

Double pulse plasma gun for parameter controlling of Globus-M

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Development of an efficient fuelling method allows controlling the burning of the discharge in the magnetic plasma confining system. The method of high kinetic energy jet injection in a tokamak is developing at the Ioffe Institute [1-2]. The plasma gun, with explosive method of gas feeding a coaxial accelerator permits to combine necessary merit of the fuel injector – high density and speed of the jet with high purity of the substance. Jet density reached $2 \times 10^{22} \text{ m}^{-3}$, total number of accelerated particles $(1-5) \times 10^{19}$, the flow velocity 200 km/s and the pulse duration 15 μs . The achieved results make the plasma gun a perspective instrument for tokamak fuelling and density profile control [3-6]. The presentation reports on latest results of jet injection in tokamak Globus-M with single pulse plasma gun. Preliminary experiments with double pulse injection are also presented.

Methods and Apparatus

The gun consists of gas generating and plasma accelerating stages. The gas generating stage supplies conventional coaxial accelerator by dense hydrogen cloud. It consists of two chambers for fresh and used titanium hydride grains, and thin channel between where

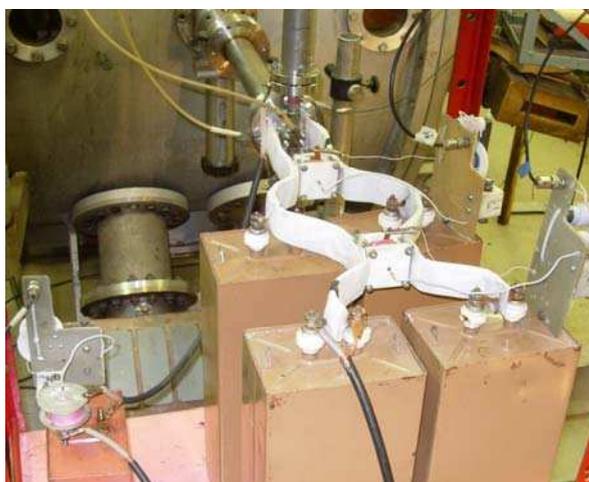
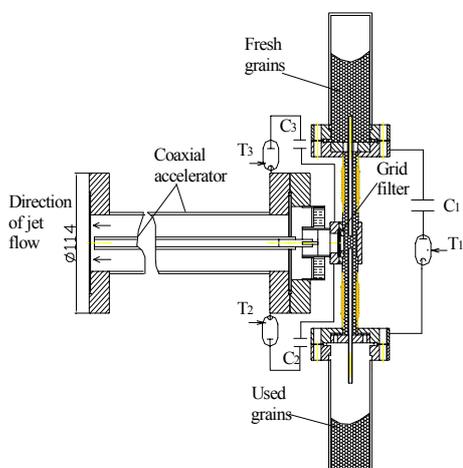
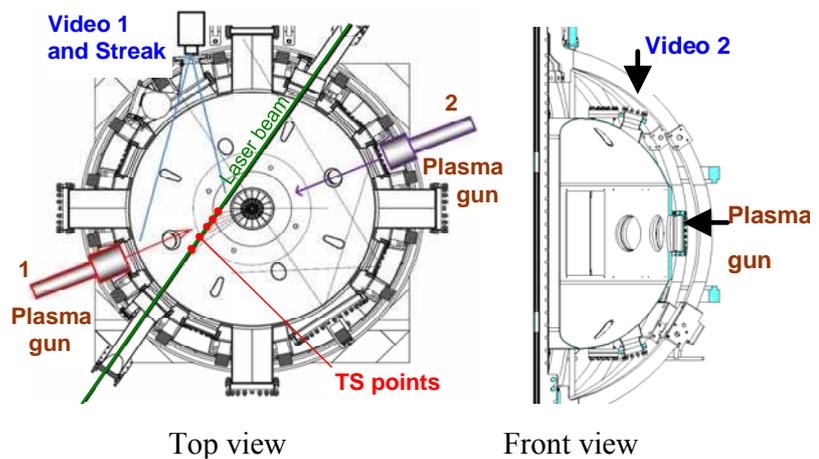


Fig.1: Double pulse plasma gun with explosive method of gas feeding a coaxial accelerator

electrical discharge releases hydrogen. High-pressure hydrogen passing through a grid filter fills the accelerator electrode gap. The accelerating stage may produce single or double jet flow. In the double jet mode the time delay between pulses may be varied in 50-1000 μs range.

Experiments on plasma jet injection in the Globus-M plasma were carried out at two different gun positions (Fig.2). The jet was injected from the low field side along the major radius direction, through two different ports placed in the equatorial plane. The plasma current $I_p = 200 \text{ kA}$; toroidal field $B_T = 0.4 \text{ T}$; average density $\langle n \rangle = (2 - 8) \times 10^{19} \text{ m}^{-3}$. Monitoring of the jet parameters during injection into the target tokamak plasma was performed. Video (RedLake MotionPro HS-3) and streak (Bifo Company K008) cameras observed the jet penetration in plasma core at the equatorial plane. Second video camera (Olympus i-speed 2) viewed the jet perpendicular the equatorial plane. Multi-pulse Thomson diagnostics measured electron temperature and density at 5 points along the major radius.



Top view Front view
Fig.2: Globus-M cross section

Results

The jet propagation speed in the plasma core of Globus-M was measured by means of radiation recorded with a streak-camera (Fig.3). In the figure on the horizontal axis is the time from the injection start and on the vertical axis is the distance from the gun port. The inclined stripes visible in the figure correspond to the separate fractions of the jet, and their slope defines the spread velocity of each

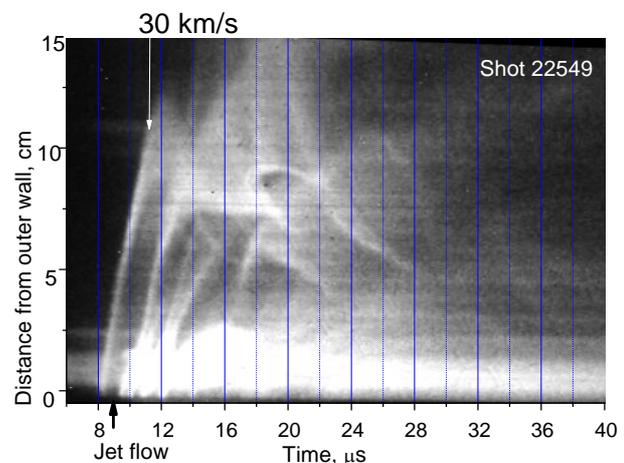


Fig.3: Jet penetration in plasma core registered with a streak camera

fraction. The photos prove the fact that the plasma jet consists of several components, each of them propagating with its own speed (≤ 30 km/s). Initial velocity of plasma jet at the muzzle edge was ≤ 120 km/s. The flux penetrates far inside separatrix.

During tokamak shot video frames of jet radiation viewed from two positions, density and temperature profiles were investigated (Fig.4). One can see central penetration of the jet.

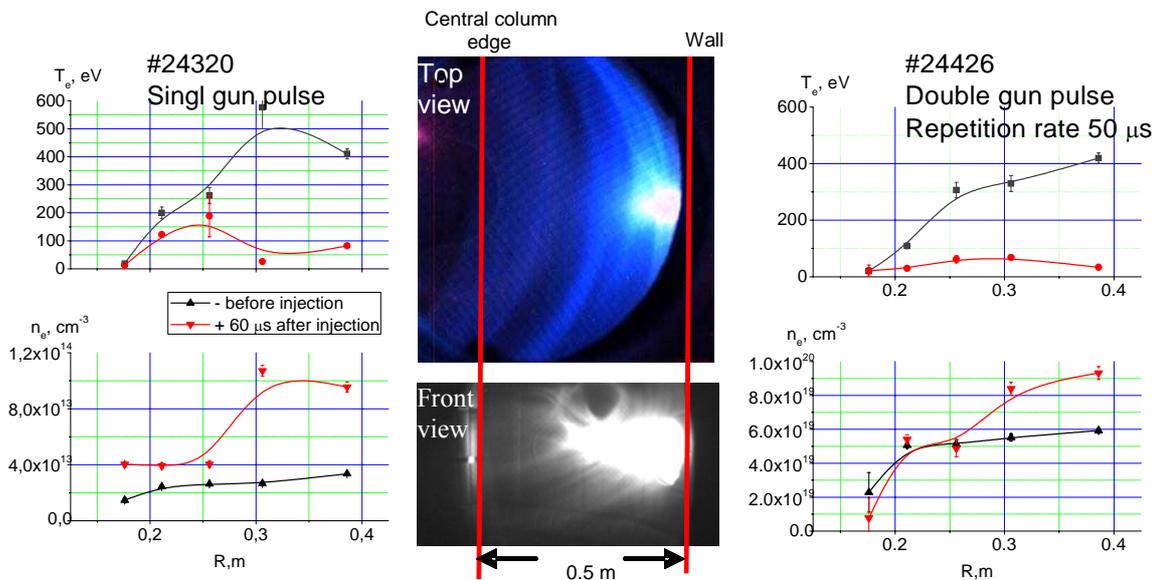


Fig.4: Electron density and temperature profiles measured before and after the jet injection. Video frames of jet radiation viewed perpendicular and parallel equatorial plane. Exposition time 250 μ s

The injected plasma is more extended along toroidal direction as comparison with poloidal one. Both single and double pulse injection produce central density increase and temperature drop.

Electron density and temperature profiles for different gun positions were measured (Fig.5). In both positions the fast density increase and temperature drop was recorded. Experiments show that for two gun positions the plasma density at the magnetic axis increases and the temperature drops already in 50 μ s after the start of the jet injection into

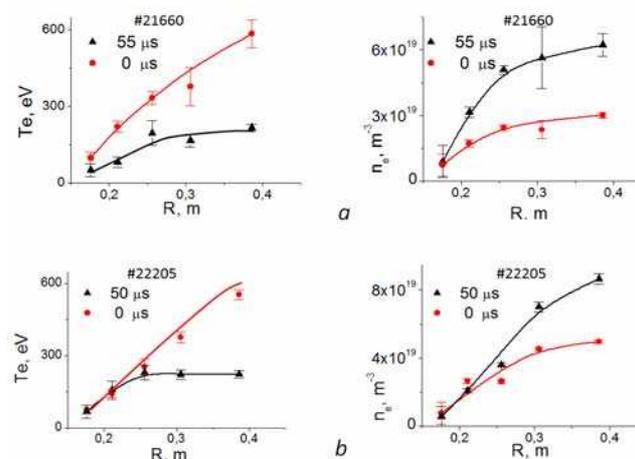


Fig.5: Electron density and temperature profiles measured before and after the jet injection, in cross section near the gun (upper pictures) and in remote cross section (lower pictures)

the target plasma. The changes in the central region are stronger than at the periphery. Observation of jet radiation (Fig.4, Top view), density and temperature profile measurements in different cross sections allow concluding that the injected plasma spreads around toroidal direction in $\leq 50 \mu\text{s}$.

The video-frame of the jet injected in the target plasma with superimposed fragments of the magnetic lines is shown in Fig.6. One can see spreading the jet along the magnetic field lines. This could be a possible diagnostic method for q profile measurements.

Conclusions

Preliminary experiments on plasma jet injection with double pulse plasma gun in Globus-M were performed. Both single and double pulse injection produce central density increase and temperature drop. By means of radiation recorded with a streak-camera the jet propagation speed (around 30 km/s) in plasma core of Globus-M was measured. During tokamak shot video frames of jet radiation, viewed from two positions, density and temperature profiles were investigated. These observations of the jet in different cross sections of tokamak allow concluding that the injected plasma spreads in toroidal direction in $\leq 50 \mu\text{s}$. The achieved results make the plasma gun a perspective instrument for tokamak fuelling and the possible diagnostic method for q profile measurements.

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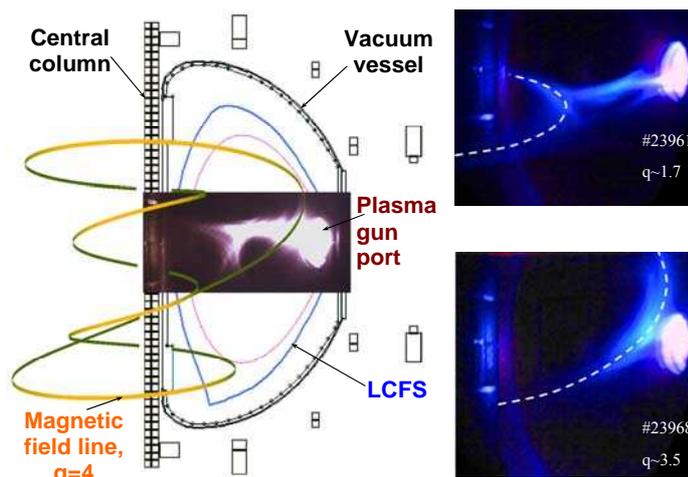


Fig.6: The video-frame of the jet injected in the target plasma with superimposed fragments of the magnetic lines.