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(CRL Research in Progress)

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PUBLICATIONS

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Microwave Spectra of CsF, CsCl and CsBr
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Phys. Rev. 92, 901 (1953).

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R. L. White and C. H. Townes
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Nuclear Moments of Se^{79}
W. A. Hardy, G. Silvey, C. H. Townes, B. F. Burke,
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SUMMARY

A. Magnetrons

Additional work has been done on high power magnetrons operating at a wavelength of 6 mm. Previous work has shown a high operating efficiency and maximum power output for these tubes. Work directed to the development of improved windows and cathodes for the tubes is reported.

The inauguration of a program directed toward a study of harmonic generation in magnetrons is reported. The program has the twofold objective of clarifying certain aspects of magnetron operation and of exploring the possibilities of developing magnetrons with useful harmonic output.

Additional magnetrons to operate at low magnetic field and a wavelength of 2.6 mm have been constructed as have tunable magnetrons at a longer wavelength. It is clear that considerable technical development is required to produce satisfactory magnetrons in either of these categories.

B. Microwave Physics

The observation of certain transitions among the components of the metastable state of hydrogen is reported which permit a preliminary estimate of the hfs separation of that state to be made

The molecular beam oscillator has been successfully operated in a preliminary way as an amplifier of microwaves rather than as an oscillator. The emission line of NH_3 which was observed appeared to be very narrow as had been expected although direct measurement of the width has not yet been made.

The high resolution microwave bridge spectrometer has allowed a number of measurements of the very small magnetic hyperfine interactions in $^1\Sigma$ molecules.

Improvement of the spectrometer for free radicals has resulted in detection of a number of new lines of OH and its isotopic species. All experimental information needed for understanding the OH hyperfine structure seems now to have been obtained.

I. THE GENERATION OF HIGH FREQUENCIES

A. 22 Vane High Power Magnetrons at 6 mm (RPB7)

(M. J. Bernstein, N. M. Kroll, and R. Steinhoff)

Two new RPB7 tubes have been built and tested during the past quarter. Several Alsimag 243 ceramic windows have also been completed using the moly-manganese powder method.

A mixture of 80% moly and 20% manganese fine powders is fired on the ceramic surface at approximately 1350° C in a hydrogen atmosphere. A layer of fine nickel powder is then sintered on the moly-manganese surface at 1000° C in hydrogen. The nickel surface is then BT brazed inside a No. 52 Alloy window cup.

RPB7-20A This tube contained an impregnated "L" cathode and was provided with a glass window so that the cathode temperature could be measured during operation. The efficiency maximum was 29.8% at 27.8 amperes and 19.1 kv. At this point 158 kw was measured. A maximum power output of 176 kw at 27.8 amperes and 22.1 kv was measured. Wavelength was measured as 6.30 mm. The duty cycle used was .00005 (21 μs, 240 cps). Temperature measurements indicate that the duty cycle may be increased by a factor of 4 without excessive back heating of the cathode. The glass window will be replaced with a ceramic one and the tube will be retested at higher duty cycles.

RPB7-21A This tube was provided with a moly-groove-oxide cathode and used a ceramic window. Severe arcing during aging resulted in a quite inefficient tube. The maximum efficiency measured was only 12.8% at a maximum output power of 100 kw. Wavelength was 6.39 mm.

Several more tubes will be built with ceramic windows utilizing both the impregnated "L" and moly-groove-oxide cathodes.

B. 22 Vane Magnetrons at 4.3 mm (RPB8)

(M. J. Bernstein)

One new tube, RPB8-6, has been built and tested during the past quarter. The tube contained a moly-groove-oxide cathode and was provided with a cathode centering jig. At 11.2 peak amperes and 13.4 kv a maximum power output of 31.6 kw at a maximum efficiency of 21% was measured (19,150 gauss). Operation at low currents, below 9 amperes, was quite mody and the high efficiencies (above 10%) were obtained only at currents above this value. Wavelength was 4.34 mm.

C. Harmonic Generation in Magnetrons

(M. J. Bernstein, N. M. Kroll, and W. Strauss)

The study of harmonic generation in magnetrons with circuits designed to resonate to a selected harmonic component was started by Ashkin, Lamb,[1] and Gourary.[2] This investigation is now being continued with the following objectives: to study the space charge distribution of an oscillating magnetron by measuring the Fourier components of the spokes, and to explore the practical possibilities of developing harmonic generator magnetrons.

An anode has been designed and a hob constructed for the XH1. The fundamental and harmonic mode spectra of this tube, whose fundamental π-mode resonance lies in the X-band (~3.5 cm) will be investigated on a pattern analyzer which is now being completed by the shop. The anode dimensions of the XH1 are as follows:

D_A = 0.473 in.	N = 18
D_{M_1} = 0.811 in.	θ = 0.06025
D_{M_2} = 1.134 in.	h = 0.588 in.

A brief comment on the design of the XH1 is in order. Since the anode diameter varies directly with the number of resonators, a choice of large N will yield a large anode and consequently also a large pattern analyzer. This has the advantage of relative ease of construction of the analyzer by obviating the need for extremely small tolerances. On the other hand, small N lends itself more readily to mode identification than large N because: there are fewer modes to identify, the pattern displayed on the oscilloscope will be less complicated, and because the probability of overlap of a higher order harmonic of a low frequency mode with some harmonic of a high frequency mode is reduced. The choice N = 18 is a compromise between these two considerations; furthermore, function tables exist for N = 18. The other anode dimensions were chosen to give:

a fundamental π-mode resonance at about 3.5 cm, a large copper to space ratio, and a resonator depth ratio and a V_o for good operation in the medium voltage range.

1. NDRC, Div. 14, Report No. 588, April 1, 1946, Centimeter Magnetrons, p. 146.
2. CRL Quarterly Report, June 30, 1949, p. 14.

D. Crown of Thorns Tuning of Rising Sun Magnetrons

(M. J. Bernstein, N. M. Kroll, K. R. Rubin, and W. Strauss)

Calculations of the effect of the resonator depth ratio, r_1, on capacitive tuning have been completed. The basic design constants were taken from the RA1; these were slightly modified to permit use of existing function tables.

D_A = 0.420 cm (0.165 in.) θ = 0.06025

$D_{M_1} + D_{M_2}$ = 1.760 cm (0.693 in.) σ = 0.634921

N = 18 d = 0.01265 cm (0.005 in.)

The pin and resonator arrangement used in these calculations is shown on page 4, CRL Quarterly Report, August 31, 1953. The results given below apply to maximum capacitive tuning (by suitable choice of pin length) for each value of the resonator depth ratio.

Depth Ratio, r_1	1.706	1.788	1.875
% tuning	18.5	19.1	19.9
r_3	5.4	5.3	5.4

where:

$\%$ tuning = $\frac{\nu_o - \nu}{\nu_o}$ x 100%

ν_o = resonant frequency with pins removed

ν = resonant frequency with pins completely inserted

$r_3 = \frac{D_{M_2}}{l_m}$

l_m = pin length for maximum tuning

The calculated results clearly show that the % tuning increases steadily with depth ratio. This trend is further borne out by an earlier calculation on a different rising sun anode block where a tuning range of 31.5% was obtained for a depth ratio of 2.65. An open ended model of the RA 17 whose anode block height is 0.200 in. was hot-tested. The π-mode tuned from 1.603 cm with the pins out to 1.5825 cm with the pins 0.081 in. below the edge of the anode block. With the pins fully inserted power output was observed at a wavelength of 1.289 cm. No power output was observed for pin penetrations lying between .081 in. and full insertion.

This failure may be due to pin to wall contact. For a penetration of 0.050 in. the observed power was 15.8 kw at an efficiency of 23.5%.

To overcome some of the above difficulties, closed and semi-closed models of the RA 17 are being tested.

A closed-end model of the RA 17 has been constructed and cold-tested. The anode height of this model is 0.334 in. Cold-test data indicate a tuning from 1.246 cm with pins out to 1.170 cm with a pin penetration of 0.275 in.

A semi-closed model of the RA 17 whose anode is 0.170 in. high, has also been cold-tested. This tube tunes from 1.260 cm with the pins out to 1.185 cm with the pin penetration equal to the height of the anode block.

E. Low Field Operation of Magnetrons

(A. H. Barrett, M. J. Bernstein, N. M. Kroll, K. R. Rubin, and R. Steinhoff)

RV1 Series (20 vane tubes)

An attempt was made to operate a low field magnetron at 1.25 cm under CW conditions. A .040 in. moly cathode, indirectly heated, was inserted into an RV1 tube (RV1-34W) of .175 in. anode diameter (σ = .23). The method of heating the cathode, by use of a .030 in. tungsten rod in the supporting stem, causes the stem to run at a higher temperature than the cathode surface. Consequently most of the emission is obtained from the stem which is inside the pole piece. The tube therefore acts like a non-magnetic diode. No oscillating current was obtained.

The ability to operate an RV1 tube under CW conditions will depend on the design and construction of a cathode in which the emitting surface is hotter than any part of the supporting structure.

RP3 Series (22 Vanes, 1.0 cm)

Another tube, RP3-2W, identical in construction to RP3-1W reported in the CRL Quarterly Report, Oct. 30, 1953, has been built and tested. Operation was very similar to No. 1W. The operating field ranged from 2860 to 4820 gauss (B/B_o = 1.17 to 1.98). The maximum efficiency was 4.8% at 4560 gauss and 19.3 kv.

The maximum peak power was 1.9 kw at 4240 gauss and 17.9 kv. The operating voltage range was 9.4 to 22.4 kv and the peak current range .8 to 11.3 amperes. π-mode wavelength was 1.02 cm. Other modes at 1.45 cm and 1.37 cm were also observed.

RPB9 Series (22 Vanes, 2.6 mm)

Two new tubes with the same geometry as the previous six were constructed and tested. Both tubes operated very poorly.

RPB9-7W Only enough power to measure a wavelength, 2.61 mm was obtained from this tube.

RPB9-8W A maximum power of .5 kw at .3% efficiency was measured at 8.3 amperes and 19.6 kv (15,000 gauss). Wavelength was measured as 2.65 mm.

Arcing at high voltages is still a problem in the RPB9 tubes. However, it has not been as serious in the last two tubes as in the earlier ones.

Several more tubes, in which the cathode diameter will be changed from the present size of .029 in., will be built to determine whether improved operation can be obtained.

F. Generation of Millimeter Waves by Cerenkov Radiation

(M. Danos and H. Lashinsky)

Some of the parts for the improved vacuum system[1] are still under construction. The completed parts have been assembled and are being vacuum tested. The "can" has been disassembled to permit the removal of carbon deposits from all electrode surfaces. When the equipment is reassembled, a search will be made for Cerenkov radiation at frequencies corresponding to harmonics of the bunching frequency.

Calculations of the Cerenkov radiation for various geometries and media are continuing.

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1. CRL Quarterly Report, Oct. 30, 1953, p. 7.

G. Molecular Beam Oscillator

(J. P. Gordon)

Several improvements of the apparatus have resulted in the first observation of the NH_3 3-3 inversion emission line. The interference effects[1] due to the 33-cycle beam chopper have been largely eliminated by constructing the beam chopper of mica so that it will not reflect microwave radiation, and by inserting a one inch long section of copper tubing at the beam entrance slit of the resonant cavity to act as a waveguide beyond cutoff.

The line was observed without lock-in detection with a strength about equal to noise. A leak in the apparatus prevented adjustment of the source position to optimise the signal strength, and no accurate estimate of the line-width has yet been made. The leak has been found, and new attempts will be made to record the line.

Further isolation of the NH_3 source chamber from the focusser and detector chamber has been effected, which should improve the signal strength. Previously a pressure of about 2×10^{-5} mm Hg existed in the focusser chamber while the source was on, which made the mean free path approximately equal to the length of the apparatus.

1. CRL Quarterly Report, Oct. 30, 1953, p. 8.

II. MICROWAVE APPARATUS AND TECHNIQUES

A. 6 mm Electronic Spectrum Analyzer

(A. H. Barrett and M. J. Bernstein)

An electronic K-band spectrum analyzer has been modified for use at millimeter wavelengths. Previous attempts to do this had not been successful.[1,2]

Because of the doubtful stability of 6 mm klystrons it was decided to mix the 6 mm magnetron power with the second harmonic of K-band power. The latter is obtained from a crystal harmonic generator driven by a K-band klystron. To increase the signal input to the IF amplifiers the same crystal was used for generation of the harmonic and for mixing with the magnetron power. No spectrum was seen when separate crystals were used.

Spectra have been obtained at 6 mm using a 2K33 klystron as local oscillator and a broadband millimeter harmonic generator.[3] A spectrum has also been obtained at 4.36 mm using a British VX5023 (8-9 mm) klystron as the local oscillator source. No quantitative data or pictures have been obtained from these spectra, but it is hoped that the equipment will be improved so that this will be possible in the future.

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1. CRL Quarterly Report, Dec. 31, 1952, p. 17.
2. CRL Quarterly Report, Dec. 31, 1951, p. 9.
3. CRL Quarterly Report, Sept. 30, 1950, pp. 13-14.

B. Crystal Harmonic Generators and Detectors

(W. R. Bennett, A. H. Nethercot, Jr., and B. Rosenblum)

In order to improve the techniques for the generation and detection of millimeter waves, investigations of several phases of the problem are in progress.

1. Detector Design.

a. Output lead design: Several methods for the prevention of rf power leakage out of the coaxial output lead have been investigated at 6 mm. The various designs are shown in Fig. 1.

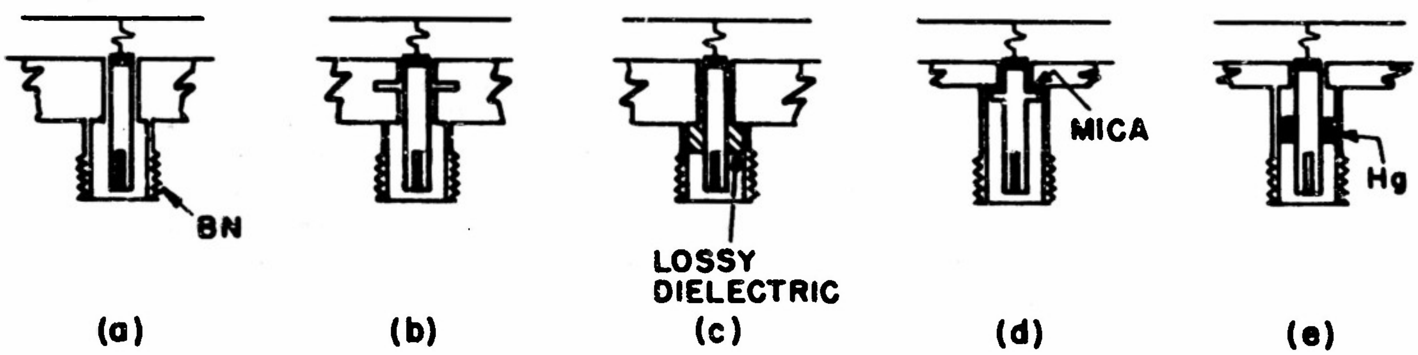

Figure 1. Output Lead Designs.

(1) Choke. A demountable version of the detector with and without choke (Fig. 1, a and b) was constructed, which permitted removal and insertion of the crystal and whisker without disturbing the whisker contact. It was found that the detection efficiency depended little on the presence of the choke. Therefore, the choke should be omitted, since it is not important and in any event would be narrow band and difficult to construct.

(2) Lossy material. The effect of lossy dielectric material in the coaxial output lead (Fig. 1, c) was investigated using the above demountable detector. The dielectric should make any power loss frequency independent, eliminating both abnormally high and low losses due to resonances in the output lead. No appreciable change was observed in the detection efficiency when the dielectric was inserted.

(3) Rf bypass condenser. A thin mica bypass condenser was inserted across the coaxial line (Fig. 1, d) without disturbing the contact. The detection efficiency was found to increase or decrease by a factor of about two depending upon the frequency, indicating that a tuning phenomenon rather than a bypass effect was occurring.

(4) The latter interpretation was confirmed by gradually raising a mercury column in the coaxial interspace, the inside surfaces of which are lacquered (Fig. 1, e). Any power loss occurring here must be very small, the only effect being to add variable amounts of susceptance in series with the antenna. A series of maxima and minima were observed in the detected signal as the height of the column was varied from zero to the top. The maxima were approximately twice the minima.

Since the broadbandness of the detectors is of great importance (they have been used over a two octave range), the decision has been made to sacrifice this possible improvement of at most a factor two and settle on the design shown in Fig. 1, a.

b. Effects of junction contact area: A differential screw was designed to lower the whisker point onto the silicon gradually, thus preserving the sharp point and hence perhaps minimizing shunt capacity due to the small contact area.

Preliminary results indicate no large improvement up to the seventh harmonic, but in view of the good results obtained by others, work will continue on the effects of contact area.

2. Harmonic Generator Design.

a. Tuning adjustments: It was found that the K-band plunger serves the double function of tuning the K-band and harmonic frequencies. Use of an adjustable shorting plunger (consisting of waveguide tapering from K-band to 6 mm guide which can slide in K-band guide with a separately adjustable 6 mm short inside) indicates that an improvement in harmonic power by a factor of two or three may be possible.

b. Variation of harmonic power with fundamental power: Since the harmonic power varies rapidly with the fundamental power, it is important to obtain as much power as possible from the klystrons. With certain 2K33's at certain frequencies, it was found possible to obtain higher powers by operating in a high voltage repeller mode (550-750 volts) and increasing the beam voltage to perhaps 2800 volts. In this manner powers of about 300 milliwatts have been obtained with tubes rated at approximately 40 milliwatts.

In order to determine the advantage to be gained from an increase of fundamental power, curves were taken of harmonic power versus incident fundamental power for the first four harmonics. Although the situation changes greatly from one contact to another, on the basis of preliminary data the following generalizations may be drawn:

(1) At low fundamental power levels (1 to 10 milliwatts) the variation of the nth harmonic power with fundamental is approximately $P_n \sim P_1^n$. There is considerable variation in the value of the exponent for a given harmonic from one contact to another (e.g., the exponent for the second harmonic varies from about 1.5 to 2.5).

(2) All curves show a definite saturation effect; i.e., at some high power level the curves begin to increase less rapidly than the original exponential. The point at which the saturation begins to be noticeable differs from contact to contact. For the second harmonic, for instance, saturation occurs at 20 to 100 milliwatts. In the 150 milliwatt region the second harmonic saturation becomes complete and there is no appreciable increase of harmonic power with fundamental power. There is some evidence to indicate that above the point of complete saturation the harmonic power may even decrease with increasing incident fundamental power.

The power levels at which successive harmonics begin to saturate appear to be displaced by perhaps 30 milliwatts toward higher powers for each successive harmonic up to the fourth. Figure 2 gives a typical curve.

We plan to extend these measurements to higher harmonics and investigate parameters, such as contact pressure, which may influence these characteristics.

c. Effect of temperature: A strong temperature dependence of the dc crystal characteristic is predicted by theory. A qualitative observation of the changes in the dc characteristic at dry ice and liquid nitrogen temperatures showed that the nonlinearity of the dc characteristics of some 1N26 crystals appeared to increase and go through a maximum around dry ice temperatures, though no temperature dependence has been found in the very preliminary results on harmonic generation.

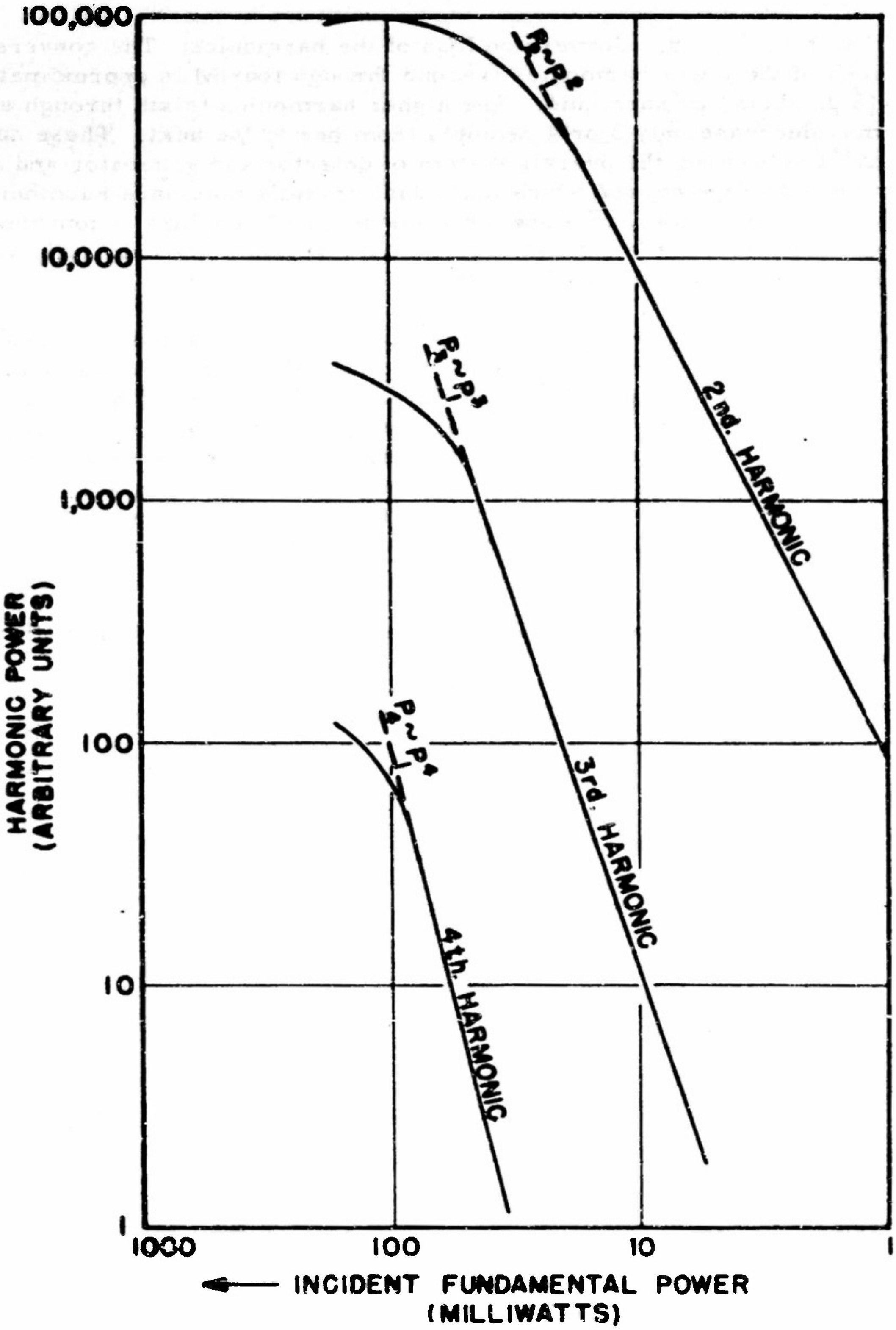

Figure 2. Harmonic Power Versus Fundamental Power

d. Conversion loss of the harmonics: The conversion loss of the lower harmonics (second through fourth) is approximately 15 decibels per harmonic. The higher harmonics (sixth through eighth) may decrease only 3 or 4 decibels from one to the next. These numbers are the loss for the overall system of detector and generator and apply to the average crystal since individual crystals may have harmonics missing completely or show other anomalous behavior. From these observations, the eighth harmonic would be down approximately 70 or 80 decibels from the fundamental.

The smallest conversion loss yet attained has been with a system having a signal to noise ratio of 1500 at the 7th harmonic and a band width of 1 cps. This type of crystal detector had been calibrated for absolute power measurements against a Golay cell some time ago.[1] If this calibration still holds, this system would have a conversion loss of 47 db for the generator alone. The early calibration[1] gave detector losses of 20 or 25 db from K-band detectors. The sum of detector and generator losses is consistent with the data of the first paragraph of this section.

Further work on conversion loss will be done with the Golay cell.

1. Klein, Loubser, Nethercot, and Townes, Rev. Sci. Inst. 23, 78 (1952).

III. TUBE FABRICATION TECHNIQUES

Hob Grinding and Hot Hobbing

(M. J. Bernstein and C. O. Dechert)

An 18 vane vitallium hob for XH1 (X-Band Harmonic Generator) tubes has been completed during the past quarter. Dimensions are as follows:

Anode diameter	.473 in.
Small Resonator diameter	.811 in.
Large Resonator diameter	1.134 in.
Vane thickness	.054 in.

Two anodes have been pushed. At 675° C approximately 15,000 pounds force is required to penetrate 15/16 in. into the copper.

IV. MICROWAVE PHYSICS

A. Hyperfine Structure of the Hydrogen Atom

(J. Heberle, P. Kusch, and H. Reich)

1. Dc Quencher

Two parallel metal plates have been mounted between the polarizer and the rf flopper so that the atomic beam passes between them. A voltage of 20 volts or more applied across the plates is sufficient to quench all metastable atoms, i.e., to cause them to return to the ground state.

A measure of the beam intensity is obtained by reading the galvanometer when the quenching voltage is on and also when it is off. The difference of the two readings is called the dc flop.

2. Rf Flopper

A new rf flopper has been installed. It has been designed so that the rf field is confined to a small region along the atomic beam.

The effect of rf is measured by reading the galvanometer when the rf field is on and when it is off. The difference between the two readings is called the rf flop.

The percentage flop ϕ is defined by

$$\phi = \frac{\text{rf flop}}{\text{dc flop}} \times 100$$

A General Radio voltmeter (type 1800-A) is used to monitor the rf voltage across the rf flopper.

3. Field Compensator

A rectangular coil 20 in. x 66 1/2 in. has been wound on a form around the apparatus at the same height as the beam. A current I_c through the coil produces a uniform vertical magnetic field in the region traversed by the beam. By adjusting I_c to an appropriate value it is possible to cancel out the vertical component of the earth's field.

4. Rf Resonances

Throughout a run the rf voltage was kept at a suitable constant value (of the order of 50 volts), while the percentage flop was measured at many different frequencies ν between 177 Mc/sec and 180 Mc/sec.

Two resonances, i.e., frequency bands within which ϕ is larger than elsewhere, were found. We interpret the resonances as being caused by transitions from sublevel 2 to sublevel 4 in one case, and from 1 to 4 in the other case. We have been able to determine ν_{24} with a precision of ± 10 kc.

We have also investigated how ν_{24} varies, as I_c is changed, and have found that ν_{24} shifted in the manner predicted by theory.

The main difficulty at present is that repeated measurements of ϕ under presumably fixed conditions, yield results which vary by as much as 3 percent; this introduces uncertainties in ν_{24} which are, however, very much less than 3%.

5. Theoretical Predictions

According to Fermi[1] the hyperfine splitting Δw of an s-term is given by

$$\Delta w = \frac{8\pi}{3}\,\frac{2I+1}{I}\,\mu\,\mu_0\,\psi^2(0)$$

where I is the nuclear spin, μ the nuclear magnetic moment, and ψ (o) the value of the normalized Schroedinger wave function at the position of the nucleus.

In a footnote Breit[2] gives

$$\psi^2(0) = 1/(\pi a_0^3 n^3)$$

Moreover Breit[2] gives relativistic correction factors for Δw. These factors are $1/[\rho(2\rho-1)]$ for 1s terms,

and $\left(\frac{2}{1+\rho}\right)^{3/2} \frac{1+(2\rho+2)^{1/2}}{\rho(4\rho^2-1)}$ for 2s terms,

where $\rho = (1-a^2)^{1/2}$

Accordingly, for the 1s term

$$\Delta\nu(1s) = \frac{8\pi}{3h}\frac{2I+1}{I}\mu\mu_0 \frac{1}{\pi a_0^3}\frac{1}{\rho(2\rho-1)}$$

and for the 2s term

$$\Delta\nu(2s) = \frac{8\pi}{3h}\frac{2I+1}{I}\mu\mu_0 \frac{1}{8\pi a_0^3}\left(\frac{2}{1+\rho}\right)^{3/2}\frac{1+(2\rho+2)^{1/2}}{\rho(4\rho^2-1)}$$

Since $\Delta\nu(1s)$ has already been measured with great precision,[3] we express $\Delta\nu(2s)$ in terms of $\Delta\nu(1s)$:

$$\Delta\nu(2s) = \frac{1}{8}\Delta\nu(1s)\frac{(2\rho-1)\left[1+(2\rho+2)^{1/2}\right]}{4\rho^2-1}\left(\frac{2}{1+\rho}\right)^{3/2}$$

After expanding in powers of α and neglecting terms of higher order than α^3, we obtain

$$\Delta\nu(2s) = \frac{1}{8}\left(1+\frac{5}{8}\alpha^2\right)\Delta\nu(1s)$$

We use $\alpha = 1/137.038$(4)

and $\Delta\nu(1s) = 1,420.4051 \pm .0002$ Mc/sec for hydrogen[3]

and $\Delta\nu(1s) = 327.38424 \pm .00008$ Mc/sec for deuterium[3]

Thus the theoretical values are

$\Delta\nu(2s) = 177.55655 \pm .00003$ Mc/sec for hydrogen

$= 40.92439 \pm .00001$ Mc/sec for deuterium

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1. E. Fermi, Z. Physik 60, 320 (1930).
2. G. Breit, Phys. Rev. 35, 1447 (1930).
3. Prodell and Kusch, Phys. Rev. 88, 184 (1952).
4. Dumond and Cohen, Revs. Modern Phys. 25, 691 (1953).

B. Fine Structure of the Singly Ionized Helium

(N. M. Kroll, E. Lipworth, and R. Novick)

Most of the parts for the new apparatus[1] have been fabricated.

1. The vacuum system and associated freon refrigeration system are ready to be assembled.

2. The interaction space has been completed and partially cold tested. The input and output couplings have been adjusted to give a loaded Q of 820 and an input voltage standing wave ratio at resonance of 1.5. Under these condititions it has been estimated that the effective power gains of the cavity will be 120.

3. In order to prevent overheating of the magnet coils it was necessary to reduce the magnet gap and modify the shape of the pole tips. The gap was reduced from 1.060 in. to 0.900 in. by allowing the pole tips to protrude through the vacuum envelope. This change reduced the current necessary for 18,000 gauss from 17.0 amperes to 13.5 amperes. The current was further reduced to 10.7 amperes by increasing the taper of the pole tips and by reducing the diameter of the tips from 4.50 in. to 4.25 in. At 11 amperes the temperature rise of the coils is 50° C while at 17 amperes the rise is 120° C.

The magnet regulator will be modified to permit operation at 11 amperes. This will be accomplished by using 30 type 6336 twin triodes as a series control element in the magnet power supply. Each of these tubes is capable of passing a current of 0.5 amperes. A new field coil is being provided for the magnetic diode current sensing tube. The coil has been designed to operate over a current range of 4 amperes to 11 amperes.

Work is continuing on the design of a pulser for the klystron.

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1. CRL Quarterly Report, Oct. 30, 1953 and June 30, 1953.

C. Nuclear Quadrupole Resonant Lines

(T. C. Wang)

Previous measurements[1] on the ratio $(eqQ)Cl^{35}/(eqQ)Cl^{37}$ by microwave absorption methods show that the ratio in GeH_3Cl is abnormally low. Since this compound is unstable and very hard to prepare in quantities sufficiently large to permit investigation in the solid state, a new measurement has been carried out with the high resolution spectrometer, in cooperation with Mr. R. L. White. Six runs were made recently and the results of measurements show some anomalies in the ratio $(eqQ)Cl^{35}/(eqQ)Cl^{37}$. Further investigation by pure quadrupole resonance techniques will be made.

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1. S. Geschwind, G. R. Gunther-Mohr, and C. H. Townes, Phys. Rev. 81, 288 (1951).

D. Very High Temperature Microwave Spectroscopy

(A. H. Barrett and M. Mandel)

The spectrometer was assembled and the NaI[1] spectrum was observed at a temperature of 630° C. An investigation of the KF molecule has been started. From our previous data on the alkali halides an internuclear distance of $r_e = 2.13$ A° is expected for KF and some lines have been predicted. At a temperature of 720° C the region from 17,000 to 17,700 Mc was thoroughly searched but no lines were found. On raising the temperature to ~800° the Stark plate shorted. The spectrometer is now being taken apart for repairs.

1. CRL Quarterly Report, June 30, 1953.

E. High Resolution Spectrometer

(R. L. White)

The microwave spectra of a number of molecules have been measured in the past quarter. The principal motivation has been in each instance to obtain the constant C in the Hamiltonian term $C(I \cdot J)$, representing an energy magnetic interaction of the nucleus with the surrounding field.

A sample of triply deuterated chloro-silane SiD_3Cl was obtained from Professor Børge Bak, of the University of Copenhagen. Professor Bak has been studying the effect of deuteration upon various molecular parameters, and was desirous of obtaining the variation in $(eqQ)_{Cl}$ with deuteration. Accordingly the K = 0 lines of the $J = 1 \rightarrow 2$ transition of SiH_3Cl and SiD_3Cl were measured, with the following results:

SiD_3Cl^{37}	$(eqQ)_{Cl}{}^{37} = -31.208 \pm .010$ Mc
	$c = +1.0 \pm 0.7$
SiD_3Cl^{35}	$(eqQ)_{Cl}{}^{35} = -39.595 \pm 0.10$ Mc
	$c = +1 \pm 0.9$ Mc
SiH_3Cl^{37}	$(eqQ)_{Cl}{}^{37} = -31.323 \pm 0.10$ Mc
	$c = +2.7 \pm 1.0$

Unfortunately the lines arising from the same transition in SiH_3Cl^{35} lay outside the frequency range of the spectrometer.

It will be noted that the deuterated compound yields an isotopic quadrupole ratio

$$\frac{(eqQ)_{Cl^{35}}}{(eqQ)_{Cl^{37}}} = 1.2687 \pm .0005$$

in good agreement with the atomic and solid state values for the ratio. Assuming the same ratio to hold for the non-deuterated chloro-silane one would calculate $(eqQ)_{Cl^{35}} = -39.739 \pm .015$ Mc. In both cases a decrease in quadrupole constant of about .037% results from the deuteration.

Chloro-germane has also been under investigation as was reported in the preceding progress report.[1] For both these compounds lines arising from states of non-zero K have also been measured. These states, since they show first order Stark effect, are extremely sensitive to the zero-basing of the Stark square wave voltage. A zero basing to better than 10 millivolts must be attained if lines are to be measured with the requisite accuracy, and the experimental problem of obtaining this zero-basing has not yet been solved satisfactorily.

A very large magnetic coupling constant c in the diatomic molecule ClF has been reported in the literature.[2] To check this remarkably large value the $\Delta J = 0 \leftrightarrow 1$ transition of ClF has been measured on the high sensitivity spectrometer with the assistance of Mr. Paul Fletcher. It was necessary to use this spectrometer because the high resolution bridge spectrometer is not sufficiently broad-band to pass the high frequency involved — over 30 kMc. Our measurements give the following parameters:

$Cl^{35}F$	$B_e = 15,418.275 \pm .003$ Mc
	$(eqQ)_{Cl^{35}} = -145.837 \pm .030$ Mc
	$c = +22 \pm 3$ Kc
$Cl^{37}F$	$B_e = 15,125.653 \pm .003$ Mc
	$(eqQ)_{Cl} = -114.977 \pm .019$ Mc
	$c = +18 \pm 3$ Kc

The isotopic quadrupole ratio

$$\frac{(eqQ)_{Cl^{35}}}{(eqQ)_{Cl^{37}}} = \frac{145.837 \pm .030}{114.977 \pm .019} = 1.2684 \pm .0005$$

is again in good agreement with atomic and solid state values.

The spectrum arising from the $J = 1 \leftrightarrow 2$ transition of $Cl^{35}C^{12}N^{14}$ has been carefully measured over the period of the last year and a half. Since this molecule has two quadrupole moments present, as well as two magnetic interactions of the form $C_i(I_i \cdot J)$, and since furthermore second order quadrupole effects are not negligible, the interpretation of the spectrum has been quite tedious. To aid in this interpretation the spectrum of $Cl^{35}C^{12}N^{15}$, containing only one quadrupole moment, has been measured in the last quarter. A sample was prepared by Dr. Gene Silvey from $(NH_4)NO_3$ containing 60% N^{15} in the NH_4 radical. The molecular parameters of interest were determined to be as follows:

$Cl^{35}C^{12}N^{15}$ $\qquad (eqQ)_{Cl^{35}} = -83.265 \pm .012$ Mc

$\qquad\qquad\qquad c = +3.7 \pm 0.6$ kc

The absorption lines due to ClCN in the excited bending vibrational mode have also been measured. The interpretation of these lines is being pursued at present.

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1. CRL Quarterly Report, Oct. 30, 1953, pp. 14 and 15.
2. D. A. Gilbert, A. Roberts, and P. A. Griswold, Phys. Rev. 76, 1723 (1949).

F. Free Radical Experiment - Microwave Spectra of OD, OH

(G. C. Dousmanis)

With the new absorption cell[1] the sensitivity of the spectrometer has increased by a factor of about two. Using the new system the $J = 17/2$ transition in $O^{16}D$, the $J = 9/2$ $\Delta F = \pm 1$ lines in $O^{16}H$, and the $J = 9/2$ $\Delta F = 0$ lines in $O^{18}H$ have been observed, all at K-band. The frequencies of the observed transitions and their quantum assignments are listed in Table I.

Table I.

Observed lambda-doubling transitions in OD, OH

Molecule	K	J		Frequency (Mc)
$O^{16}D$	8	17/2	$F = 18/2 \rightarrow 18/2$ $F = 17/2 \rightarrow 17/2$ $F = 16/2 \rightarrow 16/2$	$23,907.12 \pm .10$
$O^{16}H$	4	9/2	$F = 5 \rightarrow F = 4$	$23,837.78 \pm .30$
	4	9/2	$F = 4 \rightarrow F = 5$	$23,806.47 \pm .40$
$O^{18}H$	4	9/2	$F = 5 \rightarrow F = 5$	$23,479.14 \pm .50$
	4	9/2	$F = 4 \rightarrow F = 4$	$23,469.54 \pm .50$

The OD hfs is still unresolved in K = 8 J = 17/2 line as in the K = 5, 6, 7 lines of OD.

The frequency difference between the two $\Delta F = \pm 1$ lines of $O^{16}H$ gives the sum of the two hyperfine structure separations in the two members of the lambda-doublet. The ratio of the intensity of the $\Delta F = \pm 1$ lines (satellites) to that of the $\Delta F = 0$ lines is ~1/45 in agreement with the calculated value.

The $O^{18}H$ has been obtained from a water sample enriched 1.4% with O^{18}. The present measurements indicate that $\Delta\nu\ hfs(O^{18}H)/\Delta\nu\ hfs(O^{16}H) = 1.10 \pm .06$, whereas according to calculation this ratio should be very close to 1. The experimental error however is so large that further measurements are needed to establish whether there is or is not a departure from the calculated value.

1. CRL Quarterly Report, Oct. 30, 1953.

G. Polymeric Content of Alkali Halide Beams

(R. C. Miller)

Before proceeding with the new two chamber oven mentioned in the last Quarterly Report, it was decided to investigate the rather large previously observed[1] temperature discrepancy between the beam temperature (calculated from the velocity distribution) and the oven temperature (measured with a thermocouple). This result was obtained from essentially atomic potassium beams originating from iron ovens. It was thought that the discrepancy may be due to temperature gradients in the iron oven, hence it was decided to look at potassium beams originating from ovens of conventional design made of OFHC copper. The high conductivity of this material would rule out the possibility of significant temperature gradients.

The results from runs using the copper ovens were no different from those previously obtained with iron ovens. In all cases, the experimental distributions indicated a beam temperature above that measured with a chromel-P Alumel thermocouple peened into the oven. This discrepancy ranges from 9° C at an oven "temperature" of 461°K, to 34° C at an oven "temperature" of 573°K, where the oven "temperature" is that obtained from thermocouple measurements.

One possible source of error is the lack of defining slits between the oven and the detector wire. Thus any velocity dependent specular reflection of atoms at grazing incidence on the walls of the slots in the velocity selector would distort the true velocity distribution. To eliminate this possibility, a 0.002 in. collimating slit has been placed at each end of the velocity selector. The installation involved a rather extensive dismantling of the apparatus; hence it was decided to make long needed repairs and other alterations. When the apparatus is reassembled, the temperature discrepancies will be reinvestigated, prior to a return to the study of the alkali halide beam composition.

1. CRL Quarterly Report, August 31, 1953.

H. Millimeter Wave Spectroscopy

(A. H. Nethercot, Jr. and B. Rosenblum)

An apparatus is being constructed so that the spectrum of radioactive gases can be safely examined in the wavelength range of 1 - 2 mm.

I. Magnetic Resonance at Millimeter Wavelengths

(F. M. Johnson and A. H. Nethercot, Jr.)

The apparatus has been run at liquid nitrogen temperature. A search has been made for the absorption line of $Ni_2K_2(SO_4)_2 \cdot 6H_2O$, which at nitrogen temperatures has a marginally detectable 1% absorption; the line was not observed. The same experiment will soon be performed at liquid helium temperatures to increase the absorption.

J. Superconductive Surface Resistance at Millimeter Wavelengths

(R. Kaplan and A. H. Nethercot, Jr.)

The cryostat and temperature measuring equipment are largely completed and work has been started on the tin specimen.

V. ELECTRONIC APPARATUS AND TECHNIQUES

A. Microwave Frequency Standard

(A. W. Costello)

The microwave frequency standard described in previous CRL Quarterly Reports from June 30, 1953 to date, has been completed.

B. A Low Voltage, High Current, Regulated Power Supply

(A. W. Costello and A. Lurio)

An electronically regulated power supply to furnish 135 v at 640 milliamperes for four Hewlett-Packard Model 460A wide band amplifiers has been designed and built. It uses two type 6336 twin triodes[1] as series regulator tubes. The output voltage is constant with changes in line voltage from 95 to 135 volts and changes in load current from 400 to 800 milliamperes. Ripple voltage is 30 millivolts at full load.

1. Obtained from Chatham Electronics Corp., Livingston, N. J.

C. Klystron-Pulsing Unit

(A. W. Costello and H. Lashinsky)

In connection with the He^+ experiment,[1] it has been found necessary to "pulse" a QK289 klystron operating in a high-power mode. This is to be accomplished by applying a positive pulse to the klystron control grid which will be normally held beyond cutoff. A 1 μsec pulse at a repetition rate of 100 kc with rise and fall times of about 0.05 μsec is desired. It is expected that a pulse amplitude of about 500 v will be required and that the total input capacity representing the tube plus associated circuitry will be about 50 μμf. The design and development of a unit to meet the above requirements is now in progress.

1. CRL Quarterly Report, August 31, 1953, p. 16.