Gyrotrons with Shortened Cavities as Tunable Sources of Powerful Sub-Terahertz Radiation for Spectroscopic Applications

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Studies of forbidden resonance transitions are among the most complicated and most interesting problems in molecular gas spectroscopy. Typical transitions of this type are quadrupole transitions. Such transitions should be found in the spectra of all molecules, but currently only single vibrational-rotational lines of nonpolar molecules such as H_2, N_2, CO_2, etc. can be detected. The intensity of quadrupole transitions is very small. Therefore, an extraordinary sensitivity of the spectrometers is required for their observation and analysis. Most part of the spectrometers detecting radiation transmitted through a gas or re-emitted by a gas, have reached a sensitivity close to their theoretical limit. Only spectrometers using the method of radioacoustic detection of radiation absorption (RAD) by gases can provide a reserve of increasing sensitivity due to an increase in the power of the probing radiation [1]. Implementation of this idea requires the development of a CW coherent frequency-tunable radiation source.

In this paper, we discuss the possibility of developing powerful (>100 W) subterahertz gyrotron with frequency tuning band of about 3-5%, which is aimed to be used for RAD spectroscopy of quadrupole transitions of CO_2 at the frequency of 163 GHz. As it was demonstrated in [2], significant widening of the generation band in gyrotrons can be achieved with using of a shortened interaction space due to the weaker sensitivity to the velocity spread in the electron beam. At the same time, the shortening of the resonator will require increasing the current of the gyrotron electron beam. However, the required current value can be substantially reduced by going to operation at low transverse modes due to the growth of the electron-wave coupling coefficient. With a certain optimization, such approaches can provide a sufficiently wide band of gyrotron generation.

Further, results of PIC simulations are presented with using the KARAT code [3]. For 15 keV/0.4 A electron beam with pitch factor of 1 the TE_{13} mode, counter-rotating with electron motion in the guiding magnetic field, was chosen as an operating one. In Fig.1 the geometry of magnetron-injection gun (MIG) with above indicated parameters are presented. The gyrotron resonator was formed by a section of a circular waveguide bounded by a cutoff narrowing at the cathode end and a smooth widening at the collector end. The radius and the length of the regular part of resonator was 0.25 cm and 2.5 cm, correspondingly.

The simulations evidence that for the velocity spread of 20% the radiation power exceeds 100 W in the entire frequency tuning band of 4.1 GHz (2.5%) (Fig.2). For magnetic fields from 5.87 to 6.35 T, stationary single-mode excitation of the operating TE_{13} mode takes place. For magnetic field values outside this region, the excitation of the parasitic transverse TE_{42} and TE_{32} modes occurs, which limits the further increase in the bandwidth.

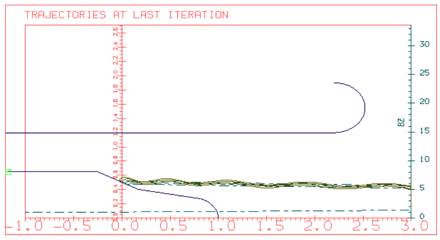

Fig. 1 Geometry of the MIG cathode part for a 163 GHz frequency-tunable gyrotron.

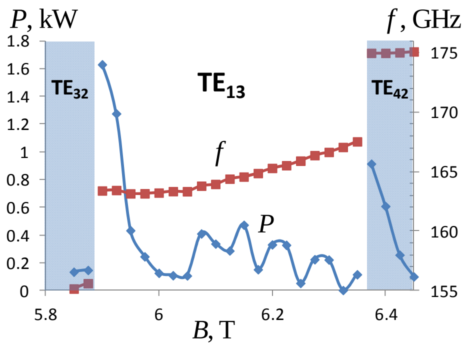

Fig. 2 Results of PIC simulations. Dependence of output power and operating frequency on the guiding magnetic field.

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