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

W. He, C. R. Donaldson, L. Zhang, P. McElhinney, H. Yin, J. R. Garner,
K. Ronald, A. W. Cross and A. D. R. Phelps
Department of Physics, SUPA,
University of Strathclyde,
Glasgow, Scotland, UK, G4 0NG
w.he@strath.ac.uk

***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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