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TWO-STAGE DENSE PLASMA HEATING IN THE GOL-3 DEVICE

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Previous experiments on a collective plasma heating by high power microsecond relativistic electron beams have shown that under certain conditions the E-beam can transfer to the plasma up to 25% of its initial energy (see, for example, [1]). High efficiency of the beam relaxation is reached with the plasma density less than $2 \cdot 10^{15}$ cm^{-3}. The energy lost by the E-beam is transferred mainly to plasma electrons, partly thermal and partly to suprathermal ones, with typical energies of the latter ~ 10 keV.

To raise the plasma density accessible for this heating technique, a so-called "two-stage" heating scheme was proposed [2], in which the hot plasma electrons were supposed to serve as a secondary source of heating of the dense plasma clouds, adjacent to the region of lower density (where an effective E-beam-plasma interaction is observed).

The present experiments were performed on GOL-3 facility which is a 7-meter long mirror trap with the 5.5 T homogeneous magnetic field and 11 T field in the end mirrors. After the discharge chamber was filled with hydrogen of 10^{14}-10^{15} cm^{-3} density, a gas cloud with a density up to $2 \cdot 10^{17}$ cm^{-3} and of 0.5-3 meter length could be created by gas-puffing. Then the preliminary gas ionization was produced by linear discharge. The electron beam (0.8 MeV, 40 kA, 5 μs, 100 kJ) was injected into this plasma with controlled delay time from the gas-puff that allowed to vary the gas cloud length.

The uniform plasma heating was studied using new diagnostics, in particular two Thomson scattering systems. The bulk of electrons with density of ~ 10^{15} cm^{-3} was heated up to 1 keV. The density of suprathermal electrons with characteristic energy of 10 keV during the E-beam pulse was of order 10^{13} cm^{-3}. The major part of energy lost by the beam was transferred to the supratermal electrons. This part of the electron distribution was formed as a result of a dynamical equilibrium between two processes: acceleration of electrons by beam-induced microturbulence and their losses through the ends of the device.

When the dense gas cloud was produced in some section of the device, a considerable growth of plasma pressure as compared to the case of uniform density was detected in this section (see Fig.1) due to collisional heating of the cloud by the bulk and suprathermal electrons - as it was predicted by two-stage heating scheme. The energy release dependence on the depth from the cloud border was measured. These data allow to separate the energy deposition from the bulk 1 keV and supra-thermal ~ 10 keV electrons. Main plasma parameters were measured inside the cloud (10^{15}-10^{17} cm^{-3} density and 1-0.1 keV temperature). Axial gas-dynamic motion of the cloud, compatible with para-meters observed, was detected.

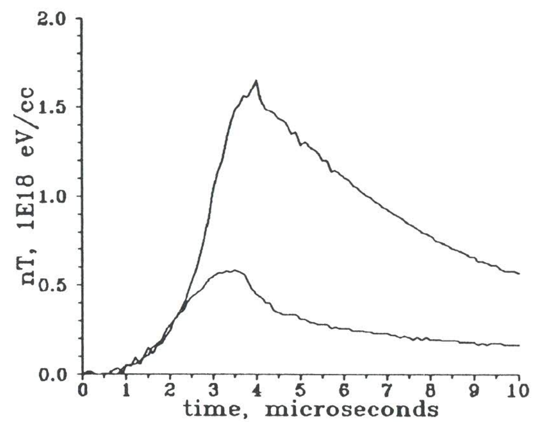

Fig.1. Plasma pressure at 240 cm distance from the entrance mirror in the case of uniform plasma (lower curve) and with dense plasma cloud (upper one).

The experiments performed show the possibility of getting dense plasma clouds with *beta* ~ 1 on GOL-3 facility. Further upgrading of the solenoid length and initial beam energy content is planned to improve plasma parameters.

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Physics Studies for the Torsatron TJ-IU

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TJ-IUpgrade is a six period, l=1 torsatron in the final stages of construction at CIEMAT, Madrid. Its major radius is 0.6 m and plasma radius 0.1 m. TJ-IU was designed as an almost shearless device and its main stability mechanism lays then, on the vacuum magnetic well created through a change in the winding law of its helical coil, $\Phi = 1/6\ (\theta + 0.4 \sin \theta)$, see fig. 1.

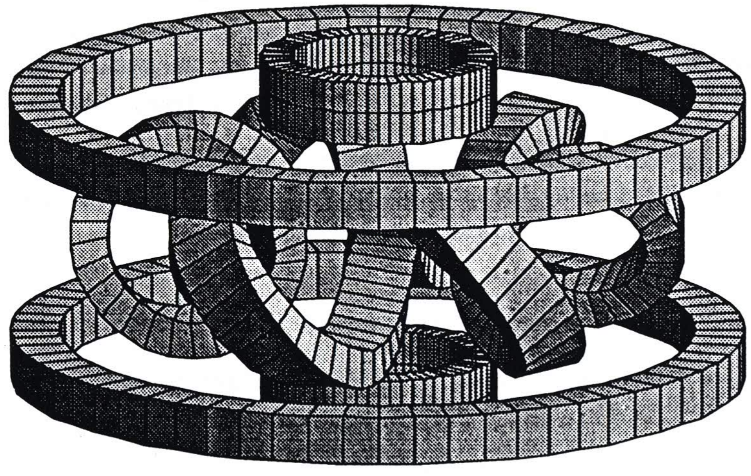

Figure 1
TJ-IU coil configuration

Start-up and heating will be done initially with a 200 kW, 28 GHz gyrotron working at the second harmonic ($B_0 = 0.5$ T) and an ICH system is under design. Initial operation is expected in June 1992. In this paper, the main physics results of the machine are presented.

Equilibrium and Stability

The 3-D stability behaviour to Mercier modes is presented for the two main operating scenarios foreseen, the standard one with the magnetic axis at its nominal position, 0.58 m, and the "inward" one with the magnetic axis 6 cm towards the center. We have chosen Mercier modes as the most ß-limiting modes to stellarator configurations but an analysis is under way to check the obtained ß-limits to ballooning modes. The studies show that the two scenarios have particle orbits with confinement properties opposite to stability properties. At the standard position the device is totally stable to Mercier modes to the achievable ß's with the available ECH power (< 1%) but its stability limit tends to zero as we push the magnetic axis inward destroying the vacuum magnetic well. Kinetic effects on stability due to the specific creation of high energy particles in the device in the "inward" position could be, then, experimentally checked. A detailed analysis of the theoretical work leading to these conclusions will be presented. A comparison between the theoretical predictions for the vacuum surfaces and the actual measurements will be started in June and results will be reported.

Transport

Calculations of neoclassical transport and bootstrap currents in TJ-IU have been made, by means of analytical expressions, a Monte Carlo code [1] and the DKES code [2]. By displacing the magnetic axis the results for both transport and currents can change in a factor two. The energy confinement time is expected to be 0.15-0.3 ms.

Heating and Current Drive

The localized power absorption of ECH power is proving to be a valuable tool to control unwanted currents like Pfirsch-Schlüter or bootstrap in stellarators. We have computed the induced current density by EC waves in TJ-IU using the relativistic Fisch response function [3] , for Zeff different from 1, multiplied by the absorbed power density in the momentum space. The integration is performed numerically for a Maxwellian distribution function. In this way, the current calculation is fast enough to be introduced in a ray tracing code. The currents predicted for one 200 kW gyrotron launching waves in the X mode, second harmonic (28 GHz), are 0.25 kA for off-axis microwave absorption and 0.5 kA for centred absorption.

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