Development of THz range CW gyrotrons at IAP RAS

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***Abstract*— The CW/263 GHz gyrotron is developed at IAP RAS for future application as microwave power source in DNP/NMR spectrometers. The new experimental facility with computerized control was built to test this and subsequent gyrotrons. The maximum power up to 1 kW in 15 kV/0.4A operation regime has been obtained. The power about 10W, which looks enough for spectroscopy, was realized in low current 14 kV / 0.02A regime. The possibility of frequency tuning with variation of coolant temperature about 4 MHz / 1 degree was demonstrated. The spectrum width of the gyrotron is about 10^{-6}. Next tubes with frequencies 527 GHz and 790 GHz are under development.**

I. INTRODUCTION

The last decade has contributed to the rapid development of THz gyrotrons. The series of CW and pulsed tubes has been developed by FIR FU (Japan), MIT and CPI (USA), EPFL (Europe) and IAP RAS (Russia). Some novel applications was developed, but the most relevant is high resolution spectrometry. The DNP/NMR spectrometers based on gyrotrons with relatively high microwave power (several tens of watts) allow increasing spectrometer signal by two orders of magnitude. Gyrotron with operation frequency 258 GHz developed by IAP RAS jointly with GYCOM Ltd. (Nizhny Novgorod, Russia) was successfully used for DNP/NMR experiments and provided 80-fold signal enhancement. In this report we present new IAP/GYCOM gyrotron developed for spectrometry and diagnostics of various media. In contrast with previous IAP tube this gyrotron is equipped with helium-free JSTD 10T100 magnet produced by JASTEC Ltd. (Japan), which provides the magnetic field up to 10 T in a warm bore with a diameter of 100 mm.

II. GYROTRON DESIGN AND EXPERIMENTAL RESULTS

The $TE_{5,3}$ mode at fundamental harmonic was selected as operating one. The cavity radius is equal 2.54 mm and is appropriate for manufacturing with high accuracy. The length of cylindrical part of the cavity is 20 mm. The possibility of single mode excitation without mode competition with parasitic modes was confirmed by numerical analysis. Optimization of the electrodynamics system and calculation of power and efficiency of generation were carried out using the self-consistent stationary codes developed in IAP RAS. Magnetron injection gun has a triode structure, but calculated (preferable for users) nominal operating regime is diode, so an anode have a ground potential. The magnetic system includes additional coil in cathode region, making it possible to adjust parameters of the electron beam. Internal quasi-optical mode converter provides narrow output wave beam with Gaussian structure. Mode converter consists of a parabolic mirror and four corrective mirrors. The depth of the corrugation mirror surface is about 0.1 mm, which looks acceptable for precision manufacturing. The output power is extracted through a vacuum window of boron nitride (BN) in the horizontal direction. The window diameter is 32 mm. Spent electron beam deposits onto the surface of the collector with conical shape that provides an acceptable thermal load even with tube misalignments. The gyrotron is manufactured by GYCOM Ltd.

The output power P was measured using a dummy load mounted directly behind the output window. The cathode voltage is 15 kV, beam current 0.4 A. The output power reaches its maximum value in excess of 1 kW for the magnetic field intensity about 9.605 T. The corresponded efficiency is about 17%. In general, most spectroscopy applications require microwave power less than 10 watts. In this regard, promising generation regime is realized with voltage of 14 kV and very low current of 0.02 A, where 10 W output power was obtained with efficiency about 3%. The frequency variation with the cooling water temperature is about 4 MHz / degree, and frequency variation with the cathode voltage is about 33 MHz / kV. The spectral width Δf is about 0.5 MHz ($\Delta f/f \sim 10^{-6}$).

The power about 10 W was obtained with the intensity of the magnetic field about 9.3 T, which corresponds to the second harmonic generation with the frequency 502.1 GHz at $TE_{10,5}$ operating mode. It should be noted, that the internal mode converter has been developed for $TE_{5,3}$ mode, so after optimization the mirrors profile the output power at second harmonic can be slightly increased. The contents of gaussian-like TEM_{00} mode at output radiation is 93%.

III. SUMMARY

The agreement between the calculated and experimental data of power, efficiency and frequency indicates the correctness of technological solutions used in the manufacturing process and gives us hope for the successful implementation of the next versions - microwave systems with frequencies of 527 GHz and 780 GHz. These systems will be based on second harmonic gyrotrons, which for additional selection of operating mode will probably use multibeam electron optical system [2].

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