DIAGNOSTICS FOR MEASUREMENT OF HIGH β PLASMA PARAMETERS IN THE GAS DYNAMIC TRAP

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Abstract. The new diagnostics based on neutral beam injectors that were installed on the GDT-device in Budker Institute of Nuclear Physics (Novosibirsk, Russia) for measurement of high-β plasma parameters are presented.

1. Introduction

The Gas Dynamic Trap (GDT) is an axisymmetric mirror device with the high mirror ratio for confinement of collisional bulk plasma with hot ion minority. The hot ions are produced in the trap by injection of high-power NBs into the collisional target plasma [1]. In resent experiment on the GDT device the high β discharge regimes were realized with the higher neutral beam power and optimization of the experimental scenario. Under these conditions, the following plasma parameters were obtained: the density of fast ions with mean energy 3-10 keV was up to 10^{13}cm^{-3}, the bulk plasma density was 3-13$\times 10^{13}$ cm^{-3}, the electron temperature achieved 80-110 eV. [2]

The experimental research of hot ion minority and bulk plasma with such parameters required the development of new diagnostics, based on neutral beam injectors, that was specially designed in Budker INP for diagnostic applications and named as "DINA" (Diagnostical Injector of Neutral Atoms). The presented diagnostics are the following:

- The multichannel system for measurement plasma density profile based on the registration of secondary D+ ions, produced by neutral D-beam injection.
- Charge-exchange energy analyzer combined with beam produced artificial target for local measurements of angular and energy distribution functions of hot ions.

The new diagnostic set were installed in central cell of GDT device. This equipment is described in detail below. The data obtained by this diagnostics and used for the study of a high-β multicomponent plasma in the GDT are submitted at the end of each section.

2. Measurement of the plasma density profile

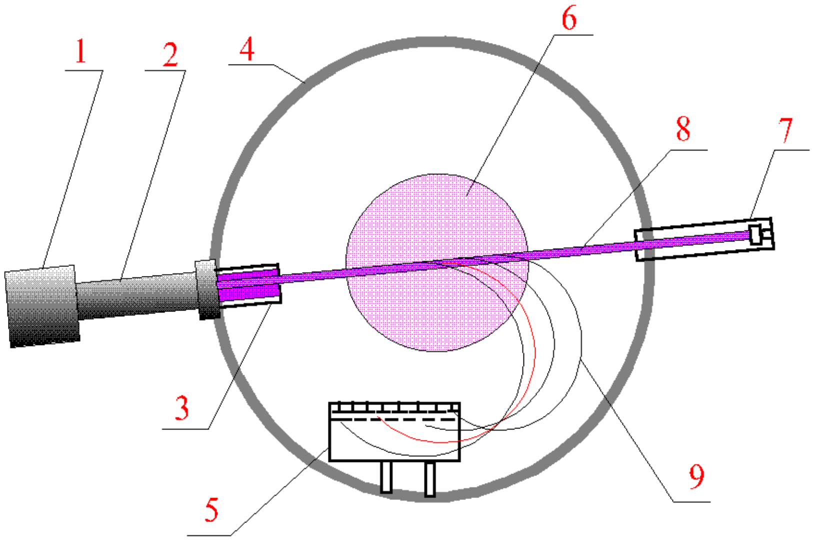

Fig. 1. The layout of diagnostic system:

1 - ion source, 2 - charge-exchange chamber, 3 - beam limiter, 4 - vacuum chamber, 5 - multichannel collector system, 6 - plasma, 7 - collimated beam dump, 8 - D-beam, 9 - Larmor orbits of D^+.

The multichannel system for the measurement of a plasma density profile based on the neutral D-beam with energy of 25 keV, total equivalent current up to 2 A, and duration of 5 ms, which is injected to plasma perpendicularly to magnetic field lines by the «DINA-5» injector. The experimental layout of the diagnostic is shown on Fig. 1. The D-beam is attenuated 2-3 times, producing secondary D+ ions which moving on the Larmor orbit in the magnetic field and are registered by the multichannel detector installed outside the plasma. The ions, that have been born in various points of the plasma column along a beam line, get in various channels of the analyzer. The amplitude of a signal in a channel depend on a local plasma density in

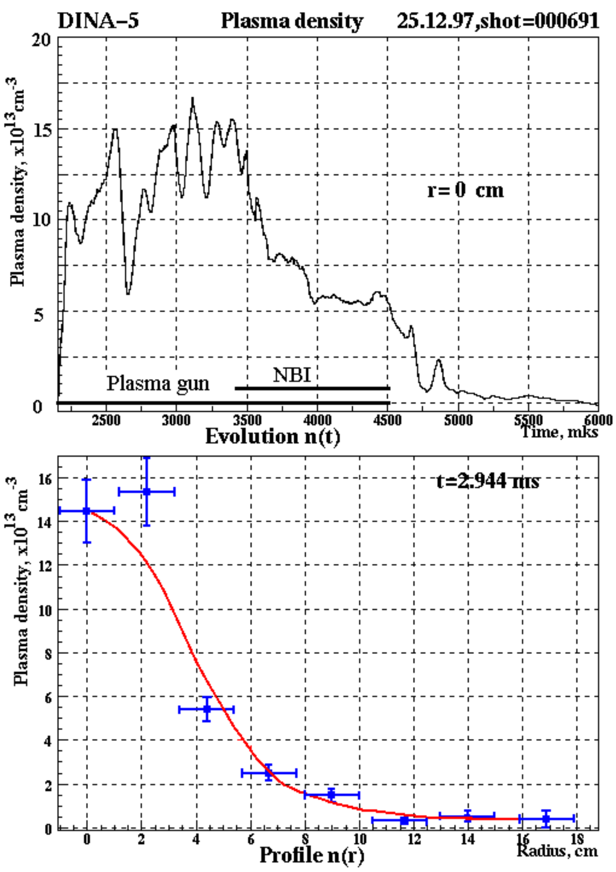

Fig. 2. Measured on axis plasma density time evolution and plasma density profile in GDT experiment.

the appropriate point:

$$U(x) \propto n(x) \cdot e^{-\sigma \cdot \int_0^x n(x')dx'}$$

where n(x) -- is the plasma density in a point x, and σ - is a total cross section of all processes, influencing to the beam attenuation (is about 8x1016 cm2), U(x) - signal in a channel, appropriate to a point x. That allows to restore a density profile along a beam. The attenuation of D-beam is also measured and used for calculation of plasma density profile in absolute units. The restored time evolution of on axis plasma density and the plasma density profile for fixed time are presented in Fig. 2.

3. Charge-exchange energy analyzer

The charge-exchange energy analyzer combined with DINA type neutral beam injector for producing artificial target was installed in central cell of GDT-device. The layout of this diagnostic is shown in Fig. 3.

The focused neutral beam of 15 keV energy with current density up to 0.5 A/cm^2 and duration of 100 μs) is injected at the GDT midplane and produces a local H-target for charge-

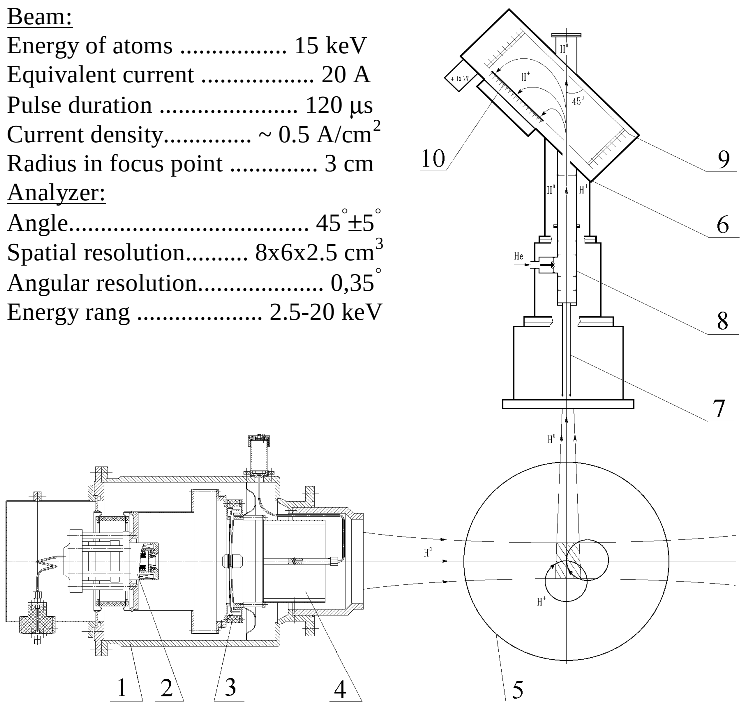

Fig. 3. The experimental layout:
1 - DINA type NBI: 2 - ion source, 3 - multigrid focusing system, 4 - charge-exchange chamber;
5 - plasma; 6 - collimator, 8 - ionizing chamber, 9 - electrostatic 45° separator,
10 - micro-channel plate.

exchange of fast ions. The current density of the H-target is up to 50 % from the current density of the NBI heating system, that allows to carry out measurements during the NBI-heating. The energy of produced fast neutrals is measured by the multichannel electrostatic analyzer, that may observe the particle energy in rang of 2-20 keV.

A shift of the local target along view-axis of the analyzer, allows to measure the local distribution function in various points along the plasma radius. A change of an inclination angle of the analyzer in limits ±5° allows to measure the angular distribution of fast ions.

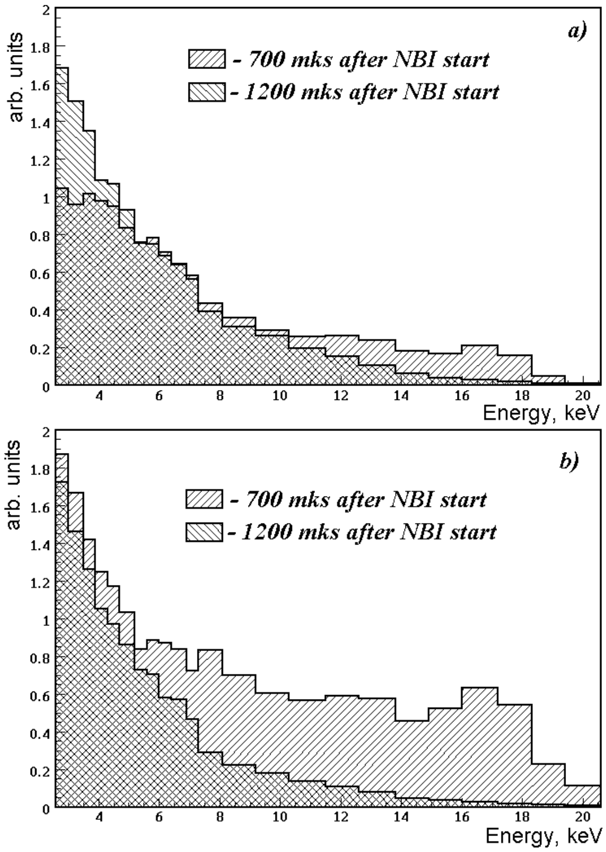

Fig. 4. Local energy distribution function of fast ions in GDT: a) on axis (r = 0 cm); b) at r = 8.5 cm

In Fig. 4, the local distribution functions of fast are presented at different time points after the start of NBI. From measurement of the energy spectra one can determine the mean energy of ions, that was estimated to be about 6-8 keV.

4. Conclusion

For measurement of plasma density profile and local energy distribution function of fast ions the new diagnostic set based on DINA type neutral beam injectors were developed. The data obtained by this diagnostics are used for the studies of a high-β multicomponent plasma in GDT and numerical simulation for the GDT-based Neutron Source. The developed equipment may be also used on other types of magnetic trap.

References

[1] A.V. Anikeev, P.A. Bagryansky et al.: "Plasma Confinement and Stability Studies in the Gas Dynamic Trap Experiment." *In Proc.16th IAEA Fusion Energy Conf.* 1996, Vol. **2,** p.283-291 (Vienna, IAEA 1997).

[2] A.V. Anikeev, P.A. Bagryansky et al.: "Energy Confinement of the Finite β Plasmas in the Gas Dynamic Trap." *This Conference.*