SPANS

SECE 2024 – Symposium on Plasma And Nuclear Systems

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SPANS Speech Information

Symposium on Plasma and Nuclear Systems (SPANS-2024)

(Hybrid Event with In-person Participation)

20-Aug-2024, Room: UA Building

Ontario Tech University, Oshawa, ON, Canada

Online Meeting Room: https://us02web.zoom.us/j/84891880844

General Chair: Dr. Hossam A.Gabbar, Professor, Ontario Tech University

General Co-Chair: Dr. Blair P. Bromley (Nuclear Engineering Scientist), Division Co-Chair – Canadian Nuclear Society – Fusion Energy and Accelerator Science and Technology Division (CNS-FEASTD)

Keynote Speakers

Title: Advances in Plasma-Based Waste Treatment for Sustainable Communities

Dr. Hossam A.Gabbar, Ontario Tech University, Canada

Title: Machine Learning for Radiometric Clustering and Classification

Dr. Angela Di Fulvio, University of Illinois at Urbana-Champaign, USA

Title: Plasma-Surface Interactions in Tokamaks

Dr. James Davis, University of Toronto, Canada

Title: A Novel Radio-Frequency Inductively Coupled Plasma (RF-ICP) Torch

Dr. Javad Mostaghimi, University of Toronto, Canada

SPANS Speech Information

Title: The Crab Pulsar Magnetosphere and its Enigmatic "Striped" Radio Emission

Dr. Mikhail Medvedev, Professor, University of Kansas, USA

Title: CNL Lattice Physics Assessments of Alternative/Advanced Fuels for PWR-SMRs

Dr. Blair Bromley, CNL, Canada

Title: Radioactive wastes in Fukushima Daiichi NPS

Ms. Yunseo Park, TEPCO, Japan

Title: New Tokamak Regime at Negative Triangularity

Dr. Oak Nelson, Columbia University, USA

Demonstration of Digitial Control Room with Human Perforance Considerations for SMR Deployments, Ontario Tech University

Demonstration of Nuclear-Renewable Hybrid Energy System Simulator, Ontario Tech University

Program Details

Talk-1: Advances in Plasma-Based Waste Treatment for Sustainable Communities

Hossam A.Gabbar, Professor, P.Eng., Fellow IET (FIET), Distinguished Lecturer IEEE NPSS, Director of Advanced Plasma Engineering Lab (APEL)

Department of Energy and Nuclear Engineering, Faculty of Engineering and Applied Science, Ontario Tech University, Oshawa, Ontario, Canada, email: hossam.gaber@ontariotechu.ca

Abstract

This talk presents advanced approaches for plasma-based waste treatment. Different designs of plasma torches and generation systems are discussed, including RF, DC, and microwave plasma, are analysed and compared for waste-to-energy applications. Novel plasma torch design is proposed to support different scales of waste treatment. Process engineering techniques for gasification and pyrolysis process are illustrated with waste characterization. The proposed approaches showed reduced greenhouse gas emissions and improved lifecycle performance. Plasma systems are utilized for nuclear waste treatment for low, intermediate, and high radioactive waste. Process design is discussed for plasma torch that can reduce the volume of radioactive waste. Potential approaches are explored for mass separation that could be utilized for high-level radioactive waste. Simulation methods and experimental setups demonstrate lab-scale process technologies for plasma-based waste treatment.

Bio

Dr. Gabbar is a full Professor in the Faculty of Energy Systems and Nuclear Science, and cross appointed in the Faculty of Engineering and Applied Science, at Ontario Tech University (UOIT), where he has established the Energy Safety and Control Lab (ESCL), Smart Energy Systems Lab, and Advanced Plasma Engineering Lab. He is the recipient of the Senior Research Excellence Aware for 2016, UOIT. He is recognized among the top 2% of worldwide scientists with high citation in the area of energy. He is a Distinguished Lecturer of IEEE NPSS, and he is a Fellow IET (FIET). He is leading national and international research in the areas of smart energy grids, energy safety and control systems, and waste-to-energy using advanced plasma technologies. Dr. Gabbar obtained his B.Sc. degree in 1988 with first class of honor from the Faculty of Engineering, Alexandria University (Egypt). In 2001, he obtained his Ph.D. degree from Okayama University (Japan). From 2001 till 2004, he joined Tokyo Institute of Technology (Japan), as a research associate. From 2004 till 2008, he joined Okayama University (Japan) as an Associate Professor, in the Division of Industrial Innovation Sciences. From 2007 till 2008, he was a Visiting Professor at the University of Toronto. He also worked as process control, safety, and automation specialist in energy and oil & gas industries. Dr. Gabbar has more than 290 publications, including patents, books / chapters, journal, and conference papers.

Talk-2: Machine Learning for Radiometric Clustering and Classification

Dr. Angela Di Fulvio, University of Illinois at Urbana-Champaign, USA

Abstract

"Machine learning algorithms' capability to perform non-linear classifications and clustering is particularly valuable in handling radiometric datasets, often including interdependent and complex signatures.

During this talk, I will illustrate the practical application of machine learning algorithms in two distinct areas: pulse shape discrimination and image segmentation. Despite the apparent differences between these tasks and the different data domains, they share common challenges, namely solving clustering and classification problems on large data sets.

The pulse shape discrimination results show that supervised classifiers such as k-nearest neighbor, support vector machine, random forest, and variational autoencoders outperform traditional deterministic charge integration methods when discriminating gamma-ray and neutron pulses detected by organic scintillators.

Notably, variational autoencoders necessitate minimal supervision and are adaptable across various radiation sources. Furthermore, I will discuss the need for advanced methods when dealing with three-dimensional data classification. Here, an adaptive point-cloud segmentation approach will be explored, aimed at reducing data size and computational time while ensuring precise segmentation. The method is successfully applied to segment the prostate in radiation therapy treatment planning, demonstrating its adaptability during successive treatment fractions by automatically adjusting to changes in organ dimensions and positions."

Bio

Dr. Angela Di Fulvio is currently an Associate Professor in the Nuclear Plasma and Radiological Engineering (NPRE) Department at UIUC. Before joining NPRE in 2018, Dr. Di Fulvio was a research scientist at the University of Michigan, where she worked on radiation detection within the framework of the NNSA Consortium for Verification Technology. Dr. Di Fulvio and her research group design, simulate, develop, and characterize radiation detection systems, with a focus on neutron spectroscopy and imaging, and use Bayesian and deep learning algorithms to maximize the information retrieved from such systems. Among other efforts, Dr. Di Fulvio is the PI of two projects for advancing safeguards and fuel management at advanced reactors, sponsored by the Department of Energy, and is the UIUC lead PI of the Nuclear Science and Security Consortium, sponsored by the National Nuclear Security Administration. Dr. Di Fulvio is also the Director of the Arms Control, Domestic and International Security Program at UIUC and has leadership roles in several professional societies, including the IEEE Nuclear and Plasma Sciences Society, where she is the Chapters' co-chair. For her scholarly work, she was awarded the 2022 UIUC Grainger College of Engineering Dean's Award for Excellence in Research.

Talk-3: Plasma-Surface Interactions in Tokamaks

Dr. James Davis, University of Toronto, Canada

Abstract

One of the major challenges in the development of nuclear fusion as an energy source is associated with the close proximity (few cm) of the fusion fuels at > 100,000,000°C to the solid surfaces which make up the walls of the reactor. The original ITER (International Thermonuclear Experimental Reactor) design called for beryllium tiles for the majority of the plasma-facing surfaces, with tungsten used in the high heat flux locations; however, the recent decision to move away from a Be first wall highlights the challenges involved in the selection of materials for plasma-facing surfaces. In his opening remarks at the 26th International Conference on Plasma-Surface interactions in Controlled Fusion Devices (Marseille, May 12-17, 2024), Dr. Pietro Barabaschi (Director General of ITER) expressed the opinion that managing plasma-surface interactions was the #1 problem for fusion development.

I tend to divide these interactions into three general categories:

1. Erosion and plasma contamination: Energetic particles from the plasma will lead to a number of erosion processes such as sputtering and melting. Some fraction of the ejected particles will make their way to the core plasma, where they will increase radiation losses, cooling the plasma.
2. Redeposition of eroded material: Eventually, all impurity particles entering the plasma will come out again. The deposition of these impurity particles tends to occur over a relatively small region near the divertor such that even relatively small amounts of erosion (µm's) over the large area of the main walls can lead to deposits of significant thickness (mm's).
3. Tritium retention in/permeation through wall materials: Tritium does not occur naturally, and if it is to be used as a fuel it will need to be produced from lithium (e.g., n + 6Li → T + 4He) using the neutron from the D + T → 4He + n reaction. With tritium breeding ratios ~ 1.1 T/n, there will only be room for small losses of tritium through the entire fuel cycle. Secondly, tritium is radioactive (T1/2 ~ 12 yrs) and its accumulation in the reactor vessel poses a safety hazard, and its decay to helium can lead to material degradation. In this talk, I will give an overview of some of the most pressing problems in current fusion PSI research.

Bio

James Davis is a Professor of Aerospace Engineering at the University of Toronto. For more than four decades his research interests have been related to the various interactions process which occur between the high-temperature plasmas in magnetic-confinement devices and the surrounding wall materials.

Talk-4: A Novel Radio-Frequency Inductively Coupled Plasma (RF-ICP) Torch

Dr. Javad Mostaghimi, University of Toronto, Canada

Abstract

Radio-frequency inductively plasma (RF-ICP) torches have established themselves as a powerful tool in materials processing. In 1961, Reed presented the first continuous operating RF-ICP torch [J Appl Phys 32:821–824, 1961]. Since then, the basic cylindrical design of the ICP torches presented by Reed has not changed. Cylindrical RF torches consume more gas and power than is needed for any process. The high consumption of gases is dictated by the need to prevent the torch from overheating and melting as the maximu Joule heating is close to the torch confinement tube. The development of a conical torch, and its considerable advantages over cylindrical torches for material processing and for trace element analysis is presented in this talk. These advantages include substantially reducing gas flow rates (50%-70%) and power consumption (40%). In addition, maximum argon plasma temperature is over 1,000 K compared to cylindrical torches. The performance of the conical torch in ceramic powder processing, and in ICP-optical emission spectrometry is demonstrated.

Bio

Dr. Javad Mostaghimi is a Professor in the Department of Mechanical & Industrial Engineering at the University of Toronto and the director of the Centre for Advanced Coating Technologies (CACT). Before joining the University of Toronto in 1990, he held positions at Pratt & Whitney Canada, Longueil, Quebec, and the Department of Chemical Engineering, University of Sherbrooke, Sherbrooke, Quebec. His main research interests are the study of thermal spray coatings, including superhydrophobic coatings, thermal barriers, corrosion and wear-resistant coatings. He has performed comprehensive studies on the flow, temperature, and electromagnetic fields within arcs and RF inductively coupled plasmas. Professor Mostaghimi has done extensive simulations of the dynamics of droplet impact and solidification in thermal spray processes, and design of novel DC and RF plasma torches. Professor Mostaghimi is elected into the Canadian Academy of Engineering and the Academy of Science of the Royal Society of Canada. He has the rank of Fellow of the following professional societies: RSC, ASME, ASM, CSME, EIC, AAAS, IUPAC. He is a recipient of the 75th Anniversary Medal of the ASME Heat Transfer Division, the recipient of the 2013 Robert W. Angus Medal of the CSME, 2012 Heat Transfer Memorial Award of the ASME, 2011 Jules Stachiewicz Medal of the CSME, 2010 NSERC Brockhouse Canada Prize and the 2009 Engineering Medal in R & D from the Professional Engineers of Ontario. In May 2019, Dr. Mostaghimi was inducted into the ASM Thermal Spray Hall of Fame. In 2023 and 2024, he received the CSME Emerging Technologies Medal, and the ASME Fitzroy Medal, respectively.

Talk-5: CNL Lattice Physics Assessments of Alternative/Advanced Fuels for PWR-SMRs

Dr. Blair P. Bromley (Nuclear Engineering Scientist)

Abstract

In the interests of long-term nuclear energy sustainability and security, it is necessary to consider the use of advanced and alternative fuels that could be implemented in LWR-SMRs, which are gaining more widespread interest for potential deployment in Canada, and around the world.

The purpose of this study was to evaluate key performance characteristics (exit burnup, fuel lifetime, fissile utilization, spent fuel compositions, and others) for various advanced/non-conventional fuels that could potentially be used in PWR-SMRs, similar to the NuScale iPWR design.

A multi-clad, multi-region heterogeneous fuel element design concept for use in a 17x17 PWR-SMR fuel assembly based on the NuScale iPWR design was tested. Different fuel types, including U, (U,Th) and (Pu,Th) fuels were evaluated. Different fuel matrix materials, including oxides, nitrides, carbides, oxy-carbides, and silicides, were evaluated. Up to 90 test cases were evaluated.

The focus for the presentation is on results obtained using 5 wt% U-235/U enriched fuel. Such fuels are potentially superior to conventional fuels, with slightly increased burnup and fuel lifetime, and improved thermal conductivity, and more resilience. Carbide fuels (UC) are particularly attractive.

Because of its small core size, the neutron leakage from the NuScale iPWR is relatively large (97 mk to 141 mk), and this neutron leakage can reduce the achievable burnup and core lifetime by nearly 30% relative to a large-scale PWR (such as the AP1000) with low neutron leakage (20 mk to 30 mk).

Spent fuel compositions suggest that the trace amounts of plutonium produced will be unsuitable for proliferation, with a high content of Pu-240 (>18 wt% Pu-240/Pu).

The results and insights gained from this study could be applicable to other LWR-SMR technologies, including the BWRX-300, under development by General Electric Hitachi (GEH), and with anticipated deployment for new builds at the Darlington Nuclear Generating Station by Ontario Power Generation (OPG).

Bio

Division Co-Chair – Canadian Nuclear Society – Fusion Energy and Accelerator Science and Technology Division (CNS-FEASTD), Canada

Dr. Bromley is a Reactor Physicist with Atomic Energy of Canada Limited (AECL), Chalk River Laboratories (2003-2014), and Canadian Nuclear Laboratories (CNL) (2014-present). In his current role, he serves as a Principal Investigator / Technical Lead on a number of multi-disciplinary Federal Science and Technology projects evaluating advanced fuels, fuel cycles and reactor concepts that are relevant for various Small Modular Reactor (SMR), micro-reactor, Gen-IV, and Gen-III+ technologies.

He also has prior work experience at Brookhaven National Laboratory (BNL) (2001-2003), and Los Alamos National Laboratory (LANL) (1994-1998). He has a B.A.Sc. in Mechanical Engineering (University of Toronto, 1993), a M.Sc. degree in Aerospace Engineering (University of Illinois, 1998) and a PhD. in Nuclear Engineering (University of Illinois, 2001), with graduate research experience in fusion energy science and technology.

Dr. Bromley continues to be active in professional activities. He is a Fellow of the Canadian Nuclear Society (CNS) and has been serving as the chair of Fusion Energy and Accelerator Science and Technology Division (CNS-FEASTD), since 2010. Dr. Bromley has also served in multiple volunteer roles in various divisions and committees within the CNS, the American Nuclear Society (ANS), and Women-in-Nuclear, Eastern Ontario Chapter (WiN-EO).

Dr. Bromley's LinkedIn Profile can be found at:

https://www.linkedin.com/in/blair-bromley-a2076b45/

A listing of a number of publications by Dr. Bromley can be found at:

Talk-6: The Crab Pulsar Magnetosphere and its Enigmatic "Striped" Radio Emission

Dr. Mikhail Medvedev, Professor, University of Kansas, USA.

Abstract
The Crab pulsar is one of the nearest and brightest "lighthouses" in our galaxy. In this talk, we first discuss the plasma model of a pulsar magnetosphere. Then, we present intriguing observations of the Crab pulsed radio emission -- in particular, its zebra-patterned spectrum -- which puzzle the community for nearly two decades. Finally, we propose a model, which explains all peculiar features of the enigmatic emission. Implications and predictions of the model are discussed as well.

Bio
MS 1993 (Moscow Institute for Physics and Technology) and UCSD (1994), PhD 1996 (UCSD), Postdoc at Harvard Astronomy Dept. (1998-2000) and CITA at U. Toronto (2000-02), KU Faculty since 2002, MIT Affiliate since 2017, Member of the Institute for Advanced Study, IAS (2010, 2023-24), Visiting Professor at: Harvard (2013, 2017, 2024), Princeton Univ. (2023-24), Niels Bohr International Academy, Copenhagen (2009-10). Elected Fellow of the APS (2018), University Scholarly Achievement Award (2013), KU PHSX Graduate Teaching Award (2014, 2016), Ambrose Monell Foundation award at IAS (2009).

Talk-7: The Negative Triangularity Tokmak: Ensuring Robust Access to a High-Performance, ELM-Free Fusion Power Plant

Dr. A.O. Nelson, Columbia University, USA

Abstract
The pursuit of commercial fusion energy, which could provide a clean and effectively limitless power source for humanity, is often heralded as one of the most important and difficult scientific endeavors of our time. One of the leading approaches for fusion, the tokamak, uses magnetic fields to confine a hot and dense plasma inside a toroidal vacuum vessel. Typically, this configuration can access plasma conditions capable of sustained fusion reactions, but in the process of doing so creates periodic edge instabilities called "ELMs" that release tremendous heat fluxes onto the machine walls. Avoidance of ELMs is essential to power plant operation, but existing techniques to do so are often extremely sensitive to plasma conditions and come with a measurable decrease in plasma performance. Enter negative triangularity (NT). Simply by changing the shape of the plasma cross-section, NT scenarios can provide a robust solution to the power-handling problem in tokamaks by eliminating the triggering of ELMs via direct regulation of the pressure gradients in the plasma edge. On the DIII-D and TCV experimental tokamak facilities, inherently ELM-free NT regimes are found to be fully compatible both with high core performance and with divertor detachment, both of which are essential for operation in future devices. Since this behavior is linked directly to geometry-induced changes in the magnetic shear, NT fusion power plants are predicted to maintain advantageous ELM-free edge conditions even in the burning plasma regimes targeted for power plant design. Further, the natural tendency for NT plasmas to avoid plasma state bifurcations at high heating power could simplify impurity regulation and auxiliary power control in a reactor setting, and the NT geometry could facilitate larger divertor surfaces for exhaust mitigation. Together, these characteristics suggest that negative triangularity may be able to provide something that no other tokamak scenario can: a robust and rapid path to a commercial fusion energy system.

Bio
After receiving his Ph.D. in Plasma Physics from Princeton University in 2021, Dr. Andrew "Oak" Nelson has quickly risen as an emerging leader in fusion energy research. Currently an Associate Research Scientist at Columbia University, Dr. Nelson's primary research interests focus around accelerating the timeline for the realization of a commercially viable fusion energy system. To that end, he is heavily involved in the study of negative triangularity (NT) configurations that have the potential to solve the power handling issue faced by tokamaks by providing robust access to high core confinement while maintaining reactor-compatible edge conditions. He believes that NT tokamaks should be considered as a primary pathway for fusion pilot plants. Dr. Nelson also collaborates extensively on the ongoing development and optimization of the SPARC and ARC tokamaks, which will exploit strong magnetic fields to achieve high fusion gains. His research features a balanced combination of modeling and experimental work, often leading to insightful results that merge the two fields. In addition to his research, Dr. Nelson is also deeply committed to outreach and community development in fusion energy. Through his role at Columbia, Dr. Nelson mentors several graduate and undergraduate students who are developing their careers in plasma science. Further, he has helped to put together various student-oriented programs in the United States, such as the growing APS-DPP Student Day, and is a board member for both the Committee for Concerns of Young Scientists (CONNECT) and the US Fusion Outreach Team.

Talk-8: Radioactive wastes in Fukushima Daiichi NPS

Ms. Yunseo Park, TEPCO, Japan

Abstract
Fukushima Daiichi Nuclear Power Station (1F) has been undergoing D&D activity since the severe accident in March 2011. This D&D activity began as an initial response to suppress the release of radioactive contamination into the environment. Now, 1F is maintaining the site stable with continuous cleanup activities, including unique D&D activities which are dealing with unique radioactive wastes only able to find in 1F site. This presentation introduces these unique radioactive wastes of 1F.

Bio
Ms. Park joined Tokyo Electric Power Company (TEPCO) in April 2019. She was assigned to processing and storage equipment engineering group where she was in charge of planning and design for construction and maintenance of contaminated water treatment facility of Fukushima Daiichi NPS for 3 and half years. Since October 2023, Yunseo has taken a new role as resident researcher at Savannah River National Laboratory, where she is responsible for development of international cooperation about Fukushima Daiichi Nuclear Power Station with DOE and partners in America. Yunseo earned BS and MS (studied reactor physics, reactor core design and advanced reactor design) in nuclear engineering from Kyung Hee University in South Korea.