*33rd EPS Conference on Plasma Phys. Rome, 19 - 23 June 2006 ECA Vol.**30I**, P-4.105 (2006)*

Progress of the Intense Jet Fuelling Source

A.V.Voronin[1], K.B.Abramova [1], V.K.Gusev[1], G.S. Kurskiev[1], B.B. Ayushin[1], M.M.Kochergin[2], R.G.Levin[1], V.B.Minaev[1], E.E.Mukhin[1], M.I.Patrov[1], Yu.V.Petrov[1], N.V.Sakharov[1], I.P. Scherbakov[1], S.Yu.Tolstyakov[1]

1) A.F. Ioffe Physico-Technical Institute, RAS, St. Petersburg, Russia,

2) Ioffe Fusion Technology ltd., St. Petersburg, Russia

Introduction

Developing of effective plasma fuelling methods for future thermonuclear reactor like ITER has special importance. One of the most attractive fusion relevant scenarios is a high plasma density regime as the fusion power depends squarely on density. Plasma accelerators, producing clean, high density, high speed plasma jets could be used for this purpose. On the other hand the problem of plasma jet accelerating to high kinetic energy has its own fundamental and application significance. Spherical tokamak Globus-M program has the density control method development as one of the main goals to achieve and maintain regimes with high and ultimately high densities. Unique technical characteristics of the machine allow the achievement of high densities [1]. Method of density control alternative to gas puffing was used and developed at Globus-M. Experiments with injection of dense fast plasma jet into the spherical tokamak Globus-M [2--4] have demonstrated the viability of such method of fuelling with minimum plasma perturbations. The results currently obtained suggest the development and injection of plasma jets with specific kinetic energies in excess of those reached in earlier study. Experiments on plasma startup with the help of the plasma gun are continued. The present report is devoted to a further development of such fuelling method.

Development of gas generating stage

The source consists basically of two stages [5]. The first (gas generating) stage contains titanium grains loaded with hydrogen. An electric discharge passing through the grains releases high-pressure hydrogen. Neutral hydrogen passing through a specially designed grid fills the accelerator electrode gap to a high pressure in a few tens of microseconds. The second (plasma generating) stage is actually a system of coaxial electrodes.

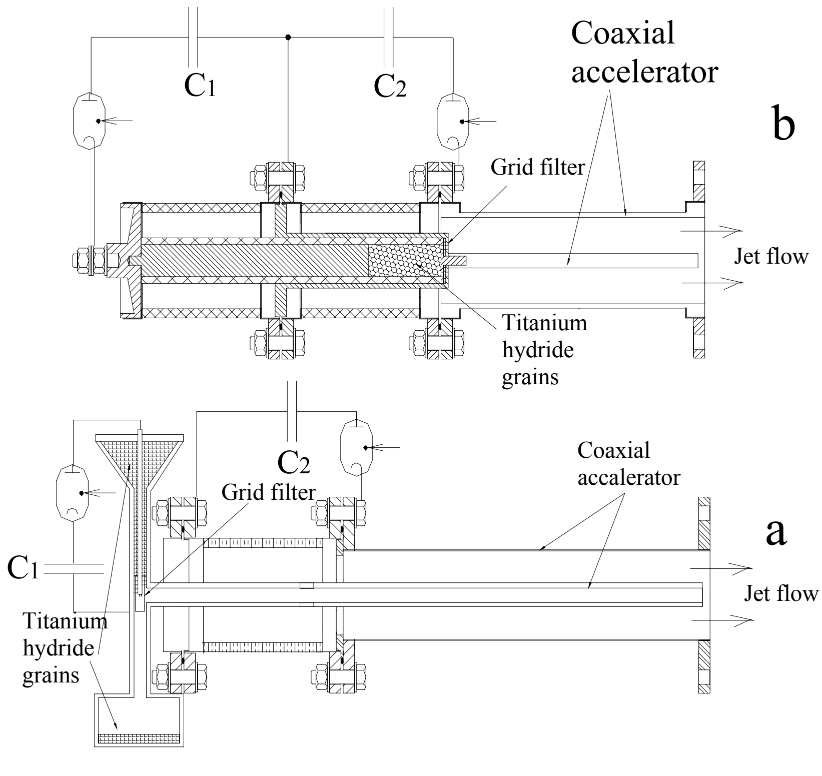

Fig.1: Two versions of gas generating stage; a- fresh grains loaded before each shot; b-fresh grains loaded before series

Electric discharge fired through the gas between the coaxial electrodes provides gas ionization and plasma acceleration in the classical "Marshall gun scenario".

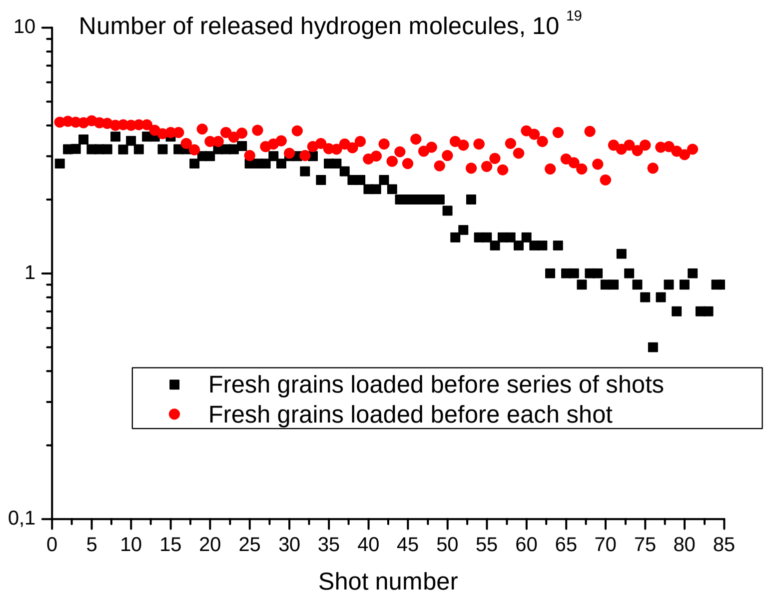

Fig.2: Dependences of number hydrogen molecules on shot number

Previous experiments were conducted with fresh titanium hydride grains loaded before the series of 50 shots (Fig.1b). An electric discharge passing through the whole package of 3 cm^3 grains releases quantity of hydrogen decreasing with a shot number. Present construction allows loading the fresh grains before each shot (Fig.1a). It consist of two chambers for fresh and used grains, and thin channel between where electrical discharge releases the hydrogen. The grains fell down through the channel immediately after discharge because of high gas pressure. An electric discharge passing through fresh 3 mm^3 grains releases constant quantity of hydrogen during each discharge. So, the stage is able to generate stable gas release for many shots. Dependences of number hydrogen molecules on shot number for two constructions are presented in Fig.2. It is seen that with a shot number gas release decreases for version (b) and stable for version (a). Piezoceramic probe registered velocity of the gas jet increase from 2 km/s (for b-version) up to 7 km/s (for a-version). Also it was seen increase of the plasma flow velocity after the second stage from 100 up to 140 km/s.

Jet injection into the Globus-M during current plateau phase

A description of the design, operational principles, and experimental program of Globus-M can be found in [6]. The basic design characteristics are as follows: aspect ratio $A = R/a = 1.5$, major plasma radius $R = 36$ cm, minor plasma radius $a = 24$ cm, average plasma density $n_e = (1\text{--}7)\ 10^{19}\ m^{-3}$, pulse duration with inductive current drive $\tau_{pulse} \leq 0.12$ s. Plasma current amplitude was in range 200--250 kA at the quazi-stationary discharge phase. The toroidal magnetic field was changed in the range 0.3--0.4 T.

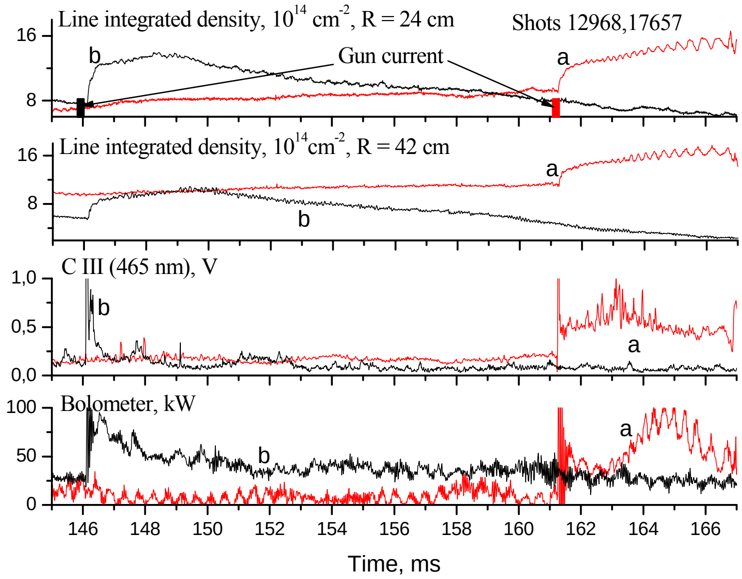

Fig.3: Waveforms of plasma discharge parameters in Globus-M under plasma jet injection; a- fresh grains loaded before each shot; b-fresh grains loaded before series of shots

The hydrogen jet was injected into Globus-M in OH deuterium plasma during current plateau phase from the equatorial plane, along the major radius from the low field side. The jet speed was increased up to 125 km/s. The jet density near the gun edge reached 2×10^{22} m^{-3}.

Waveforms of plasma discharge parameters in Globus-M under plasma jet injection are presented in Fig.3. For comparison two different versions of gas generating stages in plasma source were used. Waveforms (a) correspond to version where fresh grains loaded before each shot and (b)-fresh grains loaded before 50 shots series. It is seen that it led to fast rise (<0.5 ms) the plasma average density, line radiation CIII and black body radiation recording by bolometer.

The bolometer signal and the density increase along the peripheral (R = 24 cm) chord are equal both for a-and b version. But the increases for line radiation CIII and plasma density along central (42 cm) chords are higher for a-case. Possibly the a-version source generates the plasma with higher specific kinetic energy than b-version one. But an intense electric discharge passing through the grains in thin channel may release not only hydrogen but also some impurities. Additional efforts should be made to separate hydrogen cloud from impurities.

Plasma startup in tokamak with plasma gun in conditions of double swing central solenoid operation regime

Plasma source was placed at the equatorial plane on 0.5 m from tokamak. Initial plasma velocity reached 100 km/s; number of injected particles was comparable with total number of the particles in tokamak (5x10[18]--10[19]). The plasma discharge, initiated by means of plasma jet is shown in Fig.4. One could see that plasma current ramped up faster and to the higher value than with gas-puffing and pre-ionisation system. It is also seen that radiation of D-alpha decreases and maximum of the spectral line intensities (D-alpha and CIII) are shifted to the beginning of the discharge phase. That confirms that more intensive plasma heating is at the initial stage of the discharge.

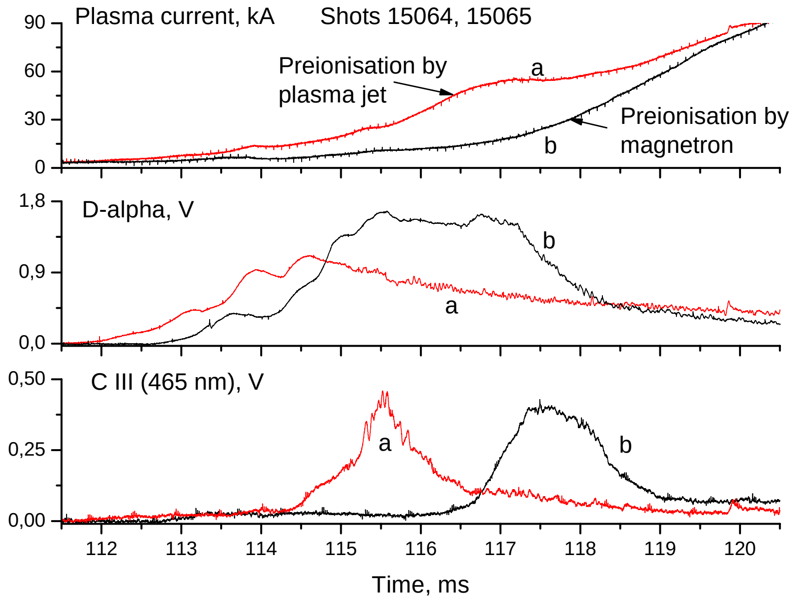

Fig.4: Time dependence of parameters in Globus-M at plasma discharge initiation; a-with plasma gun; b-with gas puffing and RF-preionisation.

Conclusions

The new gas generating stage of jet source allows loading the fresh grains before each shot and produce stable gas release for many discharges. Velocity of the gas jet was increased up to 7 km/s and plasma flow velocity up to 140 km/s. The results currently obtained confirm that the injection of plasma jets with specific kinetic energies is in excess of those reached in earlier study. Additional efforts should be made to separate hydrogen cloud from impurities. Plasma startup in tokamak with the help of the plasma gun in conditions of double swing central solenoid operation regime showed better performance tokamak startup compared to conventional scenario.

The work is supported by IAEA, Research Contract No 12408 and RFBR grant No 04-02-17606.

References

1. Gusev V.K. et al, Tech. Phys. 1999, 44, No.9, p.1054
2. Abramova K.B. et al, Plasma Physics Reports 31 (2005) 1
3. Voronin A.V. et. al, Nuclear Fusion 45 (2005) 1039
4. Voronin A.V. et al, Nukleonika 51 (2006) 85
5. Voronin A.V. and Hellblom K.G., Plasma Phys. and Controlled Fusion 43 (2001) 1583
6. Gusev V.K. et al, Nuclear Fusion 41 (2001) 919