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BOOK OF ABSTRACTS

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AXIALLY SYMMETRIC MAGNETIC MIRROR TRAPS. RECENT PROGRESS IN PLASMA CONFINEMENT AND HEATING

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At present, studies of modern magnetic mirror systems are carried out at GOL-3 and GDT devices in Novosibirsk, Russia. Both devices are axially symmetric. The GOL-3 device is intended to develop a concept of fusion reactor with multi-mirror plasma confinement. In this device plasma with density of 10^{21} m^{-3} and the ion and electron temperatures ~2keV is confined in 12m long solenoid which comprises 55 mirror cells. The plasma is heated by injection of 30kA, 1 MeV, 8μs electron beam along the axis of the solenoid. Original approach suggested strong reduction of axial plasma losses when the ion mean free path is close to the length of single mirror cell. For the reactor conditions, this corresponds to plasma density in the range 10^{23}-10^{24} m^{-3}. Recent findings in GOL-3 experiment indicate that effective confinement can be provided with significantly smaller density (10^{21} - 10^{22} m^{-3}) due to collective ion scattering on fluctuations, which are excited in the mirror cells by axial plasma flows. Thereby ion mean free path is effectively shortened to the length of the single cell even for lower plasma densities. The experiments also have shown that injection of the electron beam results in strong suppression of electron heat conduction due to their scattering on the beam excited turbulence. The paper discusses next steps in development of multi-mirror reactor concept taking into account these recent findings from the GOL-3 experiment.

"Gas-dynamic" plasma confinement in a long mirror cell with large mirror ratio is studied at the GDT device. This mode of confinement is characterized by the condition that ion mean free path of scattering into the loss cone is smaller than the length of the device. Injection of skew neutral beams with energy 18-20keV at the center of the GDT provides fast ions build up whose density is strongly peaked near the ion turning points. Plasma beta in this regions reaches value of 0.6 and density of fast ions exceeds $3 \cdot 10^{19} m^{-3}$. Note that high power 14MeV neutron source for fusion materials development, burning out of radioactive wastes, and other applications can be developed on the basis of GDT. Recently, injection system of GDT was upgraded with extension of pulse duration from 1 to 5 ms and application of geometrically focused neutral beams with increased power. This will lead to significant increase of plasma temperature and density of fast ions.

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STEADY-STATE CONFINEMENT OF ANISOTROPIC HIGH-β PLASMA IN GDT-U EXPERIMENT

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The paper reviews recent results obtained in the gas dynamic trap experiment after upgrade of the neutral beam injection system. The GDT-U NB heating system is now capable of providing six focused 20-25 keV hydrogen or deuterium beams. The total beam power delivered to the central cell plasma reached 4 MW in the 5 ms pulse. Two additional focused 25 keV beams provide up to 1.2 MW in the compact mirror cell attached to the GDT central cell at the end.

Comparison of the experimental data on global energy and particle balance with the results of the Monte-Carlo modeling of the plasma equilibrium parameters indicates that the two-component plasma in GDT reaches steady-state within 5ms shot. The characteristic plasma lifetimes are 4 - 5 times shorter than the shot duration. In these experiments peripheral gas-puff near the end mirror is used to maintain the radial profile of main plasma during the NBI pulse. The peak density of anisotropic ions with the mean energy of 10 keV exceeded $4x10^{19}$ m^{-3} near their turning points, that is close to main plasma density in the reported experiments. Accordingly, in these experiments the maximal beta value was increased from 0.4, which was reported previously, to about 0.6. Electron temperature of plasma was also significantly increased from ~100eV up to 200 eV. The stability against MHD interchange modes was established using the set of biased radial limiters and segmented end walls.

The new results of experiments with the compact mirror cell attached to the GDT central cell are be also presented in the paper. In particular, characteristics of plasma fluctuations developing beyond AIC instability threshold are presented and discussed.

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PROSPECTS OF *GOL-3* MULTIPLE MIRROR TRAP

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The paper reviews recent experimental results from GOL-3. During the last few years several key physical phenomena that determine plasma behavior in multimirror trap were identified in the experiments. These are:

- Suppression of electron heat conductance by three orders of magnitude during collective beam-plasma interaction. Electron temperature reaches 2–4 keV at a density of $3\cdot10^{20}$ m^{-3}.
- Fast ion heating which leads to increase of ion temperature up to ~2 keV at ~10^{21} m^{-3} density.
- Significant lowering of plasma density required for optimum, long confinement compared to classical theory due to ion scattering in turbulent plasma. The longest achieved energy confinement time (~1 ms) corresponds to theory, but for significantly lower density. This is beneficial for multimirror-trap-based fusion reactor concept.
- New class of plasma oscillations in the cells of multi mirror trap GOL-3 is observed. The oscillations are identified as bounce instability which can decrease the axial particle losses.
- Global plasma stabilization in GOL-3 is achieved by control of the magnetic shear.

Currently, efforts are focused on further development of a physical database for multimirror confinement systems and also on an upgrade of plasma heating systems of GOL-3 device.

During the upgrade of the relativistic diode assembly of the U-2 generator the beam duration was increased up to 11-12 μs with almost all the extra duration being in the high-power part of the beam pulse.

Parameters of electron distribution function during and shortly after the beam injection stops were studied with the longer beam. It was found that the electron distribution function has rather complex shape. In particular, preliminary data indicate that energetic electrons exists till the end of the heating pulse.

A next step in the development of multimirror systems should provide significantly longer plasma lifetime. This requires development of new techniques of plasma heating in addition to existing high-power relativistic electron beam. Neutral beam injection is considered to be effective for auxiliary plasma heating in GOL-3. High density, short lifetime, small plasma radius and high gas pressure near the wall are the challenges which complicate use of neutral beam injection in GOL-3. First results of the experiments with injection of sub-MW NBI are presented in the paper.

In general, current GOL-3 parameters demonstrate good prospects of a multimirror trap as a fusion reactor.

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SIMULATION OF PLASMA WAKEFIELD EXCITATION BY A SEQUENCE OF RELATIVISTIC ELECTRON BUNCHES

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Results of numerical simulation by the code LCODE [1] of plasma wakefield excitation by a chain of relativistic electron bunches of parameters, close to experimentally researched in NSC KIPT with the linear resonant accelerator «Agat» [2], are presented. A regular sequence of 6000 short relativistic electron bunches of energy 2MeV, charge 0.32nC, duration 60ps (i.e. length 1.7cm), radius 0.5cm each, repetition period 360ps, excites a wakefield in plasma of density $10^{11}cm^{-3}$, so the frequency of the excited wave coincides with the frequency of bunches repetition. The case of wakefield excitation by a single bunch is considered. The dynamics of spatial distribution of plasma and bunch electron density, and of exited electric field is researched. The acceleration of electrons from the "tail" part of the bunch by the exited longitudinal electrical field and focusing of various parts of the bunch by the radial electrical field of wakefield and by the azimuth magnetic field of the bunch are obtained. The excitation of wakefield, including the solitary cavity ("bubble"), by a sequence of the large number of bunches with the large total charge is being investigated.

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