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RECENT PROGRESS IN PLASMA CONFINEMENT AND HEATING IN OPEN-ENDED MAGNETIC TRAPS

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Recently, substantial progress in plasma heating and confinement was achieved in Novosibirsk on axisymmetric magnetic mirror systems. The first described system GOL-3 for multi-mirror plasma confinement has 12 meter long solenoid which consists of 55 mirror cells. The magnetic field is set to be 4.8 T in the mirrors and 3.2 T in middle planes of each cell. Dense (10^{21} m^{-3}) plasma in the solenoid is heated by high current relativistic electron beam with 1MeV energy, 30 kA current, 15 MA/m^2 current density, and pulse duration $8\cdot10^{-6}$s. According to the theory, axial velocity of plasma expansion in the multi-mirror configuration is considerably smaller than the ion acoustic speed due to appearance of specific friction force between plasma particles and corrugated magnetic field. One of the serious problems for mirrors is strong longitudinal electron thermal conductance decreasing energy lifetime of plasma in such traps. However, in the case of plasma heating by relativistic electron beam (REB) a new phenomenon of strong (by three orders of magnitude) suppression of electron heat conductance was discovered. As a result of that the electron temperature of dense plasma heated by REB was increased up to 4 keV. Beam energy deposition and electron heating power are strongly inhomogeneous along the axis. The strongest heating occurs in the mirrors of each cell and the minimum one occurs in the middle planes. The pressure drop between mirrors and middle planes is then developed giving rise to axial plasma streams in the cells . Thermalization of the streams increases the ion temperature of plasma from 50 eV up to 2 keV according to the data obtained with several diagnostics. The energy confinement time of the heated plasma is about 1 ms, and the triple product $nT\tau$ exceeds $2\cdot10^{18}$ $m^{-3}\cdot keV\cdot s$. At present, no physical limitations are seen for farther growth of parameters. The second system is Gas Dynamic Trap (GDT). The GDT is also an axisymmetric mirror system but it represents long single mirror trap with high mirror ratio ($R\sim10^2$). The distance between mirrors is 7 meters and magnetic field in the mirrors is 15 T. Plasma confinement in the GDT is studied in collisional regime. In this case, plasma behavior is classical, so that micro-instabilities do not excite in it. Recently it was demonstrated that the GDT concept based on use of "warm" target plasma and oblique injection of D-T neutral beams can lead to creation of a neutron source (NS) with 14 MeV neutron flux reaching 2 MW/m^2 on the limited part (order of 1 m^2) of the device. The principles of the GDT NS operation have been already demonstrated at moderate plasma parameters. In particular, stable confinement of plasma with β as high as ~ 0.4 was demonstrated in axially symmetric GDT device. However, confinement of high-beta plasma with electron temperature relevant to operational conditions in the GDT-based NS, has not been yet studied. To address these problems at the GDT device, neutral beam (NB) injection system was upgraded to increase beam power and pulse duration. General objectives were to increase fast ion density from $2\cdot10^{19}$ m^{-3} to $5\cdot10^{19}$ m^{-3} and bulk plasma temperature from 100 to 300eV. Note that these parameters correspond to about 0.5 MW/m^2 neutron source operated with D-T plasma. Numerical simulation shows that this would require the injected power to be increased up to 10 MW. In parallel with the increase of the injected NB power, upgrade of the injection system assumed extension of the pulse duration from 1 to 5 ms enabling to achieve "steady state" conditions. Now, the first experiments with the NB injection with higher power and extended pulse duration are under way. The increase of the electron temperature and its saturation within 5 ms injection time as the calculations predict is observed. The MHD activity is not observed. Note that, at present, the next step with full scale modelling of the NS with neutron flux of 2 MW/m^2 is discussed.