I. MICROWAVE AND PHYSICAL ELECTRONICS

A. HIGH-POWER MAGNETRON RESEARCH

Staff: Professor S T Martin
D L Eckhardt
J H Henry
V Mayper
R R Moats
W Rotman

In addition to the construction of a high-power 10 7-cm magnetron, the following subjects are being investigated by this group:

(1) Output windows of glass, mica, and ceramics.

(2) Thoria cathodes

(3) Mode stability in the magnetron

(4) R-F build-up time of magnetrons

(5) Noise output of a c-w magnetron

Output Windows. The assembly of the high-power magnetron has been delayed pending further experiments with ceramic output windows Work has been started on the assembly of a second magnetron, the parts of which are on hand. Some slight changes in assembly procedure are necessary because of the use of the ceramic windows, and the details of the new procedure is expected to cause no trouble.

Attempts are now being made to make ceramic output windows from Alsimag 243 and ZI-4 It seems very likely that vacuum-tight windows will be obtained from both ceramics in the near future

Thoria Cathodes. Work on the fabrication of thoria cathodes has continued and a technique has been developed which results in cathodes of good ceramic qualities These cathodes are formed from thoria and tungsten powder The mold used for the cathode fabrication is made from highly polished, high-chrome high-carbon steel (Crucible Steel Company, type HYCC) The internal diameter of the mold is 0 509 in at the middle tapering to 0 512 in in diameter at both ends. The central mandrel is 4½ in long, 0 410 in in diameter at one end tapering to 0 408 in in diameter at the other end. The outside diameter of the mold is 2 in and its length is 3 5 in To increase the strength a 4-in diameter "Ketos" steel sleeve is shrunk over the HYCC mold Pressing sleeves are made of Hyten "M" temper steel (Wheelock, Lovejoy and Company Inc) The walls of the mold are lubricated by allowing a solution of 50 grams of Carbowax in 100 cc of ethyl alcohol to drain through the mold, depositing a thin film of Carbowax The thoria-tungsten powder mixture is then poured into the mold and pressed at a pressure of 80 tons/sq in After removal from the mold, the compress is fired in hydrogen at 1800°C for 30 minutes and a strong ceramic of uniform density results The shrinkage after firing is 7 per cent One difficulty in the fabrication process is the appearance of several small cracks at both ends of the cathode. These are removed by machining the ends of the cathode with a carbide-steel tool bit

Initial experiments indicate that a suitable tungsten-thoria mixture contains about 30 per cent tungsten by weight, but this is influenced by the geometry of the cathode The power required for direct heating of a cathode, 0 475 in outside diameter 3/4 in long with a 0 045 in wall thickness is about 500 watts As yet no emission measurements have been made

The thoria cathode research has now resolved itself into three phases (1) to improve the molding technique, (2) to determine the emission characteristics of the cathodes (3) to determine the resistance characteristics as a function of temperature and per cent tungsten in the mixture Research designed to obtain these results is in progress

Mode Stability The mode-stability properties of a magnetron as limitations on the power output are being investigated All experimental work so far has been under conditions such that failure of oscillation in the principal mode is evidently not affected by any other possible mode of operation Under these conditions, it has been found that the failure of oscillation when the anode voltage is above a certain value can be represented by failure of the electronic impedance to match the cavity impedance The operating conditions of the magnetron thus correspond to the point of intersection of two curves in the impedance plane the curve of cavity impedance as a function of frequency and that of the negative of the electronic impedance for a particular value of anode voltage or current If there is no intersection, oscillation is impossible

The observed phenomena appear to be related to the fact that the rotational velocity of the electron stream tends to increase as the anode voltage increases, and the electron stream leads the voltage wave to which it is coupled This condition may be represented by an electronic reactance The operating frequency is shifted accordingly, giving rise to "frequency pushing " Beyond a certain value of reactance, no impedance match between the loaded cavity and the electron stream is possible Apparently the reactive component of electronic impedance has the preponderant effect in causing the loss of impedance match

As loaded Q of the magnetron increases the range of reactances possible with such a cavity increases and consequently the range of anode voltages and of currents which can be matched also increases Figure 1 indicates the greatest value of peak current attainable in pulse modulation for various values of the loaded Q of the QK-61 magnetron when it is tuned for two different frequencies and Fig 2 indicates the corresponding maximum limit of voltage Although higher loaded Q increases the upper limit of power input, it also corresponds to lower circuit efficiency of the system represented by the loaded cavity For that reason, the loading for maximum power output corresponds to a loaded Q far less than the maximum possible

Further tests are proposed to investigate the impedance characteristics of the electron stream in greater detail and to test mode stability in a magnetron in which oscillation in two different modes at the same anode voltage is possible For the latter purpose it is expected to continue the construction of the c-w rising-sun magnetron, described in the Progress Report of July 15

R-F Build-up Time The r-f build-up time of magnetrons is now being investigated This subject is of importance in predicting the performance of high-frequency oscillators

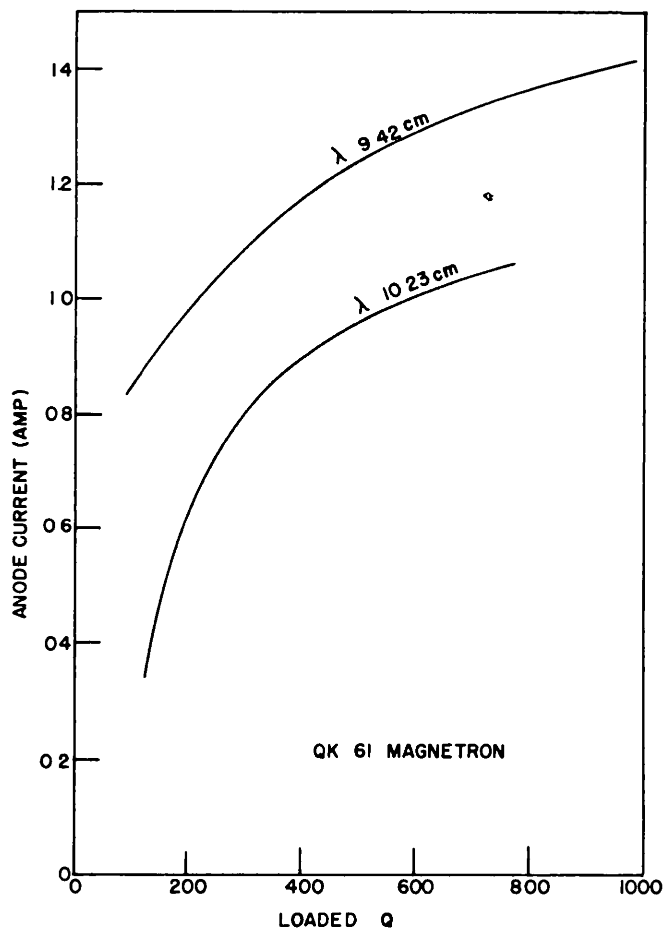

Figure 1 Peak current at point of instability

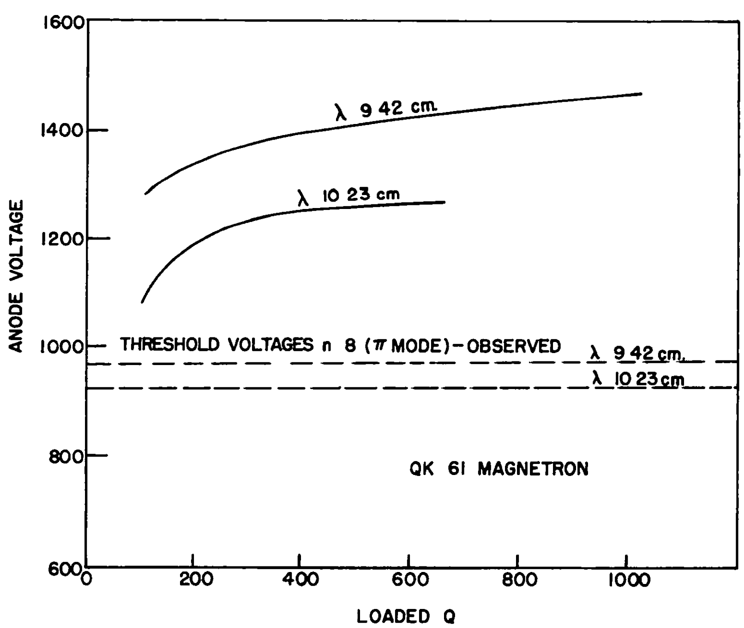

Figure 2 Peak voltage at point of instability

under the influence of rapidly rising voltage pulses

The output of a QK-61 magnetron, triggered by a 0 2-μsec pulse, is observed upon the screen of the Winterscope The build-up envelope is considered to be a function of the loaded Q of the magnetron cavity the magnitude of the applied pulsing voltage, and the initial noise level A definite time delay is observed between the application of the pulse and the beginning of r-f output from the magnetron For the QK-61 operating at a frequency of 10 cm, with a matched load, the initial delay and the time for the pulse to rise to 90 per cent of its maximum value are both observed to be of the order of magnitude of 5×10^{-8} seconds

Attempts will be made to correlate the information obtained on r-f build-up time with steady-state operating conditions and with experimentation upon the noise properties of the magnetron in its pre-oscillating state

Noise Output of a C-W Magnetron Some preliminary measurements of the noise output of a c-w magnetron operating at plate currents below oscillation have been made The noise was measured as a function of pre-oscillating plate current (or voltage), magnetic field, and frequency Results seem to indicate that, at low pre-oscillating plate currents (or voltages), the magnetron acts like a constant-current noise generator placed across the equivalent parallel-tuned circuit of the magnetron resonator The noise generator power output increases exponentially with pre-oscillating plate current and varies in a complicated manner with magnetic field These indications break down close to the beginning of oscillation and at very low magnetic fields In addition there is some doubt as to the true value of the plate current at which oscillation begins This condition must be investigated before an adequate interpretation may be made of the results

The exponential rise of noise with increasing plate current is definitely established and shows that the mechanism of noise generation is not that of the Schottky theory in the sense that the plate current is not the primary noise generator If a means were established to measure the current actually circulating in the interaction space however, there is no reason to suppose that the Schottky theory would not satisfactorily predict the noise generated by the pre-oscillating magnetron

I B CATHODE RESEARCH

I Cathode Interface Studies

Staff: Dr A S Eisenstein
W E. Mutter

Work on this project is being made the subject of a technical report

2 Conductivity and Work Functions of Oxide Cathodes

Staff G W Mahlman

The results of the preliminary experiments mentioned in the last progress report indicate that it is possible to measure coating conductivity at temperatures considerably below 750°C This becomes difficult however, as the temperature decreases, since the decrease of the conductivity of the coating with temperature causes the coating to heat up as current is drawn through it This results in a non-linear characteristic of tube current vs probe voltage (with respect to the cathode) as the tube current is increased

Equipment has been constructed to measure small d-c and a-c currents The electrometer-tube circuit constructed by W E Mutter has been changed to improve stability Sensitivity of the apparatus is about 50,000 mm/volt With a grid resistance of 10^{10} ohms, currents of 10^{-14} amperes are detectable and currents of 10^{-13} amperes are measurable with fair accuracy An audio amplifier to measure small a-c photocurrents obtained by light modulation has been construc ed It consists of three battery-operated stages followed by a tuned amplifier employing a "parallel-T" network Output voltage is measured by a Ballantine a-c electronic voltmeter The circuit for the tuned amplifier was suggested by Dr McFee of the Photoswitch Co The over-all performance of the amplifier has not as yet been tested.

The first experimental tube, designed to measure the photo-electric and thermionic work functions and the coating conductivity of an oxide cathode simultaneously was not satisfactory in all respects Other tubes are now under construction

3 Spectral Emissivity of Tungsten

Staff Professor W B Nottingham
W E Mutter

The 931A photomultiplier circuit described in the Progress Report of July 15, 1947 was completed very recently A support for the tungsten black-body source has also been constructed This support permits a finely controlled motion along the axis of the filament so that the intensity of various areas of the source image may be explored by a small rectangular aperture entering into the monochrometer and 931A detector With all the components of the apparatus now on hand it is expected that experimental results will be obtained shortly

4 **Electron Emission in Accelerating and Retarding Fields**

Staff Professor W B Nottingham
C S Hung

The new experimental tube has now been completed except for its final processing which has been postponed until the measuring equipment has been fully developed Suitable power supplies and electrometer setup are now in the process of construction, and in fact will be completed shortly Following the completion of the experimental equipment to be used for the measurement the cathode and the experimental tube will be inserted, the tube processed and experimental results on this subject again undertaken

C IONIZATION GAUGE RESEARCH

Staff Professor W B Nottingham
L Sprague

A new gauge design has been made and the gauge constructed A new gauge has not yet been tested and therefore there are no significant results to report

D PROPERTIES OF CATHODE-RAY TUBE SCREENS

Staff Professor W B Nottingham
W T Dyall

The specialized equipment used for the photometry of cathode-ray tube screens has been put in good working order, and measurements have been under way for a considerable period. Of the seven special cathode-ray tubes submitted by the R C A and the General Electric Company, four have been measured in considerable detail These include three tubes with P-14 screens and one with a P-4 screen The range of time over which these tubes have been investigated runs from 1 7 milliseconds to 1 minute The range in light intensity in all cases is slightly less than one million fold The program is to continue and it is hoped that an investigation of the four British tubes of the cascade screen type similar to the P-7 will yield information that may explain the property often described as "smoothing" This property was never very strong in the P-7 variety tube and is thought, however, to be strong in two of the British tubes and weak in two of them It is not certain at all that the investigation will explain the phenomenon of "smoothing" but an attempt will be made to discover the reason for it A technical report on the summer work will be prepared soon

E DETERMINATION OF EMISSION PROPERTIES OF SINGLE CRYSTALS

Staff Professor W B Nottingham
C J Marcinkowski
M. K Wilkinson

This work has been standing by for the summer term, and will be undertaken actively in the near future

I F CONSTRUCTION OF 5-MM OXFORD TYPE TUBE

Staff N G Parke

Attempts have been made to construct a 60,000-Mc reflex velocity-modulated tube using the same electron gun as that designed for the 2K33 Repeated failure to get sufficiently accurate gun alignment led in turn to three versions of the tube The last version described in the last quarterly report was completed but trouble with gun alignment and failure to get sufficient beam current (>4 ma) through the 0 014-in diameter hole in the resultant gap persists Work on this project will not be continued at this time, but if it is taken up again it is felt that a basic redesign including a new gun will be necessary A technical report on the project summarizing the constructional details and difficulties which arose will appear in the near future

G TRAVELING-WAVE AMPLIFIER TUBES

Staff Professor L J Chu
Professor J B Wiesner
L A Harris
J D Jackson

Description of Project As explained in the last progress report, efforts have been concentrated on the design of electron guns for use in the traveling-wave tube

Status Two electron guns and a drift-tube structure have been designed The designs of both electron-guns are based on information contained in "The Production and Control of Electron Beams", by K Spangenberg, L M Field, and R Helm, all of Stanford University, which is based in turn on Pierce's method of design [1] This method involves supplying the proper equipotential surfaces in the vicinity of the desired electron beam

The first electron gun follows the data closely, but additional flexibility is obtained through the use of a sliding anode which may be positioned by tapping the tube

The second gun consists of two stages a 1000-volt gun plus the second half of a 2000-volt gun This type of design allows a greater initial angle of convergence from the cathode, and therefore a larger cathode

The drift tubes for testing these guns consist of a series of short tubes which together make up a drift tube of dimensions comparable to those of the traveling-wave tube helix. Individual leads from each section and the final collector provide for measurement of the divergent beam current

All parts for these guns have been completed and the tube with the two-stage gun has just been completed. Preliminary measurements made on this gun, while pumping, indicate that considerable improvement over previous guns may be obtained

The tube with the single-stage gun should be completed very soon barring technical difficulties which have recently given considerable trouble

1 J.R Pierce, "Rectilinear Electron Flow in Beams" J App Phys , 11, 548 (1940)