NONSTATIONARY PHENOMENA IN THE DECAY OF A PLASMA IN THE L-1 STELLARATOR

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Plasma confinement with a quasi-constant density distribution, and accordingly with a constant decay rate over the entire volume, was investigated previously [1] with the $\ell = 2$ stellarator L-1 [2] (major radius R = 60 cm, minor radius a = 5 cm, magnetic field intensity H_0 = 2 - 10 kOe). The average plasma lifetime determined by the microwave method with resonant excitation of the entire chamber coincided in this case with the "local" lifetime determined from pole measurements [3]. In individual cases, however, density "dips" were observed. In the described operating regime, the dips appeared regularly; an investigation of the space-time characteristics of the plasma in one pulse of operation has helped explain in detail the character of the plasma decay.

The measurements were performed with single Langmuir probes installed at different azimuths, and with a system of five radially-placed single probes spaced 6 mm apart. We investigated a decaying plasma produced by external injection [1]. The initial plasma density $n_0 = 10^{10}$ cm^{-3} was smaller by one order of magnitude than the usual one [1], and the pulsed pressure of the neutral gas ($p_0 = 2 \times 10^{-6}$ Torr) was also somewhat lower. In the indicated operating regime, relatively fast density "dips," up to 30 - 50% of the value of n in this region, were observed in the central region of the plasma. Figure 1 shows typical oscillograms of the density against the time, obtained in a single pulse of operation of the setup for radii 5, 11, 17, and 29 mm, obtained with the aid of a system of probes operating in the ion-current saturation mode (H_0 = 4.5 kOe, conversion angle i = $4\pi/3$). From curve 2 on Fig. 1 we see that at a certain instant of time the density decay rate increases and the amplitude of the density
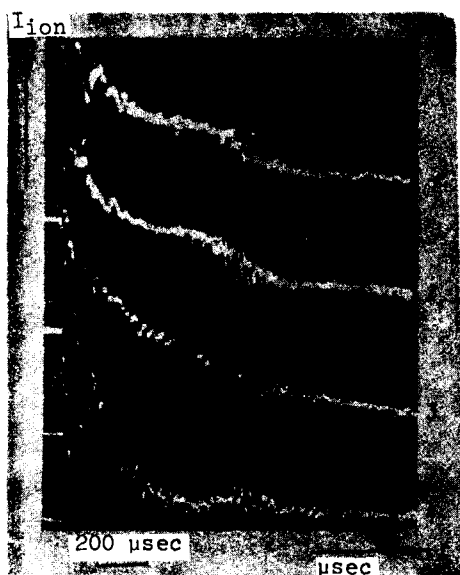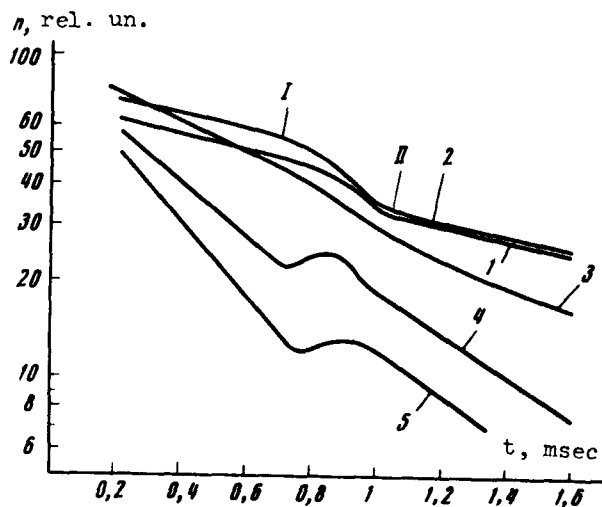

Fig. 1

Fig. 2

Fig. 1. Oscillogram: 1) r = 5 mm; 2) r = 11 mm; 3) r = 17 mm, 4) r = 29 mm.

Fig. 2. 1) r = 5 mm; 2) r = 11 mm; 3) r = 17 mm; 4) r = 23 mm; 5) r = 29 mm.

fluctuations increases simultaneously. When the decay rate and the fluctuation amplitude reach a maximum, this process extends also over the internal region of the plasma filament (curve 1 of Fig. 1). At the same time, at a radius of 22 - 29 mm, the plasma density increases (curve 4 of Fig. 1). In the external region (r = 17 on curve 3 of Fig. 1) where the oscillations exist all the time, their amplitude increases at the instant of the dip. The measurements have shown that the process occurs simultaneously over the entire given magnetic surface. Figure 2 shows plots similar to those of Fig. 1, but for greater clarity the time dependence of the density is shown on the semilogarithmic scale. From an analysis of these curves it follows that the characteristic density-decrease time depends strongly on the radius. In the central region (curves 1 and 2) the plasma loss is relatively slow, τ_s = 2 msec, and is interrupted by a fast dip (section I - II, where τ_f = 0.4 msec). Closer to the edge of the plasma (curves 4 and 5), τ_s is much smaller, 0.6 - 0.8 msec. After the end of the dip, a difference remains between the decay rates in the axial region and at the edge, and the next dip follows after a certain time[1]. The difference in the rate of plasma loss at different radii leads to a change in the radial distribution of the density with time. This becomes particularly strongly pronounced in the region r < 20 mm. Here the density gradient increases to a certain critical value, at which the distribution apparently becomes unstable, a dip occurs, and as a result the density distribution becomes less steep. The form of the distribution before the start of the fast plasma loss does not depend on the density level and has good reproducibility. Such a nonstationary character of the decay is most clearly observed at rational conversion angles, for example $i = 4\pi/3$ and $i = \pi$. In the case of non-rational values, the nonstationary process in the axial region is much less frequently observed. With increasing magnetic field H_0, the gradient-realignment region becomes narrower and the absolute value of the dip becomes smaller (20 - 30%). At a relatively small increase of pressure of the neutral gas ($p_0 > 10^{-5}$ Torr), no critical gradients arise and the dip stops.

Thus, the differences we observed between the plasma decay rates in the radial direction lead to a nonstationary distribution of the density and to the occurrence of dips. In the experiment we observed a connection between the shape of the density distribution and the development of the fluctuations. Attention is called to the sensitivity of the shape of the distribution and of the oscillation amplitude to a relatively small change of the neutral-gas pressure ($p_0 \sim 10^{-5}$ Torr). The oscillations accompanying the rapid decay have the same frequency interval ($\omega \sim 2 \times 10^{-5}$ sec^{-1}) as observed earlier [4], and the experimentally determined increment ($\gamma \sim 10^{-4}$ sec^{-1}) agrees with the theoretical estimate [4]. It can therefore be proposed that they have a similar nature and the significant increase of the amplitude is connected with the sharp increase of the density gradient. The presence of a correlation between the increase of the plasma loss rate and the buildup of the oscillations (curve 2 of Fig. 1) indicates that the latter can be the cause of the accelerated plasma loss from the central region. We were unable to establish a direct connection between the amplitude of the oscillations and the rate of plasma loss.

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[1]We note that the lifetime averaged over the entire volume of the plasma coincides with that measured earlier [1].

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ACTIVE SPECTROSCOPY OF RAMAN SCATTERING OF LIGHT WITH THE AID OF A QUASICONTINUOUSLY TUNABLE PARAMETRIC GENERATOR

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1. The purpose of this article is to describe the principles and certain results of an experimental realization of a method of active Raman-scattering (RS) spectroscopy with the aid of a quasicontinuously tunable parametric light generator (PLG).

The use of a pair of intense oscillations with tunable frequencies (ν_0 and $\nu_{1,2}$ - see Fig. 1) makes it possible to excite a selected vibrational transition (optical mode) of frequency Ω_0. By observing the scattering of a probing light beam (frequency ν_{pr} - see Fig. 1) from this mode one can greatly improve the signal/noise ratio at the output of the RS spectrometer and to measure the scattering line shape (especially in the study of broad lines) and the scattering cross section, with an accuracy exceeding the accuracy attained in the investigation of spontaneous Raman scattering. Strong mode excitation uncovered new possibilities in the investigation of anharmonic effects (combination modes, etc.). With the aid of a quasicontinuous PLG it is convenient also to carry out measurements in accordance with the inverted-scattering scheme - a promising scheme which so far has not found wide use only because there are no suitable tunable radiation sources [10].

2. The spectroscopic information obtained with stimulated RS is scanty. The principal reason for this is the strong competition of the lines, the broadening of the spectrum due to nonlinear mechanisms, etc. It is therefore of interest to search for a method combining the extensive spectroscopic capabiltiies of the spontaneous Raman scattering with the advantages of the method of stimulated Raman scattering, such as obtaining high-intensity scattered light, coherent excitation of optical phonons in a considerable volume, etc.

This problem was discussed in a number of papers (see, e.g., [1 - 6]). A procedure for scattering a probing beam by coherent optical phonons excited during the course of the stimulated Raman scattering was proposed and realized in [1, 7, 8] (see also [9]).

The spectroscopic possibilities are greater when the phonons are excited by a biharmonic light signal below the threshold of stimulated Raman scattering. Specially selected line doublets were previously used for this purpose [2,

Fig. 1. Diagram explaining the principle of active scattered-light spectroscopy with the aid of a parametric generator. Here ν_0 and $2\nu_0 = \nu_{pr}$ are the frequencies of the laser and of its second harmonic; ν_1 and ν_2 ($\nu_1 + \nu_2 = 2\nu_0$) are the smoothly tunable frequencies of the PLG; Ω_0 is the Raman shift. Curve 1 - Stokes signal of probing scattering at $|\nu_0 - \nu_{1,2}| \neq \Omega_0$; curve 2 - signal at $|\nu_0 - \nu_{1,2}| \simeq \Omega_0$.