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Development of gyrotron traveling-wave tubes at IAP and GYCOM

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Abstract

A brief review of research activity on gyrotron traveling-wave tube amplifiers (gyro-TWTs) with helically corrugated waveguides developing by the Institute of Applied Physics and GYCOM (Nizhny Novgorod, Russia) will be presented.

Introduction

The gyrotron traveling wave tube (gyro-TWT) is known as a broad-frequency-band variety of gyrotron-type amplifiers having potential for production of the highest average or continuous-wave (CW) power in the millimeter wavelength range [1] and therefore it is attractive as a microwave source for a number of applications such as radars, telecommunication and some other.

Since 1996 we are developing a concept of a gyro-TWT that is based on the use of a helically corrugated waveguide that radically changes the dispersion of the modes of a circular waveguide [2]. The operating helical-waveguide eigenmode has sufficiently high and almost constant group velocity at zero axial wavenumber which enables broadband operation of the helical-waveguide gyro-TWT with minimum sensitivity to electron velocity spread [3]. A number of experiments have proved the main theoretical predictions and advantages of gyro-TWTs of this type [4–6].

1. Ka-band application-oriented Gyro-TWTs

Since 2009 eleven tubes were manufactured by IAP and GYCOM Ltd., tested and shipped to customers. Parameters of the experimental prototypes for those tubes are summarized in the Table.

Main experimental parameters of Ka-band application-oriented gyro-TWTs

Parameter	Pulsed tube	CW tube
Accelerating voltage (kV)	70	40
Retarding voltage (kV)	25	20
Beam current (A)	10	1.5
Interaction B-field (T)	0.68	0.65
Magnet power consumption (kW)	25	22
Maximum output power (kW):		
pulsed	160	7.7
average	10	7.7
-1dB bandwidth (GHz)	2.4	2.1
-3dB bandwidth (GHz)	>2.7	2.6
Saturated gain (dB):		
at the band center	23	26
at the band sides	20	19
Pulse duration	100 us	hours

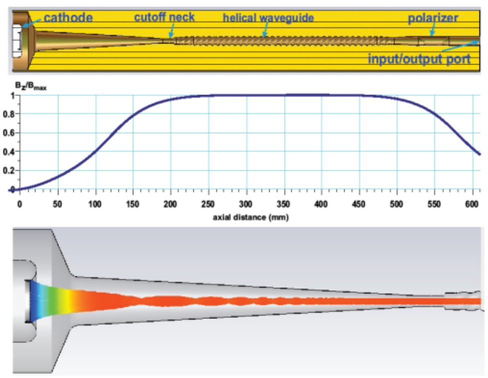

Fig. 1. CST model for simulation of a gyro-TWT from cathode to almost collector: whole geometry, B-field axial distribution and the gun part with particles' trajectories

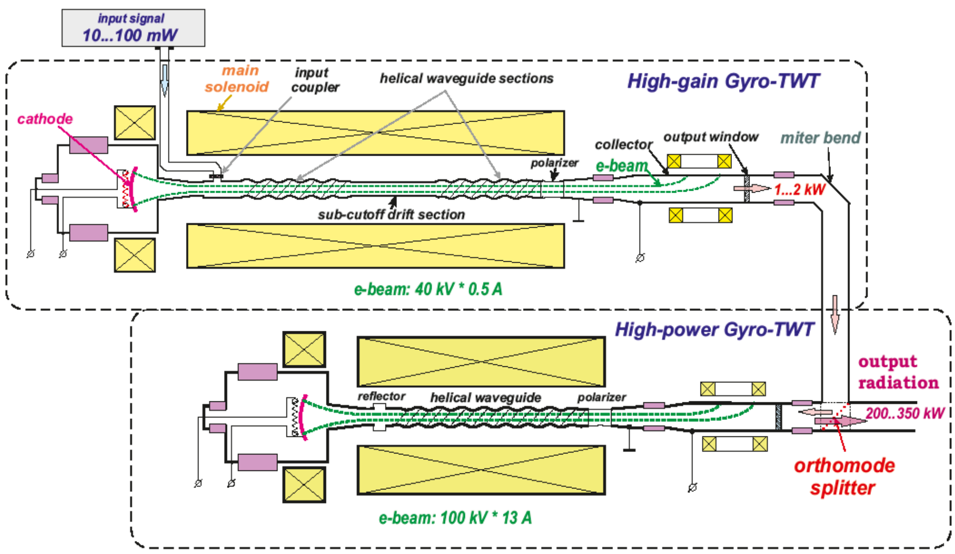

Fig. 2. Schematic view of cascade of two helically corrugated waveguide (HCW) gyro-TWTs

Due to their operation at the second cyclotron harmonic these Ka-band gyro-TWTs used relatively low magnetic fields which were generated by non-superconducting magnets with reasonable power consumption. Since no highly absorbing materials were used in the interaction circuits, these amplifiers possessed relatively low gain to avoid the reflection-induced oscillation therefore mid-power preamplifiers were needed to ensure the drive-saturated regimes.

Recently a new microwave system for feeding and extracting the radiation to and from a gyro-TWT through one oversized window was suggested and experimentally verified [7, 8] which along with significant simplification of the circuit allows principal breakthrough in the power for short millimeter waves. An implementation of this method in Ka-band can make production costs of the gyro-TWTs comparable with those for technological gyrotrons with powers of tens kilowatts.

Computer modeling of almost whole device (Fig.1: only a large-volume collector part is not included) ensures high reliability of the design and predicted behavior of the system at various experimental conditions. Basing on this modeling and previous experience a “technological” CW gyro-TWT capable for amplification of a 20-W 30-GHz drive signal to 10 kW with 1 GHz -3-dB instantaneous bandwidth or 5 kW with 2 GHz bandwidth was designed with moderate requirements to the power supplies (25 kV/2 A for the electron beam and 15 kW for the magnet).

2. Actual trends

The actual topics of research on the gyro-TWT are as follows: a cascade of two tubes ensuring the highest gain and output power in W band (Fig. 2) [9]; various microwave systems for inputting and outputting the radiation to and from a tube through one window [7, 8, 10]; tubes operating at the third cyclotron harmonic [11]; tubes prospective for DNP-NMR spectroscopy (260 GHz) [12]; tubes generating periodical sequences of ultrashort phase-coherent pulses [13].

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