Guest Editorial Special Issue of Invited Papers of 2005 Workshop on Nonlocal, Collisionless Electron Transport in Plasmas

THIS Special Issue consists primarily of invited papers presented at the 2005 Workshop on Nonlocal, Collisionless Electron Transport in Plasmas held at Princeton Plasma Physics Laboratory (PPPL), Princeton, NJ. The presentations from this workshop are available online.[1]

The purpose of the workshop was to facilitate discussion on nonlocal, collisionless phenomena in low-pressure plasmas between scientific communities working on high-temperature, fusion plasmas and low-temperature, gas discharge plasmas. Such low-pressure plasmas have remarkable property: changing condition at one place may lead to unexpected changes far away in another part of the plasma. In the last decade, there have been major developments in studies of collisionless dynamics in plasmas, particularly in glow discharges, plasma sources for material processing, and plasma thrusters. These developments have been reported in separate papers published in many different journals. The workshop and this Special Issue aimed at updating and coordinating the research advances in this field. Another important goal of the workshop was to form a bridge between high- and low-temperature plasma communities. Both communities have developed many useful tools, little known outside their own communities. Therefore, it is important to summarize the current state-of-the-art for both communities in one volume.

Low-pressure discharges (mainly capacitively coupled plasmas and inductively coupled plasmas) are widely used in industry as the main plasma sources for many plasma applications [1], [2]. Notwithstanding the significant improvements of these plasma sources for technology applications during the last decade, the majority of commercial plasma devices have far-from-optimal performance due to the lack of a detailed understanding of the underlining physics and plasma chemistry. The creation of low-temperature plasmas with controllable parameters, in particular, the plasma density, the electron temperature, and the electron and ion energy spectra, is one of the major tasks of modern plasma engineering. The need for optimization of plasma parameters and comprehensive modeling of the radio frequency plasma and sheaths calls for basic research in this area. Another growing application of collisionless and weakly collisional plasmas is the plasma thrusters (sometimes called electric thrusters). Understanding of the key plasma science underlying the operation of these devices is essential for the development of advanced thruster technology. Basic plasma phenomena in such devices include, but are not limited to, plasma–wall interaction, plasma expansion in the magnetic field, anomalous cross-field transport, waves, and instabilities.

The distinctive property of partially ionized plasmas in gas discharges is that such plasmas are always in a nonequilibrium state: the electrons are not in thermal equilibrium with the neutral species and ions, because the electron temperature is typically much larger than the temperature of the ions and of the neutrals. In addition, the electrons are also not in thermodynamic equilibrium within their own ensemble, which results in a significant departure of the electron energy distribution function from a Maxwellian. These nonequilibrium conditions provide considerable freedom to choose optimal plasma parameters for applications and make gas discharge plasmas a remarkable tool for a variety of plasma applications, including plasma processing, discharge lighting, plasma propulsion, sources for particle beams, and nanotechnology [3].

Physical phenomena in low-pressure gas discharges are substantially different from those in high-pressure gas discharges. In high-pressure discharges, due to the high rate of collisions and slow particle diffusion, the plasma parameters are determined by the local value of the electric field. In low-pressure gas discharge plasmas, the electron mean-free path can be comparable to or larger than the plasma density profile and the electromagnetic field inhomogeneity scales. Therefore, in its thermal motion, an electron can move between collisions sampling different values of electric field along its trajectory. As a result, the electron current at some point in the plasma is determined not by the local electric field, but by the entire profile of the electric field. Nonlocal electron kinetics, nonlocal electrodynamics with collisionless electron heating, and nonlinear processes in the sheaths and in the bounded plasmas are typical for such discharges. The synergism of nonlocal electron kinetics with collisionless, nonlocal electrodynamics may result in a wide multiplicity of nonequilibrium plasma states. The electrons tend to stratify into different groups depending on their origin and the confinement or heating mechanisms. The electron energy distribution functions are even more complex in molecular gases.

A very productive workshop Electron Kinetics and Applications of Glow Discharges was held in 1997 in St. Petersburg, Russia [4]. That workshop discussed the plasma self-organization in gas discharges and resulted in a broad dissemination of existing developments in theory, diagnostics and modeling

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[1]http://w3.pppl.gov/~ikaganov/PPPL2005/

of nonequilibrium electron kinetics in glow discharges. The workshop at PPPL during summer 2005 updated and summarized progress since 1997 and discussed future directions in the field.

Progress in understanding the interaction of electromagnetic fields with a real, bounded plasma created by this field and the resulting changes in the structure of the applied electromagnetic field, has been one of the major achievements of the last decade. The improved understanding of the nonlocal electron kinetics and electrodynamics in gas discharge plasma is recognized by the scientific community as one of significant achievements in plasma physics. The 2004 Maxwell Prize in Plasma Physics by the American Physics Society has been awarded to Hershkowitz and Godyak for fundamental contribution to gas discharge physics.

Workshop speakers were asked to deliver review papers suitable for students and nonexperts. A Special Issue, a collection of these review papers, was designed to serve as an advanced textbook on electron kinetics in plasmas.

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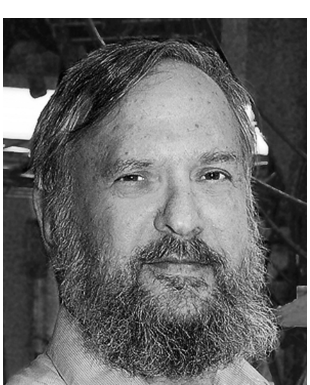

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