3D PIC simulation of interaction of an electromagnetic wave with a counterpropagating electron beam under condition of cyclotron resonance

A.A. Rostuntsova[1,2,*], R.A. Torgashov[1,2], N.M. Ryskin[1,2]

[1]*Saratov Branch, Institute of Radio Engineering and Electronics RAS, Saratov, Russia*
[2]*Saratov State University, Saratov, Russia*

*email: rostuncova@mail.ru

ABSTRACT

In the previous work [1], we have demonstrated that modulation instability [2] strongly affects the regimes of electromagnetic wave transmission through a counterpropagating, initially rectilinear electron beam under the condition of cyclotron resonance. In addition to the cyclotron absorption, depending on the parameters of the incident wave, the regimes of multifrequency self-modulation oscillations and stationary single-frequency propagation are also implemented. In particular, we have obtain the conditions at which a continuous-wave driving signal disintegrates into a close-to-periodic train of microwave soliton pulses. In this paper, 3D PIC simulations verify the theoretical predictions.

3D PIC simulation has been performing for a cylindrical waveguide with a radius of 0.4 mm and a length of 20 mm and a longitudinal magnetic field of 8.9 T [3]. In the considered model, an initially rectilinear electron beam with an energy of 1.828 keV and a current of 100 mA propagates along the system. A harmonic signal of a constant power of 1 kW is fed from the collector end with a frequency varying in different experiments in the 240–243 GHz range, which corresponds to relatively small detunings from the exact cyclotron resonance (240.3 GHz).

Stationary absorption of wave is observed in the 240.3-240.8 GHz region of the input signal frequency. In the region of 240.8-241.0 GHz, non-stationary self-modulation takes place. In particular, at 240.8 GHz, a train of soliton-like pulses with a duration of about 1-2 ns and a peak power exceeding 1 kW is generated. At higher frequencies of the input signal, there is a stationary single-frequency propagation. Such a change of regimes with an increase in frequency detuning from the cyclotron resonance fully corresponds to the theoretical studies [1].

REFERENCES

1. *A. A. Rostuntsova, N. M. Ryskin, I. V. Zotova, and N. S. Ginzburg*, Modulation instability of an electromagnetic wave interacting with a counterpropagating electron beam under condition of cyclotron resonance absorption // Phys. Rev. E **106**, 014214 (2022).
2. *V.E. Zakharov and L.A. Ostrovsky,* Modulation instability: The beginning // Physica D **238** (5), 540-548 (2009).
3. *I. V. Zotova, N. S. Ginzburg, A. S. Sergeev, E. R. Kocharovskaya, and V. Yu. Zaslavsky*, Conversion of an Electromagnetic Wave into a Periodic Train of Solitons under Cyclotron Resonance Interaction with a Backward Beam of Unexcited Electron-Oscillators // Phys. Rev. Lett. **113**, 143901 (2014).