Publ. Obs. Astron. Belgrade No. 53 (1996), 51 – 54

DYNAMICS OF A PLASMA IN A STRONG OBLIQUE LANGMUIR WAVE FIELD

V.I.Arkhipenko, V.A.Pisarev, L.V.Simonchik

Institute of molecular and atomic physics ASB, Skorina av. 70, 220072 Minsk, Belarus

Abstract. **The dynamics of plasma in resonant area of the strong oblique Langmuir wave is investigated, when the oscillatory electron energy in the wave field much exceeds the ionization energy of argon atoms.**

The interest to the laboratory investigations of the strong electromagnetic wave interaction with plasma, when the oscillatory electron energy $\varepsilon_{\sim}$ is higher than the atomic ionization energy E_i, is connected with a possibility of application of knowledge about processes at such interactions in various branches of physics and engineering. Strong non-equilibrium of plasma at such conditions have an essential influence on the electrodynamics of the discharge and kinetics of the elementary atomic processes (Gil'denburg, 1989; Vikharev, 1991). To know ionization frequency, excitation rate of atoms and ions in strong electromagnetic wave field is important for the practical applications.

In present work the dynamics of the partly ionized and magnetized argon plasma inhomogeneous both radially and axially is investigated at incidence the short (hundreds of nanosecondes) microwave pulses by power of a several kilowatt. The experiments were performed in a linear plasma device "Granite" (Arkhipenko *et.al.*, 1981) with the next parameters: intensity of an external magnetic field - 3 kOe, working gas-argon pressure - $p = 10^{-2}$ Torr, scale of the longitudinal plasma inhomogenity - 5 cm, cross scale - 0.4 cm, electron concentration - $n_e < 10^{11}$ cm^{-3}, electron temperature - $T_e = 2$ eV.

An oblique electrostatic wave basically in the form of the fundamental Trivelpiece-Gould mode was excited in plasma by influence of a electromagnetic wave with frequency $f = \omega/(2\pi) =$ 2,84 GHz essentially smaller than electron cyclotron frequency, but higher than the ion plasma frequency. The dispersion relation for this wave is $k_\perp^2 = [\omega_{pe}^2 (r, z) / \omega^2 - 1]\, k_{||}^2$, where $k_{||}$ and $k_\perp$ are the components of the wave vector parallel and transverse to the magnetic field, $\omega_{pe}(r, z) = 4\pi n_c e^2/m_e$ - electron plasma frequency, n_c - critical concentration. The wave can propagate in a plasma with density higher than the critical value ($n_e(r,z) > n_c$) in direction of decreasing density to a point of a plasma frequency resonance (focal point) $\omega = \omega_{pe}(r, z)$. Propagating in this fashion the wave slows down and its electric field increases. Both the electron-plasma collision wave absorption and the wave interaction with electrons by Landau damping mechanism occur just in the neighbourhood of the focal point. The calculated amplitude of an electrical field of the fundamental Trivelpiece-Gould mode in focal point is about 100 kV/cm for incident power P = 10 kW. Then the oscillatory electron energy will be equal $\varepsilon_{\sim} = e^2E^2 / (2m_e\omega^2) \approx 25$ keV >> E_i, that much exceeds the ionization energy of argon atom E_i = 15,76 eV.

To study of processes in plasma before and during wave influence we have used the follow diagnostics: cavity diagnostic allowing to measure the electron plasma density distribution; optical diagnostics giving the information about the change of the intensity of the integral plasma emission in visible spectrum range; registration of a light radiation spectrum in the range of 400 - 500 nm; multigrid analyzer of charged particles allowing to control the distribution function of the electron component; the information about plasma wave processes was taken from the spectral analysis of scattered microwave signals. The registration of signals from all electronic gauges was made using the stroboscope voltage converter. The gathering and the treatment of the experimental information was made under PC IBM control.

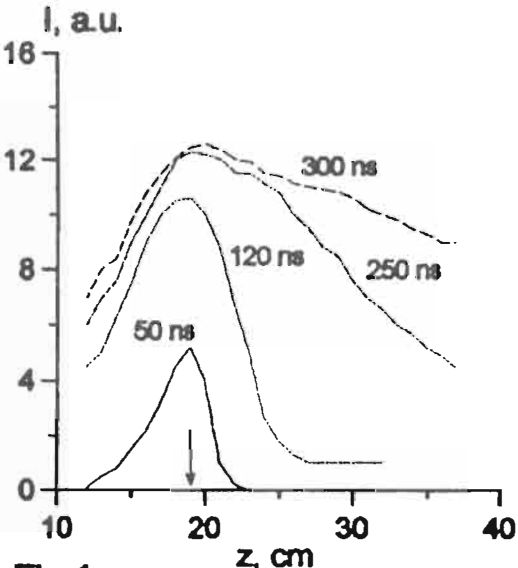

Fig.1

Parameters of microwave pump in experiment: pulse power P = 10 kW, pulse duration t ~ 300 ns, pulse front duration t_f ~ 40 ns, pulses repetition frequency - 300 Hz.

At initial moment (t < 150 ns) the longitudinal distribution maximum of the integral plasma emission is located in the area of the critical concentration (arrow in Fig. 1). There is the growth of the emission intensity from the smaller concentration of initial plasma at t > 150 ns. The uniform luminous channel is formed to the pulse end. In a cross direction the plasma emission distribution have the length ~ 1 mm and then extends in 1,5 - 2 times.

There are the low-frequency fluctuations with frequency 10-20 MHz in detected scattered microwave signal from the moment of formation of the luminous channel (150 ns). Then their frequency decreases to the pulse end. At the start-up of pulse the multigrid analyzer registers a quasi-macswell tail of the accelerated electrons with T_h ~ 500 eV. At t> 150 ns T_h decreases in 2 - 3 times, at the same time the electron concentration has a tendency to the permanent increase during the pulse. The concentration increase is followed after the microwave pulse during the tens microseconds, and then slow plasma decay is observed. It is occur due to slow relaxation of high electron temperature after a microwave pulse.

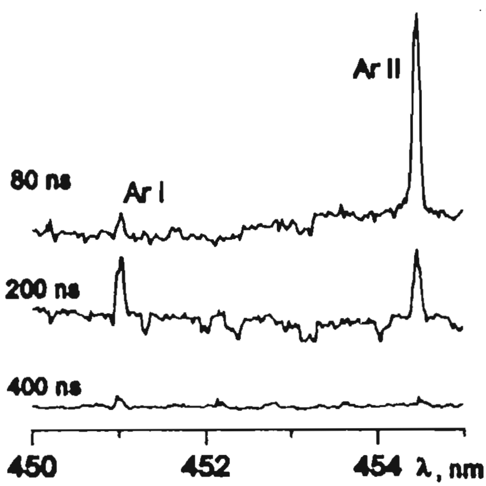

Fig.2

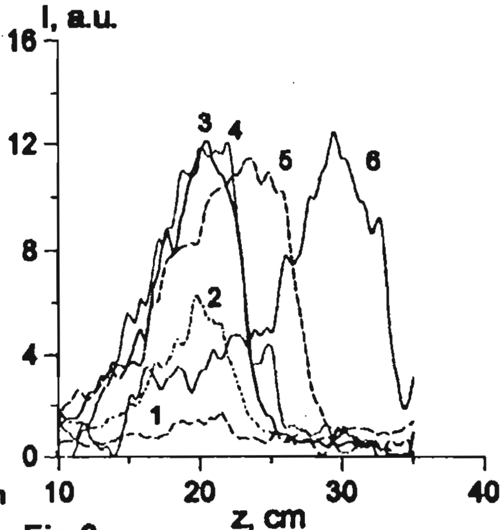

Fig.3

The ion lines are the most intensive at the beginning of a pulse and the spectrum is practically submitted by ArII lines (Fig.2). Perhaps the excitation of ions occur from the basic state of argon atoms after collisions with accelerated electrons. The plasma peremeters in focus are changed during a pulse: electron concentration is increased, wave field decreases, that results in reduction of electron energy. Therefore the lines ArII intensity to the pulse end also fall and become weaker than ArI one.

The longitudinal spectral line intensity distribution for ion ArII (454,5 nm ($4s^2P$ $-4p^2P^0$)) in various time moment from start of pulse is presented in Fig. 3 (curve 1 - t = 70 ns, 2 - 80 ns, 3 - 100 ns, 4 - 110 ns, 5 - 130 ns, 6 - 180 ns). At $t < 110$ ns, the maximum of intensity is located in the area of focus of initial plasma, similar of integral light distribution. However, in this case distribution curves have an obviously expressed maximum and repeat a theoretical picture of electrical field wave distribution in the area of focus (Arkhipenko et. al., 1987). Since $t > 110$ ns, maximum of distribution begins to displace, that is likely to connect with growth concentration of electrons and, as a consequence, displacement of focus point. Knowing electron concentration distribution in initial plasma n_{eo} and displacement time of a longitudinal intensity distribution maximum τ, it is possible to estimate ionization frequency in plasma: $\nu_i/p \sim \ln(n_c/n_{eo})/\tau \approx 3\times10^9$ s^{-1}.

The estimation of ionization frequency have been carried out also, basing on change in time of intensity of a spectral line of ion component I. Accoding to the plasma crown model $I \sim n_e$ and for ionization frequency was received the following value: $\nu_i/p \approx 3{,}5\times10^9$ s^{-1}, that is close to already received one above from the analysis of focus point displacement.

References

Arkhipenko, V.I., Budnikov, V.N., Romanchuk, I.A., Simonchik, L.V.: 1981, Sov. J. Plasma Physics, 7, 396.

Arkhipenko, V.I., Budnikov, V.N., Gusakov, E.Z., Romanchuk, I.A., Simonchik, L.V.: 1987, Sov. J. Plasma Physics ,13, 693.

Gil'denburg, V.I., Semenov, V.E.: 1989, Proc. XIX Int. conf. on Phen. in Ionized Gases, 1, 306, Belgrade.

Vikharev, A.L.: 1991,"Strong microwaves in plasmas", Vol. 1, 306, Nizhny Novgorod.