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Low-Temperature Plasmas Generated by Intense Electron Beams[1]

A. S. RICHARDSON, United States Naval Research Laboratory

A renewed effort is underway at the Naval Research Laboratory (NRL) to characterize and understand plasmas formed by injecting intense, pulsed electron beams into low-pressure (0.1–10 Torr) gases. The low-temperature plasmas formed in this way are primarily generated by direct beam-impact ionization and by the electric field induced by the rapidly changing beam current. This research effort is a combination of laboratory experiments and numerical modeling. In the experiment, an intense (∼4 kA, ∼100 keV), pulsed (∼40 ns) electron beam is injected into a low-pressure gas cell. Electrical, optical, and spectral diagnostics are used to measure the properties of the resulting plasma. By varying parameters such as gas pressure, beam current density, and gas constituents, the plasmas can be tuned from weakly to strongly ionized, from fluid-like to highly kinetic, and we can explore the impact of varying plasma chemistry. The goal of these experiments is to map out this parameter space, and gather data to use for validating numerical and plasma chemistry models. A complementary modeling and simulation effort is also underway, with the goal of testing various plasma models by comparing them to experimental results and benchmarking them against each other. New tools are in development to allow for the rapid prototyping and comparison of plasma models. The main tool for this comparison work is a new, lightweight computational physics framework for Python called turboPy [https://arxiv.org/abs/2002.08842, https://github.com/arichar6/turbopy]. TurboPy modules were created for several weakly ionized fluid models, as well as a temporally and spatially dependent two-term Boltzmann solver. By comparing turboPy results to experiment, regions of validity in pressurecurrent-density parameter space were mapped out for each model.

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