Modeling of self-consistent mode formation in an electrostatic plasma lens

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Here we described the modeling of self-consistent mode formation in an electrostatic plasma lens under transport through it a wide-aperture, high-current, low energy, metal-ion plasma flow produced by a cathode arc discharge. When the negative potential applied on the central cylindrical lens electrode, a radial directed stream of energetic electrons is formed. The formation of the electric potential jump near the inner surface of the cylinder has been modelled. High-energy electrons appear near the inner cylindrical surface by secondary ion-electron emission under surface bombardment by peripheral flow ions. These energetic electrons can accumulate on axis and provide a mechanism for the plasma flow focusing. It has been shown that the presence of fast electrons in the volume of the plasma lens improves the propagating ion plasma flow.

New approach for devise a novel plasma technology for elimination of micro-droplets or their reduction to the nano-scale from the dense metal ion-plasma flow formed by erosion plasma sources (vacuum arc and laser produced plasma sources), without loss of plasma production efficiency was proposed and described in [1]. This approach is based on application of the cylindrical electrostatic plasma lens configuration for introducing in a volume of propagating along the axis dense low energy ion-plasma flow convergent toward axis energetic electron beam produced self-consistently by ion-electron secondary emission from internal cylindrical surface of plasma lens central electrode (see Fig.1)

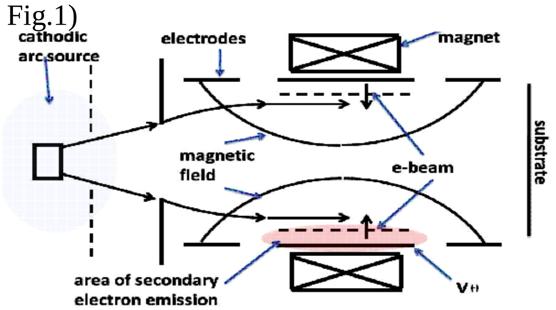

Fig.1. The scheme of model

Here we are modelling the transport through an electrostatic plasma lens of a wide-aperture, high-current, low energy, metal-ion plasma flow produced by a cathodic arc discharge. The lens consists from three electrostatic ring electrodes located in a magnetic field formed by permanent magnets. Modelling parameters were closed to experimental: the lens input aperture - 80 mm, the lens length 140 mm, the outer electrodes are ground and the central electrode voltage up to -3 kV. The plasma is a copper plasma with directed ion energy 20–40 eV, and the equivalent ion current is up to several amperes depending on the potential applied to the central lens electrode.

We modeled of electrical potential jump formation near the inner surface of the cylinder and appearance of self-consistent electron beam across the plasma flow. It is shown that beam is formed by double layer, appeared in a cylindrical channel of the plasma-optical system in crossed radial electrical and longitudinal magnetic fields. It is accelerated by electric potential jump. High-energy electrons appear near the inner cylindrical surface by secondary ion-electron emission at this surface bombardment by peripheral flow ions. Electrons are magnetized and ions are not magnetized. The electron mobility across a magnetic field is strongly suppressed. The electron movement along magnetic field is free up to region of electric potential jump. Under these conditions the magnetic field lines are equipotential up to region of electric potential jump. Thus, the magnetic field lines are equipotential inside flow. Then in space, filled with plasma, the electrical field is created, the form of which is approximately similar the structure of magnetic field lines. Because the electrons of the flow are magnetized, they in the field of the short coil are displaced to its axis, damping expansion of the flow due to electric field of plasma flow polarization. Thus, with increase of magnetic field the near axis density of flow increases. It is shown the energetic electrons accumulate on axis and provide ion focusing. Note that they can also provide additional energy pumping into system for reducing the micro-droplet component in the dense, low-temperature, metal plasma.

[1] A. A. Goncharov, Rev. Sci. Instrum., **87** (2016), 02B901