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Development of high power broadband gyro-TWAs towards the terahertz range

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***Abstract*—In this paper gyrotron travelling wave amplifiers (gyro-TWAs) based on helically corrugated interaction regions will be presented. Their operating principle and the first experiment in X-band will be reviewed. The present experiment in W-band using a cusp electron beam source with the capability of a high pulse repetition frequency of 2 kHz will also be presented. The design and performances of the amplifiers for kilowatt output and broadband operation in the millimeter-wave and terahertz frequency ranges will also be presented.**

Keywords—Gyrotron travelling wave tube, gyro-TWT, gyro-TWA, gyro-devices, gyro-amplifiers

I. INTRODUCTION

High power broadband gyrotron traveling wave amplifiers (Gyro-TWAs) have promising applications in communications, plasmas diagnostics, imaging, remote sensing, electron spin resonance spectroscopy, and so on. In the past gyro-TWA and gyrotron backward wave oscillators based on helically corrugated interaction regions (HCIR) have achieved unprecedented power bandwidth performance [1-4]. The W-band gyro-TWA is designed to amplify with a wide instantaneous frequency bandwidth of 10 GHz (90-100 GHz) and to generate output power of ~5 kW when driven by a 40 kV, 1.5 A large-orbit electron beam. An upgrade of the W-band gyro-TWA, to operate at a high pulse repetition frequency of 2 kHz, has been carried out in the university of Strathclyde.

II. PRINCIPLE

To increase the bandwidth of the amplifier a three-fold HCIR has been used. The resonant coupling of the TE_{21} mode and the first spatial harmonic of the TE_{11} mode in the HCIR gives rise to an “ideal” eigenwave for the amplifier. The eigenwave, which has an almost constant value of group velocity over a wide frequency band in the region of small axial wave numbers [5], can be readily matched by the dispersion line of an electron cyclotron mode or its harmonics allowing broadband microwave amplification to be achieved in a gyrotron travelling wave amplifier. The HCIR can also be designed to compress microwave pulses [6].

The large-orbit electron beam, generated from a cusp electron gun [7], is ideal for harmonic operation of gyro-devices as the mode selectivity nature of such a beam requires that the harmonic number is equal to the azimuthal index of a waveguide mode for effective beam wave coupling, which leads to a reduced possibility of parasitic oscillations.

III. RESULTS

Many broadband components were designed and developed for operation at a high pulse repetition rate (PRF) and their microwave properties measured including: broadband input coupler [8, 9], corrugated quasi-optical mode converter [10], output window [11,12], pulsed power system and water-cooled beam dump.

The output window in W-band operation was optimized through computer simulation, manufactured and measured to have a reflection of -30 dB. The ultra high vacuum compatible input coupler achieved -1.5 dB transmission. A water-cooled beam dump to accommodate the higher average power associated with an increased PRF has been designed and optimised through thermal simulations and manufactured .

The corrugated horn could be used to separate the output electromagnetic wave from the spent electron beam so that the energy of the spent electron beam could be recovered by a depressed collector system. The corrugated horn could also act as a mode converter so that it could convert a cylindrical TE_{11} mode into the free space TEM_{00} mode over the frequency band of 90–100 GHz with a reflection better than -30 dB and a coupling efficiency of ~99.4%.

A thyratron-triggered, double-Blumlein pulse forming network was used to provide the accelerating field for the electron beam. The electron accelerating potential was measured using a resistive voltage divider, while the electron current, typically 1.5 A at the thermionic cathode operating temperature, was measured using a current monitor. The output microwave radiation was detected by two crystal detectors situated inside screened boxes. The output power was calibrated using a known microwave source. The experimental results including the output powers and operating frequency bands were measured.

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