Particle-based simulation and experimental validation of the beam properties in electron beam physical vapor deposition

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In this paper, we compare numerical simulations of the electron beam propagation using the open-source plasma simulation software PICLas[1] with experimental measurements performed in an industry setting. PICLas was used to simulate the electron beam generation process and the subsequent transport of the electron beam through various stages of the generator, including the acceleration to relativistic speeds and the deflection by two magnetic fields. For this purpose, the Particle in Cell (PIC) method was coupled with the Monte Carlo Collision (MCC) method to consider the self-fields of the charged species as well as the ionization processes due to the presence of a neutral background gas. The self-focusing effect could be observed in the simulations, when comparing results with and without background ionization. Due to the different time scales of electron and ion movement, a species-specific time step was utilized in the simulations to accurately capture the dynamics of the electron beam and reduce the simulation duration towards the chemical equilibrium. The simulated electron beam widths were compared to experimental measurements of the electron beam width at various points along the accelerator. The measurements were performed using a metal mesh, which was placed inside the beam generator and burned through by the electron beam. The resulting hole diameter has been utilized as the beam diameter. Our results show good agreement between the simulated and measured electron beam widths. PICLas was able to accurately predict the electron beam width at different stages of the accelerator, including the cathode, the intermediate focus, and the final focus. Overall, our study demonstrates the capabilities of PICLas in predicting the electron beam properties in electron beam accelerators and highlights the potential of numerical simulations as a tool for optimizing the design and performance of these systems.

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1 Fasoulas, S., Munz, C.-D., Pfeiffer, M., Beyer, J., Binder, T., Copplestone, S., Mirza, A., Nizenkov, P., Ortwein, P., Reschke, W. (2019). Combining particle-in-cell and direct simulation Monte Carlo for the simulation of reactive plasma flows. *Physics of Fluids*, **31**(7), 072006. Open-source code is available online: https://github.com/piclas-framework/piclas