Electrostatic instabilities as a source of picosecond termination of run-away electrons beam in high-voltage gas-filled ultra-fast diode

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The fast termination of the run-away electrons beam in picosecond gas-filled diode is considered. The voltage pulse amplitude is about several hundreds of kilovolts, its duration – several hundreds of picoseconds [1,2]. Whereas the duration of accelerated in run-away regime electrons beam is about tens of picosecond 10ps<t_b<100ps, the beam current ~0.1-10A. Gas pressure is atmospheric. Cathode-anode distance is about 1cm, therefore the dense plasma from the cathode can't reach the anode plate within the ~100ps, and short-circuiting does not occur. As it can be easily estimated from voltage pulse parameters, the minimal electric field strength in the gap is about 10^5V/cm, what is only few times lower than critical field for run-away in the gas [3] (for used nitrogen ~450kV/cm, for hydrogen ~180kV/cm). Therefore the fast termination of the run-away electrons acceleration in these extremely high-voltage conditions is of interest. As a possible mechanism of such termination the collisionless collective plasma processes based on the Langmuir-oscillations are offered. It is shown that in the observed range 10-100ps lies the build-up time of the following processes.

1) The virtual-cathode oscillation (at the plasma density $n \sim 3\cdot10^{10}$-$3\cdot10^{12}$cm^{-3}) [4].
2) The Buneman-instability (at the plasma density $n \sim 3\cdot10^{13}$-$3\cdot10^{15}$cm^{-3}) [5].
3) The beam-instability (at the plasma density $n > 10^{16}$cm^{-3}) [6].

Therefore the collective plasma processes indeed can be the required mechanism of picosecond fast-electrons beam termination. It is clear that the developing of all the discussed collective mechanisms depends on the density. The faster plasma and beam densities increase, the faster an instability build-up will occur. Therefore, the lower/bigger neutral gas pressure, the longer/shorter the beam duration. Similarly, the use of more easily ionizing gas (e.g. Cs vapor 3.89eV) will lead to the fast-electrons beam shortening, and vise versa. Both these suggestions can be examined experimentally. It should be noted that the emission processes at the cathode will define not only the moment of the fast-electrons beam occurrence ([1,2]), but also the rate of the density ionization-growth, i.e. the time of instability build-up and the beam duration.

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