Nick Holonyak Jr Micro and Nano Technology Laboratory

STRATEGIC VISION 2030

EXECUTIVE SUMMARY

LEGACY

The Holonyak Micro and Nanotechnology laboratory has a strong historical legacy that stretches back to the era in which John Bardeen established semiconductor research on the Illinois campus, and Nick Holonyak's foundational work on semiconductor lasers and LEDs. HMNTL is a central intellectual hub for 42 faculty and more than 300 students from a large number of UIUC departments and schools. The unique combination of in-house fabrication facilities and strong legacy of multidisciplinary collaborative research enables the highest world-class level of impact that spans from ultra-high-speed electronic and photonic devices, wireless and optical communications, energy-efficient lighting systems, quantum computing, biosensors, fundamental life science research, translational clinical practice, and many others.

VISION

Looking into the 10-year horizon, we envision that HMNTL, building on this legendary cross-disciplinary legacy, can become a national and world leader in several emerging research areas with the highest societal and technological impact. The major research Thrusts are envisioned in high-speed electronics, photonics, quantum technologies, nanoscale low-power computing devices, power electronics, translational biotechnologies and neurotechnologies.

EDUCATION

As an integral part of the UIUC enterprise for research training, we envision that HMNTL will expand its role into education and training in non-traditional cross-disciplinary fields that are beyond the responsibilities of individual schools and departments. Besides addressing the nation's STEM competency gap for future generations, the educational component will also provide a renewable funding source for HMNTL to grow.

FACILITY

Since construction of the Microelectronics Laboratory in 1989, the lab's central feature has been the shared use semiconductor and biotech cleanroom facilities. However, with aging 30-year old infrastructure and base equipment that exceeded its lifetime limits, HMNTL needs immediate and significant upgrades. While upgrades and repairs will keep the facility operational, a more ambitious far-reaching vision for HMNTL is needed to position it as the leading academic nanotechnology research laboratory in the country.

To support our vision, we plan to establish a HMNTL-dedicated $70M endowment fund, expand the mission of the HMNTL into education and training, and secure large-scale center-type government funding. To bring about these changes, we will make fundamental changes to the lab organization and management, while strengthening our ties with other independent research units and departments across the campus.

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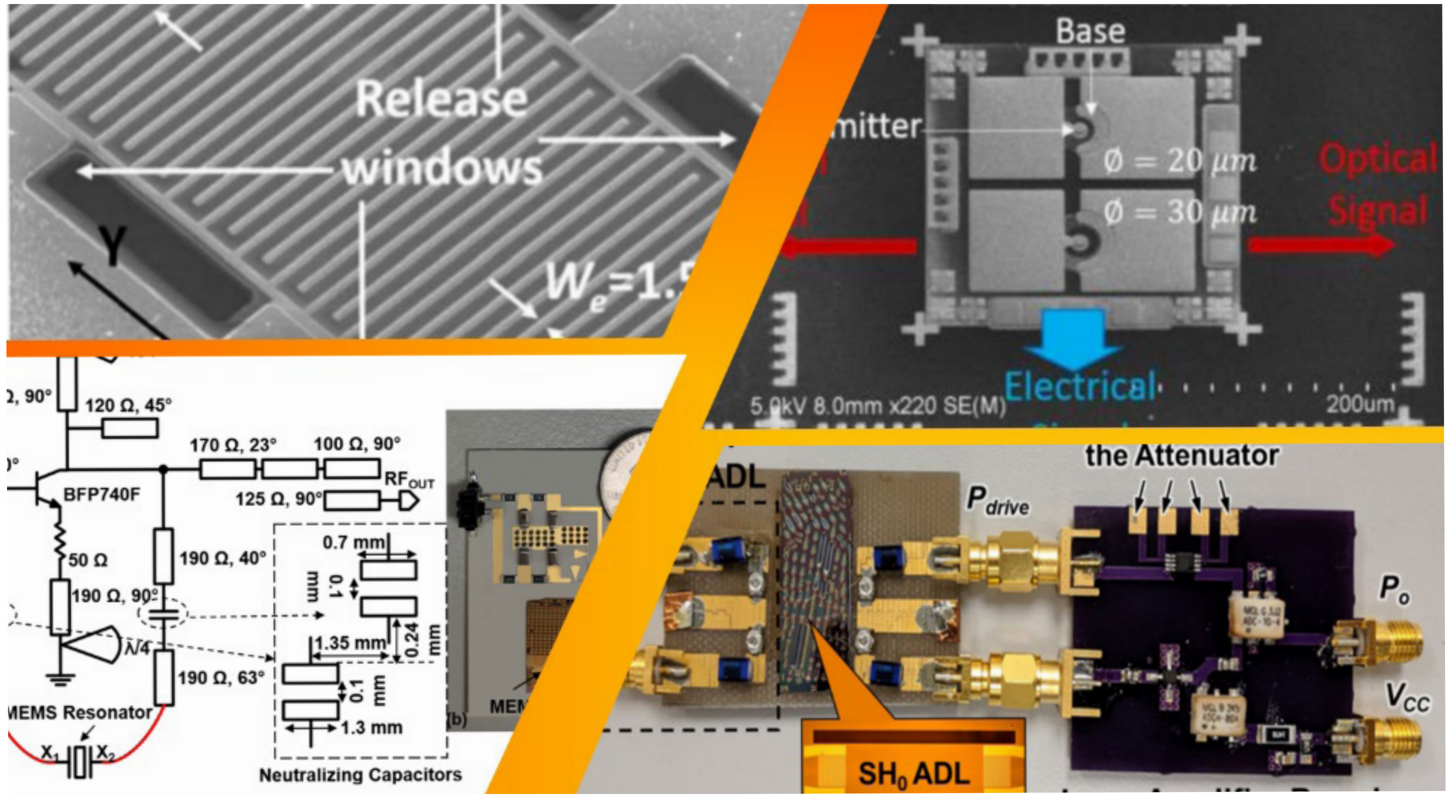
ULTRA HIGH SPEED ELECTRONIC SYSTEMS



VISION

Our society is at the cusp of a new era where wireless technology is ubiquitous and capable of addressing some of the biggest challenges related to transportation, health care, manufacturing, and how we interact and communicate with each other. Reconfigurable autonomous machines and low-cost, battery-powered sensors that pre-process data in the field and communicate with their near-real-time digital counterparts are quickly becoming prevalent. There exists a rapidly growing demand for higher speed and higher fidelity wireless communication anytime and anywhere. Wireless systems of the future will support complex computational models that predict the movement of a wildfire, hurricane, and even the occurrence and spread of pandemics—such models will have a profound societal impact not possible with present-day technologies.

The national roll out of the fifth-generation (5G) mobile network has created innovative research opportunities in areas of artificial intelligence (AI) at the edge, scientific instrumentation, and the design of novel materials with targeted electronic and magnetic properties. Moreover, 5G connectivity will enable operation of instruments in remote and extreme environments, characterized by sudden and large excursions in environmental conditions. Accessing and observing data from such extreme environments will be a major breakthrough for scientific investigations related to energy generation, national security, and space.

LEGACY

HMNTL has been at the forefront of high-frequency device fabrication and testing with significant contributions in the domain of III-V compound semiconductors. The pseudomorphic heterojunction bipolar transistor (PHBT) was invented by faculty at HMNTL, and record high-speed performance exceeding 800 GHz in InP PHBTs was also demonstrated by our faculty. Our legacy includes both technology innovators and leaders of major technical societies, which are the key differentiating factors for the University of Illinois.

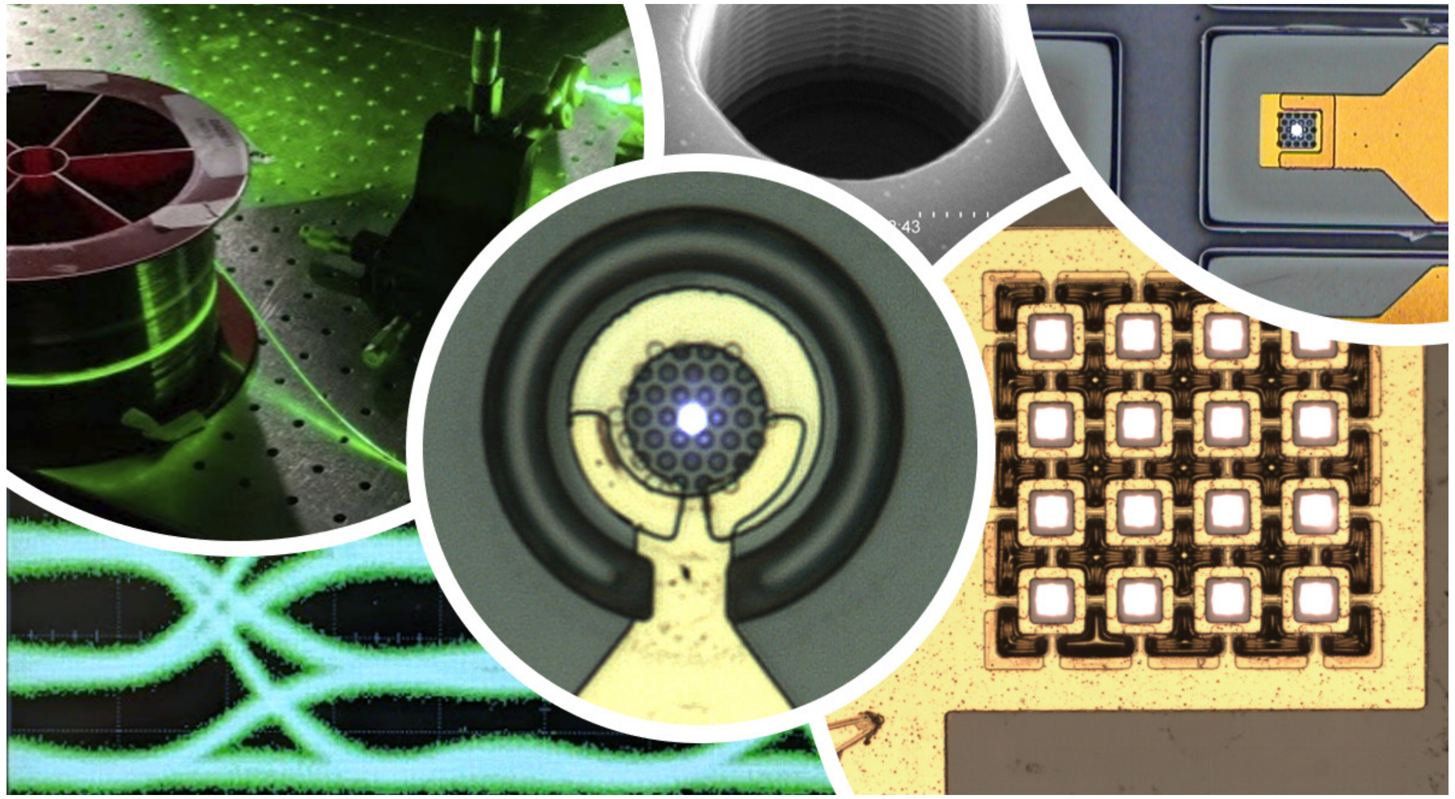
> **There is a rapidly growing demand for higher speed and higher fidelity communication anytime anywhere**

FUTURE

Within a 10-year horizon, work on wide bandgap (WBG) and ultra-wide band gap (UWBG) materials, advanced fabrication processes for heterogeneous integration, and high-speed characterization of devices under extreme conditions will drive systems advances for 5G and beyond.

The continued expansion of 5G into near-THz wireless technologies with abundant speed, fidelity, and reconfigurability will require non-traditional materials capable of efficiently processing signals at such high frequencies. For example, wide bandgap (WBG) and ultrawide bandgap (UWBG) materials, including GaN, AlN, diamond, and Ga2O3, have the foundational capability to meet the high power and high frequency requirements of 5G and near-THz networks. These materials are also well positioned to be used in sensors to collect data from extremely harsh environments, where legacy materials are unable to operate. Along with WBG and UWBG materials, new dynamic materials for high-Q filters and smart antennas that support a miniaturized form-factor will be the building blocks of next-generation, near-THz communication and sensing infrastructure. The link between materials processing, device design, and component reliability will be necessary for the future systems insertion of non-canonical device structures. It is ultimately the unification of the physics of reliability, device scalability, and computational framework that will create an ecosystem of new material systems ready for deployment in 5G and beyond infrastructure.

PHOTONIC TECHNOLOGIES



VISION

Photonic systems represent the foundational technology for digital distribution of data across oceans, cities, and datacenters, and thus are at the core of the Information Age. In addition to data communications, photonics is increasingly used to generate new data using distributed optical sensors. High-speed, low energy consumption, low latency optical networks are also required for applications including networking of self-driving vehicles, virtual presence environments for businesses, entertainment, and healthcare, transmission of multi-sensorial signals, Internet of Things networks that respond to environments and motion, and augmented reality. The continued development of compound semiconductor lasers, high speed electronic devices, and photonic integrated circuits will thus be necessary. Perhaps the most critical need to be addressed by photonic systems is energy sustainability to fundamentally reduce the energy cost of generating and successfully transmitting vast amounts of data.

LEGACY

HMNTL has had historic strength in photonic materials, processes, and devices. HMNTL-affiliated faculty have been honored by awards and recognition by professional societies, the National Academy of Engineering, and global science prizes for their contributions to semiconductor photonic device research, including extensive and significant research on semiconductor light emitters and laser diodes. Furthermore, photonic research with origins at HMNTL generated cohorts of PhDs that have profoundly contributed to U.S. and world industry. With growing demand for an educated workforce with advanced degrees in photonics, the HMNTL photonics legacy is a major differentiation factor for the University of Illinois. We are well poised to continue our leadership position, but only with an appropriate investment in people and infrastructure.

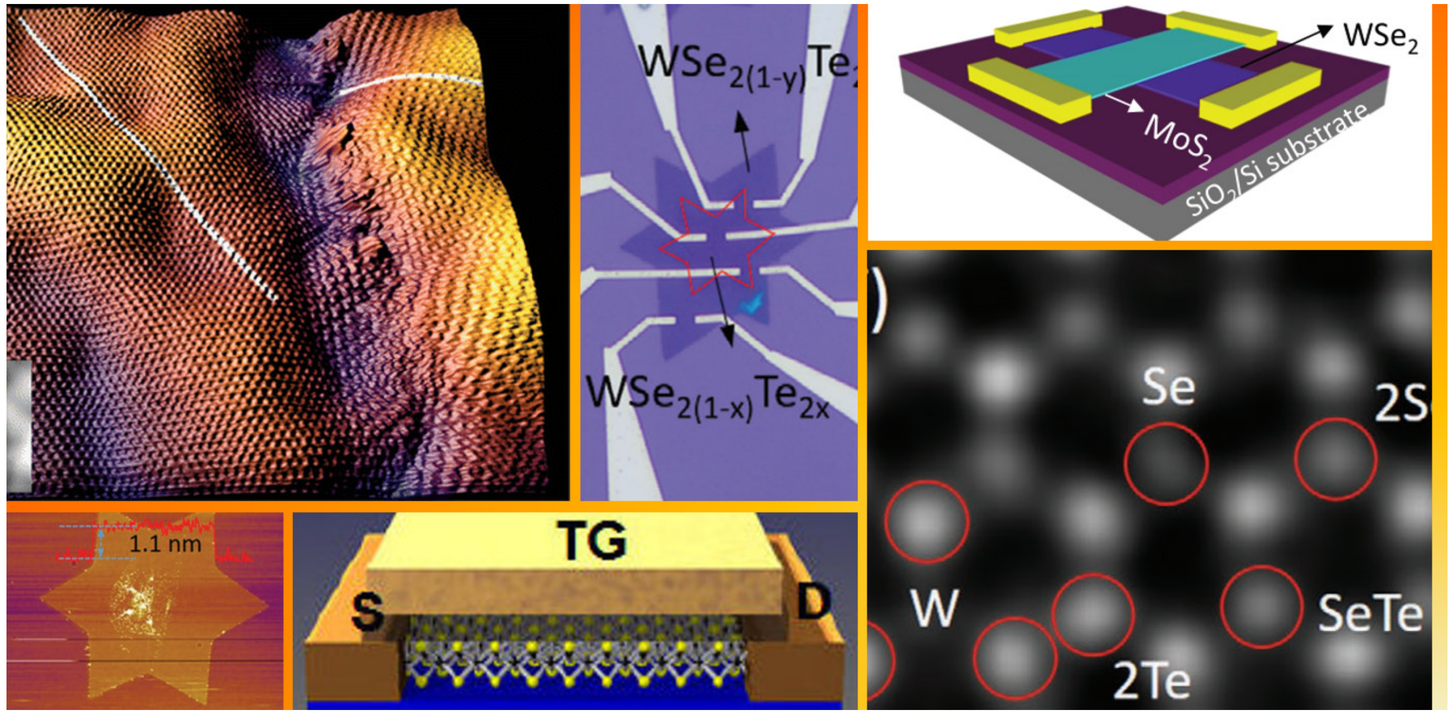
Photonic systems will fundamentally reduce the energy cost of generating and transmitting vast amount of data

FUTURE

Photonic research continues to lie at the forefront of U.S. industry and defense needs, with applications ranging from sensing (e.g. biological and environmental sensing), manufacturing (e.g. high brightness laser diode pumps), to consumer applications (e.g. LEDs, power FETs, VCSEL arrays in smart phones, LIDAR). Specifically, high-speed, energy-efficient communications demand development of novel modulation techniques with higher speed and larger modulation amplitude across a broader range of wavelengths/frequencies. Limitations are imposed by materials, device structures, scalability, and, on a more fundamental level, by the interplay between carrier lifetime and photon lifetime. Opportunities exist to explore novel materials, novel processes, and novel device architectures for devices used for both wired and wireless links. This is both a problem for today and tomorrow – device capabilities drive applications, which in turn place more demands on devices.

In order to retain and advance our leadership position in high-speed electronic and photonic III-V devices, an investment in infrastructure for growth, processing, and characterization is required. With the increasing cost of research equipment, especially in growth and high-speed test, a shared-use model that allows many different projects to benefit from a common capability base will create an environment that allows both established professors and emerging researchers to generate the next wave of innovations in materials and devices.

NANOSCALE DEVICES FOR ULTRALOW POWER COMPUTING



VISION

Digital computing technology continues to have a profound impact on human lives in areas such as energy, public health, security, business, and artificial intelligence. In the last five decades, the cost of digital computation has declined by over eight orders of magnitude, while the performance of microprocessor units has continued to improve at a rapid pace. Large-scale computing platforms are being used worldwide to tackle complex challenges in data science and scientific computing. This digital revolution is largely due to innovations across several engineering fields including materials science, ultraclean precision manufacturing, automation, and availability of electronic circuit design and computational modeling tools.

While the throughput of modern computing systems has improved tremendously, their power consumption is becoming ecologically significant on a planetary level. Nanoscale materials and devices exhibiting new physical phenomena can be used to create machines that will deliver breakthrough improvements in power efficiency.

Nanoscale devices will be used to create power-efficient computing machines

LEGACY

The landscape of computing is poised to undergo transformative changes in the next decade, and HMNTL faculty have the expertise to be at the forefront of the next phase in the digital computing revolution. Addressing the challenges of ultralow power computing will require a cohesive approach that integrates theory, materials synthesis, and atomically precise fabrication and characterization. HMNTL faculty include experts in 1D nanowire synthesis and devices, 2D chalcogenide-based heterostructures and devices, atomically precise fabrication of graphene nanoribbons and devices, and nanoscale device simulations. HMNTL faculty have done highly visible and award-winning work in nanoscale devices and nanotechnology and are well-funded from individual to MURI-level programs. HMNTL is in a strong position to make groundbreaking advances in materials and devices for ultralow power computing for the next decade.

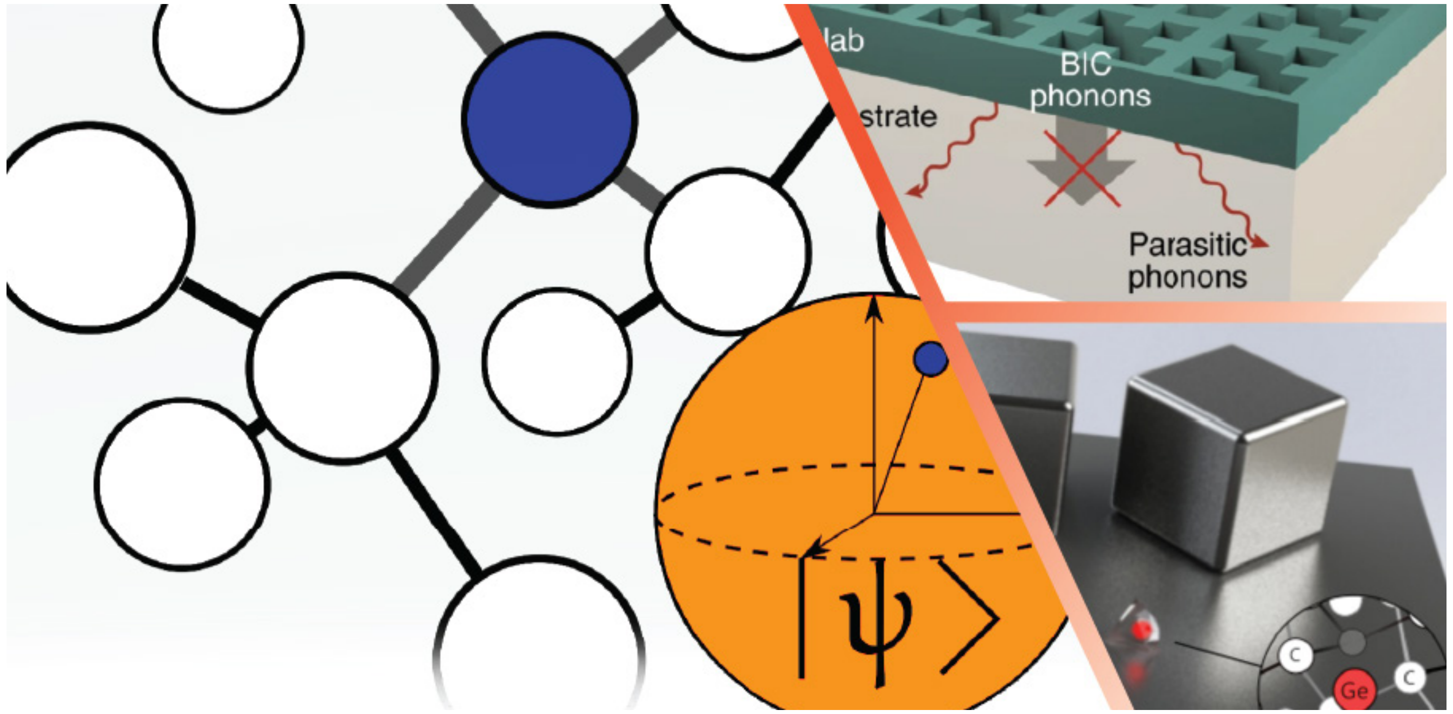
FUTURE

New digital switches based on 2D materials, such as the transition metal dichalcogenides, and 1D nanowires using germanium and silicon are promising nanotechnologies for the next-generation of digital computers. Research in new memory devices, based on ferroelectric and magnetic materials, is also gaining momentum. Due to their collective order locked together by exchange interaction, magnetic materials require energy only on the order of a few milli-electron-volts to change their state. These nanotechnologies can lead to circuits with smaller form-factor, enhanced functionality, and lower energy consumption.

Another exciting research opportunity for energy-efficient computing lies in the domain of probabilistic computing, first proposed by von Neumann in 1956, in which noise is not simply discarded as a waste product. In an experience-driven learning machine, randomness is valuable, as is the need for truly stochastic physical processes. In magnetic materials, thermal noise can lead to magnetization fluctuations on the gigahertz timescale. These fluctuations can be used as a source of low-power, high-speed, and high-density stochastic signals for further use in a probabilistic computer.

By integrating these new materials into unique circuits capable of exploiting their multi-faceted functionalities will establish new computing paradigms that have the potential to outperform existing technologies structure. The link between materials processing, device design, and component reliability will be necessary for the future systems insertion of non-canonical device structures. It is ultimately the unification of physics of reliability, device scalability, and computational framework that will create an ecosystem of new material systems ready for their deployment in 5G and beyond infrastructure.

QUANTUM TECHNOLOGIES



VISION

Achieving quantum control of light and matter in devices and systems is the focus of nascent quantum technologies. This technology promises disruptive computational speed-ups, unbreakable security for transmission of quantum information, fundamentally new limits for sensors, and the ability to simulate light and matter on the quantum level. In turn, these advances will help solve climate-related and logistical problems on the global scale, achieve ultimate communication security, measure hitherto inaccessible physical phenomena, and obtain insights into chemical and biological processes on a quantum level.

The realization of the above challenges depends on our ability to accurately control elementary quantum systems, while protecting them from unwanted interactions with their environment. Vigorous progress is expected in the next 5-10 years thanks to (i) the emergence of new materials making it easier to create, control and protect quantum systems, (ii) recent breakthroughs in nanotechnology/nanofabrication, (iii) new approaches to device architecture, (iv) transduction of quantum information between different platforms, ranging from single photons to superconducting circuits, and (v) integration with the classical electronic and photonic infrastructure to enable control of multi-qubit systems.

The importance of quantum technology is globally recognized across Europe, Asia and the US. The NSF has included quantum technology in the list of its 10 Big Ideas to serve our nation's future. Last year, the National Quantum Initiative Act was signed into law, allocating $1.4B to quantum science and technology for the 5 years ahead. Several Fortune 500 companies have invested hundreds of millions of dollars into quantum infrastructure.

LEGACY

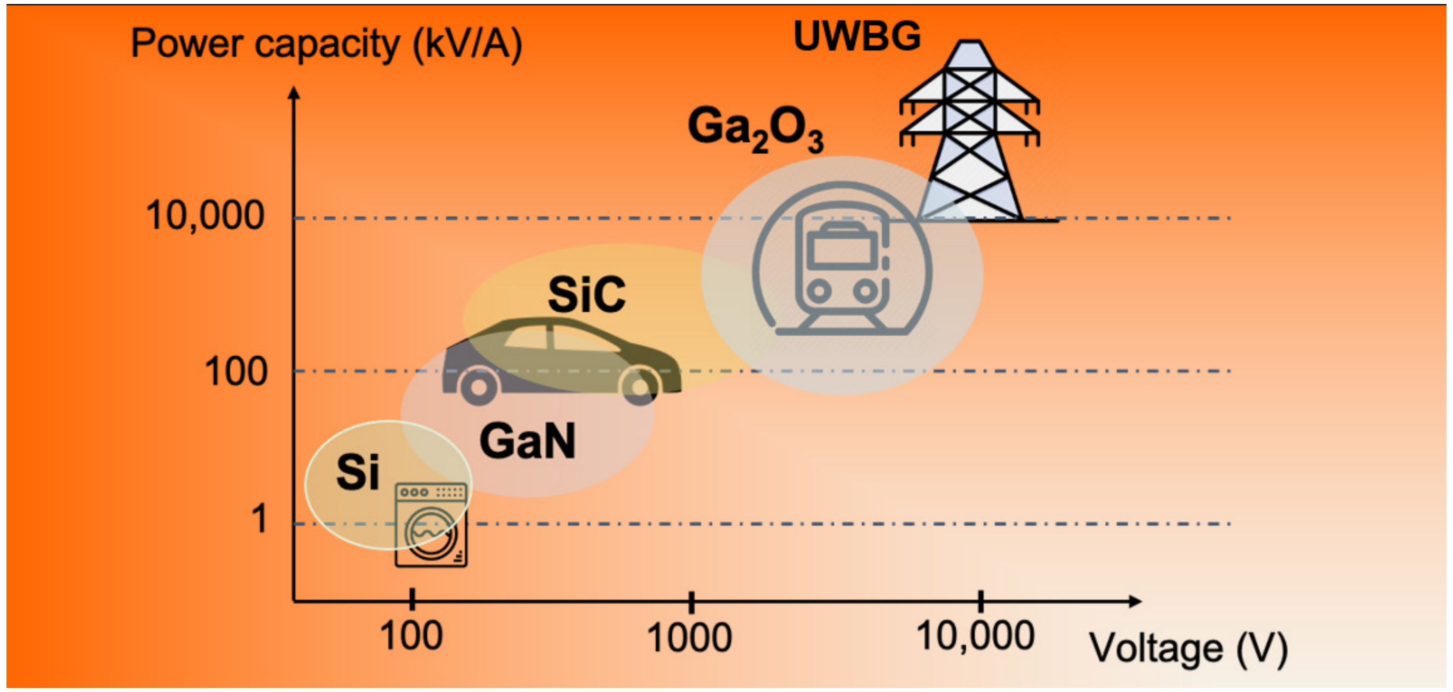
HMNTL is uniquely positioned in this effort thanks to the unique blend of its (i) world-leading expertise in both quantum physics and device physics, (ii) strategic location within the Chicago Quantum Exchange, and (iii) exceptional supercomputing capabilities second to no other university in the US. The effort in quantum technology must be interdisciplinary and requires the use of dedicated shared facilities, rather than compartmentalized labs. The inter-departmental efforts started consolidating in 2019 with the inauguration of the IQUIST. However, the existing facilities are geared towards the exploration of basic physical concepts, while the material base for technology development and integration is lacking. A targeted upgrade of HMNTL's growth, processing and characterization facilities would propel UIUC into a world-leading position in quantum technology, with an edge over neighboring peer institutions. Finally, HMNTL's legacy in integrated device technologies is critical, as the quantum computers of the future will rely on intimate heterogeneous integration of high-performance electronics and photonics.

Quantum technology promises disruptive computational speed-ups, ultimate security of information, new understanding of the world

FUTURE

Quantum technologies developed at HMNTL will arise from multi-disciplinary experiments in material science, device physics, photonics, electronics, telecommunications and life sciences. Leveraging on the traditional strengths of the HMNTL in photonics, microelectronics, and biotechnology, the center will build integrated quantum processors, sensors and networks aiming specifically at high-speed applications. The emergence of novel quantum materials to host solid-state qubits with superior properties calls for specialized fabrication techniques, devices, and system architectures to realize quantum memories, transducers, repeaters as well as scalable classical control circuitry. In particular, HMNTL aims to become a world leader in wide-bandgap semiconductor photonics and electronics and to enable next-generation integrated nanoscale devices featuring THz operation rates and operating at cryogen-free temperatures. Such devices will exhibit superior immunity to quantum decoherence and will confer practical operation bandwidths to the existing quantum information protocols. Unique expertise at HMNTL allows us to envision hybrid quantum technology operating across all solid-state platforms including superconducting circuits, trapped ions/atoms, photonics, and spintronics. The quantum devices and systems coming out of HMNTL will be at the forefront of the upcoming quantum revolution, delivering the power of quantum information processing to solve some of the most pressing societal and scientific problems.

POWER ELECTRONICS



VISION

A foundational change in electronic materials is necessary to develop novel approaches for renewable power generation and to create a smart and resilient electricity grid of the future. Power electronic devices today control distribution of over 50% of the world's electricity with projected increase to 80% by the year 2030. The aging U.S. power grid today is simply unable to continue to meet the demands associated with society's increased reliance on electricity-enabled services. The power technologies in use today, mostly based on Si, are already scaled close to their limits for the operating voltage desired in many applications. Novel ultra-wide bandgap (UWBG) materials, can provide significant gains in power distribution efficiency by enabling alternative grid architectures based on DC transmission that is projected to reduce today's AC grid losses by 90%.

LEGACY

HMNTL has a long history of developing compound semiconductor materials and devices and extensive faculty expertise. Semiconductor research has always been "in the blood of HMNTL" to be well positioned and to lead the next revolutionary wave that will enable a smart, efficient, and resilient power grid of the future. This is an exciting key research opportunity that HMNTL cannot afford to miss. Besides in-house expertise, HMNTL faculty have established long-term partnerships with other IRUs on campus, including MRL, ECE's power group, and CSL's groups working on circuit and architecture design, machine learning, and AI.

> A DC grid ultra-wide bandgap electronics is projected to reduce today's power grid losses by 90%

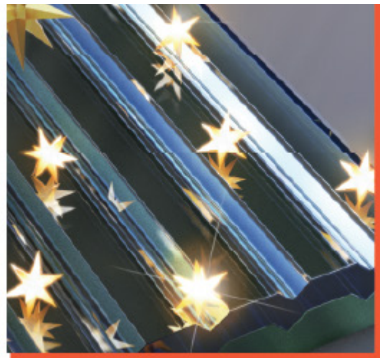
FUTURE

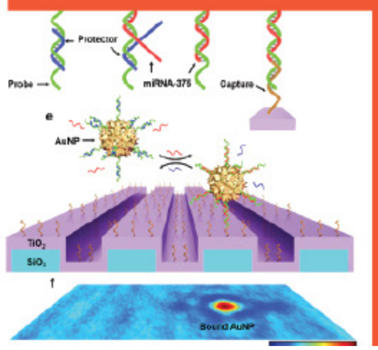
UWBG semiconductors, can provide superior energy density capabilities, and hence are attractive for next-generation power electronic devices that are higher power, more efficient, smaller, and cheaper. For example, gallium oxide (Ga2O3 – see figure), can provide breakdown voltages more than 20 times that of silicon and more than twice that of traditional WBG materials such as silicon carbide (SiC) and gallium nitride (GaN). Diamond-based power devices can potentially sustain even higher voltages (greater than 10 kV), handle high currents (above 100 A), and safely operate at high temperatures (over 700°C). With a bandgap of ~5.4 eV, breakdown field strength of ~10 MV/cm, thermal conductivity greater than 2,200 W/mK, and electron and hole mobilities of ~4,500 and ~3,800 cm2/V·s, respectively, diamond outperforms its WBG (GaN) and UWBG (Ga2O3, AlN) counterparts in terms of projected power-handling and power-switching performance.

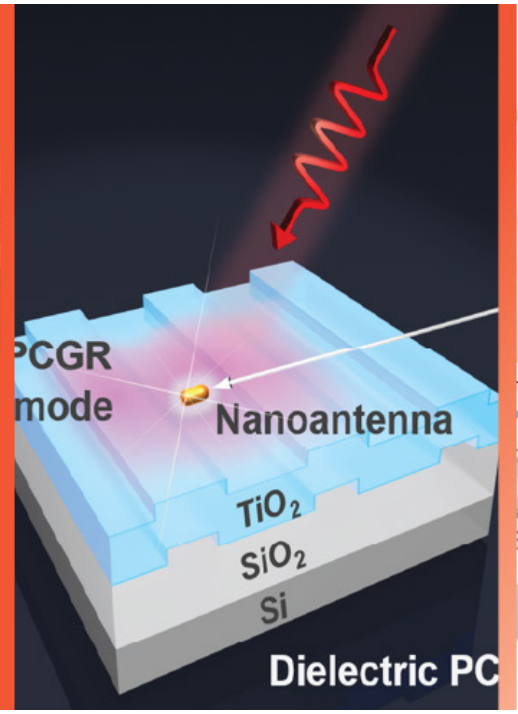
UWBG Power Electronics will enable solutions to many core energy efficiency challenges. However, at this point, UWBG semiconductor power electronics faces significant challenges at the materials and device levels, including homo- and hetero-epitaxial quality, doping control (especially hole transport), and thermal management, as well as associated processing and dielectric passivation issues. Particularly, the scientific challenges that impede the adoption of diamond-based power electronics include the inability to synthesize high-quality large-area (> 1-inch-diameter) single crystal substrates, the lack of any demonstration (as yet) that a high-impurity (> 1018 cm-3) doping electron concentration can be achieved, an inability to control the density and type of defect centers, and a lack of studies on the structural, electrical, optical, and thermal properties of metal-diamond and oxide-diamond interfaces.

The key to the efficient transmission and conversion of low-carbon electrical energy is the improvement of power electronic devices, which must be durable and reliable in high-power high-power environments to eliminate the need for auxiliary systems. "Green electronics", i.e. highly efficient electronic devices, are crucially important for our future energy system as they will increase the efficiency of electricity production and distribution with disruptive gains expected at the system level. First estimation gives a factor of 4 improvement, I.e. 75% reduction in losses, representing about 10 MW energy saving on a 300 MW HVDC converter.

TRANSLATIONAL BIOTECHNOLOGIES







VISION

As noted in a recent National Academies report, a convergent approach integrating the sciences, engineering, and medicine will drive a third life science revolution. For the past three decades, advances in life science research and the development of new tools that enhance medicinal practice have derived from fundamental breakthroughs in sensors, novel forms of microscopy, image contrast agents, and new materials. Our grand challenges include developing approaches for efficiently sequencing genomes, characterizing genomic and proteomic biomarkers in bodily fluids associated with states of disease and wellness, developing a deeper understanding of how biomolecules interact with each other at the level of single units, understanding the processes that occur within cells and tissues, and bringing high quality health diagnostics to people in the most remote parts of the world. Developing practical technologies and interventions to ensure that society benefits from this revolution needs a focused effort on engineering and basic sciences, collaborating with existing excellence in biology, biochemistry, and medicine.

A third life science revolution will bring high quality health care to people in the most remote parts of the world

LEGACY

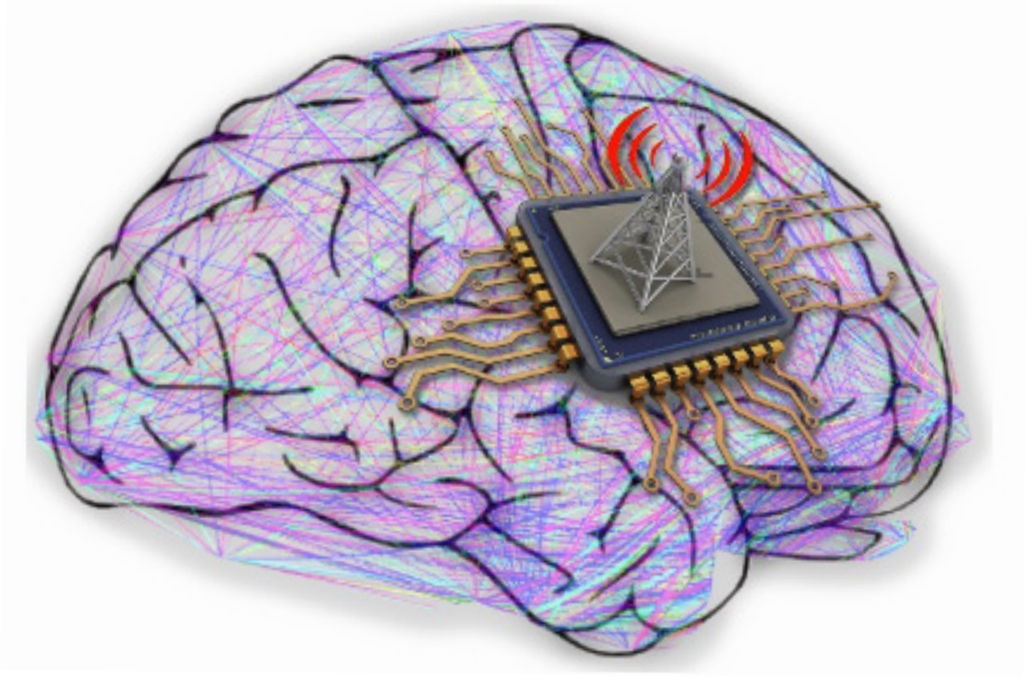
Current areas of HMNTL strength include measuring dynamic processes in live cells with single molecule precision, modeling the physics of nanopores used to determine the sequence of nucleic acid molecules and proteins passing through them, utilizing optical metamaterials and optical forces to measure the properties of individual biomolecules and their interactions, designing synthetic nucleic acids with engineered structural properties, constructing systems for identifying pathogens at the point of care, designing new contrast agent nanoparticles for medical imaging, and characterizing the concentration of biomarker molecules in blood. Based on our rich legacy in the field of semiconductor materials and devices, we envision HMNTL extending its leadership in the field of "hybrid functional systems" in which materials, micro/nanofabrication tools, and devices that originated from the field of semiconductors are adapted and merged with the components of living systems to create entirely novel capabilities that enable manipulation, measurement, and imaging of biology. To support these research directions HMNTL includes a unique BioNanotechnology Laboratory that is a shared-use facility that houses wet lab space that includes cell incubators and biosafety cabinets, microscopes, liquid handling equipment, and conventional biology tools.

FUTURE

HMNTL is an engineering and technology powerhouse with broad strengths in the underlying physics, devices, and systems that will underlie the next generation of tools that will bring new insights into biology and bring new tools to the clinic. The HMNTL strives to support a research environment in which individual faculty can nurture fundamental engineering advances, while also participating in convergent multidisciplinary collaborations with chemists, biologists, data scientists, and clinicians. To support these activities, HMNTL requires significant upgrade of existing and development of new facilities that, in addition to supporting semiconductor fabrication and metrology, also contains equipment and facility resources that are typically found in molecular and cellular biology laboratories. Requirements include a biosafety level-2 infrastructure and practices for safely working with viral/bacterial pathogens, human/animal-derived test samples, cell lines, and tissues. As faculty move forward with system-level technologies that are being prepared for clinical translation, the ability to safely store extremely valuable clinical repositories is critically important.

Investment in these resources will enable HMNTL to effectively pursue multidisciplinary funding from NIH, DoD, NSF, philanthropic sources, and disease-specific research foundations. The HMNTL is already the home for several NIH R01 grants that are ~5-year, $2.5M efforts each, along with many single/dual investigator NSF grants that support exploration of fundamental engineering concepts. Moving forward, the HMNTL will be capable of supporting larger Program Project grants from NIH, and larger grants that support moving technologies from the lab towards clinical applications. The ability to utilize BL2 facilities that can support, through staffing, equipment, infrastructure, and protocols, the clinical validation of technologies will enable HMNTL-invented technologies to attain regulatory approval, and to support clinical trials with collaborators throughout the country.

NEUROTECHNOLOGIES



VISION

The human brain - "the most complex object in the known universe" (C. Koch) - is the fastest computational machine we are aware of with capacity exceeding ExaFLOPs performance, and it is also the most power-efficient one consuming just 20W. These performance metrics are orders of magnitude beyond what our technologies can hope to achieve in the foreseeable future. While brain operation principles remain elusive and largely unknown, progress in development of our computing systems to a large extent was inspired by (von-Neuman architecture) or derived from (machine learning and AI) early breakthroughs in its understanding. Recently large-scale global international projects have been launched in US, Europe, Japan, etc, that all identified reverse engineering of the brain as a matter of priority to "realize the brain's potential to teach us how to make machines learn and think" (US NAE).

Such a "moonshot" project has also begun to materialize at HMNTL, across the UIUC campus, and beyond with the ultimate goal to develop innovative neurotechnologies that will enable recording from and manipulation of massive neuron populations in the brain to produce a dynamic picture of brain circuit interactions at the speed of a thought. Following Albert Einstein's quote, "The world as we have created it is a process of our thinking. It cannot be changed without changing our thinking," we want to change the world by understanding how our brain works, and how perception is transformed into cognition and behavior.

LEGACY

Development of implantable chip-scale engineering systems that provide massive recording, computational analytics and adaptive manipulation of brain neuron populations require deep collaborations across many disciplines including electronic and photonic device physics, nanofabrication methods, novel bio-compatible materials, high-speed communications, power efficient edge computing, novel approaches in data analytics, and AI architectures. History of HMNTL has great examples of such cross-disciplinary integrative projects in the past. The breadth of the project would require, however, to transform this collaborative culture into a fundamentally new transdisciplinary effort that will break through cultural divides between disciplines and fundamentally change the nature of training and workflow in a present-day engineering, neurobiology, and data science from silos confined within sub-disciplines to an integrative and holistic research thrust.

Neurotechnologies enable revolutionary advances in artificial intelligence, as well as in closed-loop neural interfaces for novel rehabilitative and prosthetic therapies

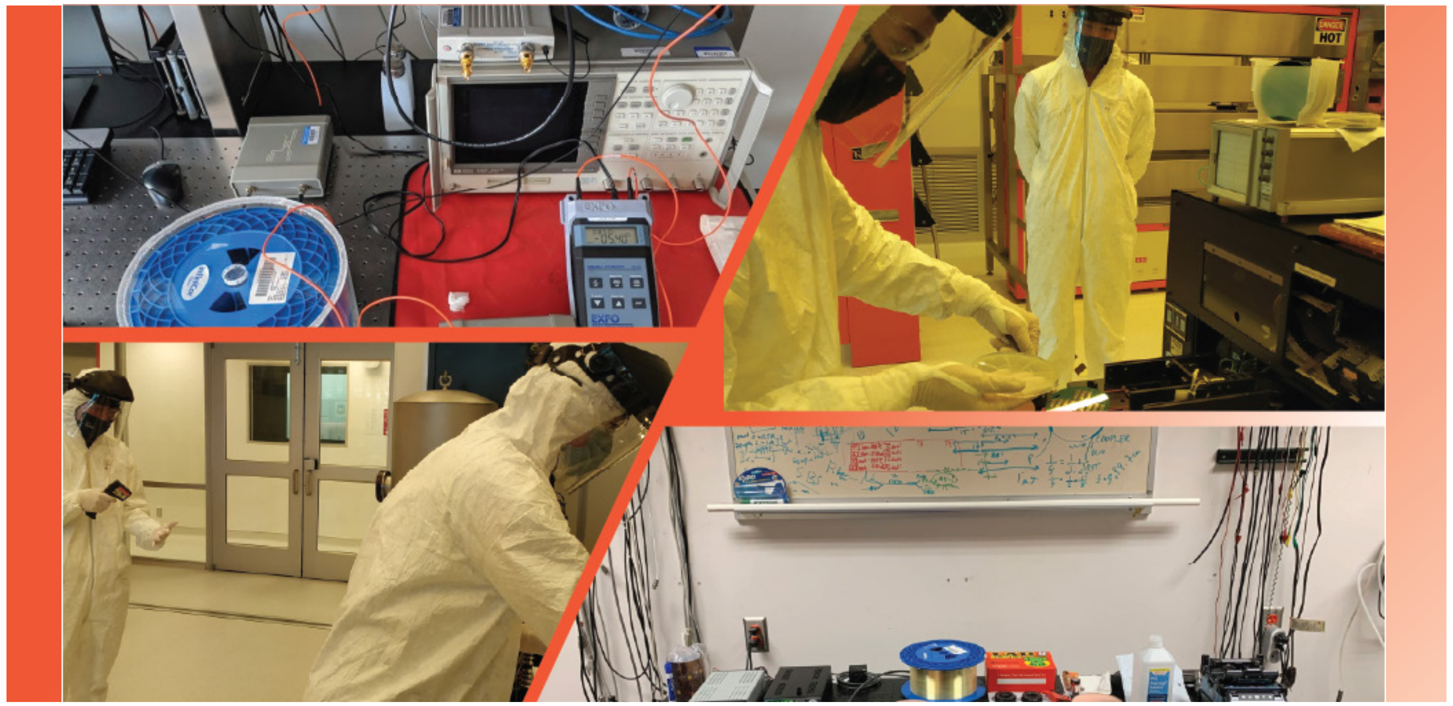
FUTURE

These neurotechnologies will shed light on the biological substrates of our thoughts and decisions – perhaps the most important question overall, and not just for science, but very much for the society as a whole, as well as for each and every individual. Besides fundamental understanding, this will enable revolutionary advances in next-generation AI analytical systems capable of interpretable mining of dynamic data streams. Immediate practical impact is also envisioned in development of next generation closed-loop neural interfaces that will enable efficient rehabilitative and prosthetic therapies, as well as brain enhancement augmentative capabilities.

In his recent press-release, Elon Musk, an active player in neurotechnology development with his startup Neuralink, projected that a whole new industry with tens of thousands of new jobs will span out of such efforts. To ensure a transformational impact on society we envision engagement with Carle Illinois College of Medicine, major hospitals in Chicago, as well as with our traditional collaborations with Mayo Clinic for rapid transition from research testbeds to commercial products.

Moreover, the transdisciplinary nature of HMNTL's neurotechnology thrust will provide opportunities for faculty, postdoctoral researchers, and students in data science, engineering, neurobiology, and medicine to learn how to cross the cultural and terminological divides between disciplines, thus enabling new paradigms in engineering education.

MULTIDISCIPLINARY EDUCATION AND TRAINING



VISION

The National Academies emphasized recently that future security, economic growth, and competitiveness of the United States requires expertise from formerly distinct academic disciplines to be brought together into an integrated and convergent effort. To address increasingly complex engineering and societal problems of the future, engineers not only should excel in their specific application field, but most importantly should also be able to bring together expertise from different disciplines in a single context. The need for cross-disciplinary training is ever increasing, especially for the most promising possibilities expected from the convergence of nanotechnology, information technology, and bioengineering that are at the core of HMNTL. MS- and PhD-level training across the boundaries of individual departments in convergent cross-disciplinary teams is the new educational paradigm
.

In view of these challenges, we foresee the HMNTL of the future not only as a research institution, but also an education unit where the educational component is seamlessly integrated with the ongoing research work of the interdisciplinary faculty. We believe this is a unique opportunity to provide a broad educational foundation beyond the boundaries of individual departments. The NSF National Science Board projected a potential shortfall of 3 million skilled technical workers with 4-year STEM degrees by 2022 that will only increase further. HMNTL is positioned well to close this gap via offering new hands-on learning opportunities in growth areas.

LEGACY

In 1989 the Microelectronics Laboratory was established at the University of Illinois as an NSF center on compound semiconductor materials and devices. Thirty years later, the Holonyak Micro and Nanotechnology Laboratory is the Nation's leading academic laboratory on semiconductor technologies and microelectronic and photonic devices, as well as their application in biological and medical applications. Thus, with its origins in electrical engineering, the Faculty and students who reside in HMNTL today represent a broad range of academic science, engineering, and multi-disciplinary expertise. Moreover, many of the initial research directions of the original building have emerged as unique and distinct topics, which no single academic department can claim. For example, the early research on semiconductor lasers that occurred in the Micro Lab during the 1990's, today has matured into a Photonics discipline that, from an academic perspective, has its own set of ABET requirements. The seminal undergraduate course that was created to teach ECE students how to fabricate silicon diodes and transistors (ECE444), today is taught within HMNTL and attracts students from all disciplines of engineering as well as physics and chemistry. Therefore, while established as a research laboratory, today HMNTL represents an educational focal point, with unique expertise, staff, and facilities. Therefore, we have a unique opportunity to establish an education and training role for HMNTL. Emerging areas such as 5G+ communication, power electronics, and optical implementation of deep learning inference present unique opportunities for HMNTL to create a revised curriculum to train the next generation of engineers, scientists, and faculty.

HMNTL is poised to close the competency training gap via offering new multidisciplinary learning and training in growth areas

FUTURE

There is a unique opportunity, perhaps even national need, for HMNTL to expand its role into education and training in non-traditional fields, which nonetheless represent HMNTL competence and expertise. Whereas many of our peer B1G and other institutions also have the potential of offer similar engineering specialty degrees, none do so yet. Part of the HMNTL cleanroom is already dedicated to teaching a hands-on course: ECE 444 IC Device Theory and Fabrication, where students learn hands-on how to fabricate Si-based transistors. With the emergence of new materials for photonics and electronics, it is critical to scale up the technical courses with experimentation, helping to (re)train the workforce in emerging devices.

The addition of an education component to the ongoing research portfolio will create more opportunity, funding, and enhanced reputation for the Lab. (Note that presently no revenue is generated for MNTL for the teaching and support of ECE444.) The possible choices range from creating undergraduate minors or new degree programs, as well as Master of Engineering degrees. An existing impediment is presently there are no institutional policies for degrees granted by interdisciplinary labs

CONTRIBUTORS: Yurii Vlasov (Editor), Shaloo Rakheja, Brian Cunningham, Minjoo Larry Lee, Lynford Goddard, Simeon Bogdanov, Xiuling Li, Kent Choquette, Can Bayram, John Dallesasse, Joseph Lyding, Peter Dragic, Kejie Fang, Milton Feng, Wenjuan Zhu, Jean-Pierre Leburton, Songbin Gong, Yang Zhao, Kyekyoon Kim, Matthew Gilbert, Gary Eden, Arend van der Zande, Andrew Smith,Joseph Irudayaraj, Shuming Nie, Xing Wang, Gregory Pluta, Ryan Wild, Kim Gudeman, Wesley Moore

mntl.illinois.edu

Grainger College of Engineering

Holonyak Micro & Nanotechnology Lab