that under the conditions in question, in analogy with [5], synchronization of the SMBE is also possible, since the main initial premise in this paper is the fact that only one resonator mode is excited in each SMBE component (if a large number of modes is excited with different frequencies, an internal parametric interaction between them is possible [2, 3] and the picture of the phenomenon can become much more complicated). Thus, in this case it is also possible to have generation of the ultrashort pulses with a spectrum width exceeding the luminescence line width of the active laser medium and apparently without a reduction in the laser efficiency, since the reflecting properties of the resonator R_1 remain unchanged during the generation process.

It is possible to avoid in similar fashion also the lowering of the laser efficiency during SRE, by using, for example, a system consisting of a ring resonator R_0 (with active laser medium) and an axial resonator R_1' for the Stokes components, subtending over a section of the resonator R_0 (together with the mirrors) containing a medium active in the SRE spectrum, as well as a hollow resonator R_1.

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TOKAMAK WITH NON-ROUND SECTION OF THE PLASMA LOOP

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Submitted 14 December 1971
ZhETF Pis. Red. 15, No. 1, 72 - 76 (5 January 1972)

The main task of the research performed with the Tokamak apparatus is to obtain a plasma with maximum possible temperature and density under quasistationary conditions. In the existing Tokamak installations, an annular plasma loop is produced with a nearly circular cross section. The plasma is heated by the Joule heat of current flowing along the loop. The magnetic field of this current performs the main function of containing and thermally insulating the plasma. To ensure stability of the plasma loop against large-scale deformations of the magnetohydrodynamic type, a strong external field is used, the annular force lines of which are parallel to the current in the loop.

The experiments performed with Tokamaks have shown that the average plasma pressure in the loop $\bar{p}$ is proportional to H_ϕ^2, where H_ϕ is the intensity of the magnetic field of the current at the plasma boundary. With increasing H_ϕ, the time τ of energy containment in the plasma also increases. In this case $\bar{p}$ and τ are practically independent of the intensity of the longitudinal magnetic field H_θ. To improve the main physical parameters of the plasma in the Tokamak installations it is therefore necessary to increase H_ϕ.

However, an analysis of the stability of the plasma loop shows that a certain limitation is imposed on the value of H_ϕ at a specified value of H_θ. The plasma loop is stable against helical deformations if the so-called safety factor,

$$q = \frac{H_\theta}{H_\phi} \frac{L_\phi}{L_\theta}, \tag{1}$$

is not too small ($L_\theta = 2\pi R$ is the length of the loop and L_ϕ is the length of the boundary of the loop cross section). Integer values of $q = 1, 2, 3, \ldots,$ correspond to field configurations such that the force line passing along the plasma boundary closes on itself after several (1, 2, 3, ...) circuits along the loop. On the basis of the available experimental data and certain theoretical calculations, one can conclude that the minimum permissible value of q is close to 2. At q = 2 it follows from (1) that for a loop with circular cross section of radius a the ratio H_ϕ/H_θ should not exceed a/2R. Owing to structural considerations, a/R in Tokamaks cannot greatly exceed 1/3. The ratio H_ϕ/H_θ should therefore be smaller than ∿1/6. In the installation now in operations, this ratio is smaller than 0.1. Because of the smallness of H_ϕ/H_θ, to obtain a dense high-temperature plasma it is necessary to produce longitudinal fields of very high intensity, and this entails serious technical difficulties. For the same reason, an important role is assumed in the plasma energy loss at high temperature by synchrotron radiation.

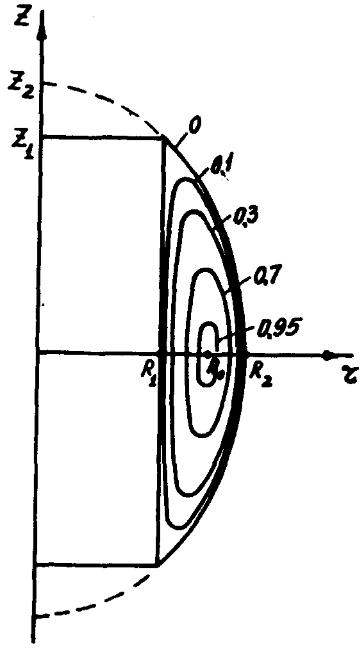

Fig. 1

One of the possible ways of increasing H_ϕ without changing H_θ and the geometrical parameter a/R is to change the shape of the cross section of the plasma loop by going from a circular cross section to one elongated along the principal axis of the toroidal system. If the height of the plasma ring 2b is several times larger than its thickness 2a, then $L_\phi/L_\theta \simeq 2b/\pi R$. At $2b = \pi R$ and at fixed values of q and H_θ, this means an increase of H_ϕ^2 by one order of magnitude and a corresponding increase of the plasma pressure (assuming that the ratio of $\bar{p}$ to H_ϕ^2 remains the same when the shape of the cross section is changed).

When considering concrete methods of realizing the aforementioned general idea, we must recognize that relation (1) applies only to one of two main types of large-scale deformations that can cause the plasma loop to become unstable.

Stabilization of certain of the deformations of the flute type is apparently due to the "magnetic well" that is produced automatically in a loop of round cross section. To retain the magnetic well in the case of an elongated cross section, the latter must have the shape of a segment [1 - 2]. By way of an example of such a system, Fig. 1 shows the magnetic surfaces of the equilibrium configuration at which the density of the longitudinal current has a distribution

$$i_\theta = i_0 \left[\beta_p \frac{r}{R_0} + (1 - \beta_p) \frac{R_0}{r}\right] . \qquad (2)$$

The equilibrium plasma column occupies the external part ($r > R_1$) of an ellipsoid with semi-axes R_2 and $z_2 = z_1 R_2/(R_2^2 - R_1^2)^{1/2}$. The radius of the magnetic axis is $R_0 = [(R_1^2 + R_2^2)/2]^{1/2}$. The numbers on the figure represents the relative levels of plasma pressure. The parameter β_p, which characterizes the ratio of the pressure gradient to the electromagnetic contraction force at $z_1 \gg (R_2 - R_1)$, is close to unity. In the vicinity of the magnetic axis, the

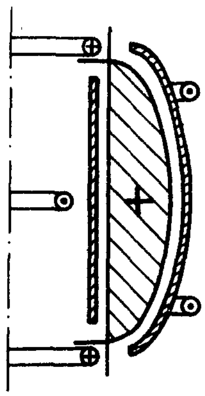

Fig. 2

cross sections of the magnetic surfaces are ellipses with semi-axis ratios

$$\frac{\ell_z}{\ell_r} = \frac{2z_1\sqrt{R_1^2 + R_2^2}}{R_2^2 - R_1^2} . \tag{3}$$

The condition for the stability of the hydromagnetic flute perturbations in the vicinity of the magnetic axis at $\ell_z^2 >> \ell_r^2$ can be written, on the basis of [1, 2], in the form

$$q^2 > \frac{2z_2^2}{R_2^2} . \tag{4}$$

In the case of the configuration shown in Fig. 1, this condition leads to the limitation $q > 1.76$, which does not contradict the condition for the stability of large-scale perturbations.

Let us see now how the elongation of the plasma-loop cross section should influence the plasma temperature. In a Tokamak with a round cross section, the temperature of the ion component of the plasma is well described by a formula derived by one of the authors [3]

$$T = 6\cdot 10^{-7}\sqrt[3]{JH_\theta R^2 \bar{n}}\,A^{-1/2} , \tag{5}$$

where J is the current in Amperes, $\bar{n}$ the average plasma density, and A the atomic weight of the ions. In the derivation of this formula it was assumed that the thermal conductivity satisfies the neoclassical formulas in the region of the so-called "plateau" [4]. Examination of the particle motion in a configuration with magnetic surfaces having elliptic cross sections makes it easy to ascertain that the neoclassical diffusion and temperature-conductivity coefficients D and χ acquire a factor $(\ell_r/\ell_z)^2$ at $\ell_z^2 >> \ell_r^2$ and at fixed parameters q and ℓ_r/R. Thus, in the plateau region we have

$$\chi \approx \frac{r_H q}{R}\frac{cT}{eH_\theta}\left(\frac{\ell_r}{\ell_z}\right)^2 . \tag{6}$$

According to [1], the parameter q for elliptic cross sections is given by

$$q = \frac{cH_\theta}{2\pi R j_0}\,\frac{\ell_z^2 + \ell_r^2}{2\ell_r\ell_z} . \tag{7}$$

Putting $-\nabla^2 T \sim 2T/\ell_r^2$, we find that $\chi\nabla^2 T$ does not depend on ℓ_r/ℓ_z. Thus, formula (5) for the ion temperature remains valid, accurate to a factor on the order of unity, also for $\ell_z^2 >> \ell_r^2$. One should therefore expect the temperature to increase with increasing current $J = j_0\pi\ell_r\ell_z$, owing to the increase of the ratio ℓ_z/ℓ_r, as follows from (7).

The foregoing configuration of the plasma-loop cross section in the form of a segment makes it possible to solve one more problem of importance to the thermal insulation of the plasma. We have in mind here the creation of a natural plasma boundary without contact between the plasma and the presently-used limiting diaphragm. The point is that to produce a plasma column with a non-round cross section it is necessary to have external currents oriented relative to the current in the plasma in the manner shown schematically in Fig. 2. Between the plasma and the conductors, in which the current flows in the same direction as in the plasma loop, there is a hyperbolic point determining the position of the separatrix of the system of closed toroidal magnetic surfaces. The charged plasma particles going outside the limits of the separatrix will move along the magnetic force lines and leave the discharge chamber through longitudinal slots provided for this purpose. By using such a natural diverter, which does not disturb the symmetry of the system, it is apparently possible to limit greatly the impurities that fall into the plasma loop as a result of the interaction between the hot plasma and the walls.

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