Institute for Research in Electronics and Applied Physics at the University of Maryland

A joint institute of the College of Computer, Mathematical and Physical Sciences and the A. James Clark School of Engineering

www.ireap.umd.edu

The mission of the Institute for Research in Electronics and Applied Physics (IREAP) is to advance modern science through nationally competitive research and educational programs that are interdisciplinary between physical science and engineering. The flow of knowledge between basic science and engineering at IREAP is bi-directional: we apply our basic science skills to problems of practical importance, and we apply our engineering skills to aid fundamental scientific exploration.

Many IREAP scientists have joint appointments with the Departments of Physics, Electrical and Computer Engineering, Mathematics, Materials Science and Engineering, and the Institute for Physical Science and Technology. Graduate students from these departments work on their research dissertation projects at IREAP. We also have an active undergraduate research program that allows students to explore leading-edge topics.

IREAP's main research areas are listed below:

Maryland Center for Integrated Nano Science and Engineering (M-CINSE)
www.nanocenter.umd.edu

Nanoscale science and engineering promise to change our world profoundly, from the manmade devices we experience in electronics and medical care to fundamental understanding in the physical sciences, life sciences, and engineering. Accordingly, nano is now a centerpiece of the international research landscape.

To promote and centrally support the nano science and engineering community at Maryland, the campus recently launched the Maryland Center for Integrated Nano Science and Engineering (M-CINSE) as a partnership between engineering, the physical sciences, and the life sciences. Organized as a Center within IREAP, M-CINSE is housed in the Kim Engineering and Applied Sciences Building.

M-CINSE is driven by two fundamental goals. First, it emphasizes close integration of science and engineering in nano research in order to provide an optimum engine for technology, products, and fundamental discoveries in the exciting and relatively uncharted waters of nanoscale science and technology. Second, it seeks to enhance the coherence and effectiveness of the Maryland nano community.
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Fusion Energy Research

The fire of the stars and the Sun comes from a process called fusion. To ignite this fire, hydrogen gas has to be heated to millions of degrees. If we could do this on earth, we could use such "starfire" in our power plants to generate electricity. Hydrogen is readily extracted from water - so all nations would have ready access to it. A fusion power plant would produce no greenhouse gas emissions. Developing controlled fusion on earth is a grand scientific challenge. Tremendous progress has been made over three decades in what is called "Magnetic Confinement Fusion". The

MCF concept holds the hot hydrogen plasma with magnetic fields as it is heated. This requires complex electromagnets, making it expensive. At IREAP, we have an innovative idea: we spin the magnetic fields to hold the hydrogen in centrifugally. We can then get away with simpler electromagnets and - potentially – generate fusion energy more efficiently. Our experiments to test our idea have just begun.
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Plasma Theory and High Performance Computation

Plasma turbulence plays a dominant role in many interesting problems and is a hot topic in the plasma theory group at the University of Maryland. On earth, turbulence causes unwanted rapid cooling of the fuel in the core of power plants designed to obtain energy from controlled thermonuclear fusion. In outer space, plasma turbulence regulates the rate of star formation and of accretion of matter onto black holes. We have active research projects in these areas, with particular emphases on high performance computation, advanced algorithm development, and theory. In the area of computation, Maryland scientists use millions of CPU-hours per year on the largest civilian supercomputer in the United States to model a range of processes, from microscopic scales to whole-device phenomena.
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Chaos and Nonlinear Dynamics

Fundamental ideas of chaos, a study of complex nonlinear systems that behave in unpredictable manners, find application in such diverse disciplines as biology, economics, chemistry, engineering, fluid mechanics, and physics, just to name a few. The importance of this field of study grew with a widespread availability of computers for numerical simulations and the demonstration of chaos in various systems. IREAP has active experimental and theoretical programs in the study of weather, the earth's magnetic core, lasers, particle beams, granular media, and biological systems. In 2000, US News and World Report ranked the Maryland Chaos Program number one in the US. *Contact: Dr. Daniel P. Lathrop, (301) 405-1594, dpl@complex.umd.edu*

Particle Beams and Accelerators

Particle accelerators, which produce high-energy, high-speed beams of charged particles, are ubiquitous. Small accelerators have found application in many areas of our lives: microwave ovens, radars, television sets, hospitals (for imaging and treatment), industry (for sterilization, imaging, and waste treatment), and microwave communications systems. Large ones are used for exploration of the fundamental structures of matter at the molecular, atomic and nuclear levels. Our research focuses on developing better and brighter accelerator and beam systems. Spin-off research involves such diverse areas as free-electron lasers, fusion energy, and the study of the dynamics of galaxies. *Contact: Dr. Patrick O'Shea, (301) 405-4977, poshea@umd.edu*

High Power Microwaves

The research on high power microwave generation exploits relativistic effects in beams of electrons traveling in vacuum, close to the speed of light, that generate microwaves at power levels beyond the present state of the art. One type of generator being investigated in the research is the gyrotron, which is a high power source of millimeter wave energy. One of the applications for this high power source is heating and controlling of plasma in fusion reactors. Gyrotrons may also be applied in certain types of nonlethal weapons, precision radars, communications systems, high-energy accelerators, and materials processing. There also is research done to evaluate the effect of high power microwaves on integrated electronics (e.g., computers). *Contact: Dr. Victor Granatstein, (301) 405-4956, vlg@umd.edu*

Nanofabrication with Focused Ion Beams

Focused ion beams (FIBs) are used to remove and add material at nanometer dimensions. The Laboratory for Ion Beam Research and Applications in IREAP is developing new applications for FIBs (e.g., for the repair of masks, for fault diagnosis, and for circuit restructuring). These techniques are widely used in the integrated circuits industry now, but are posing new challenges as circuit dimensions shrink into the nanometer regime. The techniques have a wide variety of research applications, some of which are pursued in our lab and include: nanostructuring metal films and ultra-thin optical fibers, fabricating nanodimension mechanical resonators, and patterning ferroelectric structures.
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Materials Processing with Plasmas

The research in materials processing with plasmas is aimed at efficient production of nanostructures using plasma processing and the use of low temperature plasmas in tailoring surface properties of materials. Plasmas have become indispensable for advanced materials processing in many high-tech industries, but not only. The microelectronics industry employs plasma processes for thin film etching, deposition, and surface modification for insulators, conductors, diamond films, and high-temperature superconductors. Plasmas are also used to harden the surfaces of cutting tools and to modify surfaces of plastics to allow paint application. The research at IREAP utilizes an array of state-of-the-art tools for plasma-based etching, synthesis or modification of materials. The majority of our research is aimed at exploring the science required for optimal plasma processing. *Contact: Dr. Gottlieb Oehrlein, (301) 405-8931, oehrlein@umd.edu*

Materials Processing with Microwaves

Processing materials with microwave energy offers significant advantages over conventional techniques. It is a promising but complex process involving the absorption of electromagnetic energy, heat transport within the material, and densification. Microwave heating, which can reach very high heating rates (150 to perhaps 1000^{o}C), enables the production of materials with superior or tailored properties that cannot be achieved with other means. The research at IREAP has been focused on understanding fundamental questions in the area and manufacturing materials with superior properties of interest to the commercial and defense industries. Examples of recent and current topics explored at IREAP include: advanced composite materials for dental applications, use of microwave for high speed drying of paper in the printing industry, and the use of ceramics and catalysts in the automobile industry for reducing pollution from exhaust emission of trucks, buses and locomotives.
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Computational MHD

Research includes the development of kinetic (phase space) algorithms for high performance computing, with an emphasis on Eulerian schemes and closure theory, with focus on direct numerical simulation of collisionless, magnetized plasma turbulence for first-principles simulation of turbulent transport in magnetic confinement fusion devices and turbulent heating and particle acceleration in astrophysical plasmas and the development of lightweight, portable, highperformance components for practical high performance parallel computing.

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Plasmas and Charged Particle Beams

Maryland's plasma physicists, both from the Department of Physics and in the Institute for Research in Electronics and Applied Physics, are conducting experimental and theoretical research on a variety of high-profile topics in the field, such as recent discoveries about the processes behind magnetic reconnection – which is what is responsible for solar flares, magnetic storms, etc. Maryland's plasma physicists are also conducting extensive fusion energy research through the new Department of Energy-funded Center for Multiscale Plasma Dynamics. The group also continues its long tradition of involvement in some of the field's most interesting topics, including hightemperature plasma physics, plasma spectroscopy, relativistic microwave electronics, high-brightness charged particle beams, laser-plasma interactions, ion beam microfabrication techniques and microwave sintering of advanced materials.
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