DYNAMIC STABILIZATION OF TOROIDAL PLASMA FILAMENT WITH CURRENT

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It is shown that macroscopic stability of a current-carrying plasma filament in an $\ell = 3$ stellarator has a threshold-like dependence on the ratio $\eta = \tilde{p}/\overline{p}$ of the pressure of the high-frequency field to the pressure of the poloidal field, and that when $\eta \simeq 0.4$ is reached the filament is stable at $q_{eff} \simeq 1$. In the stabilized regime $\tilde{\beta}_\phi \simeq \overline{\beta}_\phi >> 1$.

In toroidal magnetic fields with current, of the tokamak or stellarator type, the stability of the plasma filament becomes worse when $q = B_z a/B_\phi R$ reaches a value on the order of 2 - 3. As indicated in [1], $q \simeq 2$ is apparently the attainable limit for the tokamak. At the same time, a decrease of q, i.e., an increase of the current in such systems, leads both to increased heating of the plasma and to a longer plasma containment time [1].

A theoretical analysis shows that the magnetohydrodynamic (MHD) stability of a magnetized plasma with current can be reached at small q if rotating helical multipole HF fields are used [2].

We report here the results of experimental investigations, with the R-0 installation [3, 4], of the dynamic stabilization of a magnetized toroidal plasma filament carrying quasiconstant current with the aid of helical HF quadrupole magnetic fields. The purpose of these investigations was to obtain MHD stable states of the plasma filament at $q \simeq 1$. Although the R-0 installation is a stellarator, the conclusion that the plasma in it has MHD stability can be extended in principle also to a system of the tokamak type.

The installation is an $\ell = 3$ stellarator with the following parameters: minor diameter of quartz chamber d = 10 cm, major diameter D = 100 cm, toroidal quasi-constant magnetic field $B_z \lesssim 8$ kG of duration $\tau = 15$ msec, electric field producing the quasiconstant field in the plasma $E_z \leq 0.4$ V/cm of duration 1.2 msec, rotating helical HF magnetic field with $\omega = 3 \times 10^6$ sec^{-1}, duration ∿1.5 msec, and intensity $B_\phi \leq 300$ G at the boundary of the plasma filament was produced by eight helical coils making one turn around the minor perimeter on circuiting along the major perimeter. The experiments were performed at a force-line twist angle $i_0 \approx \pi$ on the limiting surface of the stellarator magnetic field. The preliminary plasma was produced with the aid of a separate HF generator.

Experiments performed without turning on the HF quadrupole field have shown that for a given value of B_z there exists a limiting value $I_{p.cr}$, above which the current in the plasma cannot increase with increasing electric field E_z. The critical current increases with increasing B_z. The flow of the quasi-constant current is accompanied by development of instability in the plasma filament; this instability increases particularly strongly when the current reaches the critical value. At $I_p \simeq I_{p.cr}$, sharp dips are observed in the energy of the plasma filament. The plasma-filament instability manifests

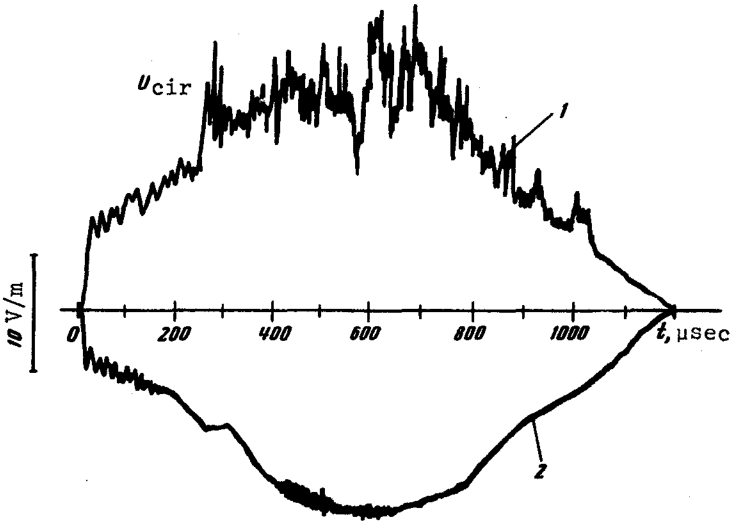


Fig. 1

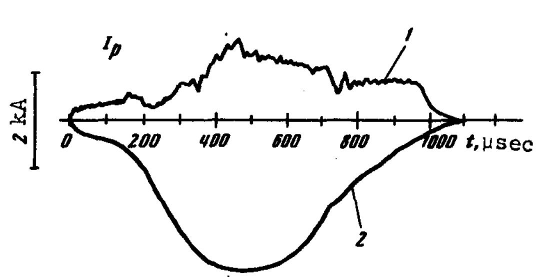


Fig. 2

Fig. 1. Oscillograms of electric field intensity E_z: 1 - without the stabilizing HF field; 2 - with the stabilizing HF field turned on. p = 4.5 × 10^{-4} Torr, B_z = 6 kG.

Fig. 2. Oscillograms of the plasma current I_p: 1 - without the stabilizing field, 2 - with the stabilizing HF field. p = 4.2 × 10^{-4} Torr, B_z = 6 kG.

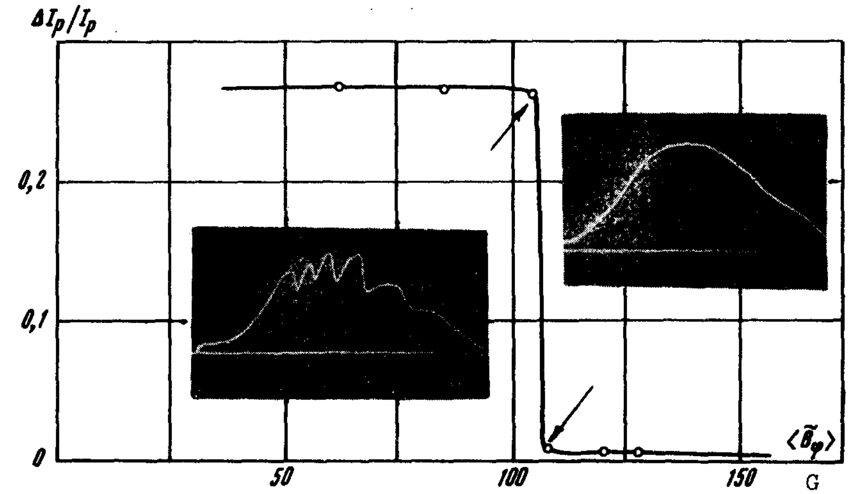
itself in the form of low-frequency oscillations of the circuit voltage (curve 1 in Fig. 1) and of the current (curve 1 of Fig. 2), of the diamagnetic signals, of the signals from the electric field, and of the plasma density measured with the aid of a microwave interferometer with λ = 2.3 mm. An analysis of the scan photographs of the plasma filament, obtained with an image converter, indicates development of large-scale helical perturbations with m = 2 and 3. In these regimes, the plasma temperature (at $n \simeq 10^{13}$ cm^{-3}) does not exceed T ≃ 20 - 30 eV. Such a behavior of the discharges is analogous to the regimes obtained in tokamaks at small q and in stellarators with ohmic current heating.

When a stabilizing HF quadrupole magnetic field is applied to the current-carrying plasma filament, the picture changes considerably. The corresponding oscillograms characterizing the discharge with the stabilizing HF field are shown in Figs. 1 and 2 (curves 2). They show that the level of the high-frequency oscillations decreases strongly. At the same time, the helical structures on the scan photographs of the plasma filament also disappear.

In the stabilized regime, the quasiconstant current in the plasma can exceed by several (2 - 3) times the value of the critical current $I_{p.cr}$. A characteristic feature of the stabilized discharge regime is the threshold-like dependence of the macroscopic stability of the filament on the ratio of the HF field intensity at the plasma boundary to the intensity of the current field. For a given quasiconstant current in the plasma, it is necessary that the intensity of the HF field exceed a certain value (Fig. 3). The ratio $\langle\tilde{B}_\phi\rangle/\bar{B}_\phi$ for the given expreiments is $\langle\tilde{B}_\phi\rangle/\bar{B}_\phi \simeq 0.65$, i.e., the ratio of the HF pressure to the pressure of the poloidal field is $\eta = \tilde{p}/\bar{p} \simeq 0.4$. At $\eta < 0.4$, the current is again interrupted and the discharge becomes unstable.

Measurements performed with electric and magnetic probes have shown that in the stabilized regime the plasma is localized within the limiting magnetic surface. The diamagnetic temperature of the plasma in the stabilized regime reaches 100 - 150 eV at $n_e \simeq 2.5 \times 10^{13}$ cm^{-3}.

Fig. 3. Relative current-oscillation amplitude $\Delta I_p/I_p$ vs. the stabilizing HF field intensity. I_p = 3 kA, B_z = 6 kG.



The effective stability margin q_{eff} ($q_{eff} = 2\pi/(i_0 + i)$, where i_0 is the twist angle of the force line of the stellarator magnetic field on the filament boundary and i is the twist angle produced by the quasiconstant current) in the stabilized regime is $q_{eff} \approx 1$. In the stabilized regime, the pressure of the HF field, as well as the pressure of the field current, was much lower than the plasma pressure, i.e., $\tilde{\beta}_\phi \approx \bar{\beta}_\phi >> 1$, thus indicating effective heating of the plasma by the current flowing through it.

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SPATIALLY-BOUNDED PHASE CAPTURE AND AXIAL ANTI-STOKES RADIATION IN SRS IN GASES

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It is shown theoretically and experimentally that the onset in all the singularities of the behavior of the anti-Stokes component of stimulated Raman scattering propagating along the axis of the pump beam are due to phase locking of the interacting waves, which occurs in a bounded segment of the interaction path.

1. We present here the results of experimental and theoretical investigations of the anti-Stokes component of SRS (ASRS), propagating along the axis of the pump beam. These investigations were undertaken for the purpose of explaining the mechanism whereby axial ASRS is produced.