LDRD

Quarterly Highlights

Mission Agility
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LLNL, LANL, SNL, NNSS

LDRD investigators drive innovation to the threshold of fusion ignition

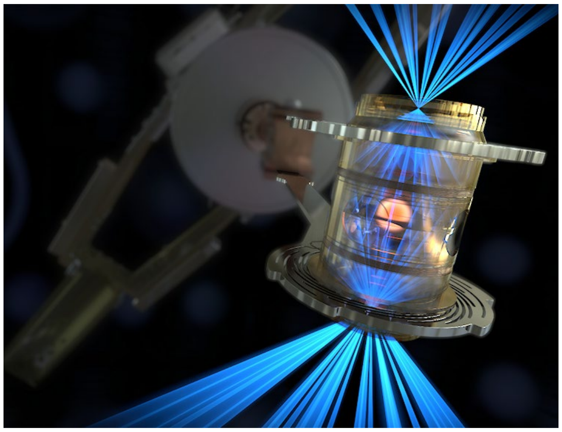
During August 2021, an experiment conducted at Lawrence Livermore National Laboratory's National Ignition Facility (NIF) made a significant step in the decades-long quest of inertial confinement fusion—attaining a yield of more than 1.3 megajoules. The ability to focus the energy from 192 high-power laser beams at NIF onto a tiny fuel capsule that is typically only a few millimeters in size, and then create a reaction that generates more than 10 quadrillion watts of power, puts researchers at the threshold of fusion ignition.

The ground-breaking experiment did not happen overnight. It was the result of many innovations, developed in recent decades by pioneering scientists and engineers at NNSA's national laboratories, working in collaboration with colleagues at other DOE/NNSA Labs and other research institutions. Those innovations came together to culminate in the recent high-yield fusion experiment at NIF.

Many of those pioneering new ideas were transformed into solutions through funding provided by Laboratory Directed Research and Development (LDRD) Programs at NNSA Labs. LDRD investments in this foundational work over the last two decades spanned key science and technology areas, including target fabrication, diagnostic tools, and laser-plasma interactions.

> ***The recent high-yield NIF experiment represents a groundbreaking achievement in inertial confinement fusion, and will no doubt spur further innovations and future LDRD-funded research in this new regime.*** — Doug Rotman, LDRD Program Director, LLNL

Target design and fabrication research at Livermore



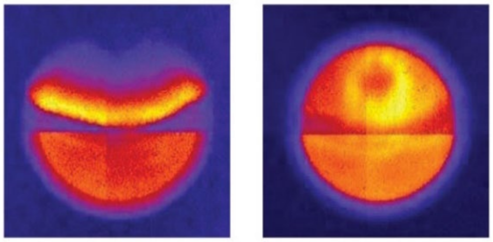
A typical hohlraum cylinder is approximately a centimeter wide with laser entrance holes at either end. The fuel capsule is suspended inside the hohlraum. (Image courtesy of LLNL.)

One key area of innovation involves a broad range of LDRD-funded work related to the design and fabrication of targets used in NIF experiments. NIF targets consist of fuel capsules suspended inside hollow metal cylinders called hohlraums. Since target design plays a major role in the success of fusion experiments, the targets are fabricated to meet precise specifications for each experiment, including the capsule's material composition, density profiles, spherical shape, and surface finish.

Over the last decade, LDRD-funded work related to target design and fabrication included a focus on developing novel materials and nanoscale fabrication techniques to assemble structures measuring less than 100 nanometers and being able to manipulate the material to carefully control the thickness of the target's layers. For example, an LDRD project at LLNL made it possible to fabricate high-density carbon (diamond) material with unprecedented precision for use as the fuel capsule's shell, known as the ablator. These innovative techniques were used for the target fabrication in the recent high-yield NIF experiment.

LDRD-funded research teams have explored other innovative target designs in recent years. Their work includes development of novel hohlraum shapes, advanced ignition target designs, as well as capsule designs that are optimized for symmetric implosions, with higher capsule-absorbed energy. These projects lay the groundwork for future NNSA pathways to even higher neutron yields.

Sandia develops diagnostic sensors and imaging systems that support NIF research



The first in-situ diagnostic images were captured using Sandia's UXI framing camera. The images above are hybrid CMOS camera x-ray images on NIF, captured in 2015, at 2ns temporal resolution. The initial NIF application was to measure the time-history of the laser entrance hole of a NIF hohlraum. (Image courtesy of Hui Chen et al., LLNL)

LDRD investments and other NNSA support have allowed scientists and engineers at Sandia National Laboratories to contribute to the ability to capture images of the recent high-yield NIF experiment—including investigations regarding integrated circuits, imaging technology, micro-electronics, and radiation.

For example, Sandia-based researchers developed an innovative ultrafast, multi-frame, digital x-ray imaging system (UXI). It features a time-gated hybrid-complementary metal oxide semiconductor (CMOS) sensor with burst mode and nanosecond gate times to capture multiple snapshots of the inside of the hohlraum as it is heated by a laser pulse. The faster frame rate reduces motion blur, while multiple frames provide a temporal history of an evolving experiment.

Icarus2, the latest iteration in the series of UXI camera imagers for application-specific needs, consists of a photodiode array bonded to a radiation-hardened custom readout integrated circuit with half a million 25μm pixels. UXI's hybrid sensor enables user-selectable exposure times as short as 2 billionths of a second—making it the fastest multi-frame x-ray imager in the world. Efforts to develop the radiation-hardened CMOS technology resulted in a novel diagnostic technology that successfully recorded critical data during the recent NIF experiment.

> *The latest high yield shot at NIF has quite a few folks abuzz with excitement. There are LDRD-funded projects in development at Sandia now with the potential to help increase the sensors' sensitivity, lower energy signals, and increase the x-ray energy."*
> — Marcos Sanchez, electronics engineer and member of Sandia's UXI system team

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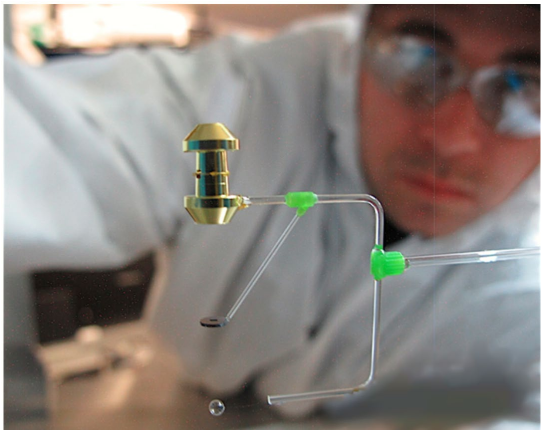
NNSS scientists help develop spectrometer to measure the opacity of material at extreme conditions

Site-Directed Research and Development (SDRD) funding enabled scientists at the Nevada National Security Site (NNSS) to help design and build a broadband x-ray opacity spectrometer. This diagnostic tool can be used to measure a material's opacity (its ability to absorb and re-emit radiation), including the opacity of a sample inside a NIF hohlraum target. In addition, they helped analyze and validate data generated by the spectrometer, enabling researchers to measure the transmission of radiation through hot, dense materials—data that helps scientists improve simulation codes used in fusion research at NIF.



NIF operator installs an opacity target assembly. The hohlraum (top) holds and heats the sample. The x-ray collimator pinhole is in the middle and the x-ray backlighting source is on the bottom. The tiny capsule becomes a bright broadband x-ray emitter when hit by NIF lasers. (Image courtesy of LLNL.)

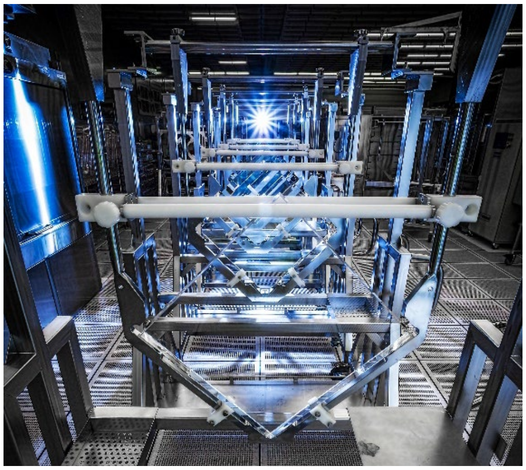
Los Alamos researchers advance technology deployed in NIF's diagnostic suite

Diagnostics engineer Francisco Barbosa checks a neutron time-of-flight detector at NIF. (Image courtesy of LLNL/James Pryatel.)

LDRD investments at Los Alamos National Laboratory have played a key role in developing diagnostic capabilities and expertise that contributed to the success of the recent NIF experiment, enabling researchers to better understand exactly what's happening during a NIF implosion under extreme conditions. LDRD researchers have been exploring this challenge for years.

For example, shortly after the multi-Lab neutron imaging team at NIF made their first successful image of a nuclear fusion experiment in 2011, an LDRD-funded team at Los Alamos started exploring ways to further advance diagnostic capabilities. Over the years, LDRD investments at Los Alamos have enabled development of key diagnostics used during the recent experiment, such as neutron time-of-flight diagnostics that measure neutron energy and drift velocity. Another example is the gamma reaction history diagnostic, which measures emission of target-produced gamma rays with respect to time, thereby providing key information regarding thermonuclear burn.

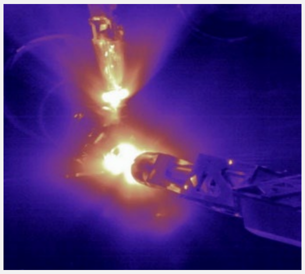
Optics research at Livermore boosts performance during high-energy experiments


NIF optics. (Photo courtesy of LLNL.)

NIF is the largest optical instrument in the world, with thousands of optical components, such as lenses, mirrors, and crystals, which are used to direct and focus laser energy onto a target. Over the years, LDRD-funded research teams have explored ways to improve NIF optics to further boost the lasers' power and energy.

For example, in 2011, an LDRD-funded team developed an advanced mitigation process (AMP)—a chemical etching method that removes damage precursors, such as fine scratches or impurities, which can be introduced to an optic's surface during the final phases of fabrication. In a follow-on LDRD study completed in 2014, investigators identified very small, sub-micrometer-scale factors that can limit the performance of optics at higher energies, and modified wet chemical processing methods used during optics fabrication to reduce damage precursors and improve the amount of energy that can pass through an optic without causing damage.

Livermore teams study laser–plasma interactions



When NIF's high-energy lasers strike the inside walls of a hohlraum target, they generate an electrically charged plasma—a turbulent mix of ions and free electrons. The plasma interacts with the laser beams and causes backscatter and laser–plasma instabilities that can drain the laser energy before it can be effectively coupled to the hohlraum. LDRD investments in recent years have enabled cutting-edge research regarding how these laser–plasma interactions drive harmful effects in the hohlraum plasma and how they can be mitigated or even leveraged to achieve a positive result.

For example, an LDRD-funded team based at Livermore studied processes that affect laser light propagation, as well as kinetic processes that influence the amplitude of electron plasma waves and ion acoustic waves in hot dense plasmas.

(LLNL-MI-827281)

Sandia National Laboratories

HIGHLIGHTS

A Sandia LDRD team produces the world's smallest, best acoustic amplifier

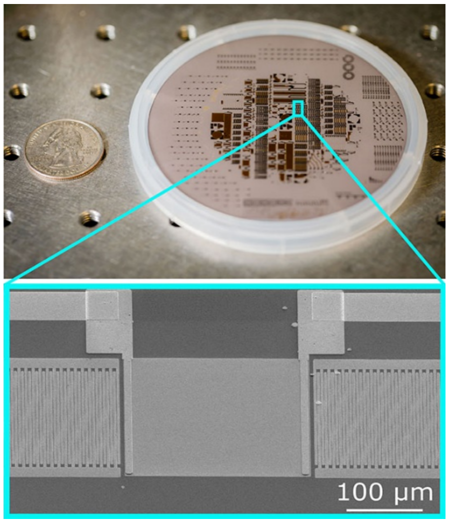
Sandia scientists have built the world's smallest and best acoustic amplifier using a concept that was all but abandoned for almost 50 years. According to a paper published in Nature Communications, the device is 10 times more effective than the earlier versions. The design and future research directions hold promise for smaller wireless technology.

Modern cellphones are packed with radios to send and receive phone calls, text messages and high-speed data. The more radios in a device, the more it can do. While most radio components, including amplifiers, are electronic, they can potentially be made smaller and better as acoustic devices. This means they would use sound waves instead of electrons to process radio signals.

"Acoustic wave devices are inherently compact because the wavelengths of sound at these frequencies are so small – smaller than the diameter of human hair," Sandia scientist Lisa Hackett said. But until now, using sound waves has been impossible for many of these components.

Sandia's acoustic, 276-megahertz amplifier, measuring a mere 0.0008 square inch (0.5 square millimeter), demonstrates the vast, largely untapped potential for making radios smaller through acoustics. To amplify 2 gigahertz frequencies, which carry much of modern cellphone traffic, the device would be even smaller, 0.00003 square inch (0.02 square millimeter), a footprint that would comfortably fit inside a grain of table salt and is more than 10 times smaller than current state-of-the-art technologies.

Scientists tried making acoustic radio-frequency amplifiers decades ago, but without modern nanofabrication technologies, their devices performed too poorly to be useful. The new and improved amplifier can boost signal strength by a factor of 100 in 0.008 inch (0.2 millimeter) with only 36 volts of electricity and 20 milliwatts of power. The amplifier was created with semiconductor materials that are 83 layers of atoms thick – 1,000 times thinner than a human hair.



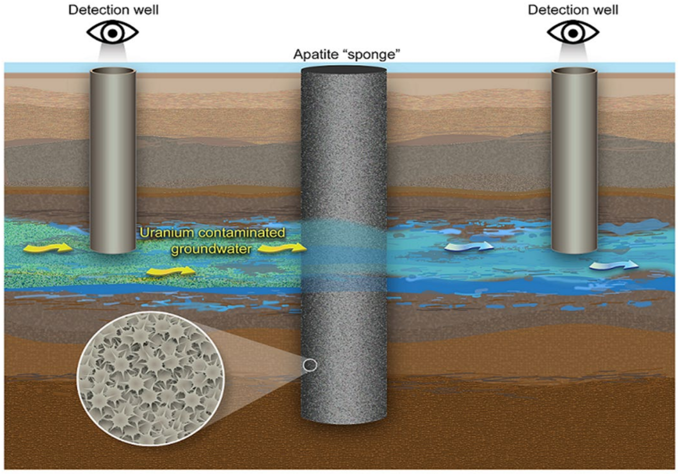
An acousto-electric chip, top, includes a radio-frequency amplifier, circulator and filter. An image taken by scanning electron microscopy shows details of the amplifier. (Microscopy image courtesy of Matt Eichenfield)

Amplifiers, circulators and filters are normally produced separately because they are dissimilar technologies, but Sandia produced them all on the same acousto-electric chip. The more technologies that can be made on the same chip, the simpler and more efficient manufacturing becomes. The team's research shows that the remaining radio signal processing components could conceivably be made as extensions of the devices already demonstrated.

Work was funded by Sandia's LDRD program and the Center for Integrated Nanotechnologies, a user facility jointly operated by Sandia and Los Alamos national laboratories. (*SAND2021-6443E*)

Sandia uses a mineral 'sponge' to catch uranium

A team of researchers from Sandia, Lawrence Berkeley and Pacific Northwest national laboratories tested a "sponge-like" mineral that can "soak up" uranium at a former uranium mill near Rifle, Colorado (150 miles west of Denver). The researchers found that the mineral, calcium apatite, soaks up and binds uranium from the groundwater, reducing it by more than ten-thousandfold. "The apatite technology has successfully reduced the concentration of uranium, vanadium and molybdenum in the groundwater at the Rifle site," said Mark Rigali, the Sandia geochemist leading the LDRD project. "Moreover, the levels of uranium have remained below DOE's target concentration for more than three years."



A graphical illustration the test of the apatite mineral's ability to absorb uranium by Sandia, Lawrence Berkeley and Pacific Northwest national laboratories researchers. (Graphic by Dan Thompson)

All forms of uranium are radioactive, and toxic when ingested. Molybdenum and vanadium, on the other hand, are beneficial at very low levels, but toxic at high concentrations. While the Rifle test site is remote, thousands of sites around the world are contaminated with radioactive elements and heavy metals that threaten groundwater, surface water and food supplies.

Calcium apatite is a mineral commonly used in fertilizer and is also a major component of bones and teeth. The researchers formed a “sponge” in the ground by injecting two inexpensive and nontoxic chemicals, calcium citrate and sodium phosphate, into a well especially designed for injecting solutions underground at the former uranium mill. Once in the ground, helpful soil bacteria ate the calcium citrate and excreted calcium in a form that allows it to rapidly react with the sodium phosphate to form calcium apatite, which coated sand and soil particles underground, forming the sponge. The apatite sponge captures contaminants, such as uranium, as it forms on the soil particles around the injection well, and afterward as the groundwater flows through the rough sponge. Once formed, the apatite is incredibly stable, and can hold onto captured contaminants for millennia. Apatite can also be “tuned” to capture different contaminants of concern including lead and arsenic.

“The apatite-based approach for uranium remediation has been by far the most effective and long-lasting without any significant negative side effects,” said Ken Williams, the environmental remediation and water resources program lead at Lawrence Berkeley.

Williams will continue measuring the contaminants in the groundwater downstream of the apatite sponge every month to learn how much uranium and other contaminants the apatite can hold, and when the sponge would need to be “refreshed” with more apatite.

“This has been one of the most rewarding projects that I’ve gotten to work on at Sandia,” Rigali said. “It’s great to have these types of opportunities because you feel like you’re doing something that is solving a problem and making a difference.” (*SAND2021-6019E*)

Sandia discovers the hidden culprit killing lithium-metal batteries from the inside

Sandia National Laboratories scientists Katie Harrison, left, and Katie Jungjohann have pioneered a new way to look inside batteries to learn how and why they fail. (Photo by Bret Latter)

For decades, scientists have tried to make reliable lithium-metal batteries. These high-performance storage cells hold 50% more energy than their prolific, lithium-ion cousins, but higher failure rates and safety problems like fires and explosions have crippled commercialization efforts.

Now, the first nanoscale images ever taken inside intact, lithium-metal coin batteries (also called button cells or watch batteries) challenge prevailing theories and could help make future high-performance batteries, such as for electric vehicles, safer, more powerful and longer lasting.

“We’re learning we should be using separator materials tuned for lithium metal,” said battery scientist Katie Harrison, who leads Sandia’s team for improving the performance of the batteries.

Through LDRD funding, Harrison’s team found a surprising second culprit: a hard buildup formed as a byproduct of the battery’s internal chemical reactions. Every time the battery recharged, the byproduct, called solid electrolyte interphase, grew. Capping the lithium, it tore holes in the separator, creating openings for metal deposits to spread and form a short. Together, the lithium deposits and the byproduct were much more destructive than previously believed, acting less like a needle and more like a snowplow. “The separator is completely shredded,” Harrison said, adding that this mechanism has only been observed under fast charging rates needed for electric vehicle technologies, but not slower rates.

Determining cause-of-death for a coin battery is difficult because of its stainless-steel casing. The metal shell limits what diagnostics, like X-rays, can see from the outside, while removing parts of the cell for analysis rips apart the battery’s layers and distorts whatever evidence might be inside. Katie Jungjohann, a Sandia nanoscale imaging scientist at the Center for Integrated Technologies, and her collaborators used a microscope with a laser to mill through a battery’s outer casing. They paired it with a sample holder that keeps the cell’s liquid electrolyte frozen at temperatures between minus 148 and minus 184 degrees Fahrenheit (minus 100 and minus 120 degrees Celsius, respectively). The laser creates an opening just large enough for a narrow electron beam to enter and bounce back onto a detector, delivering a high-resolution image of the battery’s internal cross section with enough detail to distinguish the different materials.

The original demonstration instrument, the only such tool in the United States at the time, now resides at a Thermo Fisher Scientific laboratory in Oregon. An updated duplicate tool at Sandia will be used to help solve many materials and failure-analysis problems. “This is what battery researchers have always wanted to see,” Jungjohann said. (SAND2021-7265E)

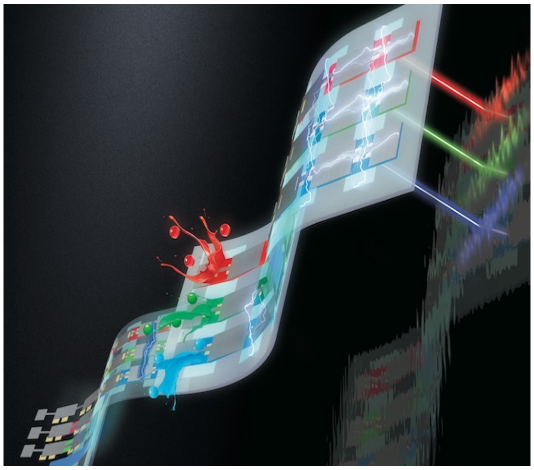
Los Alamos NATIONAL LABORATORY

HIGHLIGHTS

Los Alamos researchers paving the path to electrically pumped lasers from colloidal-quantum-dot solutions

In a new review article in *Nature Photonics*, a Lab team assesses the status of research into colloidal quantum dot lasers with a focus on prospective electrically pumped devices, or laser diodes. The review analyzes the challenges for realizing lasing with electrical excitation, discusses approaches to overcome them, and surveys recent advances toward this objective.

“Colloidal quantum dot lasers have tremendous potential in a range of applications, including integrated optical circuits, wearable technologies, lab-on-a-chip devices, and advanced medical imaging and diagnostics,” said Victor Klimov, LDRD researcher and lead author of the cover article in Nature Photonics. “These solution-processed quantum dot laser diodes present unique challenges, which we’re making good progress in overcoming.”



Colloidal quantum dot diodes can be created on the laboratory benchtop and have great potential in a wide range of practical applications. Lab researchers are developing approaches to overcome the remaining challenges for practically realizing these devices.
(Image credit: LANL)

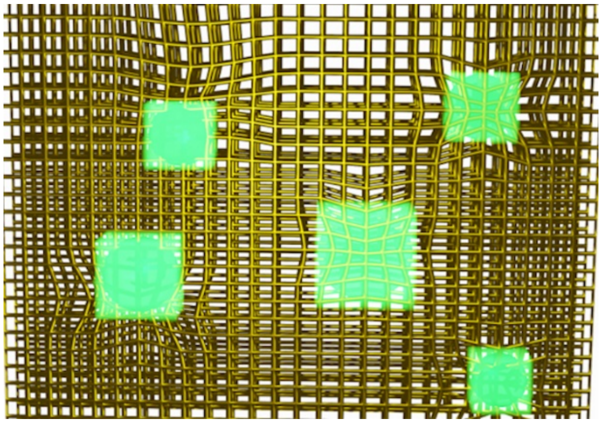
Semiconductor lasers, or laser diodes, are an essential part of many common consumer products as well as sophisticated equipment used in telecommunication, scientific research, medicine, and space exploration. Might colloidal quantum dot laser diodes soon become a reality? Read more about recent advances in this news release.

Work supported by the LDRD program was funded via projects 20200213DR, "Quantum Photonics with Semiconductor Nanocrystals" and 20210176ER, "Electrically Pumped Laser Processed from Solution." *(LA-UR-21-28631)*

Los Alamos breakthrough in stabilizing nanocrystals introduces a low-cost, energy-efficient light source for consumer electronics, detectors, and medical imaging

LDRD researchers and their collaborators have published new, breakthrough research on stabilizing nanocrystals that helps pave the way for a different type of solid-state light source. Light-emitting diodes (LEDs) made from perovskite nanocrystals offer a low-cost, energy-efficient light source that could one day enable lower-cost televisions and consumer electronics. Similar devices can detect an image, x-rays, and gamma-rays.

By stabilizing the perovskite nanocrystals in a metal-organic framework (MOF), the team was able to synthesize LEDs that exploit the performance benefits of the material while avoiding previous roadblocks. These new LEDs are based on elements that are abundant and, therefore, low cost.



Light-emitting diodes made from perovskite nanocrystals (green) embedded in a metal-organic framework can be created at a low cost, and they remain stable under typical working conditions. The nanocrystals are suited to a variety of practical applications in consumer electronics, health care, and other fields. (Image credit: LANL)

"In this work, we demonstrated for the first time that perovskite nanocrystals stabilized in a MOF will create bright, stable LEDs in a range of colors," said Wanyi Nie—a researcher for the Center for Integrated Nanotechnologies at Los Alamos National Laboratory, an early career LDRD researcher, and a corresponding author on the paper, which appeared in early September in Nature Photonics. "Metal-halide perovskite nanocrystals offer a continuously tunable optical band gap covering almost all the visible spectrum, meaning we can create different colors, improved color purity, and high photoluminescence quantum yield, which is a measure of a material's ability to produce light," Nie explained.

"The intriguing concept of combining perovskite nanocrystal in metal-organic frameworks has been demonstrated in powder form, but this is the first time we successfully integrated it as the emission layer in an LED," added Hsinhan Tsai, a former LDRD postdoctoral fellow.

Previous attempts to create nanocrystal LEDs were thwarted by the nanocrystals degrading back to the unwanted bulk phase, losing their nanocrystal advantages and undermining their potential as practical LEDs. Bulk materials consist of billions of atoms. Materials such as perovskites in the nano phase are made of groupings of just a few to a few thousand atoms, and thus behave differently. Perovskites are a class of material that share a particular crystalline structure giving them light-absorbing and light-emitting properties that are useful in a range of energy-efficient applications, including solar cells and various kinds of detectors.

In a novel approach, the team stabilized the nanocrystals by fabricating them within the MOM matrix, like tennis balls caught in a chain-link fence. They used lead nodes in the framework as the metal precursor and halide salts as the organic material. The solution of halide salts contains methylammonium bromide, which reacts with lead in the framework to assemble nanocrystals around the lead core trapped in the matrix. The matrix keeps the nanocrystals separated, so they don't interact and degrade.

The materials are deposited from liquid solution at room temperature. This method is far less expensive than the vacuum processing typically used to create inorganic LEDs. The MOM LEDs can be fabricated to create a bright red, blue, and green light, along with varying shades of each. In durability tests, the material performed well under ultraviolet radiation, in heat, and in an electrical field, without degrading and losing its light-detecting and light-emitting efficiency.

The research team on the LANL-led paper included members from Academia Sinica (Taiwan), Argonne National Laboratory, Brookhaven National Laboratory, SLAC National Accelerator Laboratory, and Stanford University. Work supported by LDRD was funded via projects "Perovskite-type Metal-Organic Framework with Strong Magnetoelectric Coupling" and "Rational Design of Halide Perovskites for Next Generation Gamma-ray Detection." (*LA-UR-21-25485*)

Lawrence Livermore National Laboratory
HIGHLIGHTS

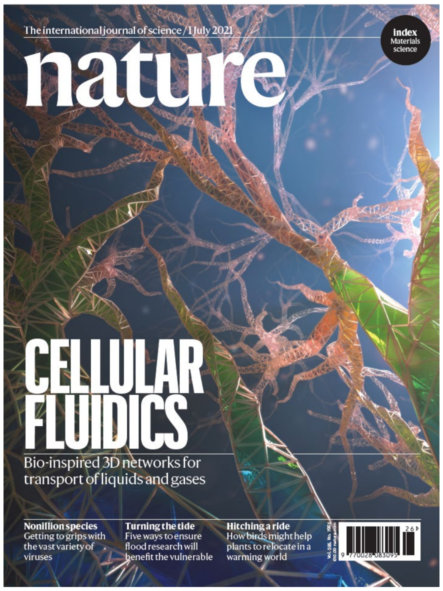
Livermore team develops cellular fluidics technology aimed at transforming how scientists control multiphase processes

Inspired by the way plants absorb and distribute water and nutrients, LLNL researchers developed a groundbreaking method for transporting liquids and gases using a 3D-printed lattice design and capillary action phenomena—similar to how a tree pulls water from soil or a paper towel soaks up a spill.

The micro-architected, porous, fluid-filled structures can facilitate controlled, tension-driven contact between liquids and gases using capillary action to move liquid though small pores in the structure.

The breakthrough technique could have transformative and broad-ranging impacts on numerous fields involving multiphase (gas/liquid/solid) processes, including electrochemical or biological reactors used to convert carbon dioxide or methane to energy; solar desalination; air filtration; transpiration cooling; and delivery of fluids in low-gravity environments.

Cellular fluidics concepts could improve current microfluidics technology by allowing for controlled fluid transport in complex geometries in 3D, whereas today's microfluidic systems are typically planar and enclosed, limiting their ability to reproduce multiphase processes.



LLNL's cellular fluidics research was featured in a recent issue of *Nature*, including an illustration depicting how the micro-architected structures mimic fluid transport systems found in nature. (Illustration by Jacob Long/LLNL.)

"Our technology combines both liquid and gas transport into a single system, using a three-dimensional system rather than a flat configuration," said LLNL engineer Josh DeOtte.

According to Eric Duoss, principal investigator of the LDRD-funded research, they were inspired by nature, as they explored ways to replicate complex systems. “We started to see that we could deterministically control how a liquid would flow into the porous architecture by programming some of the local microscale attributes of these structures,” explained Duoss. “We found that we could control the arrangement and propagation of liquids, while also controlling the arrangement and propagation of gases. When you have control over both, you can do some pretty incredible things.”

More information regarding LLNL’s cellular fluidics research can be found on LLNL’s website. *(LLNL-WEB-458451)*

Livermore investigators develop novel imaging capabilities to probe microscopic defects found deep inside materials

An LDRD-funded research team developed a new tool for probing nanoscale crystal defects embedded in materials, enabling imaging of ultrafast structural changes. This unique imaging technology, known as time-resolved, dark-field x-ray microscopy (DFXM), zooms in to image defects as they respond to stress, such as high temperatures or pressures.

Connecting a material’s microscopic defects to its macroscopic properties—such as mechanical, thermal, and electronic properties—is an age-old problem in materials science. For example, interactions between a type of defect known as dislocations play a key role in how material deforms or melts, but until now, scientists did not have tools to explore the connections between these dynamics and the material’s properties, such as its plasticity.

Dislocations are abrupt defects in the atomic lattice that enables crystalline materials to permanently change their shape under pressure. The movement of dislocations, and how they interact, directly affects a material’s ability to change shape without fracturing.

The research team demonstrated how DFXM imaging technology can be used to directly visualize how dislocations move and interact over hundreds of micrometers, deep inside bulk aluminum. By analyzing “movies” captured using DFXM technology, such as the video available on LLNL’s website, investigators showed that the thermally activated motion and interactions of dislocations resulted in weakened binding forces and destabilized the structure at 99 percent of the material’s melting temperature (660 degrees Celsius). The images map the migration of the dislocation boundary, including how the space between dislocations grows in response to high temperatures.

“This work presents a large step forward for materials science, physics, and related fields, as it offers a unique new way to view the ‘intermediate scales’ that connect microscopic defects to the bulk properties they cause,” said Leora Dresselhaus-Marais, a research fellow at LLNL who served as the project’s principal investigator, and now is an assistant professor of Materials Science and Engineering at Stanford University.

Collaborators included scientists from NNSA’s Nevada National Security Site (NNSS), the European Synchrotron Radiation Facility, and university-based researchers. For more information regarding the related work done by our collaborators at NNSS, see page 11 of their April 2021 newsletter.
More information regarding the new subsurface imaging capability can be found on LLNL’s website. *(LLNL-WEB-458451)*

Livermore team designs laser-driven semiconductor switch for next-generation communication systems

LLNL engineers designed a new type of laser-driven semiconductor switch that can theoretically achieve higher speeds at higher voltages than existing photoconductive devices. According to the research team, such a device could enable next-generation satellite communication systems capable of transferring more data at a faster rate, over longer distances.

The photoconductive device uses a high-powered laser to generate an electron charge cloud in the base material (gallium nitride) while under extreme electric fields.

Unlike normal semiconductors, in which electrons move faster as the applied electrical field is increased, gallium nitride expresses a phenomenon called negative differential mobility, where the generated electron cloud doesn't disperse, but actually slows down at the front of the cloud. This allows the device to create extremely fast pulses and high voltage signals at frequencies approaching one terahertz when exposed to electromagnetic radiation.

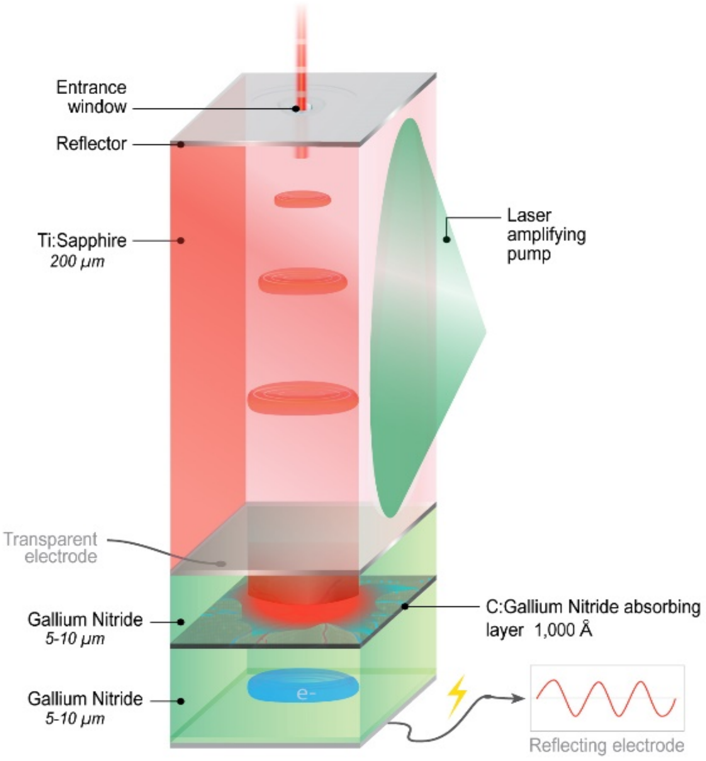


Illustration depicting a new type of laser-driven semiconductor switch developed by LLNL researchers designed to enable next-generation, smaller, more energy efficient communication systems. (Image courtesy of LLNL.)

"Our goal is to build a device that is significantly more powerful than existing technology, and can also operate at very high frequencies," said LLNL engineer Lars Voss, the project's principal investigator. "It works in a unique mode, where the output pulse can actually be shorter in time than the laser's input pulse—almost like a compression device. You can compress an optical input into an electrical output, making it theoretically possible to generate extremely high-speed and high-power radio frequency waveforms."

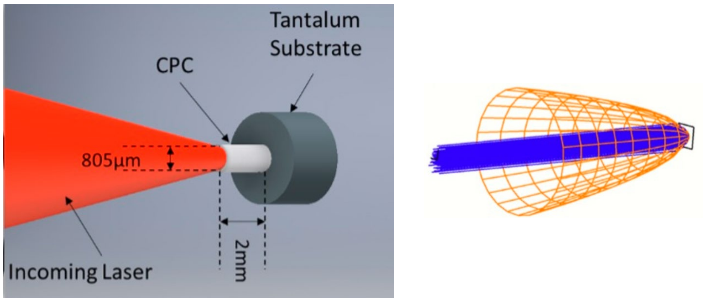
Simulation of the new switch design was performed with collaborators at the University of Illinois Urbana-Champaign. Engineers are currently building the switches at LLNL and exploring other materials, such as gallium arsenide, to optimize performance.

"Gallium arsenide expresses the negative differential mobility at lower electric fields than gallium nitride, so it's a great model to understand the tradeoffs of the effect with more accessible testing," said Karen Dowling, an LLNL postdoctoral researcher and a member of the research team.

More information regarding LLNL's laser-driven semiconductor switch can be found on the Laboratory's website. *(LLNL-WEB-458451)*

Livermore scientists enhance the temperature of laser-driven electron beams via cone targets

A team of scientists from LLNL explored a novel approach to increasing the yield and energy of high-intensity laser systems. Intense, short-pulse, laser-driven production of bright high-energy sources, such as x-rays, neutrons, and protons, play a key role in studies of high-energy-density science. They also have applications for industry and national security, such as x-ray radiography of high-areal-density objects.



Drawings depicting how the cone geometry is used to focus the laser's rays to the tip of the cone. (Image courtesy of LLNL.)

The LDRD-funded research team conducted experimental measurements of hot-electron production using a short-pulse, high-contrast laser on both cone and planar targets. The cones utilized a geometry known as a compound parabolic concentrator (CPC), which is designed to focus all of the laser's rays precisely to the tip of the cone. The CPC geometry showed higher hot-electron temperatures than can be produced using planar foils. Based on simulations, researchers identified that the primary source of this temperature enhancement is the intensity increase caused by the CPC.

The team demonstrated these temperature enhancements during experiments at the University of Austin's Texas Petawatt Laser facility. "We were able enhance the temperature of the electron beam from our high-intensity laser interactions by shooting into a focusing cone target," said Dean Rusby, an LLNL postdoctoral appointee who led efforts to assess the feasibility of this approach. "Findings show that we understand how the concentrator works under these laser conditions."

"The experiments showed that miniature plasma mirror targets improve coupling of petawatt-class lasers to mega-electronvolt electrons," explained Andrew Mackinnon, principal investigator of the LDRD project that funded this experiment. Potential applications of this capability include laser-based mega-electronvolt radiography, as well as other new diagnostic capabilities.

More information regarding work aimed at enhancing the temperature of electron beams can be found on LLNL's website. *(LLNL-WEB-458451)*

Mission Agility	Technical Vitality	Workforce Development
Enable agile responses to national security challenges.	Advance the frontiers of science, technology, and engineering.	Attract, retain, and develop tomorrow's technical workforce.

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For more information

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