Design and measurement of millimetre wave components for a W-band gyro-TWA

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Abstract

A W-band gyrotron traveling wave amplifier (gyro-TWA) with helically corrugated waveguide and cusp electron gun is presented. The beam-wave interaction, based on the cyclotron resonance maser instability, is driven by a 40 keV, 1.5 A axis-encircling electron beam generated by the cusp electron gun. Numerical simulations predict a maximum output of 5-10 kW (CW) with a 3 dB frequency bandwidth of 90-100 GHz and a saturated gain of 40 dB. Linear analysis and numerical simulation of the performance characteristics of the millimetre wave components for the amplifier will be presented as well as the latest experimental measurements.

Introduction

The gyro-TWA is a high power coherent microwave amplifier that excels at high frequencies (up to the terahertz range). The gyro-devices are suited to high frequency operation due to the fast-wave cyclotron resonance maser instability. Due to these attractive properties there are a number of applications for such devices including high resolution RADAR, communications and electron spin resonance.

There have been many gyro-TWA [1-3] and gyrotron-backward wave oscillator (gyro-BWO) [4] experiments undertaken recently at the University of Strathclyde. This paper presents the latest experimental results from a gyro-TWA operating in the W-band frequency range, based on a helically corrugated waveguide and cusp electron gun.

Results

To drive the beam-wave interaction in a helically corrugated waveguide it is necessary to use an axis-encircling electron beam [5] which selectively couples to harmonic modes. The cusp electron gun was designed using the 3D PiC (particle-in-cell) code MAGIC [6]. The design focused on a "smooth cusp" configuration where the cusp point is in the anode-cathode gap making it simpler than other designs which use extra magnetic poles and/or material [7,8]. The experimental results agree well with simulations. The interaction region dispersion has been analytically calculated [9-11] and the dispersion shows an operating band between 90-100 GHz. These results are verified through beam-wave interaction simulations using the 3D PiC code MAGIC with the electron beam detailed above. Simulations predict a 5-10 kW (CW) output over the 90-100 GHz range with 40 dB saturated gain.

A side-wall rectangular-to-circular input coupler has been designed to introduce the microwave signal to the interaction region. A pill-box cavity is used with a ceramic window to seal the vacuum. A Bragg reflector is used instead of a cut-off waveguide as this allows an enlarged beam tunnel ensuring the beam passes through this region. The coupler has been both numerically optimized to achieve better than -1 dB transmission coefficient over the whole operating frequency range, and it has been verified by the measurement. A corrugated horn was designed to convert the output mode of TE_{11} to a quasi-optical mode [11]. At the output of the interaction region a 3-layer output window has been designed and simulated to show less than -25dB reflection. The configuration of the window consists of three dielectric discs separated by a small vacuum gap. The middle disc is a ceramic with a quartz disc on either side to increase the operating bandwidth.

The experiment is currently in progress and many parts are being measured including the broadband input coupler, corrugated quasi-optical mode converter and broadband microwave window. The latest experimental results will be presented.

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