From the Chair

The Department of Physics and Applied Physics at the University of Massachusetts Lowell continues to build new academic programs through the dedication of its faculty to teaching, research and service. Leading investigations in the areas of materials science, device-fabrication techniques and source/detector technologies, our faculty are pioneering cutting edge research in nuclear physics, advanced materials, photonic devices, terahertz technologies, biomedical photonics and atmospheric and space physics. Based on the strategic growth and academic diversity of our faculty, the department continues to posture for greater achievements in each of these areas.

Leveraging the recently articulated vision for the entire university for the upcoming years—called the “UMass Lowell 2020 Five Pillars of Excellence”—our department is a destination for the next generation of scholars and students.

Recognized for their innovative research, global engagement and methods of transformational education, the faculty members of physics lead the implementation of the university’s goal of becoming a world-class research university.

With excellent graduate and undergraduate programs supported by exemplary research and scholarships, the Physics Department has partnered with local, national and international institutions in broadening its framework of academic research. The result is a major doctoral-level research department, ranging from substantial increases in externally funded research to exciting new educational opportunities for undergraduate and graduate students alike.

The synergistic goals of academic research and education have enriched our population of alumni in prominent academic institutions, government research laboratories and industrial facilities across the nation and abroad.

Students who wish to learn more about the exciting B.S., M.S. and Ph.D. programs in physics offered at UMass Lowell should review our website, www.uml.edu/physics, or contact me directly at the university. I look forward to hearing from you.

Robert H. Giles, Ph.D.
Chair

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On the Cover:
Asst. Prof. Wei Guo prepares the Photonics Center’s molecular beam epitaxy system, which is being used to grow nanomaterials for fabricating terahertz quantum-cascade lasers and quantum-nanodot detectors. Bottom inset photos, from left: a carbon dioxide laser at the Submillimeter-Wave Technology Laboratory, the uranium core of the UMass Lowell Research Reactor and a lidar scan of a forest.
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www.uml.edu/physics
At the center of all atoms in the universe are the nuclei, which provide 99.99 percent of the atoms’ mass and form the core of all matter. Learning how these tiny systems work teaches us about hidden forces in nature that are found only inside the nuclei, forces that generate almost all the energy that powers the sun and stars and make life possible here on Earth. The atomic nuclei play a crucial role in the history of our universe through the formation of heavy elements, and all the atoms that comprise us and the world we live on were forged by the stars. Thus, we are all stardust. A century after the discovery of the nucleus, new experiments, particle accelerators and detector technologies are being developed to synthesize and study thousands of previously unknown isotopes and deepen the universality of our understanding.

UMass Lowell’s Radiation Laboratory offers a balanced portfolio of academic and applied research on this field. On the academic side, we have programs that measure and calculate the lightest nuclei from first principles, study fission fragments and explore the balance of forces that dictate what the heaviest nuclei might form and how to synthesize them. To fathom the quantum mechanics of these systems has required many new experimental and theoretical techniques to be developed, methods which have devolved into all branches of science. Applied nuclear techniques are now used in medical diagnostics and therapeutics, space science, power generation, stockpile stewardship, environmental monitoring, homeland security, geology and oceanography, as well as many other new and emerging sciences.

The university has a long history of excellence in nuclear science. The Radiation Laboratory features a 1-megawatt (MW) research reactor and a 5.5-million-volt (MV) Van de Graaff accelerator, enabling both academic and applied research avenues. The facility is especially well-equipped for neutron science, with thermal neutrons produced with the reactor and fast neutrons with the accelerator. Partnerships with industry and national laboratories are in place for developing new detector technologies. For example, new scintillating detector materials from a local Massachusetts company show great promise for fast-neutron spectroscopy, while others have an extremely fast response for gamma rays. Another avenue of research is in the development of position-sensitive germanium detectors for medical imaging, space science and homeland security with a company from Oak Ridge, Tenn.

Another new direction in interdisciplinary research is the creation of a proton microprobe, funded by a Science and Tech-
nology grant from the UMass President’s Office, which will enable the focusing of the accelerator’s proton beams down to micron sizes. Potential applications range from surface modification and characterization in materials science to biomedical research, such as mapping specific metal content in the brain that has been tied to Alzheimer’s disease.

UMass Lowell students and post-doctoral researchers lead many of these projects, working with a robust in-house infrastructure for multi-parameter data acquisition and analysis as well as digital signal processing. A new grant from the National Nuclear Security Administration is funding the R&D to develop an array of new scintillators capable of detecting and differentiating between thermal neutrons, fast neutrons and gamma rays through differences in their pulse shapes. Students also repair gamma-ray detectors for the national Radiological Assistance Program teams, who are on round-the-clock alert to address nuclear accidents and emergencies.

Medical physics and radiological health research are also key areas of study with the reactor facility. Metabolic imaging using neutrons are being carried out to significantly improve spatial resolutions and lower radiation exposures to patients compared to current nuclear

Continued on page 4
Ph.D. student Nathan D’Olympia assembles one of 16 detectors in a novel scintillator array (right) that detects and distinguishes between neutrons and gamma rays through digital pulse-shape discrimination (diagram above). The project is funded by the National Nuclear Security Agency, and the array is being deployed in-house and at national laboratories for fundamental and applied research.

www.uml.edu/research/radlab

Ph.D. student Nathan D’Olympia assembles one of 16 detectors in a novel scintillator array (right) that detects and distinguishes between neutrons and gamma rays through digital pulse-shape discrimination (diagram above). The project is funded by the National Nuclear Security Agency, and the array is being deployed in-house and at national laboratories for fundamental and applied research.

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Radiation Laboratory co-director Prof. Partha Chowdhury, second from left, and Ph.D. students Yuan Qiu, Sankha Hota, Emily Jackson and Vikram Prasher gather around the proton irradiation chamber beam line of the lab’s 5.5 MV Van de Graaff accelerator.

Radiation Laboratory co-director Prof. Partha Chowdhury, second from left, and Ph.D. students Yuan Qiu, Sankha Hota, Emily Jackson and Vikram Prasher gather around the proton irradiation chamber beam line of the lab’s 5.5 MV Van de Graaff accelerator.
Medical physicists are concerned with applying physics to medicine, particularly in therapy, diagnostic imaging and nuclear medicine. These areas employ ionizing radiation for the benefit of patients. Another area is medical health physics, which is concerned with radiation safety in a hospital setting. Qualified medical physicists are graduates of accredited programs and are certified in their specific subfields by an appropriate national certifying body.

UMass Lowell's medical physics program offers dedicated master's and doctoral degrees accredited by CAMPEP, the Commission on Accreditation of Medical Physics Education Programs.

"This is the only nationally accredited program in New England that leads to a doctoral degree in medical physics," says director Prof. Erno Sajo. "We have an active research-centered student-exchange program with Heidelberg University in Germany in which courses and thesis research are mutually accepted. In addition, we have close research and clinical training collaborations with Harvard-affiliated health-care institutions, particularly Brigham and Women's Hospital [BWH], Dana Farber Cancer Institute, Massachusetts General Hospital and Beth Israel Deaconess Medical Center, where many of their researchers also serve as adjunct faculty in the program."

The UMass Lowell–BWH collaboration, under the direction of Sajo, Asst. Prof. Wilfred Ngwa of UMass Lowell's Physics and Applied Physics Department and Asst. Prof. Piotr Zygmanski of Harvard Medical School, focuses on the application of nanotechnology to diagnostic imaging and treatment of diseases with the following concentrations.

**Nanostructured Radiation Detector Development**

A novel, low-cost nanofilm radiation detector invented by UMass Lowell and BWH researchers uses thin-film sensors to harness the energy of the radiation it detects to power itself. Unlike existing technology, the device does not need external high voltage or signal amplification to operate. It is also flexible, able to conform to curved shapes while being largely transparent to radiation, including visible light. The detector's cost per unit area is only a fraction of that of present devices. It can detect the type and intensity of ionizing radiation as well as the location of its emission, and it employs simple electronics to report digital signals that may be wirelessly transmitted. Nanofilms are suitable for new radiotraining or monitoring devices for many applications, ranging from national security, disaster relief and nondestructive testing to medical imaging and treatment.

"When fully developed, this device carries the potential to be a true in-vivo implantable radiation detector that wirelessly transmits its signal to simultaneously tell its location in the body and the received radiation dose in real time, while the radiation beam is targeting the tumor," Sajo says. "In this way, organ motion will no longer impede targeting precision."

Continued on page 6
High-Z Nanoparticle Research
In recent years there has been a rapid increase in the application of nanoparticles and nanostructures to medicine—from being used as contrast agents for diagnostic imaging to potential dose enhancement in radiotherapy, to name only a few. The perturbation of the radiation field, resulting in dose enhancement or suppression near high-Z (high-atomic number) materials has been known since almost the dawn of X-ray applications. Gold nanoparticles (GNPs), owing to their biocompatibility, can be delivered to the tumor or its blood vessels without affecting the rest of the body. However, once the nanoparticles reach adequate concentration in the target, they can boost the radiation dose and either inactivate the neoplastic cells or disrupt the tumor’s blood supply.

“GNPs have been shown to yield significant radiation-dose enhancement when irradiated with low-energy X-rays,” notes Sajo. “Before practical applications could be developed, however, detailed computations and experiments of nanoparticle behavior are necessary.”

This includes characterizing the nanoparticles’ dose-enhancement properties as well as understanding their transport through the patient’s airway and bloodstream and their biodistribution.

“Our research group has developed a deterministic method to compute dose enhancement at the nanoscale and its impact on the radiobiology of cells. This is a particularly difficult task because the computations must be done at disparate scales, spanning seven orders of magnitude,” he says. “Separately, we have published a computer code that can predict the coagulation of nanoparticles en route, from the injection site to the target tissue. The significance of this research is that optimal dosimetric scenarios can be found in a methodical way as a function of irradiation conditions and potential biological targets, which will eventually lead to realistic treatment planning methods.”

The delivery method of nanoparticles that effectively transports them to the target is an active research area in which Sajo’s group has made significant advances. In brachytherapy, radioactive “seeds” or sources are implanted in or near the tumor, giving a high radiation dose to the tumor itself while minimizing exposure in the surrounding healthy tissues.

“Led by Dr. Ngwa, we introduced a method for applying brachytherapy to prostate cancer treatment with in-situ dose painting, in which the seed spacers are coated with nanoparticle-containing polymer for sustained and locally controlled drug release and subsequent radiation therapy,” he says. “We also pioneered a similar technique in which the surface of the MammoSite balloon applicator used routinely for the treatment of breast cancer after lumpectomy is coated with micrometer-thick polymer film to provide the same controlled drug delivery.”

Nanoparticle-aided radiotherapy for eye cancers is another application of nanotechnology in which Ngwa and Sajo and their co-researchers have been active. This work investigates the dosimetric feasibility of employing GNPs or carboplatin nanoparticles (CNPs) to enhance the efficacy of radiation treatment for ocular cancers, specifically retinoblastoma and choroidal melanoma, during internal and external beam radiotherapy. The results predict that substantial dose enhancement may be achieved by employing GNPs or CNPs in conjunction with radiotherapy using kilovolt (kV)-energy photon beams. The use of the brachytherapy approach yields higher dose enhancement than the external beam kV-energy devices. However, the latter have the advantage of being non-invasive.

The team also predicted, for the first time, that by using FDA-approved concentrations of the platinum-based drug cisplatin, major radiosensitization, or enhancement, may be achieved during concomitant chemoradiotherapy (CCRT). The cisplatin is released in-situ from routinely used biomaterials loaded with cisplatin nanoparticles.

“Our computer simulations estimate that radiotherapy dose to cancer cells may be enhanced via this mechanism by more than 100 percent during CCRT,” says Sajo.

www.uml.edu/medphys
Advanced Biophotonics Laboratory
Biomedical Optics and its Applications

Assoc. Prof. Anna Yaroslavsky views microscope images with post-doctoral researcher Cecil Joseph, left, and graduate student Dennis Wirth at the Advanced Biophotonics Laboratory.

Assoc. Prof. Anna Yaroslavsky directs the Physics Department’s Advanced Biophotonics Laboratory. She is also a visiting associate professor of dermatology at Harvard Medical School, Massachusetts General Hospital and Wellman Center for Photomedicine.

The major focus of her research at UMass Lowell is on the structural and functional characterization of pathology. Other research directions she pursues in her laboratory include:

- Integration of multiple optical imaging and spectroscopic approaches (i.e., elastic scattering, polarization imaging, fluorescence and fluorescence polarization imaging and spectroscopy) to monitor biochemical and physiological processes in real time on spatially different scales;
- Modeling of light propagation in and interaction with biological tissues, liquids and cells;
- High-precision quantitative measurements of optical properties of tissues and liquids and
- Development of all-optical and multi-modal image-guided intervention techniques.

**Diagnosing Cancer at Optical Wavelengths**

Recently, Yaroslavsky developed a multispectral reflectance/fluorescence imaging technique that enables both wide-field and high-resolution imaging in-vivo and in real time. The technique holds the potential to improve the diagnosis and treatment of malignancies, including, but not limited to, cancers of the skin, brain and breast.

The technique combines the ability of CCD macro imaging to rapidly inspect superficial tissue layers over large surfaces with confocal microscopy’s ability to take images within turbid tissues at resolutions comparable to that of histology. The optical system can zoom in between these modes, allowing the wider view to direct the high-resolution view. Both modes can acquire images in reflectance, fluorescence and fluorescence polarization.

“The non-invasive system and methods we have developed in the course of this project will enable us to identify tumor margins and small tumor nests in-situ, which can lead to improved outcome of cancer treatments,” she says. “The diagnostic application of the technology can potentially replace biopsy, thus reducing morbidity and time associated with this invasive procedure.”

Yaroslavsky uses her wide-field, high-resolution optical imaging system, which has proven to be successful in dermatological oncolgy, in conjunction with a variety of dyes with specific tumor affinity. In addition to skin cancer, she utilizes wide-field, high-resolution optical polarization imaging to identify boundaries of infiltrative brain tumors.

“Our goal is to improve the quality of life and survival in patients with infiltrative brain tumors,” she says. “We seek to improve the surgeon’s ability to distinguish brain from tumor on a microscopic scale at the margins. Given the demonstrated benefit of resection for patients with a variety of intrinsic brain tumors, we hope that microscopic total resection will result in improved outcomes.”

Yaroslavsky is also currently collaborating with Prof. Robert Giles of the Submillimeter-Wave Technology Laboratory on imaging malignant and benign skin structures in the terahertz spectral range (see page 14). ■

A fluorescence confocal image (excitation wavelength = 630 nm) of a thick, fresh skin sample (size: 85 × 55 × 5 mm) with basal cell carcinoma and stained with a dye (top panel) is compared to a frozen, stained section (~5 µm thick) of the same sample. The confocal image demonstrates that straightforward comparison with the histological section is possible.

These panels show confocal fluorescence (A) and fluorescence polarization (B) images of a skin sample with micronodular basal cell carcinoma (size: 0.8 × 0.6 mm). The red arrows point to cancer cells, blue to hair follicle and yellow to inflammatory infiltrates. Comparison of fluorescence emission and fluorescence polarization images shows that cancer exhibits higher fluorescence polarization than hair follicles and inflammatory infiltrates.
The Center for Advanced Materials is a multidisciplinary research and resource facility whose mission is to develop a knowledge base in the design, synthesis, characterization and intelligent processing of advanced materials in the areas of organic polymers, ceramics, biomaterials, composites, semiconductors and electro-optic materials.

In the late 1980s and early 1990s, Prof. Jayant Kumar (Physics Department), together with the late Prof. Sukant Tripathy (Chemistry Department), explored the possibility of using naturally occurring enzymes as catalysts for the synthesis of electronic and photonic polymers and oligomers. The enzymes are obtained from renewable sources, such as horseradish or soybean hull, and the reactions are usually carried out in non-toxic solvents or solvent-less conditions, and in some cases, all the starting materials are obtained from renewable sources. Over the years, this “green technology” has been extended to the environmentally benign synthesis of materials that have applications ranging from anticancer drugs and drug delivery systems to flame-retardant materials.

“This enzymatic strategy has also opened the possibility of using electrically conducting polymers for new applications such as biosensing,” says Kumar. “In addition to using enzymes, our group has modified natural porphyrins to create a new class of biomimetic catalysts, or enzyme mimics, which can be used for a variety of applications.”

Dye-sensitized Organic Photovoltaics
Among the various methods available for harvesting renewable energy, solar cells provide the means for converting sunlight directly into electrical energy. Organic photovoltaics (PVs) have several advantages that provide the opportunity for manufacturing low-cost, flexible solar cells. Among organic PVs, dye-sensitized solar cells (DSSCs) are the most efficient ones currently available.

The DSSC technology developed by Kumar and Tripathy at the center led to the formation of Konarka Technologies Inc., a UMass Lowell spin-off company based in Lowell that was involved in the roll-to-roll fabrication of flexible solar cells. Lynne Samuelson, Ph.D. (U.S. Army Natick Soldier Research, Development & Engineering Center) supported and co-developed this technology.

“While DSSCs are promising alternatives to silicon-based solar cells, they use liquid electrolytes that make them unattractive because the electrolyte is very corrosive and can easily leak out,” says Kumar.

Kumar and his group have developed a novel technique to replace the corrosive electrolyte in DSSCs. “This technique involves photocatalytically synthesizing conjugated polymer inside the pores of the titanium dioxide nanoparticles, thus paving the way to all solid-state DSSCs,” he says.
Biocatalytic Synthesis of Oligomers of ‘Green Tea’ Flavonoids for Anticancer Drugs

The upsurge in the discovery, development and use of new materials and drugs has resulted in large-scale production of potentially toxic, carcinogenic intermediates and by-products, leading to an outburst in the number of cancer cases. Ironically, most drugs that are used to treat cancer are often synthesized in multiple steps that involve the use of carcinogenic chemicals (e.g., using pyridine in the synthesis of the commercially available anticancer drug Taxol).

“Catechins derived from natural products such as green tea exhibit chemoprotective and therapeutic properties,” says Kumar. “Unfortunately, some of the naturally occurring monomeric catechins are highly unstable, losing half their activity in a few hours.”

He and Asst. Prof. Ramaswamy Nagarajan (Plastics Engineering Department) have developed a novel strategy to oligomerize naturally occurring catechins from green tea using eco-friendly methods, creating oligo(catechins) with promising anti-tumorigenic activity.

Prof. Susan Braunhut (Biological Sciences Department) has tested the efficacy of this new family of compounds on breast cancer cell lines. The oligomers have a specific growth inhibitory effect on human cancer cells and do not affect the growth of their normal cell counterparts. In contrast to natural catechins, these oligomers are stable in excess of three months under normal conditions.

“This technology has won a number of awards, including the P3 [people, prosperity and planet] award from the U.S. Environmental Protection Agency,” says Kumar. “It is envisioned that in-vivo studies can be carried out on human breast cancer tumor-bearing nude mice in order to study the efficacy of these oligomers in a biological system before moving on to clinical trials.”

Biocatalyzed Synthesis of Novel Amphiphilic Polymers for Drug Delivery

Kumar, in collaboration with Prof. Arthur Watterson (Chemistry Department), has developed a novel chemoenzymatic approach to synthesize biocompatible poly(ethylene glycol)-based amphiphilic copolymers—under mild reaction conditions that self-assemble in aqueous media—to form polymeric nanomicelles in the range of 20 nm to 50 nm. The polymerization reaction is catalyzed by lipases (novozyme-435) in benign or solventless conditions.

“The methodology we developed is very flexible as it allows the introduction of various functionalities in the polymeric nanomicelles,” says Kumar, adding that these self-organized nanomicelles are highly efficient drug delivery vehicles for hydrophobic and partially hydrophilic drugs, both transdermally and orally, as they have the ability to encapsulate guest molecules during self-organization. “In vivo studies, made by encapsulating anti-inflammatory agents Aspirin and Naproxen in these polymeric nano-micelles and by applying topically, have resulted in significant reduction in inflammation. This lipase-catalyzed polymerization reaction has also been used for the synthesis of siloxane-based flame-retardant materials.”

Enzyme Catalysis for Synthesizing Non-Halogenated Flame-Retardant Materials

The use of flame-retardant (FR) additives for making commercial flame-resistant polymers exceeds 900,000 tons per year globally. FR additives currently used consist of halocarbons like polybrominated diphenyl ether (PBDE), phosphorus and organophosphates or metal oxides that are often toxic and can threaten both air and water ecosystems. Kumar, Watterson and Nagarajan are developing a novel class of non-halogenated FR materials based on naturally occurring Cashew Nut Shell Liquid (CNSL), which is a waste byproduct of cashew nut processing. CNSL contains a phenolic compound known as cardanol.

As part of a project funded by the Toxics Use Reduction Institute, the researchers have developed a method of using naturally occurring enzymes (peroxidases from horseradish) to polymerize cardanol. “This single-step enzymatic polymerization technique using a renewable starting material and catalyst yields polymers that show promising flame-retardant properties,” says Kumar.

In addition, polysiloxane-based FR additives have been enzymatically synthesized for applications relevant to U.S. Army needs and the civilian market as possible replacement for brominated FR materials, which have been banned in Europe for environmental pollution. The military research is conducted in collaboration between Watterson and Samuelsion and Ravi Mosurkal, P.h.D. (U.S. Army Natick Soldier Research, Development & Engineering Center).

www.uml.edu/research/cam
Photonics Center
Laboratory for Advanced Semiconductor Epitaxy

Established in 1994 by Prof. William Goodhue, now professor emeritus in the Department of Physics and Applied Physics, the Photonics Center’s mission is to support government research, regional industries and startup companies, train undergraduate and graduate students and perform industry- and government-sponsored studies. The center’s design and fabrication capabilities support various university initiatives that require innovative semiconductor-based photonic and nanoelectronic device technologies.

The Laboratory for Advanced Semiconductor Epitaxy (LASE), the main part of the Photonics Center located on the university’s East Campus, is equipped with state-of-the-art facilities for growing III–V compound semiconductor materials, fabricating devices and characterization research.

“Our lab is currently developing a large variety of III–V material-based optoelectronics devices, thanks to the incredible facilities at the Photonics Center,” says Asst. Prof. Wei Guo, who heads LASE.

Asst. Prof. Xifeng Qian, right, and Research Assistant William Sanford work in the Photonics Center’s Laboratory for Advanced Semiconductor Epitaxy (LASE), which is currently developing InAs quantum-dot lasers for silicon photonic integrations.
LA SE researchers have also grown and fabricated high-performance THz quantum-cascade lasers, or QCLs (shown with arrow), with high operating temperature and large output power. High-performance InAs quantum-dot lasers are integrated with other silicon photonics components to achieve ultra-energy-efficient and large-bandwidth optical interconnections.

Asst. Prof. Xifeng Qian, the group’s co-leader, adds: “Our devices will have great impact in the areas of solar energy, data centers, medical science and homeland security.”

The center’s research efforts focus on self-assembled nanomaterials, quantum dots and nanowires and their device applications. These devices include InAs (indium arsenide) quantum-dot lasers for silicon photonics and medical imaging applications, InAs and GaAs (gallium arsenide) quantum-dot near-IR and mid-IR detectors and InGaN (indium gallium nitride) nanowire LEDs.

“Owing to unique quantum confinement effects, these devices are advantageous in many aspects compared to their bulk counterparts,” notes Guo.

LASE is working closely with other groups and researchers on campus and in other countries. At UMass Lowell, the lab collaborates with the Photonics Center’s Multiscale Electromagnetics Laboratory (see page 13), along with the groups of Prof. Xuejun Lu and Assoc. Prof. Joel Therrien in the Electrical and Computer Engineering Department.

Quantum-cascade Laser Technology

Semiconductor quantum-cascade lasers (QCLs), due to their high power and ultra-small footprint, are often used as the sources of choice at mid-IR and terahertz (THz) frequencies in multitudes of applications, ranging from health-care and pollution monitoring to homeland security.

A collaborative project between the Photonics Center and UMass Amherst, NASA’s Jet Propulsion Laboratory and the German Aerospace Center (DLR) aims to build a sensitive, compact coherent THz heterodyne transmitter/receiver system based on THz QCLs and Schottky diode balanced mixers. The UMass Lowell part of the project is directed by physics Lecturer Andriy Danylov, Ph.D., and Prof. Emeritus Jerry Waldman. University researchers have demonstrated significant improvement in spatial and temporal coherency of THz QCLs, which opens the door for applications of the system in THz astronomy, imaging, spectroscopy and plasma diagnostics. www.uml.edu/research/photonics

Nanoscale highly uniform InAs quantum dots are grown self-assembled using the Photonics Center’s state-of-the-art molecular beam epitaxy systems.
“We are using intensive pulsed laser light to study interactions between laser pulses and matter for potential applications in nanoscience and nanotechnology,” says Assoc. Prof. Mengyan Shen, head of the Lab’s Femtosecond Laser Group. The team utilizes a femtosecond (10⁻¹⁵ sec.) pulsed laser at 400 and 800 nanometers (nm) to fabricate nanostructures on a solid surface.

“The technique is highly efficient because it is several orders faster than electron-beam writing and ion-beam etching, and is applicable to different materials,” he says. “It has applications in opto-electronics such as high-efficiency photodetectors and solar cells, as well as in biology and medical research such as micro/nano tunnels for low-friction fluidity, and nanostructured metal surfaces for other applications.”

The group has successfully developed soft nanolithography to three-dimensionally replicate silicon nanospike structures made by femtosecond laser pulse irradiation to a precision of 5 nm.

The replicated nanostructures are being used to manufacture identical chemical and gas sensors at very low cost. This research has been supported by the National Science Foundation (NSF).

“With metal nanostructures formed with femtosecond laser irradiation, a natural-like photosynthesis has shown great potential for storing solar energy and saving our environment,” says Shen.

This research has been partially supported by a seed fund from the NSF Center for High-Rate Nanomanufacturing at UMass Lowell.

He says the group is also developing techniques for time-resolved spectra measurements, in the time range from seconds to femtoseconds, for other applications in nanoscience and nanotechnology.

www.uml.edu/research/nanosciencelab
Recent developments in fabrication and metrology have enabled scientists to create a new generation of complex nanostructured materials. Research being conducted at the university’s Multiscale Electromagnetics Laboratory focuses on understanding light interactions with these materials through advanced analytical and computational studies.

“Some of the fundamental problems we are trying to solve include confinement and manipulation of optical pulses at the deep subwavelength scale,” says Prof. Viktor Podolskiy. “We are also interested in computational optics and imaging.”

Engineered composites open fascinating opportunities in molding the flow of light at the nano- and micro-scale.

“Optical properties of these composite structures, or metamaterials, depend not only on the electromagnetic properties of their constituents, but also on the arrangement and shapes of their components,” explains Podolskiy.

Multiscale Electromagnetics Laboratory
Studying Metamaterials and their Interactions with Light

A beam of laser excites a slab of uniaxial metamaterial, formed by an array of aligned metallic wires (left). The resulting oscillation of electrons in the wires excites two fundamentally different optical modes with identical polarization—a plasmon-like wave where electrons oscillate perpendicular to the wire and a polariton-like longitudinal mode where electrons oscillate along the wire (shown at right).

A subclass of metamaterials, gold nanowire arrays are rapidly becoming flexible platforms for high-performance optical applications in biosensing and opto-acoustics as well as for experimental demonstrations of novel physical phenomena that include negative refraction of light and anomalous transmission. However, despite significant previous research, the physics behind the counterintuitive optics of nanowire arrays has not been completely understood.

“Over the past several years, our group has collaborated closely with the group of Prof. Anatoly Zayats from King’s College London in trying to uncover the origin of the unusual optical response often seen in experiments,” Podolskiy notes. “We now have a working model that not only quantitatively describes the optics of nanowire structures, but also reveals how the observed optical response stems from the interaction of light with the collective oscillation of free-electron plasma propagating inside the metallic wires. Our work, pushed forward by Brian Wells, a graduate student at UMass Lowell’s Physics Department, paves the way for understanding emission and absorption of light by these fascinating complex materials.”

Podolskiy’s group also explores opportunities in developing novel imaging techniques, opened by the exponential growth of computational processing power and fueled by Moore’s law. Recent developments in optical technology allowed drastic reduction in physical size and weight of consumer photo and video cameras. Unfortunately, the same technology cannot be used to reduce the size of cameras and radars working at longer wavelengths. These imaging systems, which have multiple applications in night-vision technology, pollution monitoring, safety, security and fundamental science, remain relatively bulky and expensive.

“One of the factors that limit the size of a camera is the size of the pixel on its imaging sensor,” explains Podolskiy. “In conventional, lens-based systems, the size of this pixel is determined by the wavelength of light in the vacuum. Longer wavelength means larger pixels, which in turn means larger sensors, lenses, camera bodies, etc.”

Pixel size, however, can be dramatically reduced in materials with larger index of refraction.

“In our recent work, we demonstrate that replacing lenses with diffraction, or grating-type, elements along with the incorporation of high-refractive-index materials allows one to reduce the size of individual pixels and potentially create much-smaller, long-wavelength cameras,” he says. “As an added benefit, diffraction-based systems allow one to restore volumetric image of the surroundings—similar to hologram—based on a single exposure. Sandeep Inampudi, a graduate student in the department, is now working on exploring the limitations of diffraction-based imaging.”

www.uml.edu/research/multiscale-electromagnetics
For the past 30 years, UMass Lowell’s Submillimeter-Wave Technology Laboratory (STL) has been at the forefront of terahertz (THz) transmitter and receiver technologies and has pioneered in designing and fabricating broadband solid-state multiplier sources, high-power ultrastable CO2 and far-IR lasers, and laser/microwave hybrid systems. The lab has developed and applied these technologies in the areas of military surveillance, homeland security, medical diagnostics and scientific and academic research.

At the heart of the facility is a staff of 20 full-time researchers and 40 graduate and undergraduate students. Together they design, build and maintain a variety of high-performance solid-state and laser-based measurement systems and implement a number of novel techniques for simulating microwave radar measurements in a laboratory environment.

“Our staff represents scientists and engineers of every university discipline, and every aspect of our investigative studies requires interdisciplinary collaborations,” says STL director Prof. Robert Giles.

From the Lab to the Battlefield
In 1979, then-STL director (now science adviser) Prof. Jerry Waldman recognized that emerging THz-frequency source/receiver technologies could be used to simulate the military’s sophisticated microwave radar systems in the laboratory to obtain characteristic radar fingerprints of aircraft, ships, tanks, trucks and other tactical vehicles at low cost and very high accuracy. The concept of radar scaling is embedded in the basic equations of electromagnetism and is similar to, but more exact than, aerodynamic scaling, where wind tunnels are employed with model aircraft.

Researchers at the lab spent more than a decade engineering and fabricating scale versions of the military radars and high-precision models of actual targets, as well as measuring and analyzing the resulting radar backscatter. To reduce background stray scatter, the lab developed a unique anechoic material called FIRAM™, which is vastly superior to other materials at submillimeter wavelengths.

“As a member of ERADS, the Expert Radar Signature Solutions consortium developed by the Army’s National Ground Intelligence Center, the lab is engaged in programs that are directly applicable to the military.”
Scaling the acquisition of radar-signature data requires realistic modeling of the ground terrain as well as fabricating precisely scaled replicas of tactical vehicles. A significant portion of STL's efforts concentrate on building precision scale models of a wide variety of vehicles. The lab's success also relies on carefully designed metallic and non-metallic coatings and structures that are added to the models to simulate the full-scale vehicle's radar-scattering behavior. STL produces comprehensive libraries of target radar signatures of vehicles for use by agencies developing automated target-recognition systems.

Center [NGIC], we and our government sponsors are the only research program that uses terahertz-frequency measurement systems to collect real-world radar signature data,” says Giles in explaining the lab's unique position. ERADS also includes researchers at the Aberdeen Proving Grounds and the University of Virginia.

Today, the lab's high-resolution THz imaging systems are so sensitive that, based on the radar signatures, they can distinguish a target's non-metallic materials (rubber, fiberglass and canvas) or detect the target's presence on desert, soil, asphalt, concrete and other terrains amid ground clutter found in actual military operations (troop packs, ammunition crates, fuel containers, etc.).

To help fund STL's research, in 2001 the NGIC awarded the lab a five-year, $27 million contract—the largest single award ever given to UMass Lowell. And in 2011, the agency awarded a renewal grant to the lab worth $23 million over five years.

In addition to its work for the Army, the lab has used its unique capabilities to fulfill radar measurement requests from other Department of Defense agencies as well as defense-related laboratories and companies, including MIT Lincoln Lab, Boeing, Lockheed-Martin and Raytheon.

http://stl.uml.edu

STL Engineering Director Michael Coulombe works on a solid-state, high-resolution THz radar system.
The Biomedical Terahertz Technology Center (BTTC) was established in 2012 with the goal of translating the extensive terahertz technology expertise available at UMass Lowell to biomedical applications. Terahertz radiation, which lies between the microwave and infrared regions of the electromagnetic spectrum, is highly sensitive to water content in tissues and, unlike X-rays, it is non-ionizing and has been shown to be capable of detecting intrinsic contrast between normal and cancerous tissues. This makes terahertz radiation well suited for biomedical imaging, especially for studying colorectal cancer and non-melanoma skin cancer.

Colorectal cancer is the third most common cancer in the United States, with approximately 140,000 new cases each year. Early diagnosis and surgical removal of benign neoplastic lesions is an effective method for reducing a patient’s cancer risk and preventing cancer-related death. The current standard for screening is conventional colonoscopy, which relies on visual inspection of the lining of the intestines.

The BTTC, in collaboration with Dr. Karim Alavi in the Division of Colorectal Surgery at UMass Medical School in Worcester, is evaluating the tissues’ intrinsic contrast, combining it with the center’s existing efforts on terahertz waveguide development.

“We have shown that polarized terahertz images can differentiate between healthy and cancerous tissues,” notes UMass Lowell physics Prof. Robert Giles, the center’s director. “Moreover, the contrast ratio in this modality appears to be preserved across different patients. Thus, this technique potentially offers surgeons a tool to aid in colon-cancer screening.”

Going More than Skin-Deep
Non-melanoma skin cancer accounts for half of all cancers in the country. Of the more than 3.5 million cases diagnosed each year, about 3,000 patients die from the disease. And the cost of treatments exceeds $600 million annually. The most effective treatment usually involves Mohs micrographic surgery, in which the doctor removes the tumor by excising the tissue layer by layer, with each layer examined under a microscope to help map the diseased area. This ensures the complete removal of the tumor while at the same time preserving much of the surrounding normal tissue. While the procedure is effective, it is also time-consuming, labor-intensive and costly.

Terahertz imaging has been shown to offer intrinsic contrast—i.e., no external contrast agent needs to be applied—between normal and cancerous skin. However, its resolution is limited in wavelength to approximately 0.5 millimeters. Imaging with optical polarized light offers higher resolution (comparable to histology) but lacks the contrast. This is the reason why BTTC researchers are collaborating with UMass Lowell physics
Assoc. Prof. Anna Yaroslavsky of the university’s Advanced Biophotonics Laboratory (see page 7) to explore a combination of optical and terahertz imaging for non-melanoma skin cancer that would complement current treatment techniques.

“As a non-invasive imaging modality capable of detecting cancer margins intra-operatively, this imaging technique can eliminate the need for simultaneous histological/pathological examination of the tissue samples under the microscope, greatly simplifying treatment,” explains BTTC Project Manager Cecil Joseph.

He adds: “We are working with the Advanced Biophotonics Laboratory to develop a multi-modal optical/terahertz imaging system to aid in the demarcation of cancer margins.”

The panel shows optical photographs (a) and (d) and cross-polarized terahertz reflection images (b) and (c) of fresh normal (N) versus cancerous (C) tissues from a human colon.

Examples of waveguide-enabled high-resolution terahertz images: (a) shows an optical photograph of a tiny leaf (with a penny for scale) while (b) shows its corresponding high-resolution terahertz transmission image. In the bottom row, the optical photograph of a quarter (d) is shown alongside its terahertz-reflectance image (c).

This specimen with infiltrative basal cell carcinoma (BCC) is depicted as co-polarized terahertz reflectance image (a), cross-polarized terahertz reflectance image (b), H & E-stained histology of a 5-mm frozen section of the tissue (c), cross-polarized optical image (d) and polarized light image (e).
A team of scientists, engineers and students in the university's Lowell Center for Space Science and Technology (LoC ST) directed by Prof. Supriya Chakrabarti is conducting research to study Earth, other Earthlike exoplanets, the Milky Way galaxy and the cosmos.

“The center aims to train the next generation of scientists and engineers through hands-on involvement in all phases of the mission, from instrument development to data analysis,” says Chakrabarti. “We will also mentor and train early career professionals in space astronomy and engineering and promote hands-on undergraduate participation in space and technology research.”

In 2014, NASA awarded Chakrabarti a grant worth nearly $5.6 million over five years to develop and test an instrument system that could potentially detect young, Jupiter-size planets orbiting other stars in the Milky Way. The team’s ultimate goal is to discover Earth-like planets around sun-like stars capable of supporting life.

The instrument—dubbed the Planetary Imaging Concept Testbed Using a Recoverable Experiment – Coronagraph, or PICTU RE C—is scheduled to be launched on two separate flights, in the fall of 2017 and 2019, from the Columbia Scientific Balloon Facility in Fort Sumner, N. M., where it would be carried aloft to the edge of the atmosphere using helium balloons several stories tall.

“PICTU RE C will enable us to learn about the disk of dust, asteroids, planets and other debris orbiting the stars and gain a better understanding of the processes and dynamics that formed our own solar system,” explains Chakrabarti, who is the principal investigator for the NASA study. “But in order for us to do this, we have to fly the instrument to altitudes of about 120,000 feet to get above most of the Earth’s atmosphere. Atmospheric turbulence distorts and blurs our image of the stars.”

Aside from Chakrabarti, the other members of the UMass Lowell team are physics Asst. Prof. Timothy Cook, who is the project’s co-investigator; graduate student Kuravi Hewawasam and post-doctoral associates Susanna Finn and Christopher Mendillo. Other collaborators include researchers from NASA’s Jet Propulsion Laboratory and Goddard Space Flight Center, Caltech, MIT, the Space Telescope Science Institute and the University of California Santa Barbara.

**Employing Cutting-Edge Technologies**

Five stars have been selected as test targets for the two missions, representing a wide range of brightnesses, ages, distances and spectral types: Alpha Lyrae (Vega), Sigma Draconis, Epsilon Eridani, Alpha Aquilae (Altair) and Tau Ceti.

The mission will allow PICTU RE C to test its coronagraph, a specialized optical imaging system coupled to a 24-inch-diameter telescope designed to “mask,” or block out the direct light from the star so that faint objects very close to the star—such as planets, asteroids and interplanetary dust, which otherwise would be hidden in the star’s bright glare—can be studied in great detail.

The scientists expect the instrument to be rocked by turbulence in the upper atmosphere. To keep the coronagraph aimed precisely at the target, the instrument is mounted on a special gimbal platform in the balloon’s gondola that can compensate for any unwanted movements. PICTU RE C will use the platform in conjunction with an onboard active optical pointing control system.

“Chris Mendillo designed and built this fine-pointing system and had validated it on an earlier mission,” notes Chakrabarti. “It can provide the coronagraph a pointing accuracy of 5 milliarcseconds, which is comparable to that of the Hubble Space Telescope, or even better.”
To the Threshold of Space

The researchers have also used sounding rockets to lift instruments weighing more than 1,000 pounds to altitudes of up to more than 900 miles above the ground. These rockets are not powerful enough to boost their payload to orbital speed—after scientific observations have been completed, the payload falls back to Earth, deploying a parachute to slow down its descent and allow for a safe recovery of the payload on the ground.

“Prof. Cook and I have a combined 40 years of experience launching experiments aboard sounding rockets, and we have successfully launched 20 of them during that time span,” says Chakrabarti.

For example, in November 2012 Cook launched another NASA-funded instrument, called IMAGER, aboard a sounding rocket to observe the spiral galaxy M101 and measure the properties of its dust. Cook and his team are now analyzing the data from the IMAGER flight to understand how ultraviolet light is absorbed by the dust, how it heats and destroys the dust and how new dust is formed.

Sounding rockets and high-altitude balloons offer a relatively inexpensive way to verify the flightworthiness of the science hardware before they are placed into orbit, which costs tens of millions of dollars per launch. However, scientific observations aboard sounding rockets are limited to about seven minutes or so before the rocket’s payload falls back to the ground.

“The face-on spiral galaxy M101 in Ursa Major, shown in this photo taken by the Hubble Space Telescope, was the target of Asst. Prof. Timothy Cook’s rocket experiment in 2012.”

“Prof. Cook, fifth from left, poses with Supriya and Joanne Chakrabarti, Meredith Danowski, Christopher Mendillo, Brian Hicks, Jason Martel and Ewan Douglas at the White Sands Missile Range in New Mexico. In the background is the Black Brant IX sounding rocket used in the 2012 launch.”

“For some experiments, the several hundreds of seconds of data from above the atmosphere that a sounding rocket provides are just not enough,” explains Chakrabarti. “In the case of PICTURE C, a high-altitude balloon offers a better way to lift the instrument to the threshold of space—above 99 percent of the atmosphere—and keep it aloft for hours or days, depending on the weather conditions as well as the launch site, the type of balloon, the time of day, etc.”

At the end of the mission, ground controllers would send a command to release the payload from the balloon, and the payload free-falls to the ground. A parachute is then deployed to slow it down and allow the payload to land gently for reuse in the next mission.

www.uml.edu/research/LoCSST
EXCEL: An Experimental Center for Environmental Lidar
Applications in Terrestrial Ecology, Oceanographic Bathymetry and Aerodynamics

EXCEL is a multi-campus center sponsored by the UMass Science & Technology Initiatives Fund. EXCEL’s mission is to develop and use state-of-the-art lidar (light detection and ranging) technologies for research and environmental applications relating to forestry, coastal wetland mapping, coastal changes and offshore wind and turbulence. The center will also provide field-mapping and data-analysis services to both public and private sectors.

The EXCEL team brings together existing expertise and resources within the UMass system (Lowell, Amherst, Boston and Dartmouth campuses), while leveraging its collaborations with industry and government partners to further develop advanced lidars for environmental remote-sensing.

“This effort will be supported by a comprehensive data-analysis and synthesis infrastructure. In addition, we will develop prototypes and test and evaluate new sensors and instrument technologies,” says UMass Lowell physics Prof. Supriya Chakrabarti, the center’s director.

EXCEL will utilize lidar technology to address the following critical areas of interdisciplinary environmental sensing:

Terrestrial ecology. Terrestrial lidar has been used in many applications, particularly in monitoring forests and the erosion of geologic bluffs as well as in verifying carbon biomass. A team assembled by Chakrabarti and Asst. Prof. Timothy Cook of UMass Lowell in conjunction with UMass Boston and Boston University has been at the forefront of research in this field. The team is currently completing the field-testing of the Dual-Wavelength Echidna Lidar (DWEL) funded by the National Science Foundation (NSF). DWEL operates at 1064 and 1548 nanometers to separate woody biomass from photosynthesizing foliage and provides 100-meter hemispherical scans of forest canopy structures.

Oceanographic applications. Oceanographic bathymetric lidar can be applied to the problem of sediment-transport processes associated with coastal change and sea-level rise.

“Coastal erosion both as a chronic issue associated with rising sea levels as well as due to major events such as Hurricane Sandy in 2012 or the Blizzard of 2013, will have increasing impact on the Commonwealth’s economy,” notes Chakrabarti.

A team led by UMass Dartmouth that includes Profs. Cook and Chakrabarti is developing critical tools in the maintenance, restoration and protection of the state’s coastline, with broader impacts to all coastal regions facing sea-level rise and coastal change.

Wind energy generation. Wind-turbine aerodynamics directly contributes to efficiency and reliability. One of the biggest challenges is characterizing the turbines’ aerodynamic behavior, which is needed to better understand their fundamental behavior. The use of atmospheric lidar to quantitatively characterize the wake of full-scale wind turbines would eventually lead to improved designs of turbine and commercial scale wind farms.

UMass Lowell mechanical engineering Asst. Prof. David Willis and Cook are leveraging existing research efforts in wind energy at the Lowell and Amherst campuses to become a leading environmental sensing and impact-assessment resource in the field. UMass Lowell recently received funding from the NSF to establish an Industry/University Cooperative Research Center for Wind Energy Science, Technology and Research (WindSTAR).
The focus of the Astronomy and Astrophysics Group is the multi-wavelength (infrared, optical and X-ray) study of accretion-powered X-ray binaries, or XRBs. These fascinating star systems consist of a compact companion (neutron star or black hole) and a normal star locked in orbit around each other. The normal star is slowly consumed by its companion, whose strong gravity is able to capture gas from the star and then crush it to nuclear density, releasing tremendous amounts of energy in the process. As a result, the compact object shines brightly in X-ray as it feeds.

“By observing the X-ray emission, we can study fundamental astrophysical properties that are unobtainable at other wavelengths,” says Silas Laycock, Ph.D., a lecturer in the Department of Physics and Applied Physics and the group’s leader. “Meanwhile, optical spectroscopy enables us to study the stellar companion and trace its orbital motion. X-ray binaries simultaneously probe extreme physics and provide a unique window into stellar and galactic evolution.”

One of the group’s projects is a time-domain survey of X-ray pulsars—spinning neutron stars whose magnetic fields channel the accretion stream to their poles and emit regular pulses as their X-ray beams rotate around the sky.

“Using thousands of satellite observations of about a hundred known X-ray pulsars accumulated over more than a decade, we are building the most comprehensive library of pulse profiles,” notes Laycock. “By developing computer models of the pulsars’ beams and matching them to the X-ray data, we will shed light on the structure of the magnetospheres of neutron stars and their dramatic changes over time.”

Black holes and neutron stars are the relics of the most massive and short-lived stars—the same stars that die in supernovae—which sculpt and enrich the interstellar medium and create the chemical elements needed to seed life. These natural particle accelerators are visible in X-rays at intergalactic distances. The group is using X-ray astronomy satellites (NASA’s flagship Chandra X-ray Observatory and Europe’s XMM-Newton) along with optical telescopes (such as the 8-meter Gemini telescope) to discover and monitor X-ray binaries in nearby dwarf galaxies.

“Different galaxies seem to have produced XRBs in large numbers, but at different points in their evolution, and curiously these binaries involve different types of stars and different ratios of black holes to neutron stars,” Laycock explains. “By studying galaxies of different ages all the way down to the very youngest—a mere few million years—we are unlocking the secrets of what happens in this brief but influential period of star formation.”
UMass Lowell Astronomical Observatory
Research Facility Offers a Window to the Universe

The UMass Lowell Astronomical Observatory, located on top of Olney Hall on North Campus, allows students to explore the skies above Lowell, enabling them to study the Moon, planets, stars, galaxies, nebulae and other deep-sky objects using a robotic, research-grade optical telescope.

The observatory features a 10-inch Meade LX200GPS Schmidt-Cassegrain telescope housed inside a compact fiberglass dome and equipped with a highly sensitive SBIG ST-7XMED astronomical CCD camera.

“The camera is capable of making precise measurements of the stars’ brightness,” says Silas Laycock, Ph.D., a lecturer in the Department of Physics and Applied Physics. “An integrated filter wheel enables students to measure the colors and surface temperatures of stars. The CCD detector’s very low read noise allows students to obtain long-duration exposures to record faint targets.”

Students can also use the observatory’s SBIG spectrograph to disperse light from astronomical objects with a diffraction grating to study the overall energy distribution and absorption/emission lines of elements and molecules present in the objects.

“A star’s spectrum reveals its surface temperature, chemical composition, magnetic field strength, surface gravity, gas density and motion through space by virtue of Doppler shifts in its spectral lines,” explains Laycock.

“Interestingly, we can determine a binary star’s radial velocity toward and away from Earth and, by observing it over many nights, determine the orbit of its companion star—a classic foundation of astrophysics,” he says. “Perhaps more remarkably, we can measure the redshifts of distant galaxies, reproducing astronomer Edwin Hubble’s landmark discovery that led to the Big Bang theory.”

The observatory is made possible through the generosity of UMass Lowell alumnus David Riccio ’05, who is a professional technician in the Physics and Applied Physics Department. Riccio, who has a life-long interest in astronomy, donated the telescope, dome, camera, spectrograph, filter set and associated hardware and software—worth a total of about $23,000— to the university in 2011. The department spent about $10,000 for miscellaneous electronics and the observatory’s installation on the roof of Olney.

“I wanted to provide our students with hands-on observing experience using the same type of equipment and technologies employed at today’s professional observatories,” Riccio says. “The goal is for students to be able to control the telescope from anywhere, as long as there is Internet access.”

Observing the Solar System and Beyond

Students will use the observatory to pursue capstone and graduate projects in close collaboration with the physics faculty. Faculty members will also use images, spectra and other data collected with the telescope to enhance their lectures.

Laycock plans to use the telescope to teach physics students enrolled in stellar astrophysics and astronomy, galactic astronomy and cosmology and exploring the universe, the last a general elective subject for non-physics majors.

“Undergraduates will rediscover for themselves landmark discoveries in astronomy and astrophysics,” he says. “Compelling objects that students can study include the Sun, Moon, the planets and their moons, asteroids, variable stars, pulsating stars, eclipsing binary stars, supernovae, star clusters, nebulae and galaxies as well as exoplanets, which are planets orbiting other stars.”

Observing at Radio Wavelengths

Sharing the roof of Olney Hall is the UMass Lowell Radio Telescope, which was designed and built by MIT’s Haystack Observatory as a prototype for its long-running Small Radio Telescope project. It consists of a 2.3-meter-diameter steerable dish antenna that feeds signal to a sensitive receiver/amplifier. The signal is analyzed with digital processing software.

The radio telescope has a frequency range of 1.37 to 1.80 gigahertz, which is ideal for studying the Sun and exploring the Milky Way’s structure and dynamics as well as for detecting exotic astronomical radio sources such as supernova remnants, pulsars and black holes like Cygnus X-1.

“A radio telescope is an excellent teaching tool because it involves the combined technologies of microwave engineering and digital computing,” says Laycock. “However, our radio telescope needs substantial renovation.”

www.uml.edu/research/observatory
Established in 2014, Space Science Laboratory (SSL) continues the UMass Lowell heritage of conducting scientific investigations in space weather, magnetospheric physics, ionospheric physics and radio science. Through research grants from NASA, the NSF, Air Force Research Laboratory and NATO, the SSL has developed strong engineering expertise in designing autonomous remote-sensing systems for spacecraft platforms. Computer scientists at SSL also build intelligent systems for automatic interpretation of acquired data and operate the Global Ionospheric Radio Observatory (GIRO), a worldwide network established in 1969 to conduct radio-wave experiments in Earth’s ionosphere using radar-sensing instruments, or “digisondes.” For more information, go to http://giro.uml.edu.

Other fields of research include:

**Very low frequency in space.** A self-tuning VLF transmitter will drive an 80-meter dipole antenna onboard the U.S. Air Force Research Laboratory’s DSX satellite to study the effects of space plasma on the radiation process as well as the effects of the radiation on the trapped electron population. SSL scientists designed the power transmitter and a narrow-band receiver in cooperation with the Southwest Research Institute and Stanford University. The system will measure the local plasma density and automatically tune the antenna circuit for maximum radiation.

**Plasma modeling and simulation.** Ground-based and space-borne observations have established a global picture of the space-plasma environment. The modeling and simulation, combined with observations, has proven to be a powerful tool for understanding the physical and chemical processes in space plasma and in predicting space weather. The SSL undertakes empirical modeling and computer simulation of antenna-plasma interaction, magnetosphere-ionosphere-thermosphere coupling, ionosphere and magnetosphere density distribution and plasmasphere depletion and refilling.

**“Killer” electrons.** Featured at #37 in Discover magazine’s “Top 100 Science Stories of 2007,” the discovery of the physical mechanism responsible for accelerating electrons trapped in Earth’s Van Allen radiation belts to “killer” velocities—as much as 94 percent of the speed of light—has been credited to SSL researchers.

**Space weather.** This is an emerging field of research that applies knowledge gained in space physics and space-plasma physics to forecast weather conditions in space. Constellations of satellites are to be launched into strategic orbits and global computer-simulation codes are being developed. The Space Science Lab has developed models that are being used in the National Space Weather Services.

**NECTAR.** The Non-linear Error-Correcting Technique for Associative Restoration employs recurrent neural network optimizer to infer global picture of dynamic processes in plasma from the available fragments.

**GAMBIT.** The Global Assimilative Model of Bottomside Ionospheric Timelines is a database of past space-weather events that provides a detailed look at ionospheric plasma dynamics during the most interesting periods of the Sun–Earth system activity.

http://ulcar.uml.edu
The mission of the university’s Haiti Development Studies Center (HDSC) is to engage science and engineering faculty and students in philanthropic research focused on solving life-threatening issues faced by citizens in the world’s poorest countries.

“These countries, identified by the international banking system as having Third- and Fourth-World status, suffer from over-population, soil erosion, drought and famine,” says Prof. Robert H. Giles, the center’s director. “However, the lack of potable water and sufficient food supplies are not the only barriers to economic development in the most densely populated regions of the world. Fragmented politically and socially, the general population in these labor-rich countries face environmentally induced health issues due to chemical and biological contaminants in the air, water, soil and locally grown food.”

Whether human-caused or naturally occurring, these contaminants are crippling communities in impoverished countries.

“They are compromising the health of the indigenous population, defeating foreign investment for positive change and eliminating possible global participation of the local work force,” notes Giles. “Only treating the contaminant-induced societal symptoms, international aid agencies developing programs to support public work’s projects and medical clinics are often exhausted before sustainable change occurs in the poorest regions.”

In response, Giles established the HDSC in 2013 in the port city of Les Cayes in Haiti, which he describes as a Fourth-World country with First-World possibilities.

“I believe Haiti has First-World potential by virtue of its geographical location in the Caribbean,” explains Giles, who has more than 10 years of experience working in Haiti and is now fairly fluent in Creole. “Having a permanent residence within the community will enable visiting UMass Lowell faculty and student researchers to perform health and environmental assessments across the Southern Department of Haiti.”

The HDSC employs a full-time staff comprised of an American program coordinator, Connie Barna, who resides in the facility, and a six-member team of Haitians who are responsible for housekeeping, ground transportation, security and all in-country resource requirements.

Giles and Barna advise on projects involving regional and community-based concerns and opportunities while university student interns and their faculty advisers may remain in Haiti over extended periods to gather and document the scientific data.

**Life-saving Research**

With a focus on scalable and sustainable technologies for impoverished regions of the world, faculty and students at the center are developing programs to decrease the impact of environmental contaminants and assess the efficacy of those programs.

Projects being undertaken at the center include:

- Implementing bio-sand water-filtration systems as well as investigating pilot studies to identify biomarkers for recognizing contaminated water;
- Developing low-cost, spectroscopic monitoring techniques and the instrumentation for supporting laboratory analysis;
- Investigating affordable solar energy systems and recycling of combustible waste materials as biomass fuels;
- Establishing a directed-studies, college-preparatory program for select Haitian students in the physical sciences with service-based team training on engineering projects and laboratory skills and
- Conducting an Honors College Seminar Series for science and engineering students focused on impoverished countries and the process of developing international research projects to explore scalable and sustainable solutions that address regional concerns.

“As an at-home and abroad program, internationally collaborative research projects not only challenge the critical thinking skills of our students, but also raise their awareness of socio-economic and regional factors that hinder positive world change,” says Giles.

He adds: “Education is central to our mission. For students and teachers, the opportunities to make a difference in people’s lives are limitless. The center is a place where research is a pathway to critical change.”

For more information on how to help the Haiti Development Studies Center, e-mail Giles at Robert_Giles@uml.edu.
Physics Faculty and Expertise

Robert H. Giles, Ph.D., UMass Lowell, 1986  
Department Chair  
*Experimental laser physics, optics*

Supriya Chakrabarti, Ph.D., University of California, Berkeley, 1982  
*Astronomy and astrophysics*

Partha Chowdhury, Ph.D., SUNY Stony Brook, 1979  
Graduate Program Coordinator  
*Nuclear structure, detector development, applied nuclear science*

Timothy A. Cook, Ph.D., University of Colorado, 1991  
*Astronomy and astrophysics*

Andriy Danylov, Ph.D., UMass Lowell, 2010  
*Photonics*

Clayton S. French Jr., Ph.D., UMass Lowell, 1985  
Radiological Science Program Coordinator  
*Radiological science and protection*

Wei Guo, Ph.D., Brown University, 2008  
*Nanomaterial growth and optoelectronic device applications*

Jayant Kumar, Ph.D., Rutgers University, 1983  
*Materials science, optoelectronic properties of materials, optical spectroscopy*

Silas Laycock, Ph.D., University of Southampton, 2002  
*Astronomy*

Nikolay Lepeshkin, Ph.D., New Mexico State University, 2001  
Undergraduate Program Coordinator  
*Optics*

Christopher J. Lister, Ph.D., University of Liverpool, 1977  
*Nuclear structure, detector development, applied nuclear science*

Arthur Mittler, Ph.D., University of Kentucky, 1970  
*Experimental nuclear physics, physics education*

Wilfred Ngwa, Ph.D. University of Leipzig, 2004  
*Biophysics, medical physics, health physics*

Viktor A. Podolskiy, Ph.D., New Mexico State University, 2002  
Department Assistant Chair  
*Electromagnetism, photonics, nanoscience, metamaterials*

Xifeng Qian, Ph.D., UMass Lowell, 2009  
*Photonics*

Andrew Rogers, Ph.D., Michigan State University, 2009  
*Nuclear astrophysics, nuclear structure*

Erno Sajo, Ph.D., UMass Lowell, 1990  
Medical Physics Program Coordinator  
*Nuclear science, medical physics*

Kunnat Sebastian, Ph.D., University of Maryland, 1969  
*Particle physics theory, theoretical atomic physics*

Mengyan Shen, Ph.D., University of Science and Technology of China, 1990  
*Nanoscience and technology, condensed matter and optics*

Paul Song, Ph.D., University of California, Los Angeles, 1991  
*Space Physics*

Mark Tries, Ph.D., UMass Lowell, 1999  
*Radiological science and protection*

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