White Paper for *Frontiers of Plasma Science Panel*

Date of Submission:	***July 23, 2015***

Indicate the primary area this white paper addresses by placing "P" in right column.
Indicate secondary area or areas by placing "S" in right column

	"P", "S"
• Plasma Atomic physics and the interface with chemistry and biology	P
• Turbulence and transport	
• Interactions of plasmas and waves	
• Plasma self-organization	
• Statistical mechanics of plasmas	S

Indicate type of presentation desired at Town Hall Meeting.

	"X"
Oral	
Poster	
Either Oral or Poster	
Will not attend	X

Title:	Influence of hot electrons on radiative properties of fusion plasmas
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**(Limit text to 3-pages including this form. Font Times Roman size 11.
1 page of references and 1 page of figures may also be included. *Submit in PDF format.*)**

- ***Describe the research frontier* and importance of the scientific challenge.**

Though it is a common knowledge that hot electrons are frequently observed in high temperature plasmas of very different densities, from astrophysical to tokamak plasmas to high-energy-density plasmas, a little is known about the influence of such electrons on radiative properties of plasmas when both thermal Maxwellian and hot non-Maxwellian electrons are present in plasmas. This research frontier focuses on the gaining the following understanding about the hot electrons and their generation in fusion plasmas: how much of such electrons (if any) are generated in tokamak (and other fusion) plasmas and at what conditions; what are their concentration (with respect to the Maxwellian electrons) and what minimum concentration can be detected; what is their distribution function and how does it change in space and time; and are they anisotropic and manifest like beams?

- ***Describe the approach to advancing the frontier and indicate if new research tools or capabilities are required.***

i) We need to theoretically study how hot electrons influence spectra in plasmas for a broad number of ions, spectral range and types of radiation (K-, L-, and M-shell) and whether there are specific spectral features (in addition to "cold" characteristic lines) that manifest their presence and that may be similar for various fusion plasmas. For example, for ITER plasmas, it should span from the very low-Z elements like He [1] to mid-Z elements like Fe [2, 3] to high-Z elements like W. First we need to study how atomic physics input data for kinetic modeling will change at the presence of hot electrons, i.e., for example, how are collisional and radiative rates sensitive to hot electrons? It was shown that most of collisional rates are non-sensitive to the functional form and the characteristic energy of the electron distribution function if the characteristic energy is larger than the threshold energy for the collisional process. However, collisional excitation and ionization rates are highly sensitive to the fraction of hot electrons (with the respect to the total number of electrons) [4]. This permits the development of the new advanced spectroscopic diagnostics that can be used to characterize the electron density, bulk electron temperature, and hot electron fraction of plasmas with non-equilibrium electron distribution functions [4].

ii) Based on the results of (i), the time-resolved and/or spatially-resolved spectroscopic measurements should be made along with other diagnostics that will be detecting such hot electrons to push forward developing of this new diagnostics of hot electrons in fusion plasmas.

iii) How can we establish whether the hot electrons are anisotropic and are organized in beams? Plasma Polarization Spectroscopy (PPS) [5] deals with the polarization of radiation emitted from plasma and is under developed diagnostic tool that may be extremely valuable for spectroscopic diagnostics of hot electrons. The polarization phenomena can be divided into three classes: class 1 polarization is due to the effect of electric and/or magnetic fields; i.e. the Stark effect and the Zeeman effect; class 2 when polarization is due to spatial (directional) anisotropy of a plasma, i.e. if the electron velocity distribution is shifted Maxwellian or it is beamlike, excitation is anisotropic and an atomic (ionic) ensemble excited by these electrons is polarized and as result the spectral line emitted by these atoms (ions) is polarized; and class 3 which the combination of class 2 and class 1, i.e. anisotropic excitation in the presence of fields [5]. We suggest implementing PPS for the study of beams of hot electrons in fusion plasmas. Though there is some progress in development of PPS for diagnostics of various plasmas [5-9], there are no systematic studies in USA focused on this important topic.

- ***Describe the impact of this research on plasma science and related disciplines and any potential for societal benefit.***

The plasma characteristics and electron distributions that are deduced from experiments and from models are seldom in a good agreement, in particular when hot electrons are present in plasmas. Solving the remaining discrepancies involves different fields of atomic and plasma physics and is more and more demanding. For example, a substantial discrepancy in the estimates of electron temperature and ionization balance may come not only from atomic data of insufficient precision but by a non-Maxwellian character of electron distribution. The successful development of the new spectroscopic tools of studying the characteristics of non-Maxwellian electrons in fusion plasmas will substantially decrease the number of unknown plasma parameters, help validate atomic data and non-LTE kinetic codes, and will bring the researchers closer to achieving fusion.

References (Maximum 1 page)

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