ON THE POSSIBILITY TO CREATE THE PLASMA AMPLIFIER WITH DIRECT RADIATION OF ELECTROMAGNETIC WAVES

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The possible scheme of plasma amplifier with direct radiation is proposed. Energy of amplified oscillations is coupled out due to transitional radiation on the plasma border retained by constant magnetic field. For this purpose the beam that is injected into plasma column should be slightly defocused. Paraxial electrons of the beam provide plasma-beam interaction and signal amplification. Defocused peripheral electrons modulated by HF field created in the beam-plasma system move along spiral trajectories. Thus, they periodically come into the plasma column and come out of it. Each time transitional radiation takes place. It can result to sufficiently high effectiveness of the beam modes' transformation into electromagnetic waves.
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Plasma amplifiers and HF generators belong to the plasma electronics devices [1-3]. They ensure the electronic amplification up to 60-70 dB [4]. However, the high wastes in the outlet connection channel (up to 30-40 dB) limit their practical usage [5]. Consequently, the problem of signals' direct output for such devices remains actual.

In [6-8] it was proposed to use in such devices the transition radiation that arose while modulated electron beam moved through plasma boundary. However, the concrete scheme of plasma amplifiers with direct radiation based on this effect has not been proposed.

For example, the problem of transition radiation from the anisotropic plasma boundary was examined in [9-13]. Nevertheless, the considered magnetic field was directed normally to the plasma boundary in all of those works. However, it is obvious that for plasma retention the magnetic field must be directed parallel to the plasma border.

Calculation of the transition radiation of the electron stream with the skintled modulation falling normally on the plasma boundary retained by the magnetic field paralleled to that boundary was carried out in [14] for various orientations of wave vector of the electron stream modulation. Analogous calculation for thin modulated beam has been done in [15].

Model of plasma amplifier similar to one described in [16-17] is proposed in this work. Nevertheless, in the amplifier described in [16-17] transition radiation of the modulated electron stream serves as a mechanism of the signals' direct output.

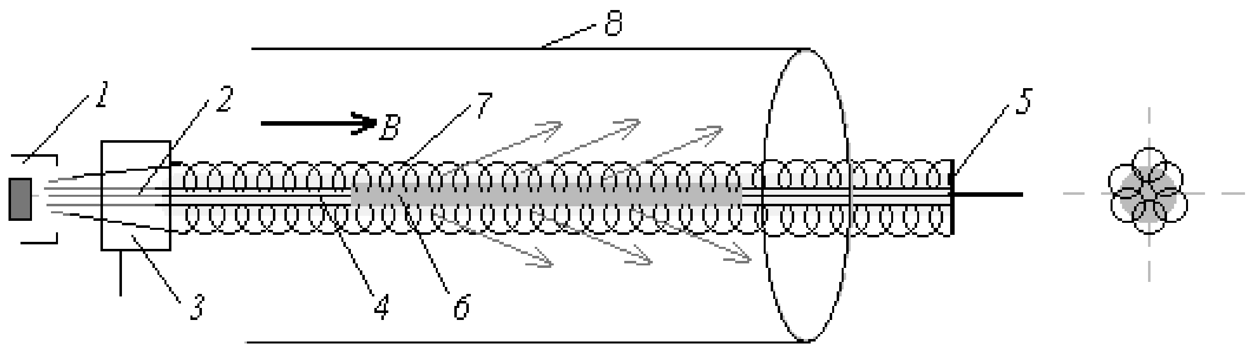

Fig.1

The proposed device (see Fig.1) consists of electron gun 1 forming the beam of accelerated electrons 2. This beam is modulated by the input signal through device 3 that usually constitutes a piece of spiral. The whole system is placed into the constant longitudinal magnetic field **B**. The beam ionises the gas along its trajectory and creates the plasma column 4 due to the beam-plasma discharge. This column is retained by magnetic field. Plasma reaches the collector 5. The input signal is amplified due to the beam interaction with plasma formed by this beam. The oscillations' intensity reaches its maximum in some region 6. Then the beam relaxes, and oscillations' amplitude decreases.

Peculiarity of the proposed model in comparison with the devices described in [16-17] is a specific choice of construction and mode of electronic gun so that the beam injected is partially defocused. Consequently, the main part of the beam electrons moves along the axis of system and provide the basic amplification. However, some part of peripheral electrons flies into magnetic field at the non-zero pitch angle and moves along the periphery of plasma column along the spiral trajectories 7.

These peripheral electrons are shifted periodically in the radial direction sometimes moving into plasma, sometimes going out from it. Due to the increase of the high-frequency signal amplitude, the peripheral electrons are modulated over speed and density at the initial part of the trajectory. They create a modulated stream that crosses periodically the diffuse border of plasma column retained by magnetic field. As a result, the peripheral electrons' bunches generate the transition radiation both in the moments of entering in plasma and in the moments of going out from it. The same electron bunches product radioemission many times up to getting to the collector. It should result to the considerable increase of transition radiation effectiveness in comparison with the models considered earlier [14] when modulated beam crosses the plasma border one time only.

If the described system is placed into the waveguide paralleled to the axis of system, the radio signal obtained can be canalised.

Let us obtain the condition of coherence of wave modes' excitation by the beam's electrons that move along the spiral trajectories and perform the transition radiation. It is possible to write down the longitudinal wave number of the waveguide mode as $(\omega/c)[1-(\omega_0/\omega)^2]^{1/2}$, where ω_0 is the cut-off frequency. The spirally modulated electronic beam contains the component of current with the longitudinal wave numbers, $(\omega+\omega_c)/v_0$, $(\omega-)/v_0$, where ω and v_0 are the modulation frequency and of the beam velocity, respectively, and ω_c is the electron-cyclotron frequency. Only the last current component can be in synchronism with the waveguide mode under the condition

$$\frac{\omega-\omega_C}{\sqrt{\omega^2-\omega_0^2}}=\frac{v_0}{c} \qquad (1)$$

It is clear from (1) that the coherent excitation of waveguide mode by non-relativistic electron beam is possible only when the signal frequency is close to the electron-cyclotron frequency and not too close to the cut-off one.

For the case of radiation into vacuum (without waveguide) the ratio (1) has a form

$$\frac{\omega-\omega_C}{\omega}=\frac{v_0 \ \cos\theta}{c}, \qquad (2)$$

where θ is an angle between the direction of the electronic beam velocity and wave vector of the radiated electromagnetic waves.

If condition (1) or (2) is satisfied, the transition radiation power should be N^2 times more relatively to the case of the single cross of the plasma border by the modulated electron beam that was treated in [15]. Here $N=\omega_c L/(2\pi v_0)$ is the number of peripheral electrons' entries into the plasma column of the length L.

The final answer to the question of the effectiveness of the proposed device can be obviously given only by the experiment.

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О ВОЗМОЖНОСТИ СОЗДАНИЯ ПЛАЗМЕННОГО УСИЛИТЕЛЯ С НЕПОСРЕДСТВЕННЫМ ИЗЛУЧЕНИЕМ ЭЛЕКТРОМАГНИТНЫХ ВОЛН

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Предлагается схема построения плазменного усилителя с прямым излучением, в котором энергия усиленных колебаний выводится наружу за счет переходного излучения на границе плазмы, удерживаемой магнитным полем. Для этого пучок, вводимый в плазменный столб, делается несколько дефокусированным. Параксиальные электроны пучка обеспечивают плазменно-пучковое взаимодействие и усиление полезного сигнала. Дефокусированные периферийные электроны, промодулированные создаваемым в системе высокочастотным полем, движутся по спиральным траекториям. Таким образом, они периодически входят в плазменный столб и выходят из него, каждый раз порождая переходное излучение. Последнее может обеспечить сравнительно высокую эффективность преобразования пучковых мод в электромагнитные волны.

ПРО МОЖЛИВІСТЬ СТВОРЕННЯ ПЛАЗМОВОГО ПІДСИЛЮВАЧА З БЕЗПОСЕРЕДНІМ ВИПРОМІНЮВАННЯМ ЕЛЕКТРОМАГНІТНИХ ХВИЛЬ

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Пропонується схема побудови плазмового підсилювача з прямим випромінюванням, у якому енергія підсилених коливань виводиться назовні за рахунок перехідного випромінювання на межі плазми, утримуваної постійним магнітним полем. З цією метою пучок, що вводиться в плазмовий стовп, робиться дещо дефокусованим. Параксіальні електрони пучка забезпечують плазмово-пучкову взаємодію і підсилення корисного сигналу. Дефокусовані периферійні електрони, промодульовані утворюваним у системі високочастотним полем, рухаються по спіральних траєкторіях. Таким чином, вони періодично входять у плазмовий стовп і виходять із нього, щоразу збуджуючи перехідне випромінювання. Останнє може забезпечити досить велику ефективність перетворення пучкових мод в електромагнітні хвилі.