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RUNAWAY ELECTRONS IN AN AIR GAP IN THE PRESENCE OF A MAGNETIC FIELD*

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The study of runaway electrons (RAEs) in over-voltage gas gaps is relevant because of their role in fast breakdown development and applications for impact on objects, media excitation, generation of electromagnetic radiation, etc. The main disadvantage of this source of fast electrons is the divergence of the RAE flow due to the electric field distribution in the gap and particle scattering by gas molecules. For practical use, RAEs need to be focused in the paraxial region in order to increase the current density.

It has been recently shown [1] that the RAE flow divergence can be reduced by using an axial magnetic field in the gas diode with a tubular cathode. Moreover, the generated tubular RAE flow can be essentially compressed [2] by a nonuniform magnetic field increasing along the electron trajectories. However, two problems arise, which lead to extension of the RAE current pulse and, as a consequence, to a decrease in current density. The first problem is related to braking of particles and their partial reflection by the magnetic mirror. The second problem is that tubular RAE flow consists of adjoining jets whose emission from different regions of the cathode edge is not synchronous (this is a result of the time spread in the onset of field-emission from the cathode micro-protrusions). Therefore, to shorten the RAE bunch, it is expedient to switch to a pointed cathode placed into a strong uniform axial magnetic field. It can be expected that RAEs will start almost synchronously from the tip and then propagate along the lines of the guiding magnetic field.

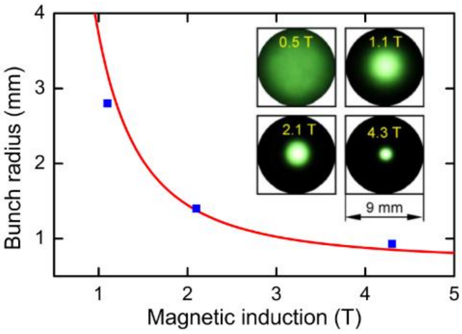

Fig.1. Dependence of the RAE bunch radius on the magnetic field (experimental data – blue squares; theory – red solid line). Insert: the corresponding glow of a luminescent screen.

In the present work, we have succeeded in applying this approach for spatiotemporal compression of the RAE flow. This made it possible for the first time to form RAE bunches of comparable radial and axial sizes of several mm. The maximal RAE current density (0.3–0.65 kA/cm^2) is effectively controlled by the magnetic field (1.1–4.3 T). The radial distribution of the RAE current density in the beam is experimentally determined, and the dependence of the RAE bunch radius on the magnitude of the applied magnetic field is found (Fig. 1). Our theoretical analysis shows that this dependence is due to two factors: the diffusion of RAEs across the magnetic field lines and a change of the character of RAE motion with a change in the Hall parameter β (the ratio of the electron gyrofrequency and the electron-molecule collision frequency). If β is relatively small, RAEs move predominantly along the electric field lines and their flow expands under conditions of an inhomogeneous electric field near the cathode tip. For large enough β, RAEs become magnetized and therefore propagate along the magnetic field lines. The results of the analysis are confirmed by numerical simulation of the RAE propagation by the Monte Carlo method.

REFERENCES

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