Application of filter method for detection of secondary electron emission in the auto-oscillating mode of beam plasma discharge

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Abstract. In this paper we studied the non-self mode of the auto-oscillation secondary-emission discharge (ASED) in a longitudinal magnetic field with autonomous electron gun to ignite the primary beam-plasma discharge (PPD).

Abnormally high secondary electron emission is the basis of a positive feedback mechanism leading to auto-oscillations at the resonant frequencies. For ASED [1], pulse amplitude of excited auto-oscillations can be much larger than the negative voltage applied to the collector plate, defining the features of the spectrum of high-energetic electron group. The experimental scheme is shown in figure1 [2].

Conventional contact probe and spectrometric research methods of diagnostics of distribution of high-energy group of electrons in the plasma column are carrying significant disturbance. Furthermore, they do not allow to separate the effects of primary and return flows including reflected and emitted by the surface of the electron collector [3].

We suggest the novel method of X-ray diagnostics of ASED, in which the spectrum of the high-energy (> 4 keV) electron group is reconstructed from X-ray radiation.

Our method uses a spectrometer based on thermoluminescent detectors (TLD) [4]. It provides 13 detection channels with TLD assemblies of lithium fluoride tablets arranged one after the other. Assemblies are closed with attenuation filters [5] of the aluminum foil. The type and thickness of the filters limits the sensitivity of the spectrometer (quantum energy > 4 keV). TLD indications were read with DVG-02TM device.

In the first experiments, the diaphragm has been deployed to the TLD thus sensors detected radiation from the primary beam after bombarding a target with primary electron flow (scheme in figure 1a). This PPR mode was obtained at an electron gun accelerating voltage of 5 kV (current 0.1A) without working gas inlet (chamber pressure of 10^{-6} Torr). Interaction of the primary beam with hydrogen plasma (hydrogen inlet, chamber pressure 10^{-4} Torr) leads to the collision less braking of the main part of electrons and acceleration of the rest electrons (about one percent) over the energy of the primary beam. These electrons provide the high energy "tail" in the distribution.

In subsequent experiments, measurements were made in the ASED mode. As shown in figure 1b, primary electron beam 1 passes through a hole in the diaphragm 4. The magnetic axis at the outlet of

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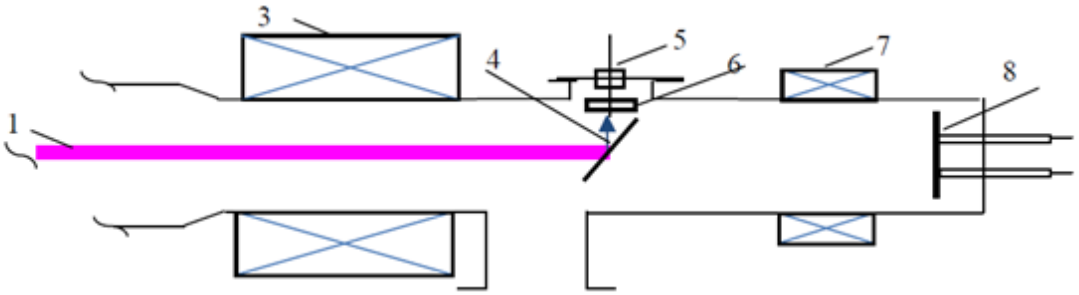
the trap has a slight deviation from the geometric axis. It can be configured by a special side coil.



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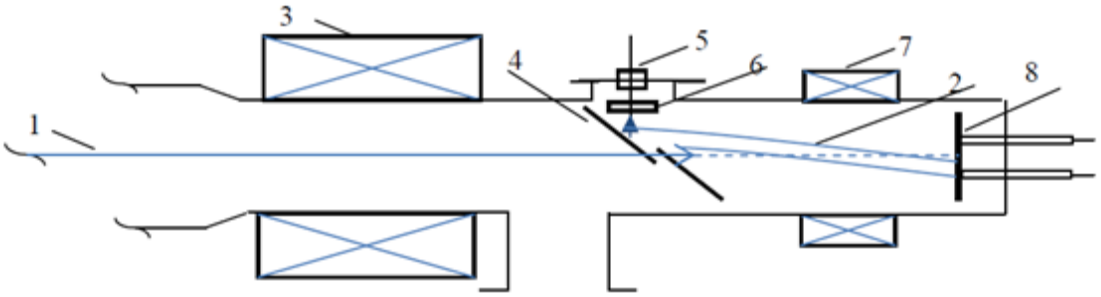

b

Figure 1 PPD measurements scheme (a), ASED measurements scheme (b). 1–primary beam; 2 – reverse flow of secondary and reflected electrons; 3,7–magnetic field coils; 4 –molybdenum diaphragm; 5 –locking device; 6–TLD cartridge ; 8 –collector plate.

When collector 8 is grounded, plasma column with the primary beam follows this rounding, since the polarization of the column under the influence of centrifugal drift is suppressed by a good electrical contact between the plasma column and the collector by a thermal electron component.

When collector potential is biased negatively with an external source, contact for electronic components is broken and flute instability is developed [3], resulting in the flattening of the plasma column. This leads to separation of the primary and secondary-emissive reverse flow - reverse electron flow is experiencing a drift in crossed magnetic and induced electric fields. It moves along the radius of curvature of the magnetic tube and falls on the solid area of the diaphragm that allows to register accompanying X-ray radiation.

As a result of the spatial separation, the X-rays of the secondary electron emission stream is detected by our sensor.

The accelerating voltage of the gun was 1.5 kV, gun emission current 0.1A, the pressure was the same as in the previous experiment - 10^{-4} Torr, the bias voltage of the collector plate - 600V, the amplitude of auto-oscillations obtained - 600V, frequency - 3 MHz. The energy of secondary-emissive electrons should not exceed 1200 eV, but the computing of the absorption curve indicates the presence of the abnormal, much harder X-ray component. Figure 2 summarizes the areas with the spectra obtained in the PPD and ASED modes.

Their comparison shows that in PPD mode a share of high energy accelerated electrons is very small, as indicated by a sharp decline of relative intensity of X-radiation when primary electron energy is exceeded (5 keV). In ASED mode X-ray radiation spectrum differs in principle - its spectrum reveals much larger relative number of multiply accelerated electrons.

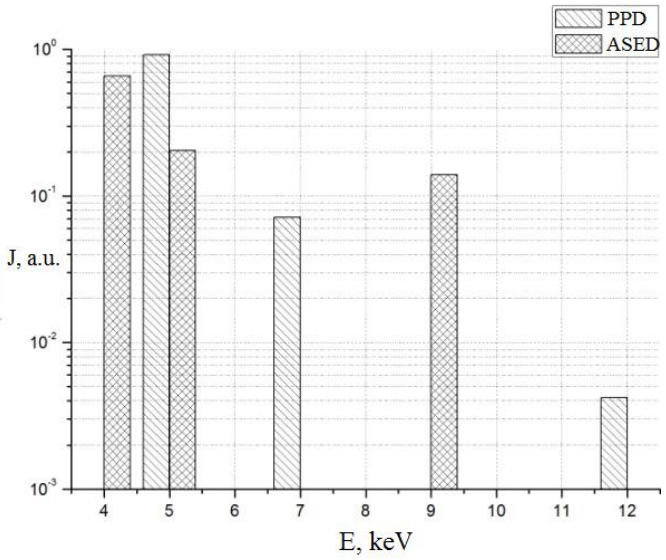

Figure 2. Spectra obtained in PPD and ASED modes.

Note that in the beam-plasma interaction a small proportion of primary electrons can be accelerated and confined between the plugs, gaining quite a lot of energy. In ASED mode experiments these electrons are captured either in a collector located in a deep cavity or in an opposite to the sensor side of the diaphragm, and generated radiation is not registered. Thus, in ASED mode with spatial separation of direct and reverse flows additional acceleration should occur only once in a single passage between the emitter and the target.

This may be due to a grouping effect. The experimental and calculated collector voltage waveforms show that ASED mode can be characterized by the growth of the time derivative on the front edge of the negative voltage pulse. As a result of the spatial and temporal compression of the electron cluster in ASED mode the beam-plasma interaction can be more efficient compared to the conventional PPD mode, and thus empower accelerated electron groups.

In addition, the anomalous acceleration of the secondary electrons can be associated with a very high-frequency modes of auto-oscillations. As a result, the actual acceleration voltage can grow much higher than the measured potential of the receiving plate relatively to the installation body.

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