

3. Deuteron-Proton Moment Ratio

The Helmholtz coils to be used in providing the field for this measurement have been assembled, and preliminary tests on cooling and winding resistance have been made. Field homogeneity will be examined by means of a probe consisting of a small oil sample (one-quarter-inch coil) which produces proton resonances at 4.5 megacycles with 1000 gauss. The deuteron-proton moment ratio is in the process of being measured roughly in the iron-core magnet at 1200 gauss. Stabilized oscillators have been obtained, and work is in progress on the high-precision frequency-measuring circuits.

T. Wimett

C. PARAMAGNETIC RELAXATION

Prof. A. F. Kip
R. D. Arnold

1. Resonance Absorption

The measurement of resonance absorption in an iron single crystal in a static magnetic field has been completed. The work has been summarized in Technical Report No. 91 and in an article submitted to the Physical Review.

2. Absorption in the Absence of a Static Magnetic Field

The resonant cavity mentioned in the previous progress report has been completed and tested. It is a singly re-entrant cylindrical cavity; a section through the axis is shown in Figure V-1. The frequency may be changed in steps from 300 Mc to 480 Mc by inserting capacitor plates (P) of various sizes; at each step a continuous variation of about 10 per cent may be obtained by distorting the diaphragm (D). Power is coupled in and out by means of magnetic loops (L). The Q of the empty cavity is about 1500 to 2500, depending on the frequency.

Measurement of Q is accomplished by comparison of the power transmitted through a calibrated attenuator. The latter consists of a stock cutoff attenuator equipped with a micrometer head, and settings accurate to about 0.1 db are possible.

Comparison of the two channels is made after the r-f signals are crystal-detected. At first, 1000-cps amplitude modulation was used but proved unsatisfactory because of the presence of a large amount of accompanying 1000-cps FM in the generator. Pulse modulation will therefore be used; 120-cps FM in the generator may be eliminated by letting the pulserepetition rate be 60 cps, synchronized to the line.

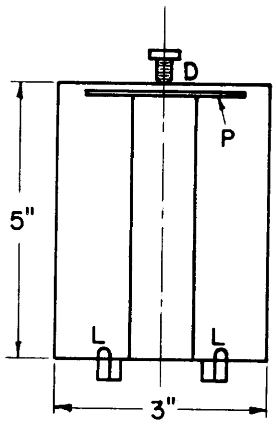

Fig.V-1 Tunable resonant cavity.

The frequency of the r-f signal is measured by mixing it with a constant signal from a TS-175/u meter and observing the beat frequency with a communications receiver. Absolute accuracy is no better than with the TS-175/u alone, but small differences of the order of the cavity width can be more accurately measured.

D. MICROWAVE SPECTROSCOPY

Prof. M. W. P. Strandberg	J. G. Ingersoll
Prof. G. G. Harvey	H. R. Johnson
Prof. A. G. Hill	G. W. King
J. R. Eshbach	R. B. Lawrance
B. V. Gokhale	C. C. Loomis
R. E. Hillger	M. T. Weiss

The work in progress is most conveniently discussed by the molecules studied: 1. atomic hydrogen (H); 2. germane monochloride (H_3GeCl) and dimethyl telluride, $Te(CH_3)_2$; 3. mercurous chloride (HgCl); 4. ketene, (H_2C_2O), formaldehyde (H_2CO) and water (HDO), and 5. oxygen (O_2).

1. Hyperfine Structure of Atomic Hydrogen

The apparatus has been operating, and several runs have been made without finding a line. Careful checking has not revealed any significantly nonoptimum parameter relationships. It seems likely that at least another factor of 10 in sensitivity is needed. It is proposed to lay aside the work on hydrogen temporarily and complete the study of the rotation operation of formaldehyde which was started a year ago by Kyhl and Strandberg.

R. B. Lawrance

2. Germane Monochloride and Dimethyl Telluride

The work on tellurium has been dropped temporarily, chiefly because no positive results have been obtained to date and because of the detrimental effects from decomposed $Te(CH_3)_2$ on the sweep spectroscope. The preparation of other molecules containing Te has been determined to be very difficult.

Work has commenced on germanium to determine some of its atomic and molecular properties, particularly to see if Ge^{73} has a quadrupole moment. It would be interesting to measure the Stark splittings of the quadrupole components of the molecular rotational levels in the microwave region. A series of symmetric molecules are available, namely: GeH_3F, GeH_3Cl^{35}, and GeH_3Cl^{37} and GeH_3 Br. The $J = 1 \rightarrow 2$ transition of GeH_3Cl lines are around 18,000 Mc, the $+J = 2 \rightarrow 3$ are around 27,000 Mc. The latter compound has been manufactured and search made for absorption covering the region 17,500 Mc – 25,500 Mc with negative results. The search will be finished (going to 26,500 Mc) and then a new sample will be tried with, it is hoped, more success than previously. R. E. Hillger

3. Mercurous Chloride

A search has been made for the $J = 2 \rightarrow 3$ and $J = 3 \rightarrow 4$ lines of HgCl in the hot-guide spectroscope but no lines have as yet been found. An improved hot-guide spectroscope which will have less attenuation than the present one, and which will work up to 250°C, is now under construction. The rotational spectrum of mercurous chloride as well as other mercury halides will be investigated in the new spectroscope. M. Weiss

4. Ketene, Formaldehyde, and Water

Time has been spent removing corona and eliminating sparking troubles from a pilot model general-purpose klystron power supply. The K/2 and K/3 sweep spectroscope system is being set up again, and further work on ketene, formaldehyde, and possibly HDO, is contemplated.

Prof. M. W. P. Strandberg, H. R. Johnson

5. Oxygen

We are continuing work on the microwave spectrum of oxygen at low pressures. It is important to measure the individual absorption frequencies in order to study the effect of pressure on line-breadth constant. We tried to locate the absorption frequencies by using a frequency-modulated signal but this attempt was not successful. We are now using a signal of fixed frequency and applying a Zeemann field to the gas so that its absorption frequencies may be varied by varying the magnetic field. It is hoped that it may be possible to detect and to measure the individual absorption lines by this method.

Prof. M. W. P. Strandberg, J. G. Ingersoll, B. V. Gokhale

6. Slow-Sweep Spectroscope

Work has been started on a microwave spectroscope which will employ a large time constant and thus an extremely slow sweep rate. The purpose of this spectroscope is to obtain higher resolution and signal-to-noise ratio than has been realized in the present sweep spectroscopes. It will be used to investigate further the fine structure on the rotational-transition absorption lines due to isotopic substitution in the molecules. From measurements of intensity ratios, relative abundance of isotopes can be determined. The spectroscope constants can be determined. The spectroscope will be employed primarily for detailed investigation of spectra already observed in the faster sweep-rate systems employing oscilloscope presentation.

The slow-sweep spectroscope will use the well-known Stark modulation scheme with a crystal detector, i-f amplifier and locked-in ammeter.

The Stark modulator is in the testing stage at present. The potential available is 0-1500 volts at 85 kc/sec. The amplifier and detector are under construction.

J. R. Eshbach, M. W. P. Strandberg

Reference

(1) Technical Report No. 98, in manuscript.

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