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MASTER

200 kW PULSED AND CW GYROTRONS AT 28 GHz

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ABSTRACT

Pulsed and CW gyrotron oscillators have been designed and constructed for use in electron cyclotron resonance heating in plasma fusion experiments. The tubes are designed for 200 kW output at 28 GHz with beam input of 80 kV and 8 A. The pulsed design has been operated at duty factors of 5% and pulse lengths up to 40 msec. The CW design has produced output of 200 kW CW with an efficiency of 50%. It also operated with 52% efficiency at an output level of 170 kW CW.

The tubes are designed for power output in the TE_{02} circular electric mode in oversize (2.5 inch diameter) circular waveguide. Some investigations of mode purity of the output will be described. The design and operation of waveguide components such as bends and mode filters for use with the gyrotrons will be discussed.

Introduction

The gyrotron is a microwave power generator based on cyclotron resonance coupling between microwave fields and electrons in vacuum.[1] The applied dc magnetic field is specifically related to the frequency of operation by the cyclotron resonance condition

$$\omega = n\,\omega_c,$$

where ω is the gyrotron output frequency, n is an integer and ω_c is the cyclotron frequency or angular velocity of the electron given by

$$\omega_c = \frac{eB}{\gamma m_o},$$

B is the dc magnetic field, e is the electron charge, m_o is the rest mass, and γ is the relativistic mass factor. The fundamental resonance condition where n = 1 has the strongest interaction. Second harmonic operation with n = 2 has also been used with good results.

These developments were performed under subcontract to Oak Ridge National Laboratory, operated by Union Carbide Corporation for the Department of Energy.

This paper describes design and operation of pulsed and CW oscillators working at the 200 kW level at 28 GHz. The tubes were developed for use as power sources for electron cyclotron resonance heating in plasma fusion experiments using magnetic confinement.

Design Parameters

The gyrotrons operating at 28 GHz were designed to use the TE_{021} cylindrical cavity mode interacting with a hollow electron beam. The beam was formed using the magnetron type of gun common to most gyrotrons. The 11 kG dc magnetic field required for cyclotron resonance was obtained from a solenoid using copper hollow core conductor windings with water cooling.

Nominal operating parameter values are summarized in Table 1.

Table 1
28 GHz Design Values

Beam Voltage	80 kV
Beam Current	8 A
Main Magnet Field	11 kG
$v_\perp/v_\parallel$ Ratio	2:1
Magnet Power Input	50 kW
Gun Anode Voltage	25 kV
Power Output	200 kW
Output Waveguide	2.5 inch diameter
Nominal Efficiency	31%

To determine the design values a combination of analysis and computer simulation was used. More details of the design procedures are included in earlier publications.[2,3]

28 GHz Pulsed Oscillators

The basic elements of the pulsed oscillator are indicated in Figure 1. The output power is brought out symmetrically on the axis through the beam collector region. The choice of the TE_{021} cavity mode leads naturally to power output primarily in the TE_{02} cylindrical mode. The output window is a flat disc of BeO material.

The pulsed oscillator is shown in Figure 2. Hardware is attached to the gun to allow the tube to be plugged directly into a socket which is operated immersed in oil. Water inlet and outlet