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Description of electron swarms in an electric field: a finite elements computation including third-order transport parameters

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Abstract In this communication we analyze the movement of an electron swarm drifting in an electric field, $\overline{E}$, under hydrodynamic conditions. We extend the analysis based on the effective ionization rate, ν_{eff}, velocity, $\overline{W}$, and diffusion tensor, $\overline{\overline{D}}$, to include a third-order transport parameter, **Q**, related to the skewness of the swarm distribution. Using the density-gradients expansion of the velocity distribution function, $f(\vec{r},\vec{v},t)$, with $j_{max} = 3$,

$$f(\vec{r},\vec{v},t)=\sum_{j=0}^{j_{Max}=3} F^{(j)}(\vec{v}) \overset{j}{\odot} (-\nabla)^j n(\vec{r},t)$$

where the expansion coefficients $F^{(j)}$ are j-rank tensors and $\odot^j$ a j-fold scalar product, on Boltzmann equation, we obtain a series of equations for the components of the expansion coefficients $F^{(0)}$-$F^{(3)}$. These equations are solved using a finite element method on a (v,μ) grid (where μ=cos(θ) and θ is the angle between $\overline{E}$ and $\overline{v}$). The algorithm used is an extension of [Segur 1983, 1984] to include third-order transport parameter, a more complete collision term and several optimizations to speed up the computation. Although for non-conservative conditions the method is iterative and depending on the reduced field value, the characteristic time for the computation of the set of expansion coefficients is on the order of seconds.

We discuss how the expansion coefficients $F^{(j)}$, with $j > 0$, integrated on μ, provide information on the velocity distribution within the swarm. E.g. $F^{(1)}$, represents the average position of electrons with velocity $\overline{v}$ and the position of all electrons, (weighted by $F^{(0)}$). The transport parameters obtained are compared with those obtained with Monte Carlo and a multi-term Boltzmann codes [Simonović 2022].

References

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