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Status of activity on GOL-NB multiple-mirror experiment

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The paper will present current results from the GOL-NB experimental program [1] that is a part of broader activities on developing the physics basis for a next-generation sub-fusion-grade GDMT linear confinement system [2] in the Budker Institute of Nuclear Physics. The current understanding of physics of open confinement systems requires a significant improvement of the longitudinal energy confinement time over the usual scalings in order to achieve reactor parameters. In the GDMT project, this will be done with special multiple-mirror magnetic sections that should decrease energy and particle losses from a central gasdynamic trap where the main plasma will be confined. The GOL-NB experiment is a low-cost device that includes all the main physical elements of the larger project.
The multiple-mirror confinement idea was introduced quite long ago in [3,4] as the method of suppression of the longitudinal plasma expansion by a multiple-mirror (periodically varying along the axis) magnetic field. The friction between transiting and locally-trapped particle populations transfers momentum from the plasma flow to the magnetic field and therefore slows down the flow. This technique is effective at moderate collisionality, at an ion free path length comparable with the corrugation period of the magnetic field. A recent review of achievements in the multiple-mirror confinement can be found in [5].
GOL-NB has modular design of the magnetic system that allows early start of plasma operations in the reduced configuration and following gradual increase of the device capabilities with newly-installed modules. In the final design variant, GOL-NB will include the central gasdynamic trap with the mirror ratio R = 15, two high-field multiple-mirror sections mounted laterally to it, and two end magnetic flux expanders. Each of the multiple-mirror sections can generate the uniform solenoidal field with B = 4.5 T or the multiple-mirror field with the same maximal induction, 13 corrugation periods of 22 cm length and corrugation depth 1.4. A typical experimental scenario will be the following. A low-temperature start plasma of 10^19-10^20 m^-3, ~5 eV will be created by an arc plasma gun located in the low-field part of one of the expanders. The plasma flow will pass through the first high-field section and fill the central trap. Then plasma will be heated in the central trap by two 25 keV, 0.75 MW neutral beams. Plasma stability will be provided by the line-tying to the plasma gun during the initial filling stage and be the so-called vortex confinement technique [6] during the heating. Our preliminary simulations had shown that in the pure gasdynamic operation mode, plasma temperature will weakly depend on its density due to partial absorption of the beams power; the typical value is around 40 eV. The main scientific task of GOL-NB is the direct demonstration of improvement of plasma parameters in the central trap at activation of the multiple-mirror configuration of the high-field sections.
During the previous Fusion Energy conference, we reported the assembly of a start configuration of GOL-NB and the beginning of plasma operations [7]. The device consisted of a 4-m-long high-field section and both expander tanks. In this configuration, the propagation of start plasma through the high-field section was studied. Additionally, both neutral beam injectors were mounted to a temporary section for the initial commissioning and for adjustment of operation regimes. One of the beams was used as the diagnostic one for the line-integrated density measurements. Now each injector performs at the design specification of the initial ion beam. Some additional tuning of gas parameters in the neutralizer will be done after relocation of the beams to the design positions.
The experimental scenario described above strongly relies on one specific feature of the multiple-mirror confinement. Theory predicts that sections with the corrugated magnetic field will not significantly slow down transport of the cold start plasma thus enabling the initial population of the central trap. In 2019, we demonstrated that start plasma propagation occurs similarly in solenoidal and multiple-mirror configurations [8]. The efficiency of plasma transport strongly depends on configuration and biasing of in-vessel limiters and plasma receiver endplates. A major upgrade of the device began in February 2020. The main central module that is the 2.5-m-long gasdynamic trap will be installed. Two neutral beam injectors will be mounted to the central trap. Results from the first experiments in this configuration will be presented. Additionally, plans on extending the device capabilities will be discussed.

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