PROBE DIAGNOSTICS OF DENSE PLASMA IN HIGH CURRENT MODE OF A RING-SHAPED CLOSED DRIFT PLASMA THRUSTER

Vasily Gushenets, Alexey Bugaev
Institute of High Current Electronics SB RAS, Tomsk, Russia
Efim Oks
Institute of High Current Electronics SB RAS, Tomsk, Russia
Tomsk State University of Control System and Radioelectronics, Tomsk, Russia

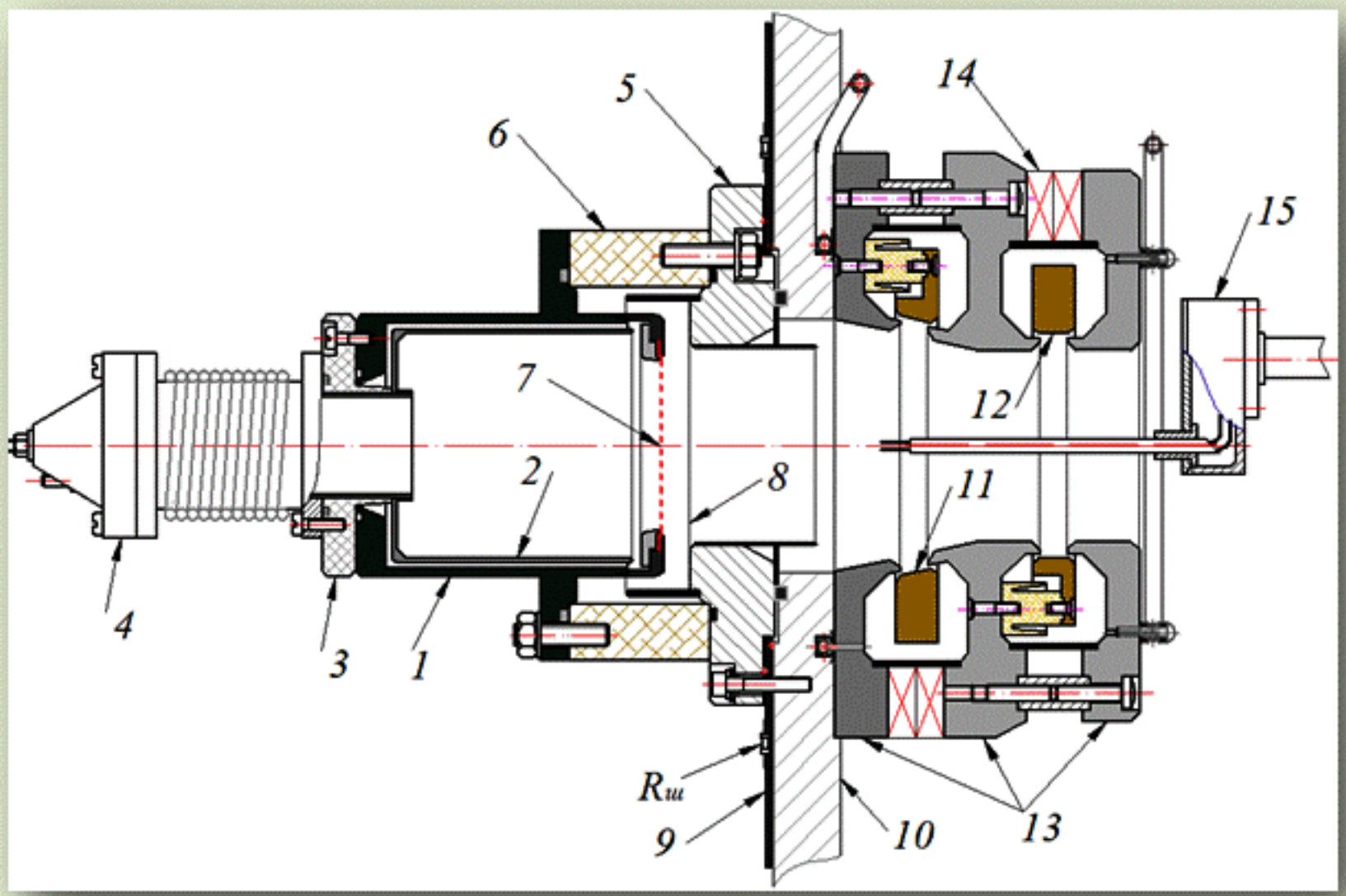
We present experimental data concerning the local plasma parameters: electron temperature, electron density; as well as their spatial distribution in a cylindrical hollow cathode formed by ring-shaped closed drift plasma thruster. This hollow cathode is a lengthy plasma-filled channel and is designed to transport an intense low-energy electron beam to the target.

The plasma thruster is based on the geometry of a gridless ion source with an anode layer. For the formation of plasma in the transport channel, the so-called "plasma" high-current operational mode of the thruster discharge system was used. The amplitude of the discharge current in this mode can reach several tens of amperes, with a current pulse duration up to several hundred microseconds.

Plasma diagnostics was carried out using the double probe method. The choice of this method is due to two reasons - the presence of a magnetic field, as well as the high plasma potential (several hundred volts) relative to the grounded electrode. The dual probe method does not require a reference electrode, and the dual probe system can be isolated or have a high floating potential.

The work was supported by the Russian Foundation for Basic Research (grant 19-08-00315-a)

EXPERIMENTAL SETUP



Electron source with plasma-filled optical system:

Plasma electron source:

1 – plasma electron emitter;
2 – hollow anode;
3 – polyamide insulator;
4 – vacuum arc plasma generator;
5 – mounting flange;
6 – high-voltage insulator;
7 – emission window;
8 – gridless accelerating electrode;
9 – current shunt;

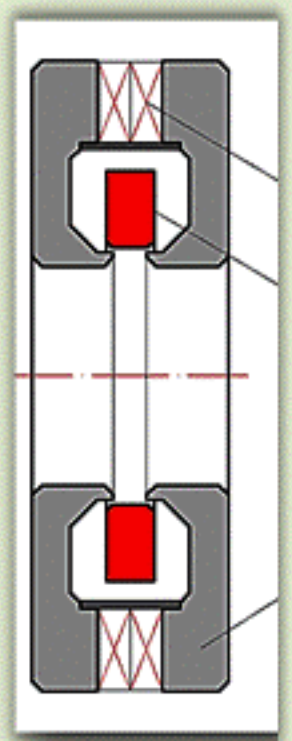
Ring-shaped thruster:

10 – vacuum chamber flange;
11, 12 – anodes of plasma thruster;
13 – magnetic cores - cathodes;
14 – magnets;
15 – double probe.

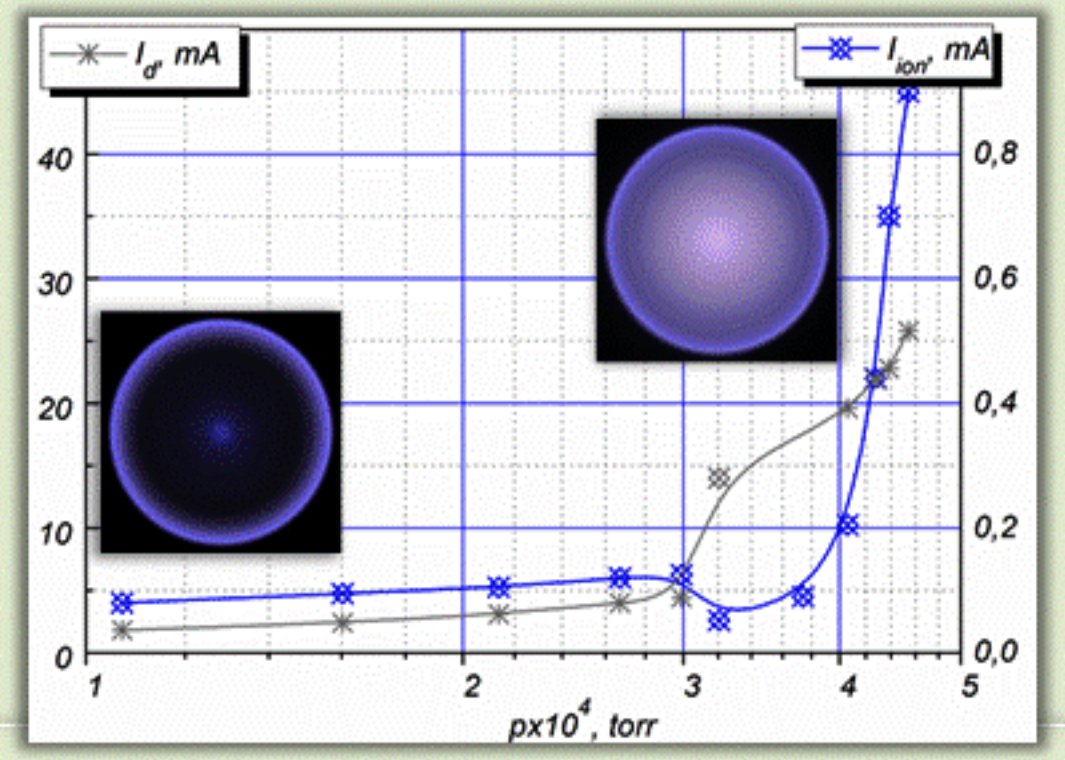
Experimental studies were carried out on the stand of an electron source with a plasma electron emitter and a plasma-filled optic system (plasma anode) of beam formation and transportation. Plasma optic system is a hollow cathode with ring-shaped thruster.

Plasma sources laboratory

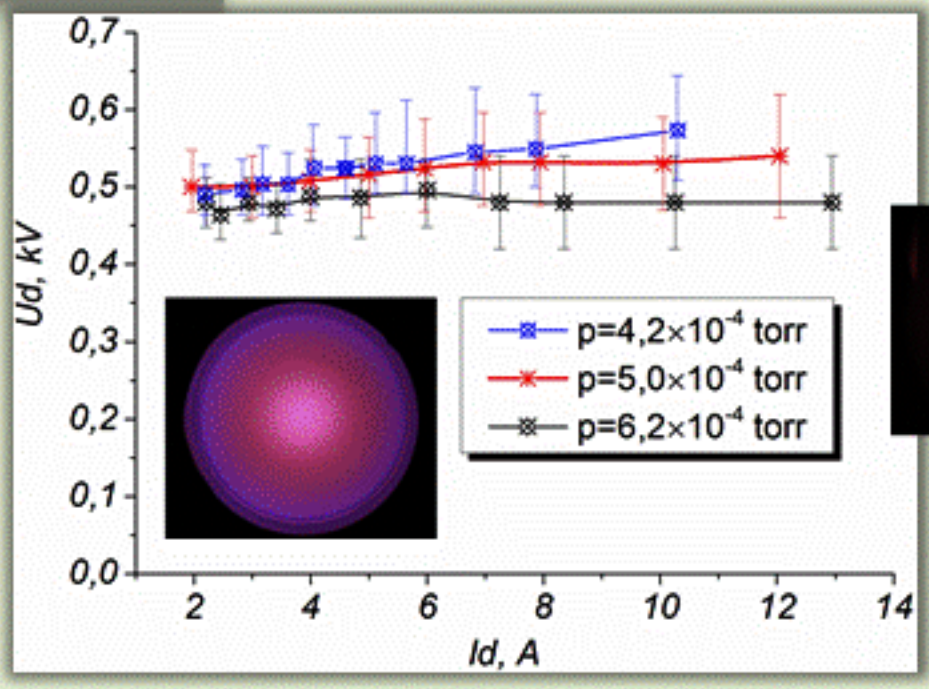
RING – SHAPED CLOSED DRIFT PLASMA THRUSTER



Plasma thruster (left figure):
1 - anode (copper or stainless steel);
2 - cathodes or magnetic cores (soft magnetic steel);
3 - permanent magnets;
and its operation modes (right figures)



Discharge current and ion beam versus background pressure in low current (ion beam) mode and transition to high current mode as well as plasma glow.

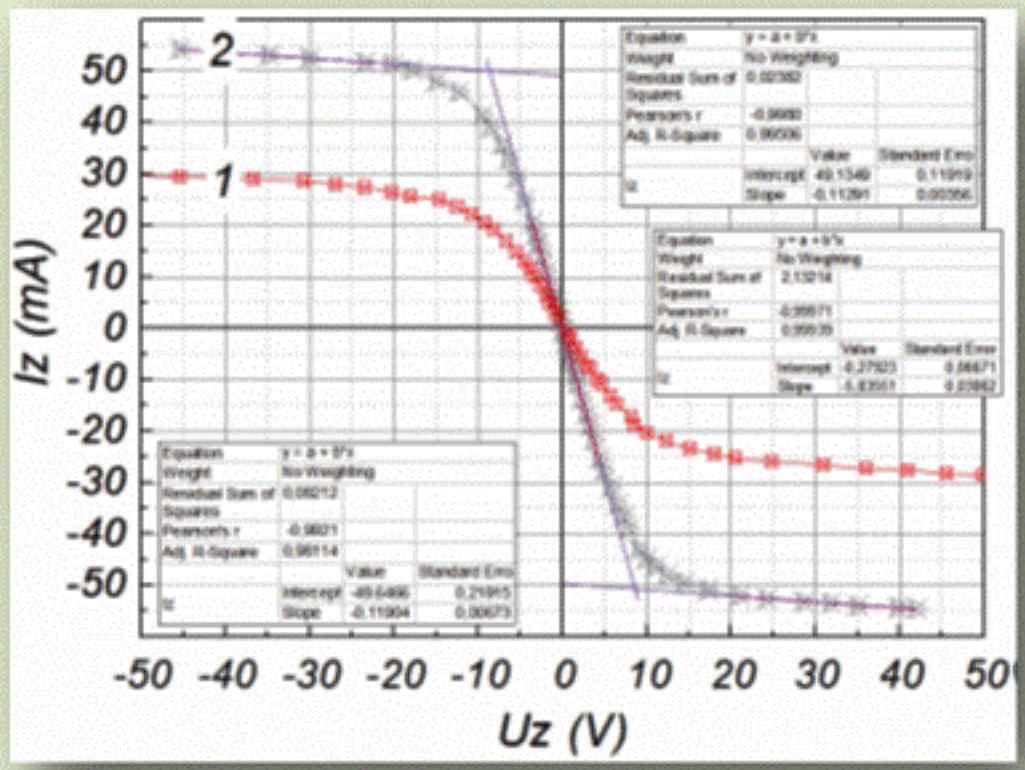


Current-voltage characteristics and plasma glow in high current plasma mode. Ar is background gas.

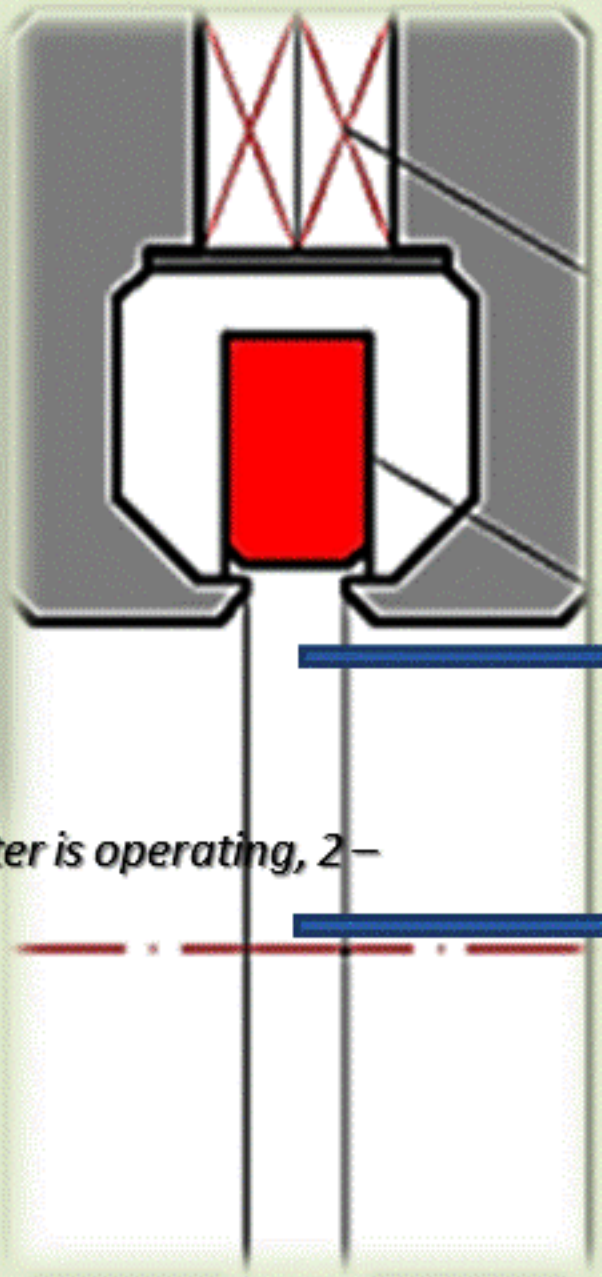
Plasma sources laboratory

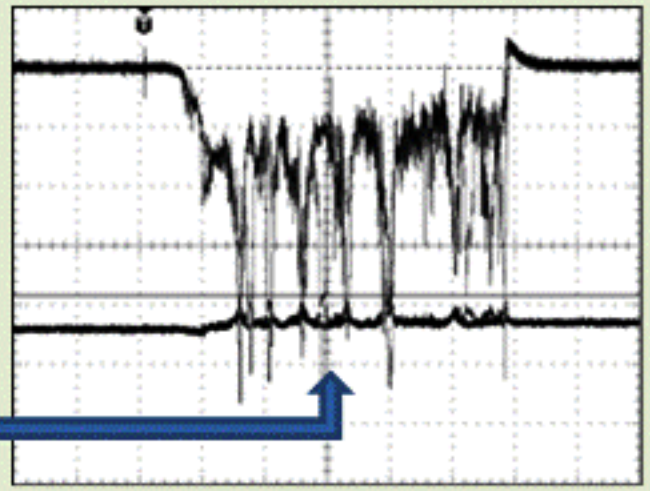
EXPERIMENTAL RESULTS

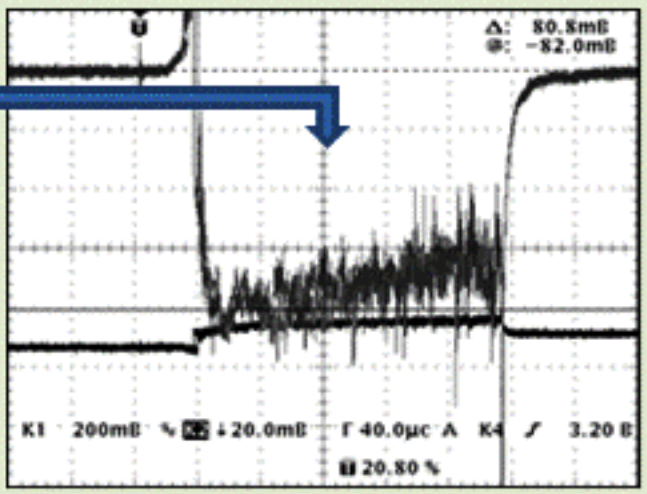
EFRE 2020



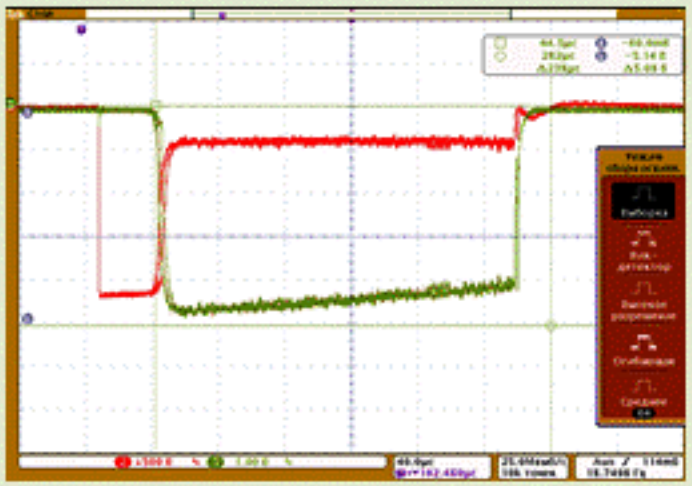
Typical Probe Characteristics. 1 – first plasma thruster is operating, 2 – second thruster is operating.







Waves of probe currents near the pole pieces (upper) and on the axis (botton).

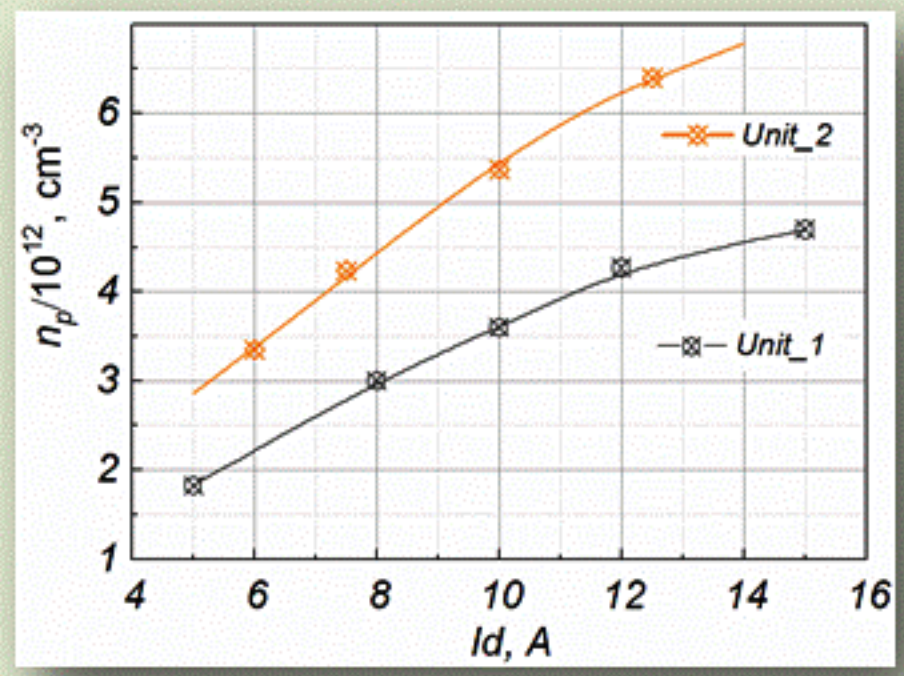


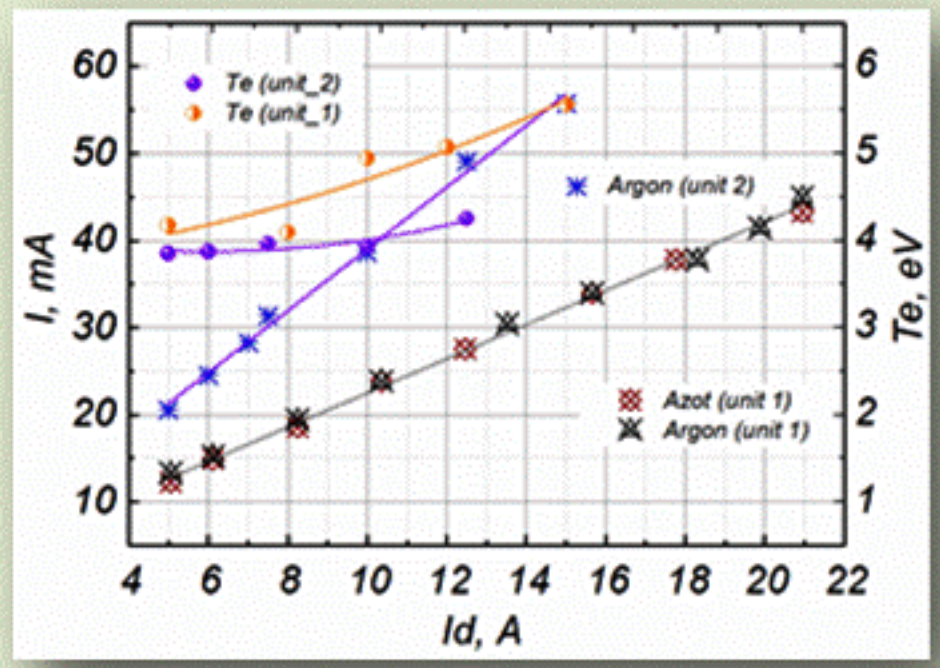
Waves of discharge currents (green) and discharge voltage.

Plasma sources laboratory

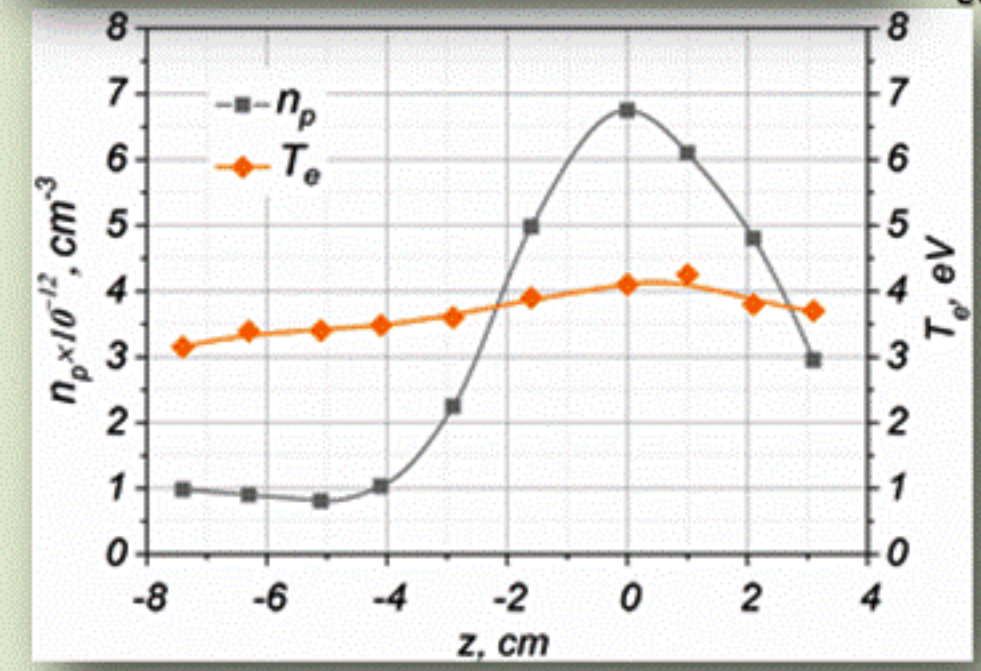
EFRE 2020

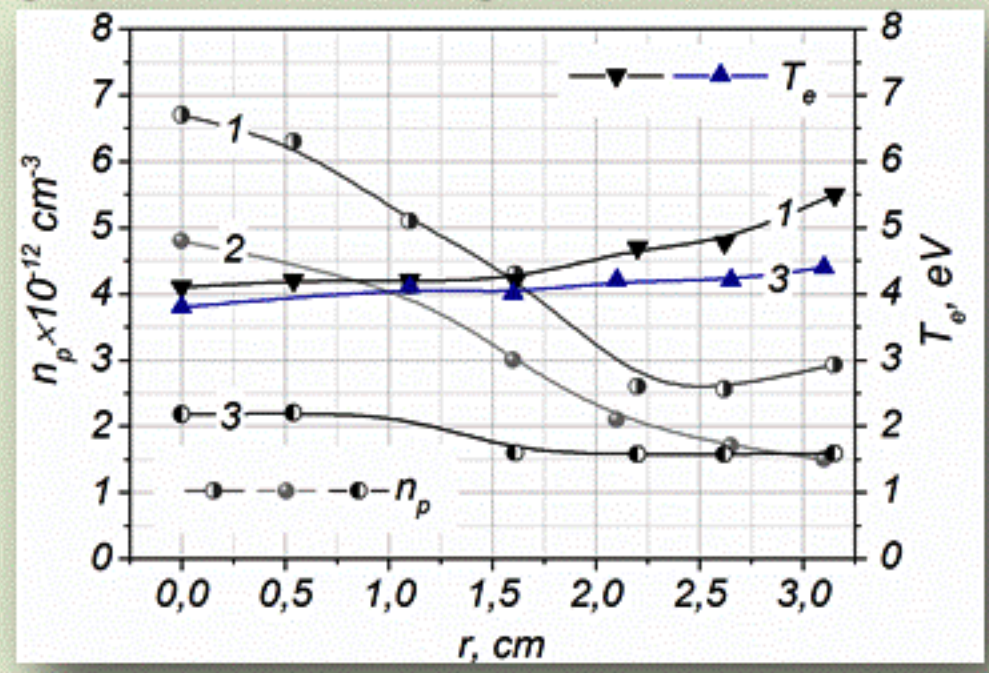
EXPERIMENTAL RESULTS





Plasma concentration (left), electron temperature and maximum probe current (right) versus the discharge current.





Spatial distribution of plasma concentration and electron temperature along the axis (left) and in the radial plane.

Plasma sources laboratory

EFRE 2020

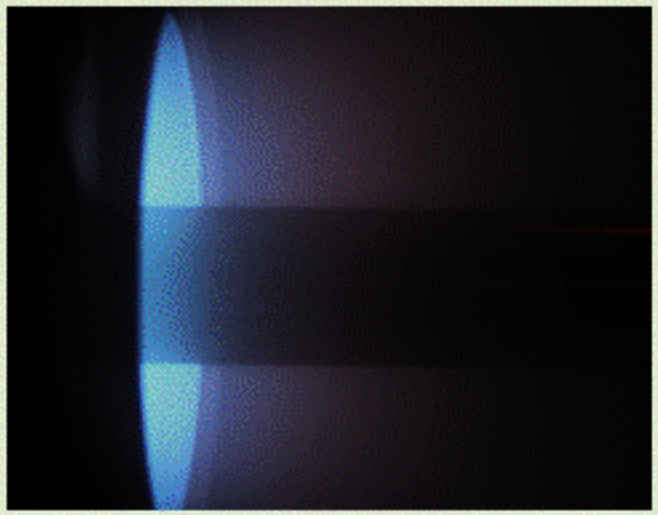
CONCLUSION

Plasma probe measurements showed that the spatial distribution of plasma density is inhomogeneous within a certain region adjacent to the axis. The length of this region along the channel axis is close to its radius. Outside this region, the distribution of plasma concentration is quite uniform. The maximum plasma density on the axis is close to 7×10^{12} cm-3, and the electron temperature is in the range of 3.5–5.5 eV.

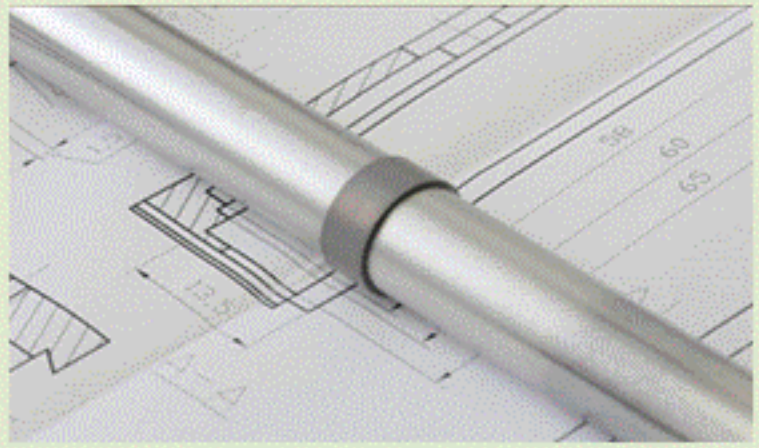
The hollow cathode geometry of ring-shaped closed drift plasma thruster was used in a wide-aperture plasma optical system for producing and transporting intense electron beams.

There are possibilities of technological application of the thruster, for example, for cleaning the outer surface of pipes. One example is shown below.

Before



After



Plasma sources laboratory