Program and Abstracts

1996 International Conference on Plasma Physics

9-13 September 1996, Nagoya, Japan

ICPP 96 NAGOYA

Experimental studying of strong Langmuir turbulence in a magnetized plasma

L. N. Vyacheslavov, I. V. Kandaurov, E. P. Kruglyakov, O. I. Meshkov, and A. L. Sanin

Budker Institute of Nuclear Physics, Novosibirsk, 630090, Russia

New detailed investigation of strong Langmuir turbulence driven by relativistic electron beam in a magnetized plasma is presented. The efforts are focused on inquire into an area that is poorly understood at present-regimes of turbulence where the magnetic contribution to the dispersion relation of Langmuir waves exceeds the thermal contribution and where the kinetic effects are important. The dimensions of the observed turbulent region and the time scale of the experiment are much greater than the size and the life-time of a single caviton that allows the study of qusistationary turbulence. The major diagnostic tool which is especially developed for these experiments is a small-angle Thomson scattering both collective and non-collective. The collective scattering of CO_2 laser light is employed for observation of spectra of Langmuir waves and the attendant ion-acoustic waves. The non-collective scattering of Nd glass laser light is used for resolution of electron distribution function including high energy tails. **k**-Spectrum of Langmuir waves from the pumping to damping regions is measured in the experiment. The spectrum is broad and has a power-low decrease toward higher k. An analysis of the obtained spectra shows that Langmuir waves are strongly unstable relative to perturbations transversal to the direction of the magnetic field so a collapse should occur under conditions used. The experiments detect two signatures of the collapse occurrence. First of it is the short-wavelength ion-acoustic turbulence which level correlates with the level of Langmuir turbulence but does not affected by the return current. These ion-acoustic waves , which spectral density increases toward the short wavelength side, are to be generated by density depletions remaining after arrest of the collapse. The second evidence of the collapse is the plasma electrons heated up to 200-300 Te. The transit-time interaction is most likely responsible for the acceleration of these electrons. Hot electrons of much less density but with energies up to the energy of the injected relativistic electrons are detected and investigated by thin-foil absorption method. Plasma emission power at $2\omega_{pe}$ in a submillimeter region of spectra is measured and related to the spontaneous emission power calculated with the use of the experimental Langmuir waves spectrum. Possible turbulence mechanisms of the energy transfer in a magnetized non-isothermal (Te>>Ti) plasma as collapse, conversion and scattering of Langmuir waves on ion-acoustic waves are analyzed on the basis of the experimental data.

A Study of Plasma-Lined Cherenkov Maser

A.M. El-Nadi, H.A. Kirolous and Hafsa A. El-Hamawy
Electrical Engineering Dept., Faculty of Engineering
Cairo University, Giza, Egypt.

Interest has grown recently in maser devices based on the interaction between an electron beam and slowed-down electromagnetic waves traveling along a waveguide. High gain, reasonable output mode purity and tunability are usual objectives. When a cold plasma is introduced into the guide, the vacuum modes will be modified but will remain uncoupled to the space charge waves of the electron beam because of the disparity of their axial phase velocities. The trivelpiece-Gould modes with their slow phase velocities provide good candidates for beam interaction down to low beam energies (Both beam and plasma are assumed to be immersed in a strong axial magnetic field). Cylindrical and rectangular geometries were studied and in each case the cross-section was divided into plasma, electron beam and vacuum regions. Exact dispersion relations were solved numerically to obtain the wave number and spatial amplification factor for a given frequency. The results were compared with those obtained by perturbing the no-beam case to obtain the range of validity of the later. By viewing the mode structure in the no-beam case it was also possible to choose the location and thickness of the beam in order to maximize the interaction. Only wave amplification (or convective instabilities) were present. Our results show that the introduction of a cold plasma can lead to a much higher gain than that obtainable in the dielectric-lined guide, while allowing for tunability. Besides, the number of competing modes can also be limited.

COLLECTIVE INTERACTION OF MICROSECOND HIGH-POWER ELECTRON BEAM WITH PLASMA ON THE GOL-3-II FACILITY

M.A.Agafonov, A.V.Arzhannikov, V.T.Astrelin, A.V.Burdakov, M.N.Chagin, P.V.Denisenko, V.S.Koidan, V.V.Konyukhov, K.I.Mekler, P.I.Melnikov, V.S.Nikolaev, V.V.Postupaev, R.V.Razilov, A.F.Rovenskikh, S.L.Sinitskij, A.V.Tarasov, K.V.Tsigutkin, C.V. Vdovin.

Budker Institute of Nuclear Physics, 630090, Novosibirsk, Russia

GOL-3 facility is aimed for study of the collective interaction of microsecond electron beam with a plasma and its heating. First stage of this facility was operated for more than six years. Recently second stage named GOL-3-II was assembled.

In the GOL-3-II the plasma column has 12 m length in magnetic field up to 5 T in the homogeneous part of the solenoid and up to 10 T in its end mirrors. Key feature of the upgrading is the increase in the energy content of electron beam. The high-current electron beam generator U-2 is in use now for beam-plasma interaction experiments. This generator was shown to produce the beam with energy content up to 0.3 MJ .

GOL-3-II facility is put into operation. First results on transport of the high-power microsecond electron beam through the 12 m turbulent plasma column, beam relaxation in the plasma and plasma heating are presented.

EFFECTS OF PLASMA FLUCTUATIONS ON THE EVOLUTION OF NONRESONANT PLASMA WAVES

S. V. Vladimirov

Research Centre for Theoretical Astrophysics
School of Physics, the University of Sydney, NSW 2006, Australia

O. Ishihara

Department of Electrical Engineering
Texas Tech University, Lubbock, Texas 79409-3102, USA

If a test wave with constant amplitude is not in resonance with plasma particles, it is often considered as having no interaction with the background plasma. However, even in the absence of the wave-particle resonance, naturally appearing fluctuations in plasma density have been known to play a role in the energy exchange in the system where plasma waves propagate. Averaging over the fluctuations gives the equation for the evolution of the averaged one-particle distribution function, and the evolution is characterized by Coulomb collisions. The nonstationarity of the averaged particle distribution then induces the modification in the frequency and amplitude of the nonresonant wave.

Here, we show that the spontaneous fluctuations of plasma particle distribution and accompanied field fluctuations affect the evolution of plasma waves which are not in resonance with plasma particles. The nonresonant wave energy changes with the variation of the eigenfrequency of the nonresonant wave, while nonlinear coupling of the nonresonant wave field with plasma fluctuations guarantees the conservation of the number of the nonresonant quanta. The conservation of the quanta number (nonresonant wave action) is a consequence of the general theorem of adiabatic invariants in closed systems or gauge invariance under changes of phase in the system's Lagrangian.

Heating of Current Filaments associated with Nonlinear Alfvén Waves in Weakly Ionized Plasmas

M. Suzuki and J. I. Sakai

Laboratory for Plasma Astrophysics, Faculty of Engineering, Toyama University, 3190, Gofuku, Toyama, 930 Japan

Abstract

When large amplitude Alfvén waves propagate along homogeneous magnetic field in weakly ionized plasmas, current filaments are formed by a small density perturbtion (Suzuki and Sakai, 1996). We show results from a 2-dimensional simulation that localized plasma heating occurs around the filaments during repeat of coalescence and fission. These processes are different between in high beta plasma and in low beta plasma, furthermore between in fully ionized and in weakly ionized plasmas.

In low beta plasma, heating and density concentration occur where current filaments bunching occurs. However in high beta plasma, heating and density concentration occur where the bunching doesn't occur, because the amplitude of Alfvén waves associated with current filaments is large. In weakly ionized plasmas structures of current filaments and density concentration and heating regions are more sharply localized than in fully ionized plasmas. We apply the results to plasma heating processes observed in photosphere and chromosphere of the Sun.

Reference

M.Suzuki and J. I. Sakai, 1996, Ap.J. June 20 issue, in press.

Bootstrap Current in Toroidal Systems in the Presence of a Nonuniform Radial Electric Field

Andrey A.Kabantsev
Budker Institute of Nuclear Physics
Lavrentyev avenue 11, Novosibirsk 630090, Russia

Recent experiments and theories show that both the radial electric field and the toroidal rotation play an important role in the L/H mode transition and have a strong influence on the improvement of plasma confinement. These effects were attributed to the creation of edge radial electric field E_r and associated plasma potential shift much larger in magnitude than T/e. The region of rapid electric field fall, the E-shear layer as we shall call it, produces a differential toroidal $E_r \times B_p$ rotation of the plasma. The published theories of the bootstrap current neglect the E_r inhomogeneity encountered by the ion along its banana orbit. The neglect of the impact of this inhomogeneity on the ion toroidal drift velocity E_r/B_p is valid if the scale length $L_E \cong |\nabla \ln E_r|^{-1}$ of the E-shear layer is large compared with the width of the ion banana orbit, $\Delta_b = q\rho_i\epsilon^{-1/2}$. Here q the safety factor, ρ_i the ion Larmor radius and $\epsilon = a/R$ the inverse aspect ratio. If L_E is comparable with ion banana width Δ_b, the shear will strongly modify the radial distribution of the toroidal rotation velocity and cannot be neglected. Since the ion banana width greatly exceeds the electron banana width, the impact of the shear on the electron toroidal rotation velocity is therefore reduced. This change in relative velocity of electron and ions in their toroidal $E_r \times B_p$ flow seems to be sufficient to produce a localized modification of the bootstrap current.

To evaluate the effect of the nonuniform profile $E_r(r)$ on bootstrap current distortion we apply a simple model integrating the radial electric field along the ion banana orbits. It was obtained that the additional term δj_{bs}, correcting the neoclassical bootstrap current value j_{bs}, is

$$\delta j_{bs} = -\alpha \Delta_b^2 \frac{e}{T_i} \frac{\partial E_r}{\partial r} j_{bs},$$

where α is constant on the order 1. For $(\partial E_r/\partial r) < 0$ the ions rotate in the direction of the plasma current (co-direction) in the $\mathbf{E_r} \times \mathbf{B_p}$ drifting frame of the electrons. It can be seen that in the case of $(\Delta_b/L_E)eE_r\Delta_b \sim T_i$ the shear current term δj_{bs} can be comparable with j_{bs} at a radius where the $E_r(r)$ gradient is largest. Particularly, the strongly nonuniform radial profiles of the E_r and the toroidal rotation velocity were observed in experiments with perpendicular neutral beam injection in JIPP TII-U [1]. The estimated value of $\delta j_{bs}/j_{bs}$ for these experiments reaches 0.2 at a radius $r \approx (2/3)a$, that help to quantify the effects of nonuniform toroidal rotation on the plasma behavior. The expected value of this term for some other present devices and its experimental evidences are considered too.

[1] K.Ida *et al.*, *Nuclear Fusion*, **31**(1991) 943.