# Ionization Waves in a Fast, Hollow-Cathode-Assisted Capillary Discharge*

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The initial, low-current stage of the evolution of a soft x-ray emitting, hollow-cathode-assisted capillary discharge initiated by a steep high-voltage pulse is investigated. The capillary is surrounded by a shield having the cathode potential. The mean electric field E of the order of 10 kV/cm and the low gas pressure (P<1Torr) provide conditions for extensive electron runaway. This is taken into account in the formulation of the theoretical approach by retaining the inertial terms in the momentum equation for the electrons. In addition, the ionization rate is calculated by considering the cross section for ionization by high-energy electrons. The two-dimensional system of the basic equations is reduced to a system of one-dimensional equations for the axial distributions of the physical quantities by introducing appropriate radial profiles of the electric potential, and the electron gas parameters and satisfying the electrodynamic boundary conditions at the capillary wall and at the shield. The resulting system of equations admits solutions in the form of stationary ionization waves transferring the anode potential to the cathode end. Numerical calculations of such solutions for argon show that the wave velocity V increases with the gas pressure P and with the density of initial electron beam ejected from the cathode hole ahead of the ionization front, while the dependence of V on the applied voltage is weak. At the instant when the virtual anode reaches the cathode hole, the plasma in the capillary is not yet fully ionized. The traverse time of the ionization wave along the capillary calculated for various gas pressures is in reasonable agreement with experimentally registered time delay for a high-current stage resulting in voltage collapse and soft x-ray emission.

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