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ON THE ROLE OF SOUND IN THE STRONG LANGMUIR TURBULENCE

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НОВОСИБИРСК

The principal proposals of work [1], where the necessity of sound role consideration in a strong Langmuir turbulence was first noted, is possible to formulate in the following way. After each act of Langmuir collapse a short-wave density perturbation of plasma is remained. In an isothermic plasma such a perturbation rapidly damps and exerts no substantial influence on Langmuir turbulence. In a nonisothermic plasma with hot electrons the sound damps quite slow, it accumulates and reaches a high intensity (remaining, however, weakly turbulent). The Langmuir waves short-length modulations produced by the sound are of essentially smaller phase velocities than the waves and are in the velocity resonance with the accelerated electrons. The decrement of Langmuir waves damping caused by such a kind of interaction (called in Ref. [1] a «conversion») is proportional to the energy density of a short-wave sound. At a sufficiently developed sound turbulence the conversion is more effective mechanism of the energy-containing (long) Langmuir waves absorbing, than the collapse; the acts of collapse are taking place only in a relatively small number required for keeping up the stationary sound level and do not put a substantial contribution to an energy balance of Langmuir turbulence. The condition for the collapse being suppressed by the conversion consists in the approximate equality of the conversion inverse time γ_{conv} to the modulational instability growth rate $\gamma_{mod}(k_0)$ for Langmuir waves from the energy- containing spatial scale k_0^{-1} of the strong turbulence:

$$\gamma_{conv} \sim \gamma_{mod}(k_0) . \tag{1}$$

This condition is accomplishable when the Langmuir waves energy density $W(k_0)$ exceeds some a critical value W_{cr} (given in the formula (4.4) of the second article from Ref. [1]).

The similar treatment of a sound role in strong Langmuir turbulence was given in Ref. [2] on a base of another model of the collapse. The author of the Ref. [2] somewhat specified the condition (1) inserting in it a logarithmic factor, which did not change the essence of principal propositions mentioned above. Nevertheless, those propositions arouse a number of the questions and, in many respects, have to be revised (though a qualitative conclusion about the important role of the Langmuir waves conversion caused by the sound in a nonisothermic plasma is, undoubtedly correct). The main directions of revision are the following:

1. According to Refs [1] and [2], the conversion suppresses the collapse on its early stage absorbing plasmons from the caverns, which is provided for by the condition (1). In fact, the conversion can suppress the collapse even at $\gamma_{conv} \ll \gamma_{mod}(k_0)$ via the energy density $W(k_0)$ of Langmuir waves going down under the threshold of their modulational instability $W_{th}(k_0)$. In the underthreshold regime the acts of collapse occur only in the places of fluctuational increase of value $W(k_0)$. An extaordinary sensitivity of such a fluctuations frequency to the average meaning of value $W(k_0) < W_{th}(k_0)$ provides any necessary (for keeping up the stationary sound level) suppression of collapse still in the applicability region of the rough estimate

$$W(k_0) \sim W_{th}(k_0)\,. \tag{2}$$

The value of γ_{conv} and, consequently, the sound level are defined by the condition of energy balance for the system.

2. In Refs [1] and [2] only the shortest sound waves were thought considerable. However, analysis shows that the sound of larger wavelengths, at certain conditions, is strongly turbulent. Such a relatively long-wave sound, even when it is weakly turbulent, can produce the diffusion of Langmuir waves up over the frequency and drastically change their spectrum. Taking into account of this process is made easier by that the Kolmogorov-type spectra arising at a diffusive interaction of the high-frequency and low-frequency waves were found in Ref. [3] (beyond the connection with the theory of strong Langmuir turbulence).

3. The influence of short-wave sound on the dynamics of Langmuir collapse was not taken into account in Refs [1] and [2]. Meanwhile, the self-similar collapse regimes distruction is possible by the growing short-wave perturbations (i. e. the unstable «quasi-modes») [4]. This possibility was confirmed by numerical calculation in Ref. [5], where also the quantitative limitation from below was given for the initial amplitude of short-wave perturbation necessary for the self-similar collapse distruction. When the limitation mentioned is fulfilled the collapse dynamics differ essentially from the one assumed in Refs [1] and [2]. As a result, the required for the collapse stopping concentration of being accelerated electrons change noticeably (as well as a form of electron distribution «tail»).

4. In Refs [1] and [2] only the average over space energy density of sound was used and the large amplitude and the coherence of sonic perturbation near the point of collapse were not taken into account. In particular, the effect was not discussed of the new Langmuir waves sucking by the cavern in the process of its postcollaptical deepening [6]. This effect plays a substantial role even in the isothermal plasma changing qualitatively the spectra of strong Langmuir turbulence and of accelerated by it electrons [7]. Even more significant role the coherent sonic perturbations have to play in the nonisothermal plasma where, after the completion of cavern deepening, the divergent sonic wave forms. At a moderate nonisothermality of plasma this wave damps before it has time enough to lose the coherence and the concept of uniform sonic turbulence is inapplicable.

5. It was not taken into account in Refs [1, 2] that at a sufficiently wide inertial interval of scales the electron nonlinearity changes the dynamics of collapse's final stage and the energy of sound generated on this stage. The corresponding correction of the condition for the collapse being suppressed by the conversion shows that in the substantially nonisothermic plasma (where the sound is absorbed by electrons) the conversion dominates automatically (formally, the value W_{cr}, mentioned while the principal proposals of Ref. [1] were considered, becomes much smaller than the modulational instability threshold $W_{th}(k_0)$).

A detailed exposition of the strong Langmuir turbulence theory improved by an account of all the factors mentioned above needs a much larger volume and has to be published separately.

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