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Kinetic Modeling of Non-Equilibrium Plasmas for Modern Applications[1]

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We have studied several non-equilibrium plasma devices where kinetic effects determine plasma self-organization: neutralization of ion beams and electron cloud effects in accelerators, negative hydrogen Ion Sources, ExB discharges (plasma switch and Penning discharge), thermoelectric converters. Neutralization of positive ion beam space-charge by electrons is important for many accelerator applications, i.e., heavy ion inertial fusion, and ion beam-based surface engineering. Past experimental studies showed poorer ion beam neutralization by electron emitting filaments, compared with neutralization by plasmas. Now researchers have found that reduced neutralization may be related to the generation of electrostatic solitary waves (ESWs) during the neutralization process, as the ion beam passes through the electron-emitting filaments. [1]. We have also developed a Global Model Code for Negative Hydrogen Ion Sources, GMNIS [2]. The codes ultimate goal is to aid developing optimized negative ion beams for ITER. The code solves volume-averaged equations: continuity for plasma species and electron energy equation for the electron temperature, and include more than 1000 volumetric and surface reactions for interactions of electrons, ground-state atomic and molecular hydrogen, molecular ions and atomic ions, negative ions, 14 vibrationally-excited states of molecular hydrogen, and excited atoms. Results of the code are benchmarked against another code [2]. Convenient analytical solution for vibrational spectrum of H2 was also derived. We performed particle-in-cell simulations and developed analytical model that can explain experimentally observed Pashen curve [3]. We have also preformed studies of rotating spoke in a Penning discharge and proposed analytical scaling law for its frequency [4]. Efficient thermal electric converter is proposed in Ref.[5]. [1] C. Lan and I. D. Kaganovich, Phys. Plasmas 26, 050704 (2019). [2] W. Yang, et al.", Phys. Plasmas 25, 113509 (2018). [3] Liang Xu, et al, Plasma Sources Sci. Technol. 27, 104004 (2018). [4] Andrew T. Powis, et al., Phys. Plasmas 25, 072110 (2018). [5] A. S. Mustafaev, et al, Journal of Applied Physics 124, 123304 (2018).

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