Crossed-field flows

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This paper surveys crossed-field flows in conventional, inverted, and planar magnetron geometries, with and without a slow wave structure (SWS) on the anode.

An electron rotating under a general combination of radial electric field and axial magnetic field may exhibit negative, positive, or infinite mass behavior, depending on the orientation and magnitude of the electric field relative to the axial magnetic field [1]. These properties are confirmed in particle-in-cell simulations [2] on a thin electron layer whose collective interactions are shown to dominate the diocotron instability [1, 2].

The Brillouin flow exhibits a strong velocity shear, and therefore the diocotron-like instability is considered to be a dominant instability [3] in the Brillouin flow. For a smooth bore magnetron, the negative (positive) mass effect in the inverted (conventional) magnetron geometry was shown to increase (decrease) the severity of the diocotron instability [4] in the Brillouin flow. Including the SWS on the anode, the resonant interaction of the vacuum circuit mode and the corresponding smooth-bore diocotron-like mode is the dominant cause for instability [5]. This resonant interaction is far more important than the intrinsic negative (positive) mass property of electrons in the inverted (conventional) magnetron geometry. This resonant interaction severely restricts the wavenumber for instability to the narrow range in which the cold tube frequency of the SWS is within a few percent of the corresponding smooth bore diocotron-like mode in the Brillouin flow.

Since the Brillouin flow, instead of the multi-stream cycloidal flow, is the preferred state in crossed-field devices [6, 7], the Bumeman-Hartree (B-H) condition was critically examined using the Brillouin flow model [8]. It is found that the traditional, cycloidal orbit model [9] and the Brillouin flow model [8] yield the same result for the Buneman-Hartree condition only in the limit of a planar magnetron. The B-H condition derived from the Brillouin flow model shows a better match to simulation and experiment of relativistic magnetrons than the single particle model B-H condition [10].

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