KINETIC EFFECTS IN THE LOCAL PLASMA RESONANCE REGION EXCITED BY MODULATED ELECTRON BEAM: 2D SIMULATION

I.O. Anisimov, D.M. Velykanets', T.Eu. Litoshenko
Taras Shevchenko National University of Kyiv, Radio Physics Faculty,
2 Glushkov Ave, build. 5, 03127, Kyiv, Ukraine, e-mail: milissent@mail.ru

Electrons' and ions acceleration in the local plasma resonance region (LPRR) excited by thin modulated electron beam was studied via computer simulation using PIC method. The region of electrons' and ions' acceleration was found out. At the late stage of the process the HF field excited in the LPRR perturbs the initial plasma density distribution. In that time the accelerated electrons velocity is directed at some angle to the plasma density gradient. Ions acceleration on the late stages of interaction is caused by ambipolar field.
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1. INTRODUCTION

Interaction of the modulated electron beam with inhomogeneous plasma is interesting for various branches of plasma electronics. Modulated electron beam excites the strong HF electric field in the local plasma resonance region (LPRR) and results to Langmuir waves' appearance [1]. The possibility of plasma electrons' acceleration in LPRR excited by the modulated electron beam was demonstrated in our previous work [2] for 1D model (similar effects take place for inhomogeneous plasma excited by the incident p-polarized electromagnetic wave [3-4]). But in laboratory experiments electron beams have a finite radius. Influence of the finite beam radius can effect strongly on the beam-plasma interaction in LPRR (see, e.g., [5]).

Dynamics of plasma electrons' and ions' two-dimensional velocity distribution function during this process is studied in this report using numerical simulation via PIC method. Simulation was carried out using modified PDP2 code.

2. SIMULATION PARAMETERS AND MODEL DESCRIPTION

Warm isotropic planarly-stratified plasma with initially linear density profile was studied. Thin modulated electron beam moved parallel to the plasma density gradient. Beam was initially modulated per density with depth of 100%. Modulation had a harmonic shape with the frequency ω.

Simulation was carried out using modified PDP2 code [6]. Plasma density was $(1,6\ldots4,8)\cdot10^8$cm^{-3}; simulation region was 60cm×10cm; plasma temperature was 2eV; beam velocity was $3\cdot10^9$cm/s; frequency of beam modulation was 0,16GHz; beam density was $2\cdot10^6$cm^{-3}.

3. ELECTRON'S ACCELERATION IN LPRR

Fig. 1 represents plasma electrons' 2D velocity distribution function for various time points. In the initial time points plasma electrons' 2D distribution function is symmetric: the field magnitude in LPRR is not enough for electron's acceleration (Fig. 1a).

As the field increases in LPRR, the accelerated electrons appear and move in the direction of subcritical plasma. It results to distribution function deformation (Fig. 1b).

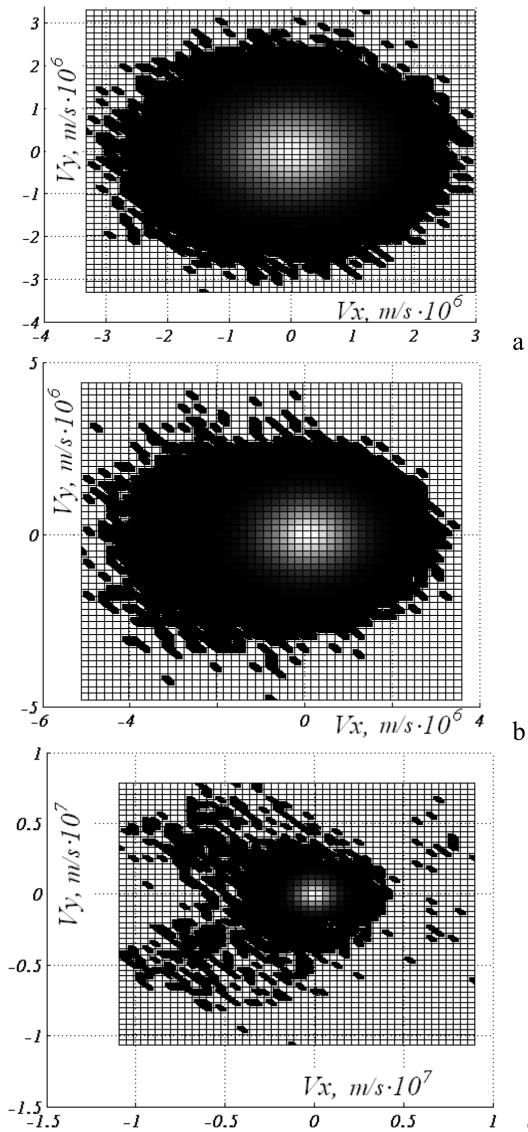

Fig. 1. Plasma electrons' 2D velocity distribution function for time points 142ns (a), 249ns (b), 316ns (c)

In the late time points plasma density profile deformation in LPRR changes the electric field configuration, and electrons are accelerated at some angle to the system axis (Fig. 1c). In contrast with 1D model transversal electric field caused by the finite beam cross-section plays the significant role in the electrons acceleration.

4. SPATIAL DISTRIBUTION OF THE ACCELERATED ELECTRONS

Spatial distribution of high energy electrons is defined as full energy of plasma electrons located in spatial interval (Δx, Δy). Fig. 2 represents the regions where electrons are accelerated for various stages of beam-plasma interaction (light areas correspond to regions with high values of electrons' energy).

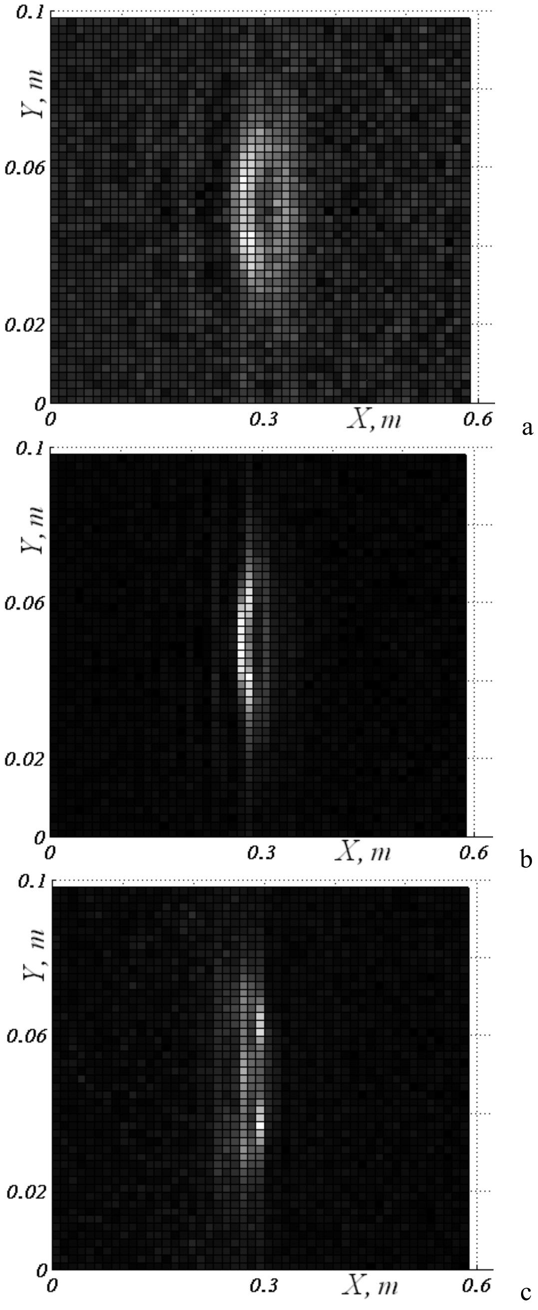

Fig. 2 Spatial distribution of electrons' mean energy for time points 142ns (a), 249ns (b), 316ns (c)

One can see from the Fig. 2 that electrons are accelerated in LPRR where strong HF field is exited. Electron's spatial distribution of kinetic energy density changes in time according to electric field spatial distribution changing in LPRR.

5. ION'S ACCELERATION IN LPRR

Fig 3 represents ions' 2D distribution function for late moment of beam-plasma interaction. The perturbation on ion's distribution function in the late period of interaction can be associated with accelerated ions that appear in LPRR.

Accelerated ions appearance is probably related with ambipolar field that is excited in LPRR at the late stage of interaction. Ponderomotive force that is caused by HF-electric field presses plasma electrons out from the LPRR. It results to electro-neutrality violation that forms the ambipolar field [5].

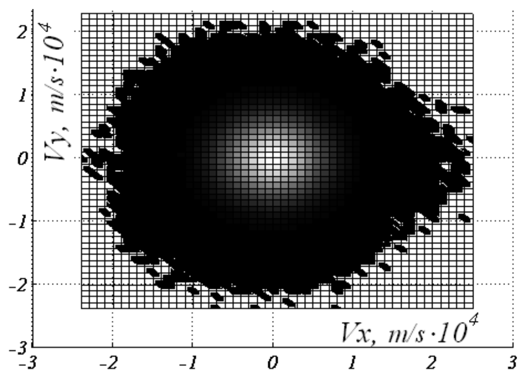

Fig. 3. Plasma ions' 2D velocity distribution function for the time point 316ns (c)

6. IONS' HEATING

Spatial distribution of ions' mean energy for late moment of interaction shows that ion's acceleration takes place in LPRR (Fig. 4). Ions' kinetic energy spatial distributions correspond to similar distributions of electric field more precisely in comparing with distributions of electrons' kinetic energy, because electrons has higher magnitudes of thermal velocities, and their energy spatial distribution is more eroded.

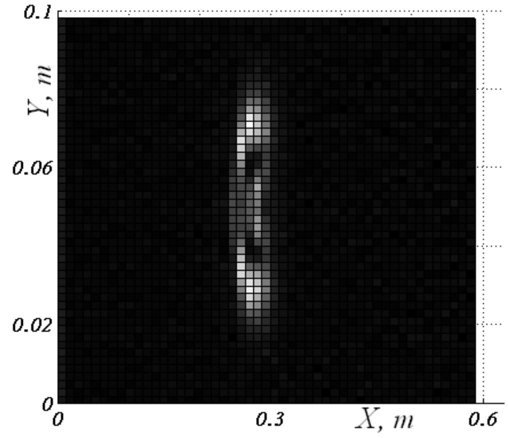

Fig. 4 Spatial distribution of ions' mean energy for the time point 316ns (c)

7. CONCLUSIONS

1. Electrons acceleration is caused by strong HF electric field exited by modulated electron beam in LPRR. Accelerated electrons move in the direction of subcritical plasma due to the motion of electric field wave.
2. At the late stage of interaction electric field decreases on the system axis, and electrons are accelerated at some angle to system axis.
3. Ions' acceleration in the late moments of interaction is caused by ambipolar field that appears in LPRR as a result of electro-neutrality violation.

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КИНЕТИЧЕСКИЕ ЭФФЕКТЫ В ОБЛАСТИ ЛОКАЛЬНОГО ПЛАЗМЕННОГО РЕЗОНАНСА, ВОЗБУЖДАЕМОЙ МОДУЛИРОВАННЫМ ЭЛЕКТРОННЫМ ПУЧКОМ: ДВУМЕРНОЕ МОДЕЛИРОВАНИЕ

И.О. Анисимов, Д.М. Великанец, Т.Е. Литошенко

При помощи компьютерного моделирования исследуются ускорение электронов и ионов плазмы в области локального плазменного резонанса (ОЛПР), стимулированной модулированным электронным пучком. Исследуются области ускорения электронов и ионов плазмы. На поздних стадиях взаимодействия высокочастотное поле, возбуждаемое в ОЛПР, деформирует профиль концентрации плазмы, и электроны ускоряются под некоторым углом к направлению градиента концентрации плазмы. Ускорение ионов на поздних этапах взаимодействия происходит под воздействием амбиполярного поля.

КІНЕТИЧНІ ЕФЕКТИ В ОБЛАСТІ ЛОКАЛЬНОГО ПЛАЗМОВОГО РЕЗОНАНСУ, ЗБУДЖУВАНІЙ МОДУЛЬОВАНИМ ЕЛЕКТРОННИМ ПУЧКОМ: ДВОВИМІРНЕ МОДЕЛЮВАННЯ

І.О. Анісімов, Д.М. Великанець, Т.Є. Літошенко

За допомогою комп'ютерного моделювання досліджується прискорення електронів та іонів плазми в області локального плазмового резонансу (ОЛПР), збуджуваній модульованим електронним пучком. Досліджуються області прискорення електронів та іонів плазми. На пізніх стадіях взаємодії високочастотне поле, що збуджується в ОЛПР, деформує профіль концентрації плазми, і електрони прискорюються під деяким кутом до напряму градієнту концентрації плазми. Прискорення іонів на пізніх часах взаємодії відбувається під дією амбіполярного поля.