High-Power Terahertz Emission at Plasma and Double Plasma Frequencies during REB-Plasma Interaction

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High-power terahertz emission from magnetized plasma during intense relativistic electron beam-plasma interaction is studied at the GOL-PET facility. The specific power density of the radiation reaches the level ~ 1 kW/cm^2 in 0.2 ÷ 0.6 THz frequency band. The spectral power density of this terahertz radiation is located close to the upper-hybrid plasma frequency and at its double value.

I. INTRODUCTION

Studies of plasma emission in terahertz band during interaction of an intense relativistic electron beam (REB) with plasma have considerable interest as base for creation of high power terahertz generators on new fundamental principles. Strong plasma turbulence pumped by the beam at presence of magnetic field can generate sub-terahertz and terahertz radiation with frequencies close to the upper- hybrid plasma frequency and at its double value.[1] To study the plasma emission processes in these frequency bands we have created the specialized GOL-PET facility (PET – plasma emission of terahertz). Results of experimental studies at the GOL-PET facility will be presented in this paper.

II. RESULTS

The GOL-PET facility, see Fig.1, consists of a device to produce a plasma column with the density (2×10^{14} ÷ 5×10^{15}) cm^{-3} in uniform magnetic field up to 4.5 T and the accelerator U-2 that generates an electron beam with the current density (1 ÷ 4) kA/cm^2 in the plasma at the electron energy above 0.6 MeV. The pulse duration of the beam is 6 μs. The diameter of the plasma column is 5 cm and its length is 2.4 m between the main entrance and exit mirrors. The plasma density is measured by a CO_2-interferometer and by a multichannel Thomson scattering system. The beam current is measured by pulse current transformers and the energy of the injected beam electrons is defined from measurements of the voltage of an accelerator diode. Energy deposition of the electron beam in the plasma is calculated from measurements by diamagnetic probes distributed along the plasma column. The electromagnetic wave emission from the plasma is analyzed by an eight-channel polychromator and a three-channel spatial resolved detector. The total energy content in the microsecond pulse of the terahertz radiation is measured by a calorimeter from Thomas Keating Limited. The THz emission propagated perpendicular to magnetic field is registered from the central area of the solenoid and axial emission is observed at the end of the device by mean of 45° mirror.

In the experiments we have recorded the temporal dynamics of spectrum and polarization of THz radiation at the upper-hybrid plasma frequency and at its double value for various plasma and beam parameters. As example of the experimental results for the plasma with density 5×10^{14} cm^{-3} (see Fig.2) and magnetic field 4.5 T, we present in Fig. 3 the waveform of the signals from the registration channels of the eight-channel polychromator. At this point, the diagnostics has been installed at the end of the solenoid.

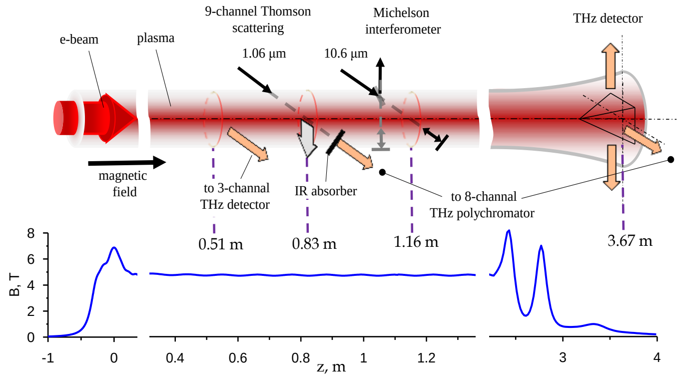

Fig. 1. Layout of experimental GOL-PET facility with the plasma and THz electromagnetic emission diagnostics.

In the Fig. 4 the experimental spectrum in different temporal intervals is presented. The signals for the frequency interval of 180 ÷ 300 GHz can be interpreted as the emission in the upper-hybrid plasma frequency band. The 400 ÷ 500 GHz frequency interval we associate with the emission in the band of double value of the upper-hybrid plasma frequency.[2,3] Although the observed THz emission was axial, the results are in the accordance with previous experiments that have been carried out on the GOL-3 facility with long magnetic solenoid (12 m) and the same vacuum ribbon diode that generates relativistic electron beam.[1] In the maximum of THz emission at the moment of $t = 0.3$ μs the specific power in the band of 400 ÷ 500 GHz achieves $P_{max} = 50$ W·sr^{-1}·cm^{-2}.

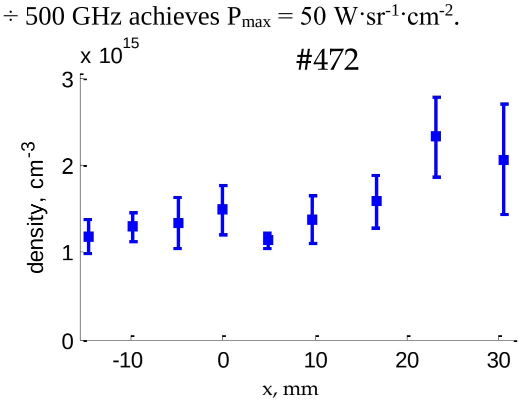

Fig. 2. Plasma density distribution across the axis in z = 83 cm from entrance mirror measured by nine channel Thomson scattering system based on Nd: YAG laser.

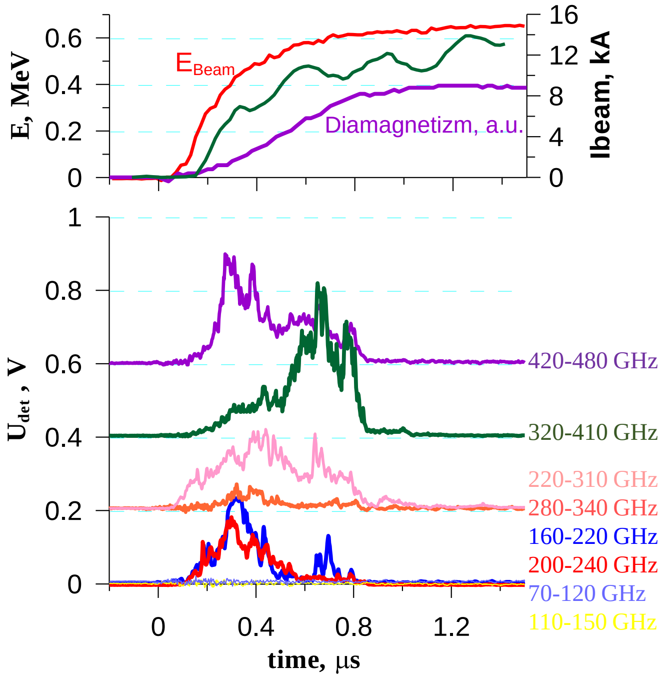

Fig. 3. Temporal evolution of electron beam parameters and plasma diamagnetism (top diagram). The waveform of the signals from the registration channels of the eight-channel polychromator (bottom diagram).

This value is calculated in supposing of uniform distribution of emission at the end cross-section of plasma column. For the frequency interval of 180 ÷ 300 GHz the specific power has the value of 800 $W \cdot sr^{-1} \cdot cm^{-2}$. The maximum of specific power of transverse THz emission achieved P_{max} = 100 $W \cdot sr^{-1} \cdot cm^{-3}$ in discussed experiments.

One can see that terahertz emission from the plasma column exists only during the period of plasma diamagnetic energy growth, Fig. 3, i.e. during the effective pumping of the beam-induced turbulence in plasma.

III. Summary

The research have shown that the specific power density of the radiation has a level ~ 10^2 W/cm^3 in a frequency interval ~ (0.2 ÷ 0.6) THz at the intense REB-plasma interaction in the uniform confining magnetic field.

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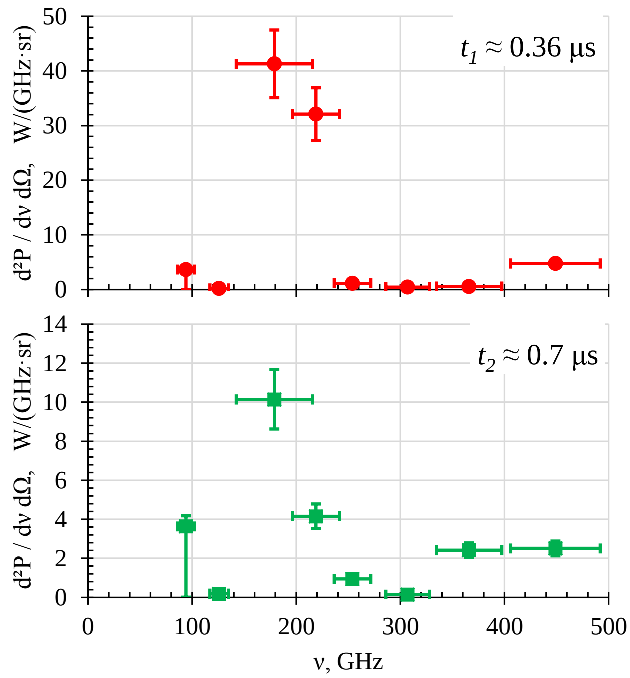

Fig. 3. Temporal evolution of electron beam parameters and plasma diamagnetism (top diagram). The waveform of the signals from the registration channels of the eight-channel polychromator (bottom diagram).

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