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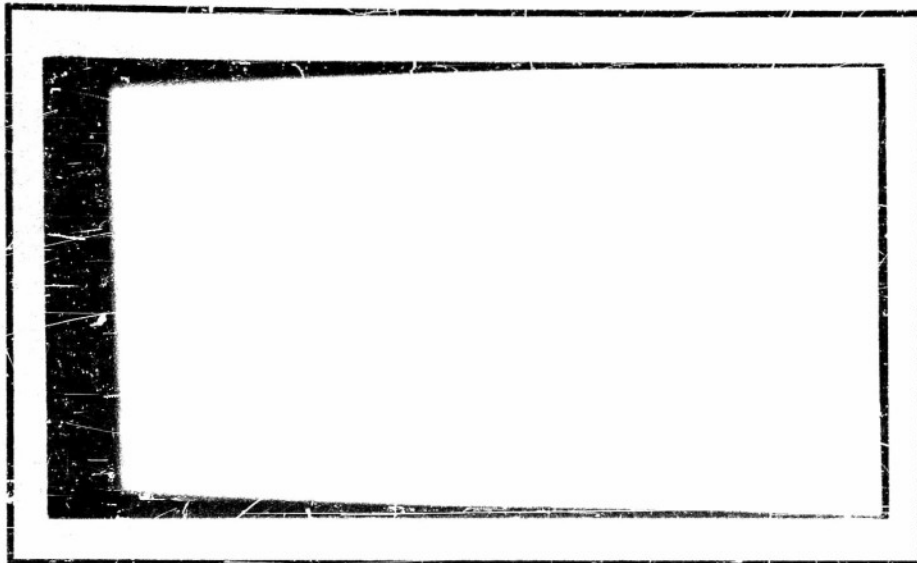
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STANFORD UNIVERSITY
STANFORD, CALIFORNIA

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INVESTIGATION OF
HIGH-POWER MICROWAVE DEVICES
U. S. Navy Contract No. N6onr 25123
Code No. NR 073 361
STATUS REPORT
1 March to 31 May, 1954
M. L. Report No. 243
August, 1954

Prepared by: The Staff of the
Microwave Laboratory

Approved by: E. L. Ginzton, Director
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Contract N6onr 25123
1 March to 31 May, 1954

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I. INTRODUCTION AND SUMMARY

The period covered by the present report is 1 March to 31 May 1954. The progress of the major projects is summarized in this section; the details are described in subsequent sections.

The new Microwave Laboratory building is being completed on schedule and will be fully occupied by the summer of 1954. Virtually all the personnel under this contract will then be concentrated in one building.

1. ACCELERATOR KLYSTRONS. Studies of the characteristics of accelerator klystrons, especially with regard to their life and the various causes of failure, are still continuing. Most of the work is being financed through the ONR-AEC accelerator contract (N6onr 25116), and some work pertaining to extensions to higher power and sealed-off versions is being financed by AEC Contract AT(04-3)-21 (Project Agreement No. 1). In addition to studying the causes of failure, the accelerator klystrons are being continually improved by way of improving efficiency and power output. It is expected that the work on high-power klystrons will be ultimately shifted entirely to projects under the above-mentioned contracts, with the present contract sponsoring only work of a basic nature.

Some success has been achieved in sealing off a high-power klystron. This tube operated satisfactorily from the viewpoint of maintaining a high vacuum, and its use was discontinued for another reason. A second similar tube is being fabricated. It is possible that a sealed-off tube may be capable of being operated over a longer period of time without emission failure because of the absence of such contaminants as might enter a continuously pumped tube through the pump system; but this possibility cannot be fully established as a fact until the 'life histories' of a suitable number of such tubes have been accumulated.

2. BASIC STUDIES. Further improvements in beam transmission are being sought with the help of a number of modifications introduced in a special model of a high-power klystron. The performance of a tube embodying these modifications has been sufficiently satisfactory to justify their inclusion in future tubes (including sealed-off models).

The design of a hollow-beam electron gun that might serve to improve the efficiency of klystrons and traveling-wave tubes has been executed and successfully tested in an especially constructed beam tester. This project is nearing completion.

Two other projects have been completed during this quarter and technical reports have been issued: the reduced-

(II. ACCELERATOR KLYSTRONS)

voltage-collector scheme for increasing efficiency of high-power velocity-modulated tubes, and a study of a method of controlling an electron beam by periodic focusing of the electrostatic or magnetic type.

3. PULSED TRAVELING-WAVE TUBES. Tests on a space-harmonic traveling-wave tube have continued during the last quarter. Much of the effort was directed toward measuring the variation in gain as a function of frequency.

The studies of new types of periodic structures are quite encouraging, and a large number of structures suitable for high-power operation has been tested.

Theoretical and experimental work on cross-wound helices, which represent an entirely new type of traveling-wave structure, has also been going forward.

4. MILLIMETER-WAVE GENERATION. The experiment on utilizing the transverse acceleration of electrons is nearing completion. It is expected that the project will be discontinued within a few months owing to the departure of the present project leader, Dr. H. Metz, who has accepted a faculty appointment at Oxford University for the coming school year. The work is going forward on a full scale and it is hoped that successful operation of the 'undulator' will be achieved during the summer of 1954.

II. ACCELERATOR KLYSTRONS (Staff: J. H. Jasberg)

The objective of this project is the study of high-power pulsed klystrons of the type that are used with the Stanford Mark III accelerator. The cost of construction and maintenance of these tubes is borne by the ONR-AEC Contract N6onr 25116. The progress of the research pertaining to these klystrons is reported here for the sake of completeness.

Seven tubes were added to the Mark III machine this quarter, partially replacing the nine tubes that failed. There are now seventeen tubes in use. Most of these tubes became temperature limited in use and in four cases this resulted in a punctured main seal. Two tubes were lost when their vacuum pumps failed. The average life of the failures was 942 hours. One tube, operated since June 1953, logged 2038 hours.

Why some tubes become emission limited after a short life is still a puzzling question which cannot be easily answered. The program to seal off the tubes should indicate whether this phenomenon is due to contaminants entering through the pumps or to some element in the tubes themselves.

(III. BASIC STUDIES)

The tube which was sealed off last quarter was run on the test stand whenever possible over a six-week period, and accumulated 150 hours of operating time. During this test there was no evidence of deterioration of performance at levels of 10 Mw output. Due to its poor emission prior to seal-off, the tube was never usable on an accelerator. The cathode has been taken out of the tube and seemed normal, except for a large amount of dark material on its surface. This may have been decomposed oil from the diffusion pump. A second tube should be on the pumps early in the next quarter.

There was one output-window failure in this quarter. This window had been on two tubes with a total life of 2130 hours. It failed due to arcing from a small solder fillet at the metal-to-ceramic braze.

III. BASIC STUDIES

A. SPECIAL KLYSTRON, K-14 (Staff: J. H. Jäsberg)

The improvement of the klystron of the type used to power the Mark III accelerator is being carried out to a large extent on tubes of a special type, designated as the K-14 tube. This tube has the following modifications:

- (a) Reamed throat at anode.
- (b) Cathode moved 0.1 in. farther away from anode.
- (c) 5-cm oscillation suppressors in middle cavity.

The modified tube on the Mark II accelerator was lost because of failure of the vacuum-protection device to turn off the modulator during reprocessing the tube after replacing a leaky output window. (See previous quarterly report.) It has been replaced by another tube of this type which gives as good performance. Future sealed-off tubes will probably be of this type

B. HOLLOW-BEAM STUDIES⁴ (Staff: M. Chodorow, C. Susskind)

The tests with the hollow-beam electron gun have been completed. The beam appears to remain hollow for a considerable distance into the drift tube, both under d-c and pulsed voltage condition. The magnetic field required to focus the beam as a sharp annular ring on a viewing screen differs slightly along the drift tube. In other words, for a given magnetic field, the beam exhibits the scallops predicted by theory.

The numerical data obtained during the tests will be presented in a technical report (now in preparation), which will also show the details of the special beam tester employed.

⁴This project is supported under Contract N6onr 25132.

(IV. PULSED TRAVELING-WAVE TUBE)

C. REDUCED-VOLTAGE COLLECTOR (Staff: R. H. Winkler)*

This project is completed with the issuance of a technical report, "A method for improving the efficiency of klystrons," by R. H. Winkler (Microwave Laboratory Report No. 235, May, 1954).

D. GRADIENT FOCUSING (Staff: M. Chodorow, C. W. Barnes, Jr.)

The present activity of this project has been completed with issuance of a technical report entitled "Periodic focusing of electron beams," by C. W. Barnes, TR-No. 33 (Contract N6onr 25132), 3 May 1954.

IV. PULSED TRAVELING-WAVE TUBE **

(Staff: M. Chodorow, E. J. Nalos, R. A. Craig, B. Arfin, E. L. Chu, J. E. Nevins, W. P. Ayers)

A space-harmonic tube has been tested under a variety of conditions. Performance on the original tests was roughly something greater than 500 kw at 2700, 170 kw at 3100, and about 100 kw at 3300 Mc/s. The gains at these frequencies vary from about 25 to about 10 db. The variation in gain was much greater than expected. This discrepancy between the theoretical value and the experimental value is attributed to the beam diameter being much smaller than the value used in the original calculations, resulting in excessive space-charge effects which are particularly noticeable at the low-frequency end where the tube impedance is low. This explanation of the variation in gain has been experimentally verified. By measuring the difference between the synchronous voltage and the voltage for optimum gain it is possible to determine the plasma wavelength from existing theoretical curves. One can then calculate a beam diameter and also the small-signal gain which agrees well with the experimentally measured gain. As corroboration, it was found that by moving the cathode and changing the beam focusing, with the presumable result of a larger beam diameter, it was possible to increase the gain at 3300 Mc/s from 10 to 17 db.

As an indication of the possible performance of the tube at constant voltage it is possible to pick a voltage such that one can get 200 kw or more between 2700 and 2950 Mc/s with 1 kw of drive with the output-power variation being no greater than 3 db over this band.

The tube is going to be dismantled so that a different cathode can be put into it.

*This project is supported under Contract N6onr 25132.

**This project is partially supported under Contract N6onr 25132.

(IV. PULSED TRAVELING-WAVE TUBE)

The structure with negative mutual inductance coupling which permits operation on a fundamental component has been tested. The impedance of this structure is about as good as the simple disk-loaded guide, so that the slots and fins necessary to produce the equivalent negative inductance apparently do not change the impedance characteristics markedly. From the impedance measurements made, and large-C curves, it seems that one can get a flat gain characteristic over a band of about 350 Mc/s. A report is being prepared on all the various structures which have been measured as possibly suitable for high-voltage operation. Measurements on a modified interdigital structure are continuing; particularly, the impedance is being determined to compare the modified interdigital structure with the ordinary one.

During the past six months, work has also been progressing on cross-wound helices. The previous calculations of phase velocity used a particular assumption as to the current distribution in the tapes. This current distribution, strictly speaking, could exist only if the tapes were not in contact. If the tapes are in contact, the results would still be accurate for the case of very narrow tapes; but for very wide tapes with a considerable region of overlap, the current distribution is apt to lead to some error in the phase velocity. These are merely numerical differences and do not affect the fundamental properties of the cross-wound helices. However, to find out what the effect of a large overlap region with contact had on the phase velocities, calculations have been started on an equivalent structure, namely one consisting of a series of tape rings which are alternately connected at 0° and 180° by a strip of some width. In this case, one assumes a field distribution in the gaps between the rings, and one can calculate the phase velocity. One has at his disposal as variable parameters the width of the tape rings, or, what amounts to the same thing, the width of the gap between them; and also the width of the strip connecting alternate rings. This width corresponds to the overlap region in the case of helices. These calculations have proceeded and curves of the velocity as a function of the relevant parameters have been added. Since in many cases it may be useful actually to make a traveling-wave-tube structure using joined rings rather than a tape helix, these curves will be useful for design also. A technical report on these new calculations is being prepared.

Work is also proceeding on building a traveling-wave tube for 3 cm using a cross-wound helix. The preliminary tube was built and its gain was less than anticipated, probably because of excessive dielectric loading which reduced the phase velocity and also the impedance. Another tube will be built with the dielectric envelope separated from the helix by sufficient distance so as to reduce the loading. This 3-cm tube is to be operated as a pulsed-amplifier at about 10 kv and 1 amp.

V. MILLIMETER-WAVE GENERATION

(Staff: H. Motz, H. P. O. Golde, L. M. Winslow)

The objective of this project is the generation of pulsed-microwave energy at millimetric wavelengths, notably by means of the acceleration of electrons by spatially periodic magnetic fields.

During the period under review almost all of the construction work has been completed. The performance of the accelerator section at high power was much less than expected from low-power tests. This is presumably due to a fault in the manufacture of the pipe which causes bad disk contacts. In order to get the electron energy needed for the project, a 1-Mw klystron had to be used in place of the 0.5-Mw magnetron. These difficulties have delayed the experiment.

It is anticipated that work on this project at Stanford University will be terminated in the Fall of 1954, although some work may be continued with the same equipment at another institution under a subcontract from Stanford University.

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1 March to 31 May, 1954

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