White Paper for *Frontiers of Plasma Science Panel*

Date of Submission:	**June 13, 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	

Indicate type of presentation desired at Town Hall Meeting.

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

Title:	Monochromatic X-Ray Activated HED Nanoplasmas for Biomedical Applications
Corresponding Author:	Anil Pradhan
• Institution:	Ohio State University
• email:	Pradhan.1@osu.edu
Co-Authors:	Sultana Nahar, Sara Lim

(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.**

While X-rays are widely employed in medical diagnostics and therapy, their usage is highly inefficient. Generally, medical devices produce broadband radiation that lacks specificity: low energy part of the output x-ray spectrum does not penetrate the body sufficiently, whereas the high-energy part interacts little with biological tissue made of light elements such as H, C and O. Conventional radiation therapy relies on high-energy Linear Accelerators (LINAC) that require unnecessarily large dosage for treatment since they predominantly produce X-rays with E ~ 1-2 MeV [1-3]. X-ray imaging including CT scans is usually done with X-rays at E < 100 keV.

However, X-rays interact strongly with high-Z elements. One solution to improve efficiency lies in using high-Z nanomoities, such as gold nanoparticles or platinum chemotherapeutic drugs such as carboplatin, that would preferentially absorb low-energy X-rays with E ~ 100 keV [1-3].

In addition, it has been recently demonstrated both theoretically and experimentally that monochromatic or quasi-monochromatic X-ray sources may be "tuned" to activate resonance phenomena and accelerate radiative Auger decays via below-threshold resonances [1-3].

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

This would be a novel research field in atomic-plasma physics requiring the development of monochromatic or quasi-monochromatic X-ray sources such as high-intensity laser produced HED plasma devices on the one hand, and precise theoretical calculations and modeling to compute and match the resonance X-ray energies with the high-Z targets and moieties on the other hand. Sophisticated computational tools such as the R-Matrix methodology that incorporates resonances in an ab intito manner, and Monte Carlo simulation packages such as Geant4 that enable consideration of a variety of biological environments, can be further developed to explore potential medical applications [3, 5, 6].

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

HED plasma science would be extended to nanoscales and phenomena. For example, high-Z nanomoities in cancerous tumors can be activated by monochromatic X-rays with minimum radiation dose for imaging and radiotherapy [2, 4].

References (Maximum 1 page)

[1] Pradhan A. K., Nahar S. N., Montenegro M., et al. ``**Resonant x-ray enhancemnt of the Auger effect in high-Z atoms, molecules and nanoparticles: Biomedical applications**.'' J. Phys. Chem. A 2009 113 12356

[2] Lim S, "**Low-Energy X-ray Radiosensitization Activated with High-Z Elements**", PhD Thesis, Biophysics Graduate Program, The Ohio State University (2014).

[3] Nahar S. N., Pradhan A. K. and Lim S. ``**Kα Transition probabilities for platinum and uranium ions for possible X-ray biomedical applications.**"

[4] Nahar S, Pradhan A, "**Kα resonance fluorescence in Al, Ti, Cu and potential applications for X-ray sources", Jour. Quant. Spec. & Rad. Transf., 155, 32 (2015).**

[4] Lim S N, Pradhan A K, Barth R F, et al. ``**Tumoricidal activity of low-energy 160-KV versus 6-MV X-rays against platinum-sensitized F98 glioma cells**." J Radiat Res. 2014 .

[5] Lim S. N. and Pradhan A. K. ``**Spectral dependence of X-ray propagation in biological environments sensitized with High-Z elements.**" (submitted)

[6] Lim S. N, Nahar S. N. , Pradhan A. K. et al. ``**Broadband-To-Monochromatic X-ray conversion of Zr Kα/Kβ Lines and Plasma Diagnostic**s" (submitted)

Figures (maximum 1 page)

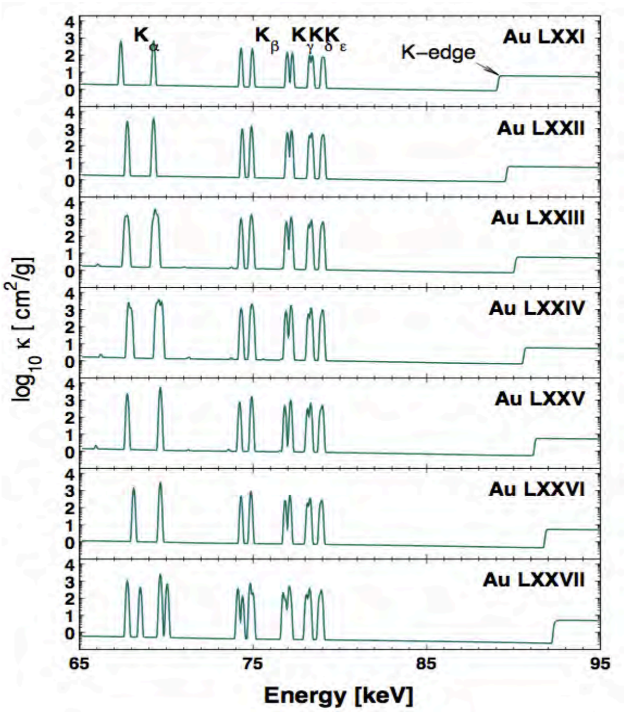

Fig. 1: **Kα Resonances below K-edge in gold**

Pradhan et al., J. Phys. Chem. A, 113, 12356 (2009)

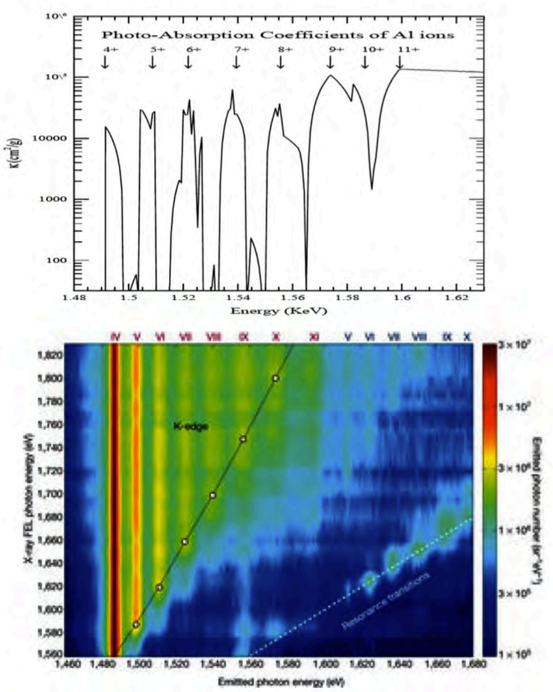

Fig. 2. **Kα resonances in aluminum: theoretical calculations (upper panel, Nahar and Pradhan 2015) LCLS-XFEL measurements of below-threshold Kα resonance fluorescence** in “warm dense matter” (lower panel, Vinko et al., Nature, 2012)