Development of the high kinetic energy plasma jet for central fuelling

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Introduction

One of the main problems of the controlled fusion is reactor plasma fueling. To allow central penetration into the ITER plasma core an injection of a fuel jet with a density of > 10^{23}m^{-3} and flow velocity of ≥ 100 km/s should be used. At present time coaxial plasma guns allow one to obtain dense, highly ionized plasma jets with a density of ~10^{22} m^{-3} and flow velocity ≥ 100 km/s [1,2]. A high plasma density is provided by an intensive gas feeding into the accelerator. For this purpose an electrical discharge passing through the titanium hydride/deuteride grains was used. However higher density and velocity parameters require designing of the new systems, such as: gas feeding, electrode systems and so on. This presentation describes the experimental studies aimed at development of an effective plasma source based on the coaxial type accelerators with the slot-hole channel geometry for plasma current extension. The results show that the plasma jet obtained in our studies has a high kinetic energy and suggested method of acceleration of the pure plasma is efficient. Measurements of the plasma parameters, i.e. - density, plasma elemental composition and jet

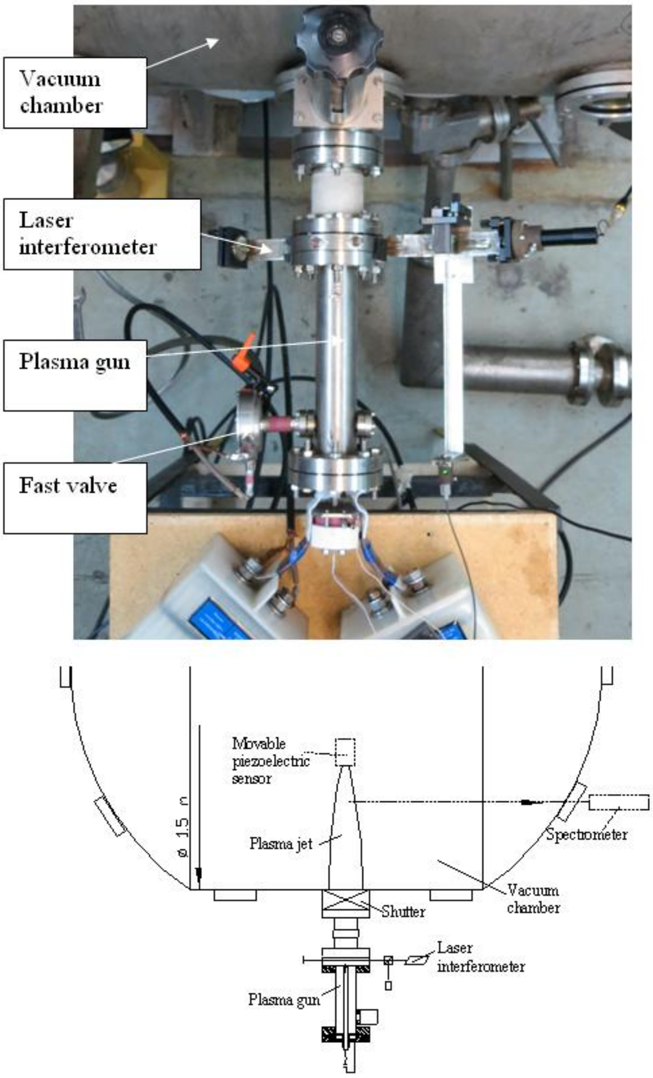

Fig.1: Top view of plasma gun with diagnostics

pressure were carried out. Comparative analysis of the accelerators with coaxial and slot-hole channel geometries was performed.

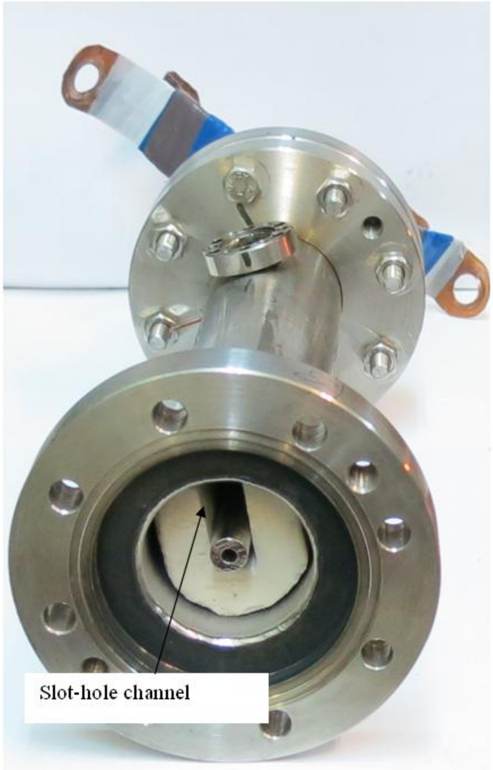

Fig.2: Coaxial accelerator equipped with slot-hole channel

Test bench for plasma gun investigation

The test bench consisted of the 2.5 m^3 vacuum chamber, plasma gun, and diagnostics for plasma jet parameter measurements. (Fig. 1). The Marshal type gun had a plasma generating stage made of coaxial electrodes and fast electro-dynamical gas puffing system. The 532 nm Michelson laser interferometer measured plasma density at the gun muzzle end. A piezoelectric detector measured jet pressure near the gun axis at different distances from the accelerator. By using an AvaSpec-ULS 2048XL-RS-USB2 spectrometer a visible jet irradiation at a distance of 0.5 m from the muzzle was observed. A possibility to increase the density by placing a ceramic piece (Al_2O_3) with the slot-hole channel geometry between the electrodes was investigated (Fig. 2).

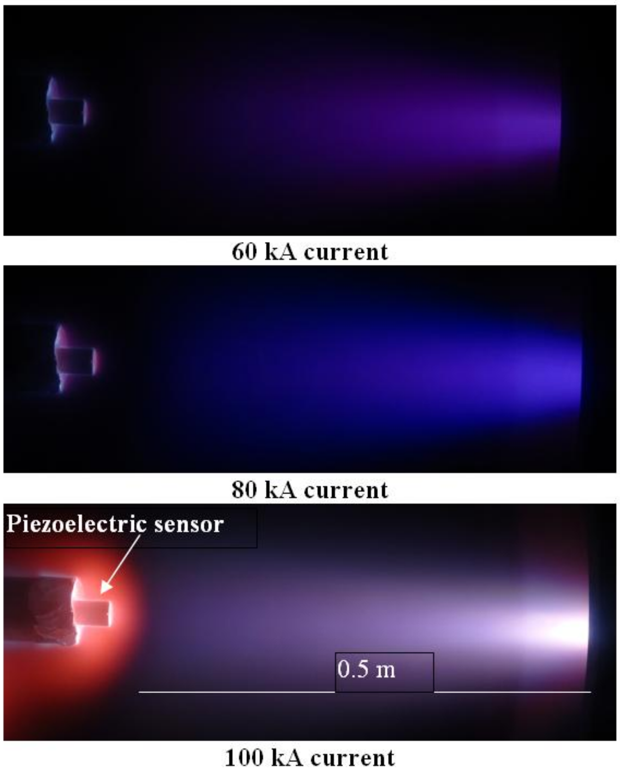

Fig.3: Video frames of plasma jet at different discharge currents

Experimental results

Experiments on plasma jet acceleration at different discharge currents were carried out. Fig. 3 shows video frames of the jet extended in the vacuum chamber far from the walls. One can see that the intensity of the jet irradiation increases with increasing discharge current. The jet hits the piezoelectric sensor and produces some luminosity near its surface. The divergence of the jet does not exceed several degrees.

The elemental composition of the deuterium plasma jet at different discharge currents is presented in Fig. 4. One can see that a lower current provided a lower impurity contamination. It is also evident from the figure that the gun produces a sufficiently pure plasma jet at 60 and 80 kA.

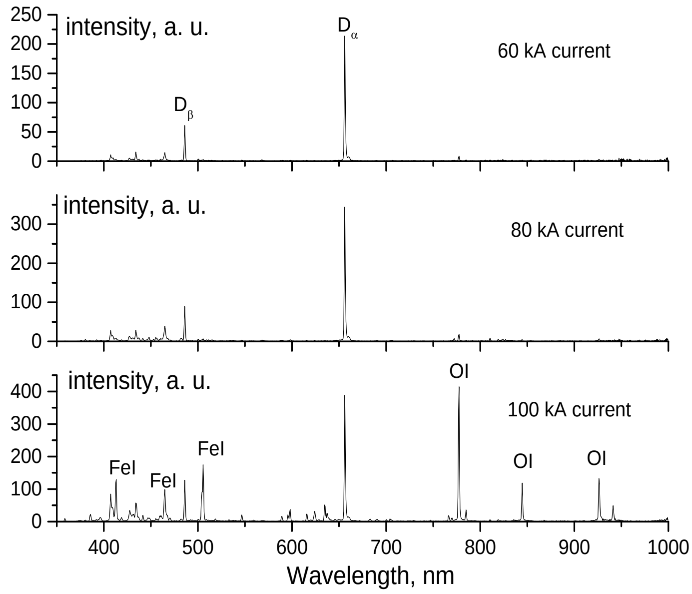

Fig.4: Plasma jet spectra viewing at 0.5 m from the gun muzzle

Comparative analysis of coaxial and slot-hole channel accelerators was carried out. The dependence of the jet pressure on the distance from the gun edge is presented in Fig. 5. One can see that the slot-hole channel accelerator had a higher jet pressure than a coaxial one, especially at large distances from the gun edge. This pressure exceeded 10 N/m ^{2} at a distance of 0.7 m.

Temporal dependences of plasma density at different discharge currents was also investigated (Fig.6). The discharge current varied from 60 to 100 kA. Top graph in Fig. 6 represents a typical current evolution. It can be seen from the bottom graph that a lower current produces lower plasma density. In the experiments plasma density was in the range of (2.5 – 5) $\times 10^{22}$ m^{-3}. These values exceeded the density obtained with a coaxial (Marshal type) plasma gun at above mention discharge current. The velocity of the plasma flow was estimated by means of expression:

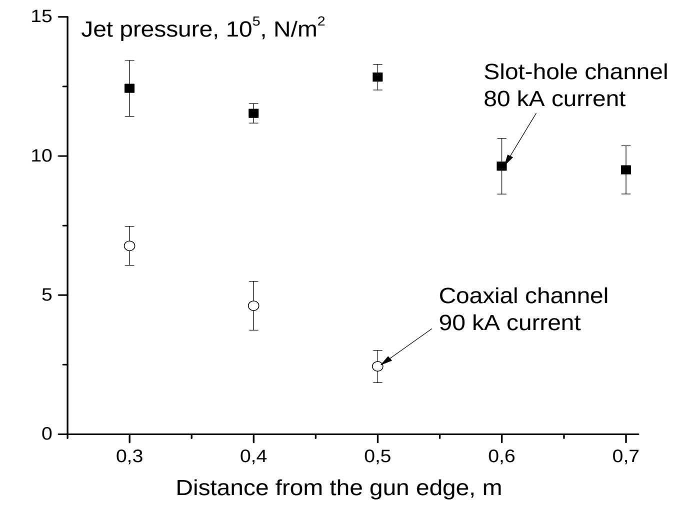

Fig.5: Dependence of jet pressure on distance to the gun edge for coaxial and slot-hole channel electrode geometry

$V = \sqrt{\frac{2P}{m \times n}}$ = 140 km/s, where: P – jet pressure (~10^6 N/m^2), m – deuterium mass (3.34×10^{-27} kg), n - plasma density (~3×10^{22} m^{-3}).

Conclusions

A plasma gun with the slot-hole channel geometry was investigated. The gun produced a sufficiently pure plasma jet at 60 and 80 kA current. The gun provided a higher jet pressure than a coaxial one, especially at large distances from the gun edge. The plasma density also exceeded the density obtained with a coaxial (Marshal type) plasma gun.

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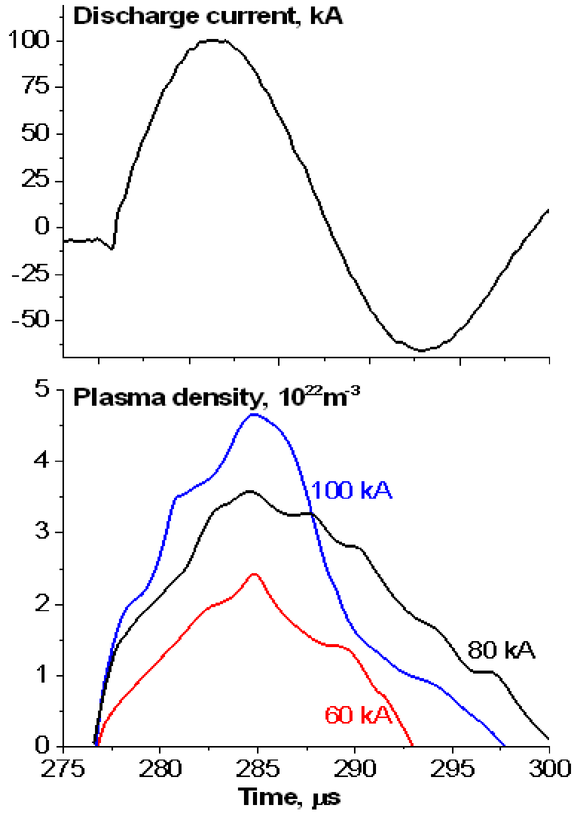

Fig.6: Dependences of plasma density on time for different discharge currents

References

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