NANO-SPECTROSCOPY and BIOMEDICINE Multidisciplinary Program for Cancer Treatment (2004 - present): "Resonant Nano-Plasma Theranostics"

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i) RESEARCH:

My research interests are in the areas of atomic astrophysics, spectroscopy, and nanoscience for biomedical applications. I study dominant radiative atomic processes, such as radiative transitions and lifetimes, photoionization, electron-ion recombination excitation in astronomical objects. The research also includes dielectronic satellite lines, opacities, theoretical spectroscopy of relativistic Breit-Pauli R-matrix (BPRM) energies, and collisional excitations. I carry out both the theoretical quantum mechanical and computational developments of the projects. One main objective is to obtain high precision atomic data for modeling and diagnostics of astrophysical and laboratory plasmas, and biomedical applications.

Since 2004, my research has extended to multidisciplinary initiatives in nanospectroscopy for biomedical applications, particularly for cancer treatment. The program aims to implement a narrow band spectroscopy over the existing broadband imaging for cancer diagnostics and therapy (theranostics). The method is based on the same physics that we use to study astronomical objects, such as, stars, blackholes, galaxies etc. It involves researchers from physics, chemistry, astronomy, radiation oncology and pathology at OSU and Thomas Jefferson University, as well as other partners specializing in nanobiotechnology. Our method *Resonant Nano-Plasma Theranostics* (RNPT) which has been under development since 2004 is based on the precise irradiation of cancerous tumor doped with heavy element nanoparticles (radiosensitizing agents) using a monochromatic X-ray source. Irradiation by a beam of monochromatic x-rays tuned at the resonant energies of the radiosensitizing agent could lead to enhance Auger electrons for malignant DNA destruction. Development and implementation of RNPT require theoretical, computational, and experimental work. The theory has been developed, similations has been carried to support the theory. Current study is with cell liners and rats for in vitro and in vivo experiemtns. Efforts are also being made for development of a prototype for a monochromatic x-ray source for biomedical imaging and therapy.

The work on RNPT has gained considerable visibility by news media (over 100 media news. The work was highlighted by Ohio Supercomputer Center a few times. After my presentation at the International Symposium on Molecular Spectroscopy in June 2011, a press release was published worldwide over 100 news media, such as, "Physics Inventions", "Cancer Dicovery", "Innovations of Nano Patent", "Discovery News", "MSNBC.com", "Science Daily", "TechColumbus", "Rockefeller News", "Chicago Chronicle", "The Columbus Dispatch", "Eurekalert", "R&D Magazine", "Fox News",

"PhysOrg", "Astro Biology", "Sky News", etc and 11 interviews. This work is now showing predicted results in the rat experiments. *Astronomy magazine* (May 2012) has listed RNPT as one of the four items of great impact (GPS, wireless Internet, RNPT and optical laser surgery) that astronomy has given to human daily life.

ii) PUBLICATIONS:

1. "Energy dependence of high-Z radiosensitization with platinum using broadband x-ray sources", S. Lim, A.K. Pradhan, M. Montenegro, S.N. Nahar, Y. Yu (submitted 2012)

2. "X-RAYS USING ULTRA INTENSE LASERS FOR EFFECTIVE THERANOSTICS", Sultana N. Nahar, proceedings of the 4th international workshop on Ultrafast Laser Technology and Applications (UFLTA), Cairo-Luxor, Egypt, April 8-12, 2012 (submitted, 2012)

3. "Astronomy and Cancer Research: X-Rays and Nanotechnology From Black Holes to Cancer Therapy", Anil K. Pradhan and Sultana N. Nahar, proceedings of 3rd international conference on Current Development in Atomic, Molecular, Optical and Nano Physics, University of Delhi, Delhi, India, December 14-16, 2011, "New Trends in Atomic & Molecular Physics - Advanced Technological Applications" (Ed. Man Mohan, Springer, in press, 2012)

4. "X-Rays of Heavy Elements for Nanotechnological Applications: W and Pb Ions" (refereed contribution), Sultana N. Nahar, Proceedings of the 4th international conference on *Modern Trends in Physics Research* (MTPR-10), Sharm El Sheikh, Egypt, December 12-16, 2010 (World Scientific, in press, 2012)

5. "Broadband and Monochromatic X-ray Irradiation of Platinum: Monte Carlo Simulations for Dose Enhancement Factors and Resonant Theranostics", S. Lim, M.Montenegro, A.K. Pradhan, S.N. Nahar, E. Chowdhury and Y. Yu, (refereed), World Congress on Medical Physics and Biomedical Engineering, IFMBE Proceedings 39, pp. 2248-2251 (Ed. M. Long, Springer, 2012)

6. "X-Ray Astronomy to Resonant Theranostics for Cancer Treatment", Sultana N. Nahar, Annual magazine "Physics Bulletin" celebrating centenary year of independence of Physics, Aligarh Muslim University (AMU) (Editor: Rashid Hasan, AMU press, 2012), p.1-9

7. "RESONANT THERANOSTICS: A New Nano-Biotechnological Method for Cancer Treatment Using X-ray Spectroscopy of Nanoparticles", S.N. Nahar, A.K. Pradhan, M. Montenegro, Chap 9 in *Simulations in Nanobiotechnology*, CRC Press - Taylor & Francis Group (Ed. Kilho Eom, 2011), p.305-330

8. "K_α Transition Probabilities for Platinum and Uranium Ions for possible X-ray Biomedical Applications", S.N. Nahar, A.K. Pradhan, S. Lim, Can. J. Phys. 89, 483-494 (2011)

9. "Multi-Disciplinary Role of Atomic Astrophysics: From Stellar Interiors to Cancer Research Via Nanotechnology", A.K. Pradhan, S.N. Nahar, M. Montenegro, E.A. Chowdhury, K. Li, C. Sur, and Y. Yu, invited review in proceedings of the *International Conference on Recent Advances in Spectroscopy: Theoretical, Astrophysical, and Laboratory Perspectives*, Jan 28 - 31, 2009, Kodailkanal Observatory, Indian Institute of Astrophysics (Eds. R.K. Chaudhuri, M.V. Mekkaden, A.V. Raveendran, A.S. Naayanan, Springer-Verlag 2010) p,123.

10. "Monte Carlo Simulations and Atomic Calculations for Auger Processes in Biomedical Nanotheranostics", M. Montenegro, S.N. Nahar, Anil K. Pradhan, Y. Yu, K. Huang, J. Phys. Chem. A 113, 12364-12369 (2009)

11. "Resonant X-Ray Enhancement of the Auger Effect in High-Z atoms, molecules, and Nanoparticles: Biomedical Applications", A.K. Pradhan, S.N. Nahar, M. Montenegro, Y. Yu, H.L. Hang, C. Sur, M. Mrozik, R. Pitzer, J. Phys. Chem. A 113, 12356-12363 (2009)

12. "Geant4 Estimation Model of High Z Atom Concentration for Tumor Vessel Ablation", Ke Huang1, Anil Pradhan2, Sultana Nahar3, Maximiliano Montenegro3, Kaiguo Yan1 and Yan Yu1, proceedings of *31st Annual International IEEE EMBS (Engineering in Medicine and Biology Management System) Conference*, Hilton Minneapolis, Minnesota, USA, September, 2-6, 2009, p.3060-3063

13. "Oscillator strengths and radiative transition rates for K_α lines in gold X-ray spectra: 1s-2p transitions", S.N. Nahar, A.K. Pradhan, C. Sur, J. Quant. Spec. Rad. Transfer 109, 1951 (2008)

14. "Computational Methodology For Resonant Nano-Plasma Theranostics For Cancer Treatment", Anil K Pradhan, Yan Yu, Sultana N Nahar, Eric Silver, Russell Pitzer, The Radiotherapy Dynamics, XVth Int. Conf. Use of Comput. in Radiat. Ther. Vol. 2, 89 - 93 (2007) (http://www.iccr2007.org/)

iii) PRESENTATIONS:

1. "Monochromatic and Broadband X-ray Irradiation of Heavy Element Radiosensitizers: Simulations and In-vitro Studies for Therapeutic Efficacy", S N Lim, M Montenegro, A Pradhan; S N Nahar; E H Bell; C Turro, R Barth, Y Yu, Conference of the The Radiological Society of North America (RSNA), November 25-30, McCormick Place, Chicago, 2012

2. X-RAY RESONANT IRRADIATION AND HIGH-Z RADIOSENSITIZATION IN CANCER THERAPY USING PLATINUM NANO-REAGENTS", S.N. NAHAR, S. LIM, M. MONTENEGRO, A. K. PRADHAN, R. BARTH, E. BELL, C. TURRO, R. PITZER, the 67th International Symposium of Molecular Spectroscopy, Ohio State University, June 18-22, 2012

3. "Enhancement of X-ray dose absorption for medical applications", S. Lim, M. Montenegro, S.N. Nahar, A.K. Pradhan, R. Barth, R. Nakkula, E. Bell, Y. Yu, 43rd Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics, Bull. APS. Volume 57, Number 5 (2012), June 48, 2012; Orange County, California

4. "AUGER ELECTRONS VIA K alpha X-RAY LINES OF PLATINUM COMPOUNDS FOR NANOTECHNOLOGICAL APPLICATIONS", Sultana N. Nahar, Sara Lim, Anil K. Pradhan, Russel M. Pitzer, 66th International Symposium of Molecular Spectroscopy, OSU, Columbus, Ohio, June 20-24 (2011)

5. 'Monochromatic X-Ray Irradiation of High-Z Atoms and Nanoparticles for Biomedical Applications,'¡/a¿, S. Lim, A. Pradhan, S. Nahar, E. Chowdhury, Y. Yu, K. Huang, K. Yan, 42nd

Annual Meeting of the APS Division of Atomic, Molecular, and Optical Physics June 13-17, 2011, Atlanta, Georgia

6. "K_α transition probabilities for Platinum and Uranium Ions", Sultana N. Nahar, Program and Abstracts of the 10th *International Colloquium on Atomic Spectra and Oscillator Strengths for Astrophysical and Laboratory Plasmas* (ASOS10), Berkeley, California, USA, August 3-7, 2010

7. "X-RAY SPECTROSCOPY OF BROMINE COMPOUNDS AND BIOMEDICAL APPLICATIONS", Sultana N. Nahar, YI Luo, Linh Le, A. K. PRADHAN, E. CHOWDHURY, R. PITZER, M. Montenegro, WF06, *65th International Symposium on Molecular Spectroscopy*, The Ohio State University, Columbus, Ohio, June 21-25, 2010, p. 197

8. "THEORETICAL STUDY OF X-RAY SPECTROSCOPY OF BROMINE COMPOUNDS FOR BIOMEDICAL APPLICATIONS", Sultana N. Nahar, YI Luo, Linh Le, A. K. PRADHAN,E. CHOWDHURY, R. PITZER, M. Montenegro, 5TH annual conference on "Ohio Collaborative Conference on Bioinformatics", Ohio State University, Columbus, Ohio, June 15-17, 2010

9. "X-RAY SPECTROSCOPY OF GOLD NANOPARTICLES", S.N. Nahar, M. Montenegro, A.K. Pradhan, R. Pitzer, *64th International Symposium on Molecular Spectroscopy*, The Ohio State University, Columbus, Ohio, June 22-26, 2009

10. "STUDY OF ENHANCED ABSORPTION OF X-RAYS BY NANOPARTICLES IN CANCER TREATMENT", M. Montenegro, S.N. Nahar, A.K. Pradhan, *Spring Educational Symposium of the Ohio River Valley Chapter of AAPM* (American Association of Physicists in Medicine), University of Cincinnati, Cincinnati, Ohio, March 7, 2009

11. "ATOMIC SPECTROSCOPY: ASTRONOMY TO BIO-MEDICAL SCIENCE" (invited talk), S.N. Nahar, Theory Session honoring Professor R. Pitzer in 63rd annual "International Symposium on Molecular Spectroscopy", Ohio State U., Columbus, Ohio, USA, June 16-20, 2008

12. "Resonant X-Ray Attenuation by Highly Ionized Ions of High-Z Elements", Anil Pradhan, Sultana Nahar, Yan Yu, C. Cur, M. Montenegro, M. Mrozik, R. Pitzer, in the *39th Annual Meeting of the APS Division of Atomic, Molecular, & Optical Physics (DAMOP)*, May 27-31, 2008; State College, Pennsylvania, Bull. Am. Phys. Soc. B6.00001

13. "Resonant X-ray Irradiation of High-Z Nanoparticles For Cancer Theranostics", A Pradhan, S Nahar, M Montenegro, C Sur, M Mrozik, R Pitzer6, E Silver, Y Yu *, SU-GG-J-212, 50th Annual Meeting of the American Association of Physicists in Medicine in Houston, TX, July 27 - 31, 2008 (Joint Imaging-Therapy General Poster Discussion)

14. "Resonant X-ray Irradiation of High-Z Nanoparticles For Cancer Theranostics", Anil Pradhan, Sultana Nahar, Max Montenegro, Chiranjib Sur, Mike Mrozik, Russ Pitzer, Yan Yu, Eric Silver, *Ohio: The Global Pioneer in Biomedical Imaging*, October 19, 2007, Ohio State University, Columbus, Ohio; Poster Presentation

15. "Computational Methodology For Resonant Nano-Plasma Theranostics For Cancer Treatment", Prof. Anil K Pradhan, Dr. Yan Yu, Dr. Sultana N Nahar, Dr. Eric Silver, Prof. Russell Pitzer, *15th International Conference on the Use of Computers in Radiation Therapy*, Toronto, Ontario, Canada, June 4-7, 2007

16. "Resonant X-ray Irradiation of High-Z Nanoparticles For Cancer Theranostics", A.Pradhan, S. Nahar, M. Montenegro, C. Sur, M. Mrozik, R. Pitzer, Y. Yu, E. Silver, 3rd Annual *Ohio Nanotechnology Summit*, April 24-25, 2007, Akron, Ohio, Poster Sessions and Abstracts, NB-3, p.37

17. "Nanospectroscopy of Materials and biomedicine at fundamental atomic and molecular scales", M. Mrozik, R. Pitzer, J. Oelgoetz, M. Montenegro, S.N. Nahar, A.K. Pradhan, B. Larkins, P. Sadayappan, W. Eissner, 2nd Annaul Ohio Nanotechnolgy Summit, Columbus, April 4-5, 2006

18. "Nanospectroscopy of Materials and biomedicine at fundamental atomic and molecular scales", A.K. Pradhan, S.N. Nahar, R. Pitzer, P. Sadayappan, J. Oelgoetz, R. Tyagi, B. Larkins, W. Eissner, Y. Yu, M. Schell, 1st Annual Ohio Nanotechnolgy Summit, Dayton, Ohio, March 2-3, 2005