MIT and Electronics & Photonics Industries

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MIT and Electronics & Photonics Industries

The Massachusetts Institute of Technology (MIT) is a leading center of research and education on topics important to the electronics, optics and photonics industries such as:

- Circuits and devices
- Computers and networked devices
- Electronic, optical, and photonic materials
- Microsystems and nanosystems
- Product development and manufacturing
- Signal processing, networking and control systems

Below are brief descriptions of a selection of MIT centers, departments, groups, and labs conducting research and education in these areas. Please note that this is not a comprehensive summary of research being conducted at MIT in the topic areas listed above and the center or lab, etc., may fall into more than one category.

CIRCUITS AND DEVICES

The ***Center for Integrated Circuits and Systems (CICS)*** serves to promote closer technical relation between MIT's Microsystems Technology Lab's (MTL) research and industry, initiate and fund new research in integrated circuits and systems, produce more students skilled in the same area, address important research issues relevant to industry, and solicit ideas for new research from industry.

The ***Energy-Efficient Circuits and Systems Group*** is involved with the design and implementation of various integrated systems ranging from ultra low-power wireless sensors and multimedia devices to high-performance processors. Research spans multiple levels of abstraction ranging from innovative new process technologies and circuit styles to architectures, algorithms, and software technologies. A key focus of this group is developing energy-efficient integrated solutions for battery-operated systems.

The ***Laboratory for Electromagnetic and Electronic Systems (LEES)*** research areas include electronic circuits, components and systems, power electronics and control, micro and macro electromechanics, electromagnetics, continuum mechanics, high voltage engineering and dielectric physics, manufacturing and process control, and energy economics. The laboratory's extensive automotive electrical system research program brings together experts in digital and analog circuit design, simulation, electromechanics, micro-fabrication, power electronics, electrochemistry and economics.

The vision of the ***Medical Electronic Device Realization Center (MEDRC)*** is to transform the medical electronic device industries: to revolutionize medical diagnostics and treatments, bringing health care directly to the individual; and to create enabling technology for the future information-driven healthcare system. Specific areas that show promise are wearable or minimally invasive monitoring devices, medical imaging, laboratory instrumentation, and the data communication from these devices and instruments to healthcare providers and caregivers.

The RLE ***Millimeter-wave and Terahertz Devices Group*** develops novel devices operating from millimeter-wave to THz frequencies, and explores system-level applications enabled by those devices. Specifically, the group is working on high-performance THz quantum cascade lasers based on intersubband transitions in quantum wells; ultrafast time- and phase-resolved study of dynamics in quantum structures; sensing and real-time imaging THz systems for a variety of applications including remote sensing, biomedical imaging, and security.

The RLE ***Photonic Microsystems Group*** develops microphotonic elements, circuits, and systems for a variety of applications, including communications, sensing, and coupled microwave-photonic circuits, often enabling fundamental advantages over traditional implementations. Microphotonic devices are combined to form large-scale circuits and systems such as low power inter-chip networks, thermal imagers, nanophotonic phased-arrays for high-speed beam-steering, and optical-microwave oscillators for precision timing.

The RLE ***Quantum Photonics Group*** is developing quantum technologies in scalable semiconductor systems, building on the dramatic achievements of semiconductor technology in past decades. Goals include quantum simulators using scalable silicon photonic circuits and high-performance quantum memories based on electron spins in diamond color centers, high-speed quantum key distribution, and spin-off applications in opto-electronic devices for classical information processing. The group is also pursuing applications in precision measurements, including the development of electron spin-based timing devices and biosensors.

COMPUTERS AND NETWORKED DEVICES

The ***Advanced Network Architecture (ANA)*** group explores the future of network architectures, systems and protocols. The group's research targets core design principles and technology for large, decentralized, open-access networks, such as the Internet. ANA's projects are broad in scope—ranging from detailed TCP performance analysis to the interplay of economics and technology in future internetworks. The group is particularly concerned with the fundamental design principles that underlie tomorrow's networks—the architecture of networks. Research methods include engineering studies, software and prototype development, and the study of networks using a multidisciplinary approach.

Computer Science and Artificial Intelligence Laboratory (CSAIL) researchers have been key movers in developments like time-sharing, massively parallel computers, public key encryption, the mass commercialization of robots, and much of the technology underlying the ARPANet, Internet and the World Wide Web. CSAIL's approximately 50 research groups are organized into three focus areas: artificial intelligence, systems, and theory. Research is conducted in almost all aspects of computer science, as well as exploring revolutionary new computational methods for advancing healthcare, manufacturing, energy and human productivity.

MIT Media Lab researchers work in 24 research groups on more than 350 projects that range from digital approaches for treating neurological disorders, to a stackable, electric car for sustainable cities, to advanced imaging technologies that can "see around a corner." The focus is on the study, invention, and creative use of digital technologies to enhance the ways that people think, express, and communicate ideas, and explore new scientific frontiers.

The ***Networks and Mobile Systems Group (NMS)*** conducts research in many areas of networking: wireless networks, Internet architecture and protocols, overlay and peer-to-peer networks, sensor networks, network security, and networked systems. Projects span datacenter networks and cloud infrastructure, to mobile and sensor computing, to transport protocols and mechanisms.

The goal of the MIT ***Center for Wireless Networks and Mobile Computing (Wireless@MIT)*** is to develop next-generation wireless network technologies and mobile computing systems. The features include: An interdisciplinary focus that brings together over fifteen MIT professors and their groups conducting research in networking, communication and information theory, systems, security, hardware, algorithms, and societal applications; strong industrial partnership and an emphasis on influencing and impacting standards and products; neutral ground where companies, academics, and government representatives can discuss the future of the wireless industry.

ELECTRONIC, OPTICAL, PHOTONIC MATERIALS

The ***Center for Excitonics*** works to develop the science and technology of excitons, to reveal the fundamental characteristics of these crucial quasi-particles, and enable new solar cells and lighting technologies.

The ***MIT-MTL Center for Graphene Devices and 2D Systems (MIT-CG)*** brings together MIT researchers and industrial partners to advance the science and engineering of graphene-based technologies. The center explores advanced technologies and strategies that enable graphene-based materials, devices and systems to provide discriminating or breakthrough capabilities for a variety of system applications ranging from energy generation and smart fabrics and materials, to RF communications and sensing. The MIT-CG supports the development of the science, technology, tools and analysis for the creation of a vision for the future of graphene-enabled systems.

The ***Center for Materials Science and Engineering (CMSE)*** fosters research and education in the science and engineering of materials. Example research areas: Harnessing in-fiber fluid instabilities for scalable and universal multidimensional nanosphere design, manufacturing, and applications; simple engineered biological motifs for complex hydrogel function; and nanoionics at the interface: charge, phonon, and spin transport.

Research in the ***Crystal Physics and Electroceramics Laboratory*** is devoted to the modeling, processing, characterization and optimization of energy-related devices (sensors, batteries, fuel cells, solar/photolysis cells) and the integration of sensor, actuator and photonic materials into microelectromechanical (MEMS) systems.

The ***Electronic Materials Research Group*** at MIT (EMAT) explores silicon-based microphotonics. The group's focus is materials processing and device engineering for the creation of micron and sub-micron scale device elements for vertical integration with circuit systems. Primary applications include telecommunications, computation, and imaging.

The RLE ***Laboratory for Organic Optics and Electronics (LOOE)*** group studies physical properties of organic thin films, structures, and devices. The group's fundamental findings are applied to the development of practical optoelectronic, electronic, and photonic organic devices of nano-scale thickness, including visible LEDs, lasers, solar cells, photodetectors, transistors, chemical sensors, and memory cells. In addition to working on small-molecular-weight van der Waals bonded organic thin films, we are also examining hybrid organic/inorganic structures, polymer solids, and self-assembled materials.

The ***Materials Processing Center (MPC)*** research covers the full range of advanced materials, processes, and technologies including: electronic materials; batteries and fuel cells; polymers; advanced ceramics; materials joining; composites of all types; photonics; electrochemical processing; traditional metallurgy; environmental degradation; materials modeling; materials systems analysis; nanostructured materials; magnetic materials and processes; biomaterials; and materials economics.

The RLE ***Nanomaterials and Electronics Group*** is designing new strategies to make graphene, MoS2, h-BN and other novel 2D materials with desired physical, chemical qualities. The in-depth understanding in how to make those materials is enabling the group to develop brand new architectures for high-performance electronics and energy conversion.

The ***Photonics and Modern Electro-Magnetics Group*** research interests explore the new and exciting physical phenomena supported by material systems (e.g. photonic bandgap crystals, or various surface plasmon systems) whose optical properties are dramatically different than those of any naturally-occurring material. Examples of work include one-way waveguides, plasmons in graphene, Dirac points in Photonic Crystals, a unique way of trapping light, novel transparent displays, systems for angular selectivity of light, as well as Weyl points, and exceptional rings. The group is also interested in various topics in nonlinear optical physics.

The ***Research Laboratory of Electronics (RLE)*** major research themes include: Atomic Physics; Biomedical Science & Engineering; Energy, Power, and Electromagnetics; Information Science & Systems; Nanoscale Materials, Devices & Systems; Photonic Materials Devices and Systems; and Quantum Computation & Communication.

The ***George R. Harrison Spectroscopy Laboratory*** **Laser Biomedical Research Center (LBRC)** is engaged in research in the field of modern optics and spectroscopy for the purpose of furthering fundamental knowledge of atoms and molecules and pursuing advanced engineering biomedical applications. Research activities can be grouped in two major categories: physical science research, including atomic physics/quantum optics and chemical/molecular spectroscopy, and research in biomedical physics and engineering.

The ***Spin & Excitonic Engineering Group***'s work spans two applications: optoelectronics and digital logic. The group's optoelectronics focus includes organic light-emitting devices and low-cost solar cells. The logic focus is on building systems using spintronics to overcome perhaps the greatest weakness of conventional field-effect transistor logic—power dissipation.

MICROSYSTEMS AND NANOSYSTEMS

The ***BioInstrumentation Laboratory*** develops technologies in projects that may integrate any and all of biology, chemistry, electronics, mathematics, mechanics, and optics. Research at the BioInstrumentation Laboratory includes a number of fields including conducting polymer chemistry, medical devices, wireless instrumentation, and actuator design.

The ***Center for Bits and Atoms (CBA)*** studies how to turn data into things and things into data. Example CBA projects: have led to advances at the boundary between bits and atoms including what were among the first complete quantum computations; physical one-way cryptographic functions, implemented by mesoscopic light scattering; recoding the genome; and the additive assembly of functional digital materials.

The RLE ***Fibers @ MIT*** group focuses on extending the frontiers of fiber materials from optical transmission to encompass electronic, optoelectronic and even acoustic properties. What makes the group's fibers unique is the combination of a multiplicity of disparate materials arranged in elaborate geometries with features down to 10 nanometers. Two complementary approaches toward realizing sophisticated functions are utilized: on the single-fiber level, the integration of a multiplicity of functional components into one fiber, and on the multiple-fiber level, the assembly of large-scale fiber arrays and fabrics.

The ***Institute for Soldier Nanotechnologies (ISN)*** is a team of MIT, Army and industry partners working together to discover and field technologies that dramatically advance soldier protection and survivability capabilities. Team members collaborate on basic research to create new materials, devices, processes, and systems, and on applied research to transition promising results toward practical products useful to the Soldier. Strategic research areas include: Lightwieght, multifunctional nanostructured materials; soldier medicine; blast and ballistic threats; hazardous substances sensing; and nanosystems integration.

The ***Microphotonics Center (MPhC)*** is a research community in which industry, government, and academia collaborate to create new materials, structures, and architectures for the emerging microphotonics platform—the menu of on-chip and circuit-board level devices and components that will comprise future optoelectronics for telecommunications, computing, and sensing.

The ***Microsystems Technology Laboratories (MTL)*** supports microsystems research encompassing work in circuits and systems, MEMS, electronic and photonic devices, and molecular and nanotechnology. MTL research is enabled by a set of shared experimental facilities, as well as the Microsystems Industrial Group (MIG), and is home to the Center for Integrated Circuits and Systems, Medical Electronic Device Realization Center, Center for Graphene Devices and 2D Systems, and the Gallium Nitride (GaN) Energy Initiative.

The RLE ***Nanostructures and Computation Group*** pursues investigations in two primary areas. The first is work on photonic crystals and electromagnetism in structured media. This is work is conducted in close collaboration with the RLE ab initio Physics Group. The second primary area of investigations are in high-performance computation, from fast Fourier transforms to large-scale eigensolvers for numerical electromagnetism.

The RLE ***NanoStructures Laboratory (NSL)*** develops techniques for fabricating surface structures with feature sizes ranging from nanometers to micrometers, and uses these structures in a variety of research projects. The NSL includes facilities for lithography (photo, interferometric, electron-beam, imprint, and x-ray), etching (chemical, plasma and reactive-ion), liftoff, electroplating, sputter deposition, and e-beam evaporation. Much of the equipment, and nearly all of the methods, utilized in the NSL are developed in-house. The research projects within the NSL falls into three major categories: development of nanostructure fabrication technology; nanomagnetics, microphotonics and templated self assembly; periodic structures for x-ray optics, spectroscopy, atomic interferometry and nanometer metrology.

The RLE ***Optics and Quantum Electronics Group*** pursues fundamental investigations of ultra-scale optical and quantum phenomena to advance the technologies of lasers, large-scale photonic integration, all-optical networks, photonic bandgap devices, frequency metrology, optical communications, nano-electronic devices, biomedical optical imaging, and quantum computing. Work includes the development of solid state lasers and femtosecond pulse generation techniques which can achieve extremely high time resolutions on the femtosecond time scale, novel double-chirped mirrors, optical fiber lasers that can produce either high power femtosecond pulses, as well as short cavity fiber lasers, semiconductor saturable absorber mirrors, photonic bandgap resonators, and semiconductor quantum dots.

The RLE ***Physical Optics and Electronics Group*** works to invent new optoelectronic devices to solve problems in communications, energy, and bioengineering. The group's research focuses on the boundary of systems and device physics. Research is centered the following themes: Advanced photonics; silicon photonic integration; integrated biosystems and biosensing; thermophotonics; optical systems; and nanoparticle physics.

The RLE ***Quantum Nanostructures and Nanofabrication Group*** research focuses on pushing nanofabrication technology to the few-nanometer length-scale by using charged-particle beams combined with self-assembly. The group uses the technologies it develops to push the envelope of what is possible with photonic and electrical devices, focusing in particular on the nanowire-based superconductive photodetectors. The group's research combines electrical engineering, physics, and materials science and helps push the boundaries of what is considered possible in nanoscale engineering.

The ***Space Nanotechnology Laboratory (SNL)*** is the premier laboratory in the world for research in interference lithography and diffraction grating fabrication. The lab's expertise is in the fields of nanofabrication, nanometer-accuracy x-ray optics fabrication, assembly and metrology, ultra-high resolution lithography, nanometrology, and nano-accuracy diffraction grating fabrication. SNL's scientific focus is on high-performance space instrumentation for x-ray astronomy and the physics of the magnetosphere and the sun, but technology developed along the way has also been used to address questions in fields such as quantum mechanics (wave-particle duality) and more.

The Ultrafast Optics and X-Rays group develops novel table-top ultrafast light sources extending from the terahertz (THz) through the x-ray wavelength range. The group contributes enabling technologies for large-scale x-ray free-electron lasers (XFELs) and applies those sources in order to study ultrafast dynamical processes in matter. Principals areas of research include femtosecond- to attosecond-precision timing distribution systems, and high-energy (joule) pulsed and high-average-power (kW) diffraction-limited laser amplifiers based on cryogenic composite thin-disk lasers.

PRODUCT DEVELOPMENT AND MANUFACTURING

The MIT ***Forum for Supply Chain Innovation*** (the Forum) is composed of academics and industry members whose support allows Forum researchers to provide customer-focused solutions to design and manage the new supply chain. The rigorous approach used by the Forum guides businesses through the latest innovations in supply chain management, technology and implementation techniques. Members of the supply chain community have the flexibility and opportunity to participate in both industry-wide research into the supply chain as well as initiating their own specific research project.

The ***Industrial Performance Center (IPC)*** studies innovation, productivity and competitiveness in the U.S. and around the world. The Center specializes in bringing together multidisciplinary teams of researchers in engineering, science, management and the social sciences to carry out innovative, applied research on industrial growth and transformation, national and regional economic growth and competitiveness, and innovation performance. The IPC research program is organized around the following broad themes: energy; globalization; innovation; production.

The ***Laboratory for Manufacturing and Productivity (LMP)*** is an interdepartmental laboratory dedicated to the development and application of the fundamental principles of manufacturing systems, processes, and machines. Research and education is focused in the areas of design, analysis, and control of manufacturing processes and systems.

The ***Micro-Nano Systems Laboratory (MNSL)*** is working to better design and manufacture products with micro- and nanoscale components and structures. The design and manufacturing across scales with newly developed materials such as piezoelectric thin films, photonic crystals or carbon nanotubes (CNTs) has become increasingly complex. The group's research aims to establish a fundamental product-design-development framework to mitigate the complexity by developing adequate design and manufacturing processes for new materials and by creating new functionalities at the systems level.

The ***Operations Research Center (ORC)*** education and research draws upon ideas from engineering, management, mathematics, and psychology to apply scientific methods to decision-making. ORC faculty contribute to a wide range of application domains such as flexible manufacturing systems; financial engineering services; air traffic control; transportation systems; public services, such as urban emergency systems; safety and risk analysis in air transportation; and more.

SIGNAL PROCESSING, NETWORKING, AND CONTROL SYSTEMS

The ***Laboratory for Information and Decision Systems (LIDS)*** is committed to advancing research and education in systems and control; communications and networks; and inference and statistical data processing. LIDS research spans the full range from fundamental research and the development of new methodologies, to applications of major significance. Sample areas include: Coordination of unmanned autonomous systems; energy information systems; intelligence, surveillance, and reconnaissance (ISR) systems; network scheduling and routing; sensor networks; ultra-wideband and other emerging communications technologies.

The ***Digital Signal Processing Group (DSPG)*** focuses on the development of signal processing algorithms with the view that signal processing spans a host of application areas. While the development of meaningful and potentially useful algorithms is done best with attention to potential applications, the commitment in the group's research is to the algorithms in general rather than to specific applications. DSPG has successfully looked to application areas such as speech and image processing, sensor networks, communications, and radar and sonar.

The RLE ***Signals, Information, and Algorithms Laboratory***'s research ranges from the development of fundamental limits and architectural principles, to implementation issues and experimental investigations. Of particular emphasis has been problems arising in the context of information representation, extraction and security; statistical inference and machine learning; multimedia applications and streaming media; computational neuroscience; computational imaging and sensing; distributed computation, storage, and databases; and wireless networks.