USING STOCHASTIC DECOMPOSITION PROCESSES FOR FORMATION SPECTRA OF OSCILLATIONS

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In work results of research of spread spectrum of superhigh-frequency oscillations in the polymodal resonator filled by plasma, placed in a magnetic field, due to stochastic disintegration of own modes of the resonator with participation of low-frequency plasma oscillations are presented. Experiment is executed in conditions electron-cyclotron resonance for oscillations with frequency 2.77 GHz and powers up to 1 MW in plasma with density 10^9 cm^{-3} and electron temperature ~60 eV. The opportunity enlarge of a spectrum of oscillation formed by magnetron generator in hundred times is shown.

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1. INTRODUCTION

There are certain difficulties of creation of the superhigh-frequency generators of the big level of power, with adjustable width of a spectrum and spectral density of power. It is caused by that, as a rule, generators provide effective excitation of oscillations only at the certain parameters of its operation, the deviation from which leads to sharp deterioration of characteristics of oscillations and their efficiency of excitation.

In work it is offered and investigated the formation of spectra due to use of plasma nonlinear processes in conditions of excitation the oscillations of the big amplitude when stochastic disintegration processes take place.

It was investigated increase the width of a spectrum of the super-high-frequency (SHF) oscillations on frequency 2.77 GHz in the polymodal resonator with plasma in a longitudinal magnetic field in conditions of an electron-cyclotron resonance. Plasma was created by the beam-plasma discharge. The density of plasma was made 10^9 cm^{-3}, with temperature ~60 eV. The level of exited field in the resonator is more threshold value for development of stochastic decay of a exited wave at which nonlinear interaction of two microwaves of own modes of the resonator and one own low-frequency (LF) of a fashion of plasma takes place.

2. THEORETICAL ESTIMATIONS

Theoretical researches are put in a basis of statement of experiment three-wave disintegration processes in plasma. They are in detail enough stated in works [1, 3]. In them stochastic disintegration of the microwave on high-frequency and low-frequency plasma (LF) is considered.

As an example process of disintegration of a wave in electrodynamics structure with tubular plasma can be considered. In such plasma there are two superficial waves. Frequencies of these waves of the order $\omega_p/\sqrt{2}$. These waves are raised by electron beam. When the amplitude of an exciting wave reaches some threshold value, the mechanism of three-wave disintegration of this wave on electromagnetic cross-section and lower hybrid joins. To one of variants of three-wave interaction it is presented on fig. 1.

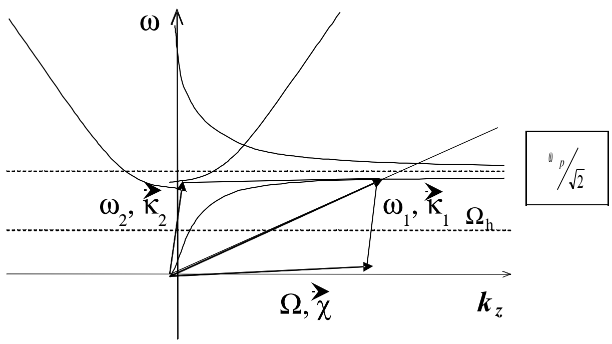

Fig. 1. Dispersive curves of a tubular plasma wave guide

The system of the equations describing disintegration process has a following appearance:

$$
\begin{aligned}
& i\frac{d\varepsilon_i}{d\tau} = \varepsilon_s\rho\,\exp(i\Delta\tau), \\
& i\frac{d\varepsilon_s}{d\tau} = \varepsilon_i\rho\,\exp(-i\Delta\tau), \\
& \frac{d^2\rho}{d\tau^2} + \Omega^2\rho = -\varepsilon_i\varepsilon_s^*\exp(-i\Delta\tau),
\end{aligned}
\tag{1}
$$

where ε_i – amplitude of a breaking up wave, ε_i – amplitude of an electromagnetic wave, ρ – amplitude of a low-frequency wave, Ω – dimensionless amplitude of a low-frequency wave, Δ – normalized difference of frequencies of the waves. Transition to stochastic waves is defined by factor [1]:

$$K = \frac{\sqrt{3}}{2\Delta} > 1 \tag{2}$$

that is carried out under condition of $\Omega^2 >> 1$.

Numerical modeling of system of the equations (1) has confirmed that disintegration (decay) process begins only at performance of a condition (2). At performance of criterion (2), a spectrum of oscillations spreads, and Lyapunov's exponents accepts positive values.

3. DESCRIPTION OF THE EXPERIMENTAL SETUP

The experimental setup (fig. 2) consists of following basic units: chambers of interaction - the polymodal resonator (7) in a longitudinal magnetic field, the magnetron generator (15), an electronic gun (2) in the chamber (1, 5), probes of registration of oscillations in the resonator (14), vacuum pumps (3, 6, 9), the solenoid (10), a collector (12) in the chamber (11, 13), an electron beam (8) and a data-acquisition equipment.

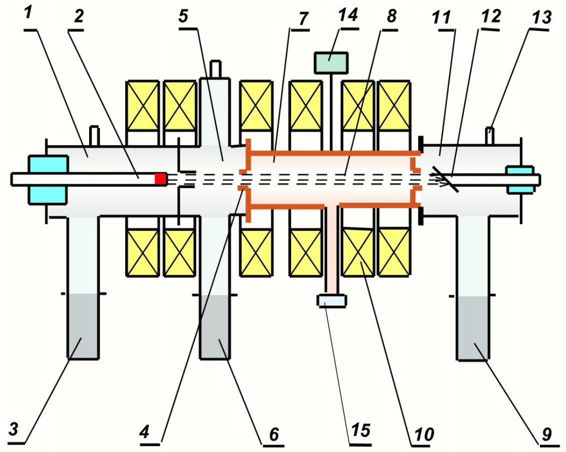

Fig. 2. The schematic image of the experimental setup

The chamber for creation of plasma is the cylindrical copper resonator, with internal diameter 160 mm, long 650 mm. Face surfaces of the resonator are formed by mobile plungers, with apertures in diameter 30 mm on an axis, for posting through it of an electron beam in it. Inside of the resonator pressure of gas (argon) was adjusted from $5 \cdot 10^{-5}$ up to 10^{-3} mm Hg, for creation of plasma of necessary density.

The resonator is excited on frequency 2.77 GHz by the magnetron generator with power up to 1 MW. The microwave power was brought by a rectangular wave guide 72x34 mm., which was jointed with the resonator on the average section on its length. As a result of experimental researches optimum communication with the resonator is picked up at orientation of a wave guide for excitation on one frequency of simultaneously necessary fashions in it. Wide walls of a wave guide were guided along an axis of the resonator. Following own modes of oscillations could be excited in the resonator with the lowest indexes: $H_{0\,1\,5}$, $H_{2\,1\,7}$, $H_{1\,1\,9}$, $H_{2\,1\,8}$, $H_{1\,1\,10}$, $H_{0\,1\,6}$, $E_{1\,1\,5}$, $E_{0\,1\,8}$, $E_{0\,1\,9}$, $E_{1\,1\,6}$. Identification of excited modes of oscillations was spent by a method of a trial body [2].

The electronic gun with termoemission cathode from LaB in diameter 18 mm settled down on an axis of the solenoid of a magnetic field. The accelerating voltage of a gun changed from 0 up to -600 V a current 0-100 mA. Simultaneously with measurements of frequency characteristics of oscillations the registration accelerated electrons in raised waves on brake x-ray radiation from volume of the resonator was made. For this purpose the system consisting of crystal NaJ and the photo multiplier was used.

4. EXPERIMENTAL RESULTS

Studying of a spectrum of excited oscillations has shown that the width of a spectrum of the SHF waves is defined by their strange in the resonator. Prominent feature of a spectrum is enlarge of it with displacement in area of higher frequencies and presence of red and dark blue satellites at frequency magnetron. Such spectrum is characteristic for nonlinear disintegrations processes in plasma. On fig. 3 the spectrum of excited oscillations is presented for introduction of power of SHF oscillation in the resonator ~1 MW.

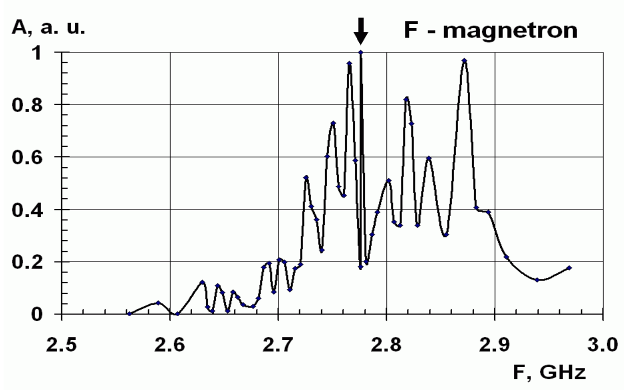

Fig. 3. The microwave spectrum of oscillations in the resonator.

Raised SHF oscillation test complex modulation on frequencies 10…100 MHz. This modulation corresponds to own plasma frequencies.

The spectrum of these low-frequency oscillations is presented on fig. 4.

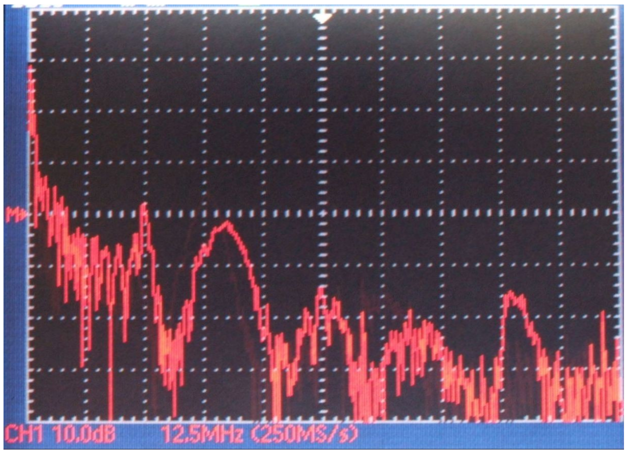

Fig. 4. A spectrum of low-frequency oscillations

On fig. 5 are resulted the oscillogramm of low-frequency oscillations registered in the detected SHF signal. Excitation of low-frequency oscillations has threshold character, and their amplitude depends from intense the microwave oscillations in the resonator. The oscillogramm of intensity of x-ray radiation from volume the resonator caused by braking accelerated electrons in field exited waves is present on fig. 5 too.

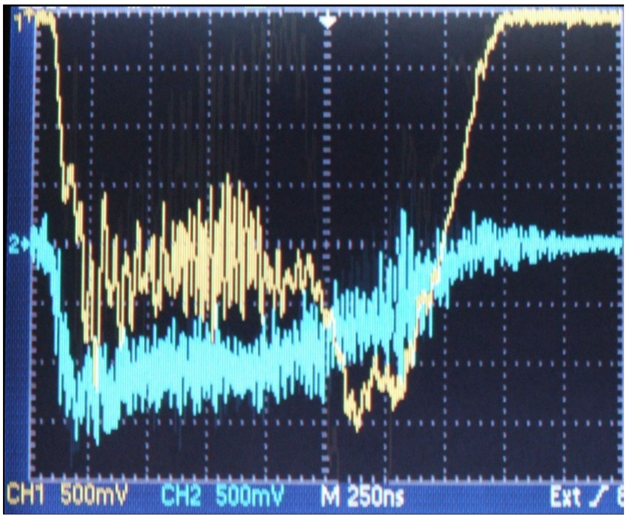

Fig. 5. Oscillograms of low-frequency oscillations (top) and x-ray radiation (bottom)

5. CONCLUSIONS

It is necessary to consider as the main-core result of the executed experimental researches an illustration of an opportunity of adjustment of width of a spectrum and distribution of spectral density of oscillation power due to use of nonlinear interaction of waves in plasma.

Qualitatively observable effects in experiment coincide with theoretical representations in the description of stochastic instability at nonlinear interaction of type a wave-wave [1-3]. For it occurrence in a spectrum of SHF oscillation of satellites and excitation with growth of their capacity of the low-frequency plasma oscillations causing complex character of modulation of high-frequency oscillations is characteristic.

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ИСПОЛЬЗОВАНИЕ СТОХАСТИЧЕСКИХ РАСПАДНЫХ ПРОЦЕССОВ ДЛЯ ФОРМИРОВАНИЯ СПЕКТРОВ КОЛЕБАНИЙ

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Представлены результаты исследования уширения спектра сверхвысокочастотных колебаний в многомодовом резонаторе, заполненном плазмой, помещенных в магнитное поле, за счет стохастического распада собственных мод резонатора с участием низкочастотных плазменных колебаний. Эксперимент выполнен в условиях электронно-циклотронного резонанса для колебаний с частотой 2.77 ГГц мощностью до 1 МВт в плазме плотностью 10^9 см$^{-3}$ при электронной температуре ~60 эВ. Показана возможность уширения в десятки раз спектра колебаний, формируемых магнетронным генератором.

ВИКОРИСТАННЯ СТОХАСТИЧНИХ РОЗПАДНИХ ПРОЦЕСІВ ДЛЯ ФОРМУВАННЯ СПЕКТРІВ КОЛИВАНЬ

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Представлено результати дослідження розширення спектру надвисокочастотних коливань в багатомодовому резонаторі заповненому плазмою, розміщених в магнітному полі, за рахунок стохастичного розпаду власних мод резонатора з участю низькочастотних плазмових коливань. Експеримент виконано в умовах електронно-циклотронного резонансу для коливань на частоті 2.77 ГГц з потужністю до 1 МВт в плазмі густиною 10^9 см$^{-3}$ при електронній температурі ~60 еВ. Показана можливість розширення в десятки разів спектру коливань, що формуються магнетронним генератором.