ENT
DES

NOTICE

**CERTAIN DATA
CONTAINED IN THIS
DOCUMENT MAY BE
DIFFICULT TO READ
IN MICROFICHE
PRODUCTS.**

UCRL-CR--104813

DE91 001680

by 6571

1 1990

RECENT LONG-PULSE AND HIGH-AVERAGE-POWER
TESTS ON A 140 GHz GYROTRON

K. FELCH
C. HESS
H. HUEY
E. JONGEWAARD
H. JCRY
J. NEILSON
R. PENDLETON
M. TSIRULNIKOV

VARIAN ASSOCIATES, INC.

OCTOBER 1990

MASTER

lib
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

This document was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor the University of California nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or the University of California, and shall not be used for advertising or product endorsement purposes.

Recent long-pulse and high-average-power tests on a 140 GHz gyrotron

K. Felch, C. Hess, H. Huey, E. Jongewaard, H. Jory, J. Neilson,
R. Pendleton, and M. Tsirulnikov

Varian Associates, Inc., 811 Hansen Way, Palo Alto, CA 94303 USA

ABSTRACT

Varian is carrying out the development of high-power, CW gyrotrons at frequencies ranging from 100-140 GHz. Initial test vehicles at 140 GHz have been designed to generate short-pulse power levels of 1 MW and up to 400 kW CW. Thus far, short-pulse power levels of 1040 kW have been measured at 38 % efficiency and average powers of 200 kW have been achieved. Output power levels of 400 kW have been obtained for pulse durations of 0.5 sec.

1. INTRODUCTION

To address future requirements in the area of electron cyclotron resonance heating of magnetically-confined plasmas, Varian is developing gyrotrons capable of generating power levels of 1 MW CW at frequencies in the range 100 GHz to 140 GHz. In working toward the 1 MW CW output power goal, several experimental vehicles will be constructed and tested to verify the design of the important elements of the gyrotron. The first two tubes in the program have been designed to generate short-pulse power levels of 1 MW and CW or long-pulse (> 1 second) power levels up to 400 kW at a frequency of 140 GHz.

The design of the first two experimental tubes and the results from tests on the first experimental tube and the first two test iterations of the second experimental tube have been published elsewhere.^{1,2} Below we discuss the results obtained during the third test sequence on the second experimental tube.

2. RECENT TEST RESULTS ON SECOND EXPERIMENTAL GYROTRON

The present series of tests on the second experimental tube were begun in June 1988 and are still in progress. During short-pulse operation, output powers up to 1040 kW at 38 % efficiency were obtained. A plot of output power and efficiency as a function of beam current is shown in Figure 1. We note that the efficiency was relatively flat over the range of beam currents shown in the figure. Efficiency was optimized for each value of beam current by adjusting the cavity magnetic field and the gun-anode voltage (that controls the perpendicular-to-parallel velocity ratio, α). In general, the gun-anode voltage was increased to the point where current was drawn to the gun-anode electrode.

In Figure 2 we plot the value of α estimated from electron gun simulations for each experimental point shown in Figure 1. As noted on Figure 2, the maximum gun-anode voltage without gun-anode current generally decreased with current. This effect is thought to be due to increasing velocity spread with beam current. The increased velocity spread leads to electron beam mirroring at lower values of α or gun-anode voltage. In addition to the lower achievable value of gun-anode voltage, the decrease in α with beam current is also due to the increased space charge in the beam formation region of the electron gun.

In Figure 3 we have plotted the same experimental efficiencies as well as those predicted by self-consistent, large-signal calculations for $\alpha = 1.5$ and 2.0. (The theoretical efficiencies have been adjusted to include the rf losses measured in the tube.) These results show that there is good agreement between the observed and predicted efficiencies when

the estimated value of α for each experimental point (see Figure 2) is used.

Figure 1. Output power and efficiency vs. beam current during third test of second experimental gyrotron.

Figure 2. Estimated alpha (α) vs. beam current for experimental points shown in Figure 1.

Figure 3. Comparison of theoretical efficiencies with results obtained during third test of second experimental gyrotron.

At output powers of around 400 kW, short-pulse operation has been extended to duty factors of nearly 50 %, resulting in average output powers of 200 kW. The output efficiency for 200 kW average power operation was not optimized. Instead, tube parameters were adjusted to enable operation in a regime where tube performance was relatively insensitive to changes in the settings of various parameters (i.e. gun-anode voltage, beam current, cavity magnetic field, beam voltage, etc.).

Long-pulse operation has been extended to pulse durations of 500 ms at output powers of 350-400 kW. Again, these tests were not carried out at optimum efficiency in order to remain at conditions that enabled operation over a wide range of parameter settings. Parameters for the three operating regimes, short-pulse operation at 1040 kW, 200 kW average power and 500 ms pulse, are listed in Table I.

Table I
Parameters for different operating regimes during
third test of second experimental gyrotron

	<u>1040 kW PEAK</u>	<u>200 kW AVERAGE</u>	<u>500 ms PULSE</u>
FREQUENCY	140.155 GHz	139.837 GHz	140.066 GHz
OUTPUT POWER	1038 kW	412 kW	384 kW
PULSE DURATION	0.5 ms	4.0 ms	500 ms
REPETITION RATE	10 pps	120 pps	0.01 pps
DUTY FACTOR	0.5 %	48 %	0.5 %
AVERAGE POWER	5.2 kW	198 kW	---
BEAM VOLTAGE	80 kV	80 kV	80 kV
BEAM CURRENT	34.3 A	17.2 A	17.1 A
OUTPUT EFFICIENCY	38 %	30 %	28 %
MEASURED LOSSES	138 kW	61 kW	---
TOTAL GENERATED POWER	1176 kW	473 kW	---
INTERACTION EFFICIENCY	43 %	34 %	---

Further long pulse tests are still in progress. The current test plan is to extend long-pulse operation at 400 kW to pulse durations in excess of 1 second.

3. CONCLUSIONS

The results obtained during the most recent tests performed on the second experimental 140 GHz gyrotron have essentially met the 1 MW pulsed and 400 kW CW or long-pulse goals of the initial test vehicles. These results also represent an important step in reaching the 1 MW CW goal of the current development program. Tubes based on the 140 GHz, 1 MW pulsed, 400 kW CW design will be useful in a variety of ECR heating applications in several present-day fusion experiments.

ACKNOWLEDGMENT

The 1 MW gyrotron oscillator is being developed under contract with Lawrence Livermore National Laboratory, operated by the University of California for the U. S. Department of Energy, under Prime Contract W-7405-eng-48.

REFERENCES

1. K. Felch, J. Feinstein, C. Hess, H. Huey, E. Jongewaard, H. Jory, J. Neilson, R. Pendleton, D. Pirkle, and L. Zitelli, "Design Considerations in Achieving 1 MW CW Operation with a Whispering-Gallery-Mode Gyrotron," International Electron Devices Meeting, Washington, D.C., Technical Digest, 1989, pp. 755-758.
2. K. Felch, E. Jongewaard, H. Jory, C. Hess, H. Huey, J. Neilson, R. Pendleton, and M. Tsirulnikov, "Progress in Producing Megawatt Gyrotrons for ECR Heating," Proc. Symp. Fusion Tech., Sept. 1990, in publication.

END

DATE FILMED

11 / 13 / 90