III MODERN ELECTRONIC TECHNIQUES APPLIED TO PHYSICS AND ENGINEERING

A DESIGN AND CONSTRUCTION OF A MICROWAVE ACCELERATOR

Staff Professor J C Slater
Professor A F Kip
Dr W H Bostick
B J Debs
P T Demos
L Maier
S J Mason
I Polk
J R Terrall

Description of Project Work on the 20-foot model of a microwave electron accelerator was initiated for several purposes One of these was to investigate the problems connected with feeding power from a group of magnetrons into a single system Another was to determine methods of calculation of dimensions and construction of a high-Q cavity and associated system suitable for accelerating electrons A third was to determine what possible limitations exist on the maximum size of accelerator which could be built and the maximum electron energy which could be expected

Status Seven feet of the accelerating cavity are essentially finished of which a three-foot section has been tested and operated at high voltage The associated mechanical and electrical system has been designed and is now being constructed The framework for mounting the system is nearly completed and the vacuum pump is installed

In addition to actual construction the following experimental progress has been made

(1) Work on the problem of phasing magnetrons

Since in a very long cavity there are many possible modes of oscillation at almost the same frequency it is necessary to consider methods of preventing the excitation of any but the desired mode One method of accomplishing this is to control by some means the relative phase between magnetrons and one way of controlling the phase has been investigated in some detail It consists of placing a "phasing cavity" in parallel with the accelerating cavity The phasing cavity is of such construction that its adjacent modes are far apart in frequency so that the moding problem is not important The power from each magnetron is fed into an appropriate position in the phasing cavity and a series of output from the cavity feeds the power into the accelerating cavity Under these conditions it is believed that only one mode will be possible within the frequency spread of the magnetrons Therefore the magnetrons should lock in phase just as they have been found to do when feeding into a short (3-foot) section of the accelerating cavity where the adjacent modes are far apart in frequency A critical test of this method will be possible and this test will be made on a three-foot section of phasing cavity in parallel with the accelerating cavity in the near future

It must be noted that even if this method of controlling the phase of the magnetrons works well as expected it still leads to an ultimate limitation of the maximum length of accelerator This limitation is due to the fact that in any phasing cavity the mode separation will decrease as the length is increased, until at some length the moding problem in the phasing cavity will be as severe as in the original accelerating cavity We expect to determine the limitations of this method of phase control

We are also beginning to investigate another method of phasing the magnetrons which if it works should remove all limitations on length of cavity The method is based on the ideas contained in a report[1] by J C Slater on the phasing of magnetrons A number of experimenters have shown that with a suitable external signal it is possible to lock a magnetron in frequency and arbitrarily close to a given phase We shall investigate the possibility of starting all the magnetrons with phase relationships such that only the desired mode can be excited in the accelerating cavity In this case the phasing signals will come from a single signal which has been amplified by klystrons a klystron feeding a phasing signal into each magnetron

(2) Work on electron source for the accelerator

An electron beam of about 2-Mev energy is required to feed into the 20-foot accelerator tube A 2-Mev Van de Graff generator has been ordered for this purpose but auxiliary sources are being designed for use prior to delivery of the generator and some work is in progress on electron guns The various sources under consideration all include the use of a section of a microwave accelerating cavity so constructed as to give acceleration to electrons starting from relatively low energies By arranging to have the phase velocity change with distance down the tube it will be possible to keep the electrons in a high accelerating field until they are traveling fast enough to be injected into the 20-foot cavity

III B ULTRASONICS RESEARCH PROGRAM

Staff Dr C Kittel
J K Galt
J R Pellam
R A Rapuano
W Roth
Professor C F Squire Low Temperature Group

The Ultrasonics Program was discussed at some length in the last progress report Summaries of progress since that issue are given below

1 a Ultrasonic Measurements in Liquid Argon

No work has been done on this project since the last progress report It is expected that this project will be completed in the next quarter

1 b Ultrasonic Measurements in Liquid Helium

Attempts are being made to extend the ultrasonic measurements to temperatures below the 1 76°K previously obtained No further results are available at present

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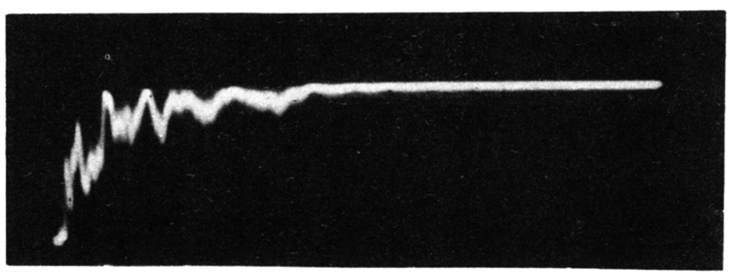
1 J C Slater "The Phasing of Magnetrons" RLE Technical Report No 35 April 3 1947

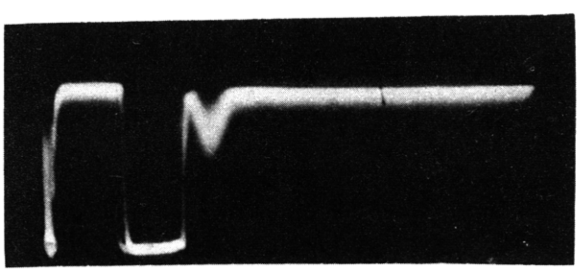
III. B. 2. Ultrasonics Measurements above 100 Mc/sec.

Accurate attenuation measurements have been made up to 280 Mc/sec in propyl alcohol, while echoes have been detected up to 400 Mc/sec. It is planned to improve the technique between 280 and 400 Mc/sec so that routine measurements can be made anywhere between 100 and 400 Mc/sec.

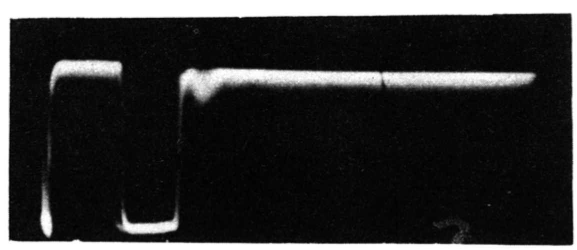
Extension of the upper frequency limit above 400 Mc/sec is complicated by the many variables present in a pulse-echo setup, such as attenuation in the liquid medium, non-parallelism of the quartz crystal with the reflector, reflection losses, attenuation losses and electrical losses. A very sensitive method free of most of the above variables was developed for determining whether or not the crystal is being excited, thus making possible the reduction of electrical losses and the estimation of crystal efficiency at very high frequencies. It had been noticed that there were a great many transverse modes of high Q accompanying the main mode of X-cut crystals. When excited by an r-f pulse of the correct frequency, these modes gave a very long decay pattern, much as an untuned echo box (Fig. 1). For exploring the very high frequencies an unloaded crystal is used and the behavior of the "ringing time" observed as a function of tuning and of the impedance-matching circuits. Characteristic patterns have been observed at the odd harmonics of a 15-Mc/sec crystal up to a frequency of 845 Mc/sec;



Frequency = 290 Mc/sec; 120-µsec sweep.



Frequency = 815 Mc/sec; 24-µsec sweep.



Frequency = 845 Mc/sec; 24-µsec sweep.

Figure 1. Delay pattern of excited X-cut quartz crystal.

the upper limit is apparently set by the electrical losses in the matching circuits rather than in the crystal. It appears that with the correct circuits, crystal excitation up to about 2000 Mc/sec could be obtained. Echo measurements at these high frequencies could then be attempted. A tank (Fig. 2) which was to be used for this work was delivered, but is unusable because of a mechanical difficulty. When this is corrected, it is hoped that the length of a sound path can be measured to 5×10^{-5} cm.

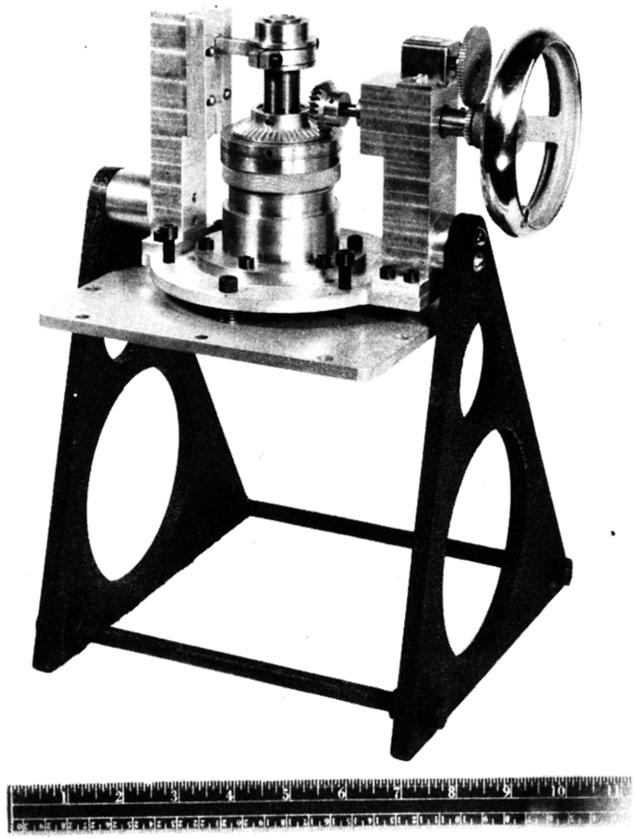


Figure 2. Reflector drive mechanism for precision tank.

3. <u>Ultrasonic Absorption in Metals</u>

<u>Experimental Study</u>. A large amount of absorption data has been taken with magnesium samples of known grain size and several points of interest have appeared. For the lower frequencies (10-20 Mc) the absorption remains fairly constant with change in grain size, but varies linearly with frequency. At higher frequencies the absorption drops considerably for the larger grain sizes and appears to be reaching a value independent of frequency.

Measurements made to determine the ultrasonic reflection coefficients for waves propagating from water to metal and from the metal to water show that the former increases with frequency while the latter remains constant at a value which is in excellent agreenent with theoretical predictions This behavior is being examined more closely to see if it can serve as an accurate measure of grain size

Theoretical Study A theory is being developed which explains the non-reciprocity of reflection coefficients as noted above At present it explains the observed data in a qualitative way but further work is in progress to obtain quantitative verification

A theoretical analysis of piezoelectric transducers for any general loading conditions is nearing completion Power output impedance and admittance curves as a function of frequency have been poltted for loading conditions of particular interest and a matrix representation of the transducer as a six-terminal network has been obtained Reciprocity relations have been established A detailed report on this subject is in preparation

4 Paramagnetic Relaxation Experiment

For the time being this project has been dropped for lack of a crystal of one of the salts and because personnel time for it is not available

5 Attenuation in Single Crystals

The experiments on alkali-halide crystals are now largely completed Much calculation from the raw data remains to be done however so that final results cannot yet be quoted The four parts of the program will be d scussed separately as in the previous progress reports

Elastic constant measurements are made using the technique described in the last progress report Room temperature values for NaCl KCl, KBr have been re-measured In addition the KBr constants are being measured to low temperatures This is done by placing the crystal in the Collins cryostat and making measurements as the temperature changes One more run with the cryostat will complete this job Low-temperature elastic constants are of interest for specific heat and indeed any lattice theory since usually the lattice is assumed at rest and therefore at absolute zero temperature The main experimental problem to overcome here is to find a film which will cement the quartz and KBr together from room temperature down to the low-temperature region in spite of their different thermal contractions The best cement found so far is a stopcock grease made up of natural rubber and paraffin dissolved in vaseline Even yet cracking of the KBr does occur This has limited measurements on c_{12} to the range above 120°K With one more run data on c_{11} and c_{44} however will extend down to 4 5°K

Attenuations have all turned out to be so low that an upper limit is all hat can be put on them This is true in NaCl KBr and KCl Geometrical factors in the propagation cause apparent attenuation but no definite indication of a real attenuation has been obtained An attempt has been made to measure attenuation in NaCl at higher temperatures, but the silver paste film used to cement the quartz onto the crystal did not remain firm and the data show nothing significant

No new indications of permanent strain production have been obtained

Strain-optical constant ratios P_{12}/P_{11} and $P_{44}/(P_{11}+P_{12})$ for NaCl KCl KBr have been measured by a technique suggested by Professor Mueller[1] It is expected that these data taken together with Bridgeman's data on the variation of index of refraction with pressure will determine the three constants for these substances

III C CYCLOTRON R-F PROJECT

Staff Professor G G Harvey
T Moreno
M Plotkin Brookhaven National Laboratories

Work on this project was discontinued shortly after the last progress report was written and a final technical report is now being prepared

D THREE-CM SWEEP-FREQUENCY OSCILLATOR

Staff Professor R M Fano
R B Adler
R Cohen

A cavity similar to the one used in McNally tube applications has been tried but results have not been satisfactory The conclusion has been reached that this kind of tube is not suitable for the operation intended and the project has therefore been temporarily discontinued until a more satisfactory type of tube is available

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1 H Mueller "Determination of Elasto-optical Constants with Supersonic Waves" Zeitschrift fur Kristallographie (A) 99 122 (1938) The method used at RLE is method B described on pages 1?4-5