White Paper for *Frontiers of Plasma Science Panel*

Date of Submission:	***July 22, 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:	Discovery atomic physics and plasma science using an intermediate z-pinch facility to be built for US Universities
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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.**

This research frontier aims to address, at least in part, the well-recognized needs for the high-energy-density-laboratory-science community to advance Z-pinch physics, to develop excellent educated students in the field, and to enhance experimental and theoretical capabilities in High-Z, Multiply Ionized HED Atomic Physics and in Collision- or Radiation-Dominated HED plasmas.

It will fulfill a long-lasting need for the intermediate-scale Z-pinch facility for university users that does not currently exist in USA, will allow to ionize the atoms of much heavier elements up to L shells and even K shells (compared to what can be done at the existing 1-2 MA z-pinch facilities [1-6]), and by creating such higher ionization stages will result in much better knowledge and understanding of atomic processes and generation of particle beams that can be created in such pulsed power driven plasmas through systematic experimental and theoretical time-resolved spectroscopic and imaging studies and possible applications to astrophysics.

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

Specific areas of focus should include, but not necessarily be limited to:

i) X-ray and extreme UV spectral line intensity as well as radiation yield temporal and spatial resolved measurements at well characterized plasma conditions and benchmarking of and future advancing in non-LTE kinetic codes using these new experimental measurements;
ii) measurements of absorption and emission spectra from X-ray-driven, photoionized plasmas with well characterized radiation fluxes and benchmarking of and future advancing in atomic data for photoionized plasma and non-LTE kinetic codes using these new experimental measurements;
iii) temporal and spatial resolved measurements of the cold Kα lines from HED plasmas of a broad range of atomic number ions to push forward the studies of electron beams and diagnostics and benchmarking of and advancing in the codes describing cold Kα emission [4];
iv) detailed Stark-broadened line shape and line shift measurements in emission and absorption and benchmarking of the existing theoretical codes;
v) creation of opacity-free Z-pinch plasmas by using the new load configuration and measurements of optically thin X-ray spectra [6] and benchmarking of and advancing in the non-LTE kinetic codes using these new data;
vi) measurements of photon-energy-dependent opacities of mid- and high-Z elements with open shells using the optimized wire loads to produce a desired and well-controlled level of opacities and benchmarking the existing opacity codes with these new data;
vii) gaining an understanding of the scaling laws of K-shell and L-shell radiation for a broad range of atomic number ions [7-9] to create a bridge between 1-2MA University and 20-26 MA SNL-Z data;
viii) creation of extreme field environments to develop new diagnostic signatures.

Any of these focus areas might deliver surprises because theory, if available, is largely untested. Consequently, all of these areas can provide exciting discoveries and challenges for the next generation of graduate students and for the advancement of HED science. By suggesting and implementing such studies we believe to be able to access presently unexplored regions of HED plasma parameter space.

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

To overcome the paucity of experimental data on any size device on implosion and radiation properties for constraining the models used to predict natural and artificial behavior of material subjected to extreme conditions and to scale this behavior for applications, a 5-6 MA z-pinch generator (preferably linear-transformer-driver (LTD) generator) should be provided for collaborative research and sited at a university having a reputation for expertise and training in z-pinch physics. Having such a facility will provide a capability that presently exists only at 1-2 MA current (see, for example, [10-12]) which is insufficient for deriving the full scientific benefit, whereas the proposed facility's capability could be increased incrementally at incremental cost and, most importantly, the proposed facility could exploit modern technology for compact (university scale) installation. Increasing and optimizing the radiation yield and power and new unique spectral signatures of mid- and high-Z multiply-charged ions influenced by opacity effects and electron beams can be investigated with maximum diagnostic access and at moderate current for the purpose of maintaining U.S. leadership in radiation-dominated physics, wire array and gas puff physics, and high-Z, multiply ionized HED atomic physics.

The study of the atomic physics and spectroscopy of multiply-charged ions is also important for magnetic confinement fusion plasmas and astrophysics.

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