Plasma Science and Fusion Center

Overview

MIT's Plasma Science and Fusion Center (PSFC) is known internationally as a leading university research center for the study of plasma and fusion science and technology. It is also internationally recognized for its advances in Nuclear Magnetic Resonance (NMR) spectroscopy, and in advanced magnet development.

The Center's research focuses on the science of magnetically confined plasmas in the development of fusion energy; general plasma science including plasma-surface interactions, development of novel high-temperature plasma diagnostics, and theoretical and computational plasma physics; the physics of high energy density plasmas (HEDP); the physics of waves and beams: gyrotron and high gradient accelerator research, beam theory development, non-neutral plasmas, and coherent wave generation; development of high field superconductors and superconducting magnet systems, and; research in magnetic resonance, which includes nuclear magnetic resonance (NMR), electron paramagnetic resonance (EPR), and magnetic resonance imaging (MRI); and on the aforementioned NMR and MRI magnet development, and nanoscience condensed matter physics (quantum coherent behavior charge and spin transport).

The PSFC is made up of six research divisions – Magnetic Fusion Experiments (MFE); Plasma Theory and Computation (PT&C); High Energy Density Physics (HEDP); Plasma Science and Technology (PS&T); Magnets and Cryogenics (M&C), and; Magnetic Resonance (MR).

There are approximately 250 personnel associated with PSFC research activities. These include: 25 affiliated faculty and senior academic staff; 54 graduate students, with participating faculty and students from Aeronautics and Astronautics, Chemistry, Mechanical Engineering, Nuclear Science and Engineering, and Physics; 85 research scientists, engineers, postdoctoral associates/fellows and technical staff; 44 visiting scientists, engineers, and research affiliates; 18 technical support personnel (technicians, designers); and 24 administrative and support staff.

Center wide, funding has grown to over $40 million. This past year was the third year of funding for the private industry funded SPARC program. With the cessation of the DOE-supported Alcator program in 2017, industry support is now the single largest portion of PSFC support, at 47%. DOE's Office of Fusion Energy Sciences (OFES) is now about 28% of the total, other DOE (i.e., non-OFES support is at 10% and National Institute of Health support is at about 11%.

Magnetic Fusion Experiments (MFE) Division

Professor Zachary Hartwig

Professor Zachary Hartwig, the Robert N. Noyce Career Development Professor, continues to lead multiple research and engineering initiatives within the Department of Nuclear Science and Engineering (NSE) and the Plasma Science and Fusion Center (PSFC).

These efforts are principally focused on advancing the state of large-scale high-field superconducting magnets and deploying new techniques for high-fidelity irradiation of materials for nuclear environments. Professor Hartwig oversees the Vault Laboratory, which hosts a 12 MeV superconducting proton cyclotron, a 2 MV ion tandem accelerator, and 2 D-T neutron generators within a large concrete vault. These accelerators are being used for the bulk irradiation of fusion-relevant structural (e.g. steels) and plasma-facing (e.g. refractory metals) materials, development of diagnostic instruments for core plasma physics and plasma-material interactions in magnetic confinement fusion devices, experimental assessment of tritium breeding systems for fusion energy devices, and for active nuclear security techniques in collaboration with Professor Areg Danagoulian of MIT NSE.

Professor Hartwig also oversees work in applied large-scale superconductivity, including experimental work to make superconducting magnets defect-tolerant (and, thus, lower cost, easier to fabricate, and more robust in operation) and radiation-tolerant (and, thus, suitable for fusion energy and high energy physics machines). Professor Hartwig was also appointed the Head of Engineering at the PSFC, overseeing a team of approximately 35 professional engineers, designers, and technicians that provides large-scale scientific and engineering support to MIT Principal Investigators and students to carry out their experimental research work at MIT and the PSFC.

Phase Contrast Imaging for Multiscale Measurements of Turbulence and Helicon Waves in DIII–D

The Phase Contrast Imaging (PCI) diagnostic at DIII-D continued its high resolution measurements of fluctuations and transport in high performance tokamak plasmas, with a focus on the comparison of experimental measurements to numerical models via a synthetic diagnostic method to mimic the physical process of the measurement. Additional work included studying turbulence and transport in negative triangularity plasmas in DIII-D that promise high performance, ELM free plasmas for future fusion reactors. Gyrokinetic modeling of such plasmas support the interpretation of the favorable properties of such plasmas, owing to reduced levels of turbulence.

The Development of a novel technique based on Electro Optical Modulation (EOM) of the CO-2 laser beam, combined with a heterodyne method will allow us to measure high frequency (476 MHz) MW level electromagnetic ("helicon", or whistler waves) in DIII-D plasmas (Marinoni et al, Rev. Sci. Instrum. 93, 083502 (2022) DOI:10.1063/5.0101715). Unfortunately the first modulator tests based on a CdTe crystal modulator ("Pockels" cell) has failed, delaying this project by one year. The failed component was sent back to the manufacturer, and a second vendor was consequently also contacted for an additional "backup" modulator unit.

Alfven Eigenmode (AE) Active Diagnostic (Investigations of Alfven Eigenmode stability in JET plasmas through active antenna excitation).

The world's largest operating tokamak, JET in the UK, that has been operating for nearly 30 years mainly in Deuterium plasmas, with a short record breaking DT operation phase in the 1990s. During the past year limited periods of DT plasma operation has been resumed, and will hold its final Deuterium-Tritium (D-T) campaign from August to October 2023. In preparation, the operation of MIT's Alfven Eigenmode (AE) Active

Diagnostic has been optimized to resonate with stable AEs. An extensive database of thousands of measurements has been assembled for Hydrogen, D, T, and Helium plasmas and is being analyzed for interaction (damping or growth) with energetic particles, including alpha particles in DT plasmas. Simulations will identify modes, assess their stability, and evaluate the contribution from DT-fusion alphas.

Experimental studies of turbulence and transport in the Wendelstein 7-X (W 7-X) stellarator .

The phase contrast imaging (PCI) system, operated in collaboration with the Max Planck Institute for Plasma Physics, at the Wendelstein 7-X (W7-X) stellarator in Greifswald, Germany, has been active throughout the first long-pulse W7-X experimental campaign, running from late September 2022 to late March 2023. PCI measurements of electron density fluctuations, which are paramount for understanding of stellarator turbulence and associated transport, have been carried out in virtually in every plasma configuration of the campaign. A particular example is the milestone 1.3 GJ energy turnover program performed on February 15, 2023, which illustrated the successful operation of the PCI system in the record long-pulse, high-performance, high temperature plasmas of W7-X.

Other PCI highlights of the recent W7-X experimental campaign are the first regular application of localization masks, the detailed observation of the impact of magnetic configuration on fluctuation levels, and the investigation of the role of reduced levels of turbulence in high performance plasmas with peaked density profiles.

Turbulent Transport Studies

Professor Anne White is currently the Vice Provost and Associate Vice President for Research Administration and the MIT School of Engineering Distinguished Professor Engineering. Professor White's research group focuses on the study of turbulent transport in fusion plasmas, with the goal of controlling and optimizing the transport and improving performance of tokamaks and stellarators. The group's research includes diagnostic development and validation of high-fidelity simulations that will inform design of future net-energy fusion devices. This year the team has worked primarily at the ASDEX Upgrade tokamak, where the experimental team leads experiments and develops diagnostics and leads validation projects using advanced turbulence simulation codes. They study turbulence and transport in negative triangularity plasmas, perform predictive modeling for SPARC, develops new optimization tools at ASDEX Upgrade (AUG), and lead the Plasma Science and Fusion Center 's (PSFC) collaboration with the JET tokamak on integrated modeling, where the work as focused on analysis of data from the JET D-T campaign. Group members have been leaders on the study of edge turbulence in ELM-free high-performance plasmas, on new diagnostic development via development of novel tomographic reconstruction algorithms, and exploring the use of ML/AI applied to understanding scaling of turbulence and transport across a wide range of engineering and plasma parameters. Of note this year, PSFC Research Scientist Pablo Rodriguez Fernandez has been the leader at PSFC of the Integrated Modeling thrusts for magnetic confinement fusion, and PSFC Postdoctoral Associate Branka Vanovac has been a lead on the negative triangularity thrust at the Max Planck Institute for Plasma Physics at the AUG tokamak.

Plasma Theory and Computation Division

The Plasma Theory and Computation Division conducts basic and applied plasma theory and simulation in support of domestic and international toroidal confinement devices. The Division Head is Dr. Paul Bonoli and the Assistant Head is Professor Nuno Loureiro from the Nuclear Science and Engineering (NSE) Department. Research highlights for the past reporting period (July 1, 2022 to June 30, 2023) include:

Professors J. Freidberg and L. Guazzotto (U. Auburn) completed fusion neutron source studies comparing the effects of high magnetic field on steady state and possible pulsed neutron sources for application to fusion. Professors Freidberg and D. Whyte with NSE graduate student J. Jerkins have continued their investigations of the Liquid Sandwich Vacuum Vessel (LSVV) developing a 2-D large aspect ratio model of the LSVV, and transitioning from a solid conducting wall to the LSVV by the introduction of an anisotropic resistivity tensor. Professor Freidberg, in conjunction with post-doctoral associate S. Frank and graduate student M. Clingerman have made substantial advances in revisiting the idea of MHD Energy Conversion topping cycles with the expectation of substantially improved performance because of the recent development of high field superconductors.

Dr. P. Catto was involved in three major projects. The first with Dr. Libby Tolman (Flatiron Institute) and Prof. Felix Parra (Princeton University and PPPL) evaluated alpha particle energy transport in a weakly collisional limit that was shown to occur when two regimes of concern merge (2023 Journal of Plasma Physics 89, 905890106). The second with Dr. Muni Zhou (Institute for Advance Study) confirmed the attractiveness of oblique whistler waves to drive current at high density while being launched from the low magnetic field side of a tokamak (2023 Journal of Plasma Physics 89, 905890405). The third with graduate student Rachel Bielajew evaluated the poloidal variation of impurity density and electrostatic potential as well as the direction of the poloidal flow in the strong gradient region just inside the last closed pressure surfaces at the edge (2023 Journal of Plasma Physics 89, 905890411).

Prof Loureiro's group activities revolved mainly around two topics: (i) turbulence and magnetic reconnection in plasmas, and (ii) and the development of quantum algorithms for simulating nonlinear dynamics of plasmas on quantum computers. Aspects of the former were the topic of graduate student Lucio Milanese's thesis (defended in March 2023), and work by former graduate student Muni Zhou, published in Proceedings of the National Academy of Sciences and elsewhere. On the topic of quantum algorithms, graduate student Abtin Ameri published an investigation into efficient quantum algorithms for the solution of the linearized Vlasov equation; and postdoctoral researcher Erika Ye pioneered the use of quantum inspired Tensor Networks for the nonlinear Vlasov-Poisson system. Finally, Prof Loureiro was elected a fellow of the American Physical Society via the Division of Plasma Physics.

Dr. Darin Ernst (MIT PI), Dr. Manaure Francisquez (PPPL), and FASTMath SciDAC Institute members Prof. Dan Reynolds (Math Dept. Chair, SMU), Dr. Carol Woodward (LLNL), and Cody Balos (LLNL) continued their work in the SciDAC Partnership for Multiscale Gyrokinetic Turbulence (MGK), implementing and testing a new multi-rate method to accelerate simulations of coupled ion and electron scale turbulence. An initial GPU-based version of their multiscale gyrofluid code was developed.

As part of the SciDAC Partnership for Integrated Simulation of Fusion Relevant RF Actuators, graduate student Samuel Frank, working with Drs. Bonoli and Wright, completed his thesis work showing that lower hybrid (LH) full-wave and ray tracing simulations coupled with a Fokker Planck solver agree quite closely in a variety of present day and future tokamaks. He published papers on this work (2022 Journal of Plasma Physics 88, 905880603] and 2022 Plasma Physics and Controlled Fusion 64, 105023). Graduate student Christina Migliore, working with Dr. J. Wright and M. Stowell (LLNL) has developed an electromagnetic field solver which includes a non-linear radio-frequency sheath boundary condition in a realistic tokamak and RF antenna geometry to study impurity sources during radi-frequency (RF) heating experiments in Alcator C-Mod. Papers on this work will appear in the 2022 AIP RF Topical Conference Proceedings and Nuclear Fusion (2023).

Dr. Nathan Howard worked with PSFC Scientist Pablo Rodriguez-Fernandez utilizing machine learning and nonlinear gyrokinetic simulation to predict plasma profiles in the JET tokamak and study the origin of the isotope effect in H, D, and T plasmas.

In an important study led by graduate student Efstratios Koukoutsis (National Technical University of Athens, Greece) and published in Physical Review A, Dr. Abhay Ram along with co-authors Professor Kyriakos Hizanidis (Greece), and Professor George Vahala (William and Mary) have developed a formulation for implementing Maxwell equations in quantum computers. While awaiting necessary development of quantum computers, a qubit lattice algorithm based on this study is being tested on present day classical supercomputers. This publication was reported in a MIT News.

Dr. J. Wright completes the ARPA-E RF Project at the end of funding year 2023. This project contributed to the science of linear fusion devices and in particular to the new fusion startup, REALTA out of Madison, Wisconsin. MIT is a subawardee on a new DoE Fusion Milestones grant that will apply this work to a linear mirror fusion device.

Dr. D. Ernst led the 2022 DOE OFES Joint Research Target (JRT) on *Intrinsically Non-ELMing Regimes*, while co-leading three of its five working groups, completing the final 153 page report. Dr. Ernst also co-leads the DIII-D Thrust *Develop High Performance Non-ELMing Regimes*, under which he led two DIII-D experiments. Two main results include the first demonstration of turbulence broadening (doubling) of the divertor heat flux profile in H-Mode plasmas (the Quiescent H-Mode regime), quantitatively matched by XGC electromagnetic gyrokinetic particle simulations; and a new understanding of impurity sourcing and transport, demonstrating greatly reduced impurity content in hydrogen Wide Pedestal QH-Mode plasmas. An overview of JRT results was presented by Ernst in an invited talk at the 2023 European Physical Society Plasma Physics Meeting.

Research on the EAST Tokamak in Hefei, China continued despite restrictions on travel to China. Dr. C. Rea performed research that leverages EAST data in disruption prediction studies. This resulted in a recent publication [J. X. Zhu, C. Rea et al, Nuclear Fusion 63 046009 (2023)] on the development of an integrated deep learning (DL) based model that combines disruption prediction with the identification of disruption precursors. In an on-going effort to develop and identify an optimized RF actuator mix for high-performance plasmas in EAST, a modeling study led by Dr. S. G. Baek is being conducted to explore the synergistic effect between lower hybrid and electron cyclotron (EC) waves and future experiments are being planned on EAST in order to take advantage of this synergy.

High Energy Density Physics Division

The High-Energy-Density-Physics (HEDP) Division focuses on developing and using advanced diagnostics for studying Inertial Confinement fusion (ICF), laboratory astrophysics and HEDP, while at the same time training and educating graduate students in these fields.

An important part of the division's activities is the use of the Magnetic Recoil Spectrometer (MRS) in support of the ICF programs at the National Ignition Facility (NIF) and OMEGA. The data obtained with the MRS have been critical for guiding the campaign at the NIF toward achieving ignition and energy for the first time in the history of laboratory fusion research. This happened on December 5, 2022.

Maria Gatu Johnson, Richard Petrasso and Johan Frenje were part of a team who was honored with the American Physical Society's John Dawson Award for Excellence in Plasma Physics Research for "the first laboratory demonstration of a burning deuterium-tritium plasma where alpha heating dominates the plasma energetics." Frenje was also selected as recipient of the 2023 Fusion Power Associates Leadership Award, which is presented to individuals demonstrating outstanding leadership in accelerating the development of fusion as a commercial power source.

Patrick Adrian and Graeme Sutcliffe were awarded distinguished fellowships to further their studies in HEDP. Adrian was received the Director's Postdoctoral Fellowship in HEDP from Los Alamos National Laboratory; and Sutcliffe was selected for the HEDP Postdoctoral Fellowship to conduct research at Lawrence Livermore National Laboratory. Six new graduate students will join the HEDP division in 2023.

Plasma Science and Technology Division

High Gradient Electron Acceleration at THz Frequencies

Research on high-gradient accelerators is focused on greatly reducing the size and cost of future accelerators. In 2022-2023, we successfully used a vector network analyzer to test a high gradient structure built at SLAC in order to verify that it is tuned to the correct frequency near 110 GHz. The structure will be tested using megawatt power level pulses from a gyrotron. In 2022-2023, we have completed a pulse compressor that can compress microsecond pulses from a gyrotron into nanosecond pulses with a peak power gain of 35.

Instumentation for Dynamic Nuclear Polarization in NMR Research

Dynamic nuclear polarization is a method of exciting the electron spins in a biomolecular sample resulting in increased signal to noise for nuclear magnetic resonance spectroscopy and biomolecular structure determination. The technique requires efficient coupling of THz radiation into the biomolecular samples. In 2022-2023, we measured the dielectric constants and absorption coefficient at THz frequencies of the samples and their holders. The results allow us to optimize coupling to the samples and to greatly improve spectroscopic results.

Geothermal Energy

The ARPA-E project at MIT PSFC "Millimeter-Wave Technology Demonstration for Geothermal Direct Energy Drilling" continued through FY2023. The partners in this project are: AltaRock Energy, Inc., Geoffrey Garrison, PI; Quasie, Inc., Carlos Arque CEO, a company founded to lead this development and commercialize the technology; MIT with Paul Woskov at the Plasma Science and Fusion Center, Prof. Herbert Einstein at the MIT Rock Mechanics Laboratory, Civil Engineering Department; Ken Oglesby of Impact Technologies LLC; and Tim Bigelow at Oak Ridge National Laboratory (ORNL). The goals of the planned three-year effort, which has entered its 5th year due to COVID pandemic delays, are to advance the depth to diameter borehole ratio from about 1:1 achieved at the PSFC to 10:1 and then to 100:1 by the end of the grant using one of ORNL's 100+ kW continuous wave gyrotrons. The continuing experiments during the past year at ORNL have not succeeded in bringing full beam power onto the rock target due to problems with waveguide transmission at atmospheric pressure caused by poor beam quality and associated arcing. Four iterations of the transmission line/ mode converter system using existing components have been tried to date. It was decided to move the experiments to Quaise Houston where a dedicated 28 GHz gyrotron facility with better beam quality and transmission line has been set up. Additional gyrotrons at 95 and 105 GHz have also been acquired by Quaise to support commercialization development. Negotiations for a follow-on research program at MIT with Quaise were also started during this time period following the end of the ARP-E funding. It is planned that Quaise will provide a 20 kW, 170 GHz gyrotron system to the PSFC for scaled high intensity millimeter-wave research on technologies and science as applied to deep drilling.

Magnetic Resonance Division

Mei Hong, Professor of Chemistry

In 2022-2023 the Hong lab made substantial advances in understanding the structure and mechanism of the SARS-CoV-2 envelope (E) protein. We determined that the E protein forms pentamers in lipid bilayers using 19F solid-state NMR 1, thus answering a long-standing question about the oligomeric state of this ion channel. We discovered that a cluster of three regularly spaced phenylalanine residues in the E protein change their sidechain conformations to regulate the opening and closing of this cation channel 2. We showed that the cytoplasmic domain of E forms b-strand conformations and derived their structural models 3. Finally, we solved the atomic-resolution structure of the open state of E, providing mechanistic insights into how this cation channel is activated 4. The structure of this highly hydrophobic yet ion-conducting membrane protein not only informs drug development against COVID-19 but also gives insight into how to design functional artificial ion channels 5.

In a second major research direction, the Hong lab has made major strides in elucidating the structure and dynamics of the tau protein, which is involved in many neurodegenerative diseases, including Alzheimer's disease. Two-dimensional solid-state NMR spectra of microtubule-bound full-length tau indicate that tau anchors onto microtubules with a different domain from previously concluded 6. This microtubule-bound domain, R', lies outside known amyloid fibril cores of tau in tauopathy brains. Therefore, this important result suggests that stabilization of this functional domain might be a method to retard the formation of pathological tau fibrils. We studied how tau interacts with lipid membranes by solid-state NMR and electron microscopy, and found that high-curvature lipid membranes that contain cholesterol can trigger tau fibrils 7. We characterized the conformation of these membrane-induced tau fibrils. Finally, temperature-dependent NMR chemical shifts 8 reveal that the R2 repeat of the tau protein is conformationally more plastic than the R3 repeat. This result gives insight into the structural variations of tau fibrils in different tauopathies. These studies provide detailed mechanistic insights about how tau misfolds from an intrinsically disordered microtubule-bound protein to conformationally distinct amyloid fibrils in different neurodegenerative diseases.

Educational Outreach Programs

The PSFC's educational outreach program is dedicated to communicating research to the public, fostering interest in physical sciences, and creating opportunities for engagement for residents of the greater Cambridge area. The program is currently managed by Jennifer Scarborough, and Prof. Nuno Loureiro is the PI for the DOE Fusion Energy Sciences grant that funds a portion of the program.

On site outreach focuses on school open houses in December and April. The PSFC also plays a major role in the annual American Physical Society Division of Plasma Physics conference, including serving on the conference's education outreach organizing committee.

National outreach activities include supporting the Coalition for Plasma Science and US Fusion Outreach Teams in the production of digital assets, the results of which have included curriculum design, website maintenance, and professional development sessions.

At MIT, the PSFC participated in the annual MIT Energy night. A series of talks were presented by students and researchers during the Independent Activities Period. The PSFC hosts an annual Computational Physics School for Fusion Research, open to both MIT and non-MIT students.

Graduate students at the PSFC have been working on constructing a new demonstration device, Altator, for use in public tours and undergraduate initiatives. Support for this work has included social media and conference abstract advising for involved students.

Finally, tours of the facility are given by graduate students and are offered on a weekly basis to groups ranging from families to industry members.

Appointments

HQ:

- Ms. Julianna Mullen, Communications Officer
- Mr. David Horn, Fiscal Officer
- Ms. Jennifer Scarborough, Education and Outreach Coordinator

Magnetic Fusion Experiments Division:

- Dr. Gregorio Trevisan, Research Scientist
- Dr. Weiyue Zhou, PDA
- Dr. Stefano Segantin, PDA

- Dr. Theodore Mourtidis, PDA
- Dr Xinyan Wang, PDA
- Dr. Enrico Panontin, PDA
- Dr. Remi Delaporte-Mathurin, PDA
- Ms. Sarah Chamberlain, Mechanical Engineer
- Dr. Aaron Rosenthal, Research Specialist Limited-MIT Doctoral
- Dr. Mirela Cengher, Research Scientist, MFE
- Dr. John Boguski, PDA
- Dr. Woonghee Han, Research Specialist Limited-MIT Doctoral
- Mr. Mark Winkel, Software Developer
- Dr. Lucas Spangher, PDA
- Mr. James Danz, Software Developer
- Ms. Rachel Shulman, Fusion Education Program Administrator
- Dr. Raul Gerru Miguelanez, PDA
- Dr. Arsene Tema Biwole, PDA
- Dr. Alex Saperstein, PDA

Plasma Theory and Computation Division:

- Dr. Samuel Frank, PDA

High-Energy-Density Physics Division:

- Dr. Gabriel Rigon, PDA
- Dr. Graeme Sutcliffe, PDA
- Dr. Antonio Magnanimo, PDA
- Ms. Eleanor Russell, Research Specialist
- Mr. Ian Rudnick, Software Programmer for Scientific Data

Magnets and Cryogenics:

- Dr. Armen Sihvashi, PDA

Magnetic Resonance Division:

- Dr. Junseong Kim, PDA

Promotions

HQ:

- Ms. Jennifer James, Facilities Administrator
- Ms. Julianna Mullen, Communications Director
- Ms. Matthew Fulton, Director of Operations

Magnetic Fusion Experiments Division:

- Dr. Ethan Peterson, Group Leader, Neutronics
- Dr. Theresa Wilks promoted 8/1/2022 to Research Scientist, promoted 3/2023 to Lead Scientific Coord for DIII-D Collaboration
- Dr. Kevin Woller, Principal Research Scientist
- Dr. Nathan Howard, Principal Research Scientist
- Dr. David Fischer, Research Scientist
- Dr. Michael Wigram, Research Scientist
- Mr. James Ridzon, Mechanical Engineer II
- Ms. Corinne Cotta, Project Manager
- Dr. Sara Ferry, Group Leader Fusion Materials Components
- Dr. Pablo Rodriguez, Group Leader MFE Intgrated Modeling Group
- Dr. Cristina Rea, Group Leader Disruption Studies

Magnetic Resonance Division:

- Dr. Hang Chi, Research Scientist

Graduate Degrees

Nuclear Science and Engineering:

- Mr. Aaron Michael Rosenthal, PhD
- Mr. Woonghee Han, PhD
- Samuel Frank, PhD

Physics:

- Graeme Sutcliffe, PhD

Dennis Whyte
Director
Head, Nuclear Science and Engineering
Hitachi American Professor of Engineering