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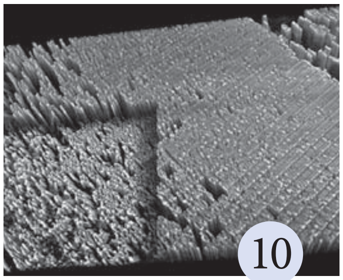

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From the Executive Director

The end of summer is quickly approaching and you know what that means – Pumpkin Spice Latte season is almost here! But in all seriousness, for those of us in the CSA world, it means the first ever *virtual* Space Cryogenics Workshop will be taking place in just a few short months on November 15-17, 2021.

With COVID-19 cases on the rise across the country and numerous in-person events being cancelled, myself and the co-chairs of the SCW have all agreed that moving the event to a virtual format was the right decision this year. As much as we'd all love to be on a beach in Hawaii, the safety of our attendees, presenters and staff is of the utmost importance. As a reminder, we do plan to hold the 30th Space Cryogenics Workshop in Hawaii prior to the CEC-ICMC which will be in July of 2023. Full details will be announced as the date nears.

In the meantime, we are in full planning mode for this year's virtual SCW. If you haven't done so already, I encourage you to register for the event prior to October 1 in order to take advantage of Earlybird rates. Because the event is virtual, registration rates have been substantially reduced. For full details and registration, visit **www.spacecryogenicsworkshop.org.**

I would be remiss if I didn't give a major shout-out to the presenters and coordinators of the virtual CEC-ICMC which took place July 19-23, 2021. I was able to attend many of the sessions, and I was incredibly impressed not only by the content, but also by the virtual platform and organization of the event. I would also like to thank CEC-ICMC for allowing CSA to host a number of Short Courses on the Sunday leading into their event. A full breakdown of the CEC-ICMC is in this issue of ***Cold Facts*** on page 40, "Conference Connect."

If you missed attending one of the CSA Short Courses held prior to CEC-ICMC, don't worry! The recordings and materials are now available for purchase on the CSA website. Course materials are available for $125 each, and the recordings plus materials are available for $225 each. The courses offered are as follows:

- **Theory, Modeling and Design of Regenerative Cryocoolers** instructed by Dr. Ray Radebaugh, NIST Fellow Emeritus
- **Aspects of Cryostat Design** instructed by Dr. John Weisend II, European Spallation Source ERIC; CSA Chairman
- **Getting Started with Cool Fuels: Liquefied Hydrogen and Natural Gas** instructed by Dr. Jacob Leachman, Associate Professor, Washington State University

Visit the CSA website at **http://2csa.us/shortcourses** to purchase your short course recordings today.

Lastly, I want to remind our readers that ***Cold Facts*** would not be possible without the support of all of you. Your stories, ideas, company and personnel news are welcome at any time. In the coming months, we will be announcing our 2022 Editorial Calendar. I encourage you to read through the calendar, and plan to submit an article or news for one of next year's issues. We will also be preparing the 2022 Buyers Guide in the near future. If you are listed in the Buyers Guide, expect to see an email from us requesting that you review and update your listing.

As always, I hope you enjoy this issue of ***Cold Facts***. ■

Cold Facts Editorial Board

Around the Labs

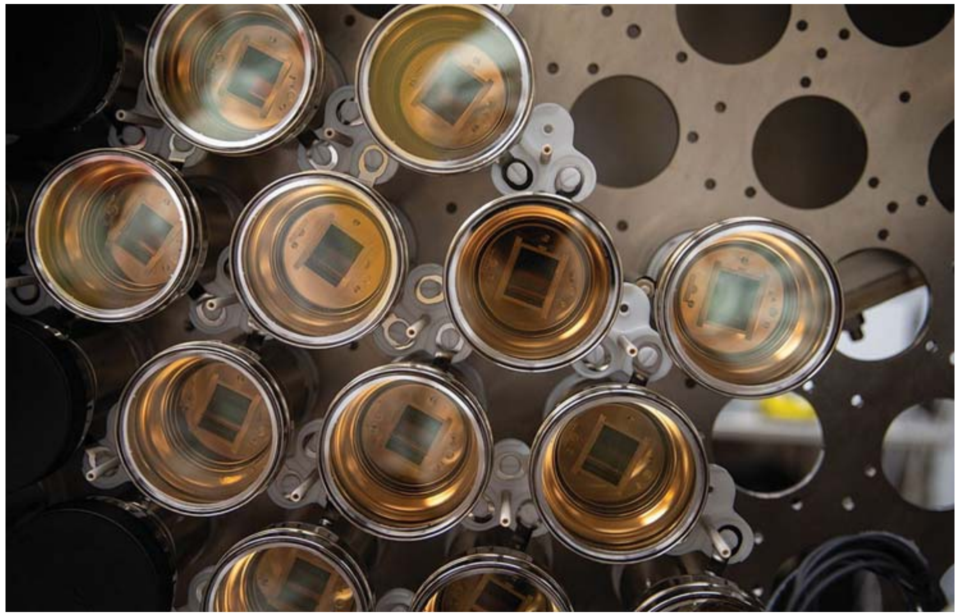
Leading Xenon Researchers Unite to Build Next-Generation Dark Matter Detector

The DARWIN and LUX-ZEPLIN collaborations have now joined forces to work together on the design, construction and operation of a new, single, multi-tonne scale xenon observatory to explore dark matter. The announcement was made July 20. The detector will be highly sensitive to a wide range of proposed dark matter particles and their interactions with visible matter. Over the last 20+ years, experiments using liquefied xenon targets have delivered world-leading results in the global quest for direct dark matter detection. This next-generation detector aims to continue the pursuit. The experiment's location has yet to be finalized.

Dark matter makes up 85% of the matter in the Universe, but its nature remains a mystery. The direct identification of the dark matter particle is amongst the highest priorities in science and also one of the most challenging. The primary science goal of the new joint observatory is to reach a sensitivity for detecting dark matter in our galaxy by at least a factor of 10 beyond that of the current generation of detectors.

The current xenon-based experiments, XENONnT (***Cold Facts***, Vol. 36, No. 4) and LUX-ZEPLIN (***Cold Facts***, Vol. 35, No. 6), will start their first science runs in 2021, to lead the race to detect the first signs of new particles and interactions. These experiments employ 5.9 and 7.0 tonnes of liquid xenon for the search, respectively. The LUX-ZEPLIN experiment operates at the Sanford Underground Research Facility (SURF) in the USA. The XENONnT experiment is located at the INFN Gran Sasso Laboratory (LNGS) in Italy. DARWIN is the evolution of the XENON program and includes additional groups, focusing on several R&D aspects required for the much larger detector.

Beyond its unparalleled sensitivity to dark matter, the detector's large mass and unprecedented low background level will also enable world-leading searches for additional signatures of physics beyond the Standard Model that would similarly revolutionize our understanding of the Universe. In particular, the secondary science goal will be the search for neutrinoless double-beta decay in xenon, shedding light on the nature of the neutrino and the imbalance of matter and antimatter in the Universe. The observatory will also perform searches for other rare processes and particles such as axions, hypothetical particles that might be emitted from the Sun. It will also measure neutrinos created in the Sun, the Earth's atmosphere and, potentially, those from galactic supernovae.



An array of light detectors, built at Brown, is a critical part of the LUX-ZEPLIN experiment that will begin searching for dark matter. Already, researchers are planning for the next detector, which will confirm and characterize the finds of current detectors. *Image: Al Johnson, Nick Dentamaro*

The new multitonne liquid xenon detector will combine the most successful technologies employed in rare-event searches with xenon detectors, including those developed for XENONnT and LUX-ZEPLIN, and from targeted R&D including that supported under DARWIN.

After a very successful first joint workshop on the Next-Generation Liquid Xenon Detector for Dark Matter in April 2021, more than 100 research group leaders from 16 countries signed a memorandum of understanding on July 6, 2021. Scientific cooperation has now begun to realize this next-generation rare event observatory. ■

An Exotic Particle Had an Out-of-Body Experience; These Scientists Took a Picture of It

by Theresa Duque, Lawrence Berkeley National Laboratory, tnduque@lbl.gov

Lawrence Berkeley National Laboratory (Berkeley Lab) scientists have taken the clearest picture yet of electronic particles that make up a mysterious magnetic state called quantum spin liquid (QSL). The achievement could facilitate the development of superfast quantum computers and energy-efficient superconductors. Announced on August 19, the scientists are the first to capture an image of how electrons in a QSL decompose into spin-like particles called spinons and charge-like particles called chargons.

"Other studies have seen various footprints of this phenomenon, but we have an actual picture of the state in which the spinon lives. This is something new," said study leader Mike Crommie, a senior faculty scientist at Berkeley Lab and physics professor at the University of California.

"Spinons are like ghost particles. They are like the Big Foot of quantum physics – people say that they've seen them, but it's hard to prove that they exist," said co-author Sung-Kwan Mo, a staff scientist at Berkeley Lab's Advanced Light Source (ALS). "With our method we've provided some of the best evidence to date."

A surprise catch from a quantum wave

In a QSL, spinons freely move about carrying heat and spin – but no electrical charge. To detect them, most researchers have relied on techniques that look for their heat signatures. Now, as reported in the journal ***Nature Physics***, Crommie, Mo and their research teams have demonstrated how to characterize spinons in QSLs by directly imaging how they are distributed in a material.

To begin the study, Mo's group at Berkeley Lab's Advanced Light Source (ALS) grew single-layer samples of tantalum diselenide (1T-TaSe2) that are only three atoms thick. This material is part of a class of materials called transition metal dichalcogenides (TMDCs). The researchers in Mo's team are experts in molecular beam epitaxy, a technique for synthesizing atomically thin TMDC crystals from their constituent elements. Mo's team then characterized the thin films through angle-resolved photoemission spectroscopy, a technique that uses X-rays generated at the ALS.

Using a microscopy technique called scanning tunneling microscopy (STM), researchers in the Crommie lab – including co-first authors Wei Ruan, a postdoctoral fellow at the time, and Yi Chen, then a UC Berkeley graduate student – injected electrons from a metal needle into the tantalum diselenide TMDC sample.

Images gathered by scanning tunneling spectroscopy (STS) – an imaging technique that measures how particles arrange themselves at a particular energy – revealed something quite unexpected: a layer of mysterious waves having wavelengths larger than one nanometer (1 billionth of a meter) blanketing the material's surface. "The long wavelengths we saw didn't correspond to any known behavior of the crystal," Crommie said. "We scratched our heads for a long time. What could cause such long wavelength modulations in the crystal? We ruled out the conventional explanations one by one. Little did we know that this was the signature of spinon ghost particles."

How spinons take flight while chargons stand still

With help from a theoretical collaborator at MIT, the researchers realized that when an electron is injected into a QSL from the tip of an STM, it breaks apart into two different particles inside the QSL – spinons (also known as ghost particles) and chargons. This is due to the peculiar way in which spin and charge in a QSL collectively interact with each other. The spinon ghost particles end up separately carrying the spin while the chargons separately bear the electrical charge.

In the current study, STM/STS images show that the chargons freeze in place, forming what scientists call a star-of-David charge-density-wave. Meanwhile, the spinons undergo an "out-of-body experience" as they separate from the immobilized chargons and move freely through the material, Crommie said. "This is unusual since in a conventional material, electrons carry both the spin and charge combined into one particle as they move about," he explained. "They don't usually break apart in this funny way."

Crommie added that QSLs might one day form the basis of robust quantum bits (qubits) used for quantum computing. In conventional computing a bit encodes information either as a zero or a one, but a qubit can hold both zero and one at the same time, thus potentially speeding up certain types of calculations. Understanding how spinons and chargons behave in QSLs could help advance research in this area of next-gen computing.

Another motivation for understanding the inner workings of QSLs is that they have been predicted to be a precursor to exotic superconductivity. Crommie plans to test that prediction with Mo's help at the ALS. "Part of the beauty of this topic is that all the complex interactions within a QSL somehow combine to form a simple ghost particle that just bounces around inside the crystal," he said. "Seeing this behavior was pretty surprising, especially since we weren't even looking for it." ■

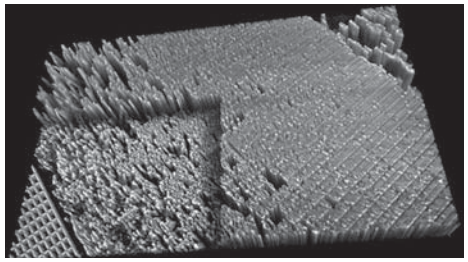
New Argonne Method Improves X-Ray Nanotomography Resolution

by Andre Salles, Argonne National Laboratory

Using the powerful X-ray beams of the Advanced Photon Source (APS) with new computer-driven algorithms, scientists at Argonne National Laboratory (CSA CSM) and beyond will be able to study batteries and electronics at nanometer scales. To that end, a group of scientists led by the Argonne team has created a new method for improving the resolution of hard X-ray nanotomography. Nanotomography is X-ray imaging on the scale of nanometers. For comparison, an average human hair is 100,000 nanometers wide. The team constructed a high resolution X-ray microscope using the powerful X-ray beams of the APS and created new computer algorithms to compensate for issues encountered at tiny scales. Using this method, the team achieved a resolution below 10 nanometers. The team's research was published in ***Advanced Materials***.

It's been a truth for a long time: if you want to study the movement and behavior of single atoms, electron microscopy can give you what X-rays can't. X-rays are good at penetrating into samples – they allow you to see what happens inside batteries as they charge and discharge, for example – but historically they have not been able to spatially image with the same precision electrons can.

Scientists are working to improve the image resolution of X-ray techniques. One such method is X-ray tomography, which enables non-invasive imaging of the inside of materials. If you want to map the intricacies of a microcircuit, for example, or trace the neurons in a brain without destroying the material you are looking at, you need X-ray tomography, and the better the resolution, the smaller the phenomena you can trace with the X-ray beam. "We hope this will be a powerful tool for research at smaller and smaller scales," said Viktor Nikitin, assistant physicist at Argonne National Laboratory.



This image of a plate with 16-nanometer-wide features was captured in resolutions of less than 10 nanometers, allowing scientists to see the tiny defects in its shape. *Image: Vincent De Andrade*

"We want to be at 10 nanometers or better," said Michael Wojcik, a physicist in the optics group of Argonne's X-ray Science Division (XSD). "We developed this for nanotomography because we can obtain 3D information in the 10-nanometer range faster than other methods, but the optics and algorithm are applicable to other X-ray techniques as well."

Using the in-house Transmission X-ray Microscope (TXM) at beamline 32-ID of the APS – including special lenses fashioned by Wojcik at the Center for Nanoscale Materials (CNM) – the team was able to use the unique characteristics of X-rays and achieve high resolution 3D images in about an hour. But even those images were not quite at the desired resolution, so the team devised a new computer-driven technique to improve them further.

The main issues the team sought to correct are sample drift and deformation. At these small scales, if the sample moves within the beam, even by a couple nanometers, or if the X-ray beam causes even the slightest change in the sample itself, the result will be motion artifacts on the 3D image of the sample. This can make subsequent analysis much more difficult.

A sample drift can be caused by all kinds of things at that small a scale, including changes in temperature. To perform tomography, the samples also must be rotated very precisely within the beam, and that can lead to motion errors that look like sample drifts in the data. The Argonne team's new algorithm works to remove these issues, resulting in a clearer and sharper 3D image. "We developed an algorithm that compensates for the drift and deformation," said Nikitin. "When applying standard 3D reconstruction methods, we achieved a resolution in the 16-nanometer range, but with the algorithm we got it down to 10 nanometers."

The research team tested their equipment and technique in several ways. First they captured 2D and 3D images of a tiny plate with 16-nanometer-wide features fabricated by Kenan Li, then of Northwestern University and now at DOE's SLAC National Accelerator Laboratory (CSA CSM). They were able to image tiny defects in the plate's structure. They then tested it on an actual electrochemical energy storage device, using the X-rays to peer inside and capture high resolution images.

Vincent de Andrade, a beamline scientist at Argonne at the time of this research, is the lead author on the paper. "Even though these results are outstanding," he said, "there is still a lot of room for this new technique to get better."

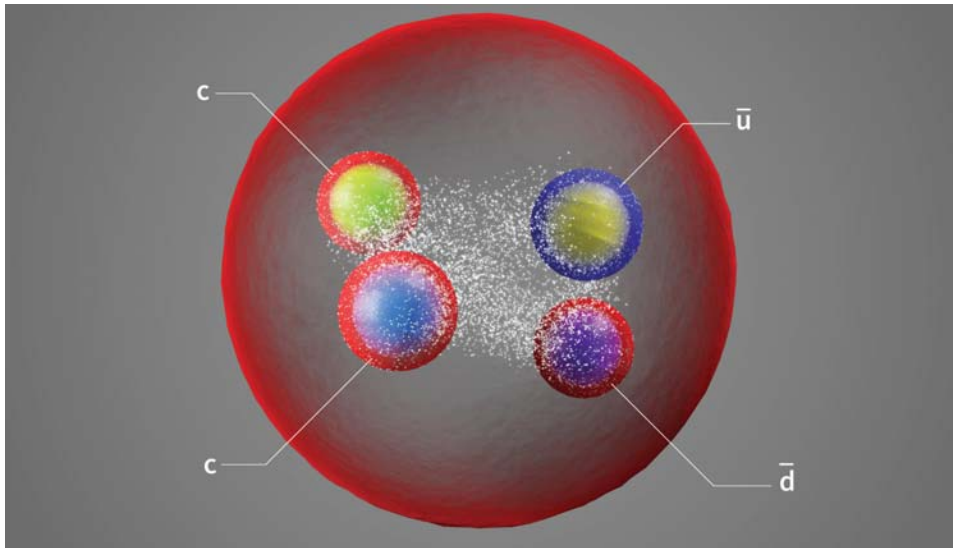
The capabilities of this instrument and technique will improve with a continuing research and development effort on optics and detectors, and will benefit from the in-progress upgrade of the APS. When complete, the upgraded facility will generate high-energy X-ray beams that are up to 500 times brighter than those currently possible, and further advances in X-ray optics will enable even narrower beams with higher resolution. "After the upgrade, we will push for eight nanometers and below," said Nikitin. "We hope this will be a powerful tool for research at smaller and smaller scales." ■

LHCb Discovers Longest-Lived Exotic Matter Yet

by Sarah Charley, CERN, sarah.charley@cern.ch

The LHCb experiment at the Large Hadron Collider at CERN is adding a new particle to its family of exotic matter. In the last seven years, the LHCb experiment has detected about a dozen types of exotic particles made up of four quarks (called tetraquarks) or five quarks (called pentaquarks). The newly discovered tetraquark, announced on July 1, is by far the most stable exotic particle they've found.

The tetraquark they found owes its stability to its unique quark content: two heavy "charm" quarks and two light antiquarks. However, it's not yet clear how exactly this object is put together. Figuring this out will help nuclear physicists better understand the inner workings of larger atomic nuclei, which are currently too complex to describe with the fundamental laws of physics. "This tetraquark lives at least 10 times longer than the other forms of exotic matter we've discovered," says Syracuse University postdoc Ivan Polyakov, who worked on this research with his colleagues on the LHCb experiment.



An artist's impression of Tcc+, a tetraquark composed of two charm quarks and an up and a down antiquark.
Image: CERN

The messy world of quarks

Quarks are the point-like, fundamental particles that live inside hadrons, such as protons and neutrons. Most hadrons are made from two or three quarks. But in 2014, the LHCb experiment confirmed the existence of tetraquarks (and later, pentaquarks). Since this revolutionary discovery, LHCb and other experiments have continued to find new tetraquarks and pentaquarks, each with a distinctive internal configuration.

The LHCb experiment searches for new forms of matter in the collisions generated by the Large Hadron Collider. It's difficult to disentangle exactly what's happening when two protons collide inside the LHC, says Syracuse professor Sheldon Stone. "You have this mess of things going on in this very small region of space and time," he says.

In this mess, quarks are liberated from the protons and swimming through a broth of gluons, a force-carrying particle that "glues" quarks together. Because quarks cannot exist for long alone, they spontaneously create more quark-antiquark pairs from the gluon broth. If quarks come close enough together, they can bind together and form rare hadrons.

These rare hadrons decay into more stable byproducts, which are captured and recorded by the LHCb detector. Those detections allow scientists to learn more about what was produced during the collision and, by retracing these byproducts back to their origins, scientists can determine the properties of the original particle.

Polyakov decided to search for this doubly charmed tetraquark in data recorded by the LHCb experiment after numerous discussions with Stone and Syracuse professor Tomasz Skwarnicki. "And nevertheless, it was a big surprise as it was not clear if such a state would exist at all," Polyakov says. "It was a real gift, as we couldn't have anticipated that it would have such exceptional properties."

Doing physics with Heisenberg

The long lifetime of this new tetraquark means that for the first time, scientists can precisely measure the mass of an exotic hadron. That's been difficult to do with its shorter-lived compatriots. "It's because of the Heisenberg uncertainty principle," Polyakov says.

This famous tenet of quantum mechanics dictates that it's impossible to precisely know multiple attributes of a quantum-mechanical object at the same time. For instance, if the position of a particle is precisely known, then the momentum will remain largely a mystery. The same goes for the lifetime of a particle and its mass. "So if the particle decays fast, there must be a big uncertainty in its mass," Polyakov says.

In the data, scientists see this uncertainty as a wide peak smeared across numerous possible masses. But if a particle is more stable – and thus has more flexibility in its lifetime – then its mass can come into focus. In the data, this looks like a sharp peak springing up at a well-defined mass.

A precise measurement of the mass of this tetraquark will answer a question that physicists have been wrestling with since they discovered their first exotic hadron: How do the quarks bind together? Are they in a tight clump, or do they look more like a loose molecule made up of two quark pairs? Or maybe even something in between?

"Right now, it's not yet clear," Polyakov says. "We have measured its mass and the width of the peak very precisely. This will prompt theorists to make more accurate calculations and hopefully develop a deeper understanding of exotic hadrons."

Going nuclear

According to Polyakov, these exotic forms of matter could be the missing links in our understanding of a much more ordinary form of matter: the atomic nucleus. "We have a theory that gives good predictions on very small scales – 1/100th the size of a proton and less," he says. "But when we get to the size of a proton or more, the calculations get so complicated that nobody is able to do them."

When modeling the interactions of quarks within a stable atomic nucleus, theorists must currently make assumptions and simplifications. However, for systems containing heavy quarks, the exact calculations are better defined. Because of this, scientists use particles with heavy quarks (and their well-defined mathematical models) as a test for the theoretical assumptions about atomic nuclei.

"This new tetraquark can be viewed as a simplified model of a proton and a neutron bonded together into a deuteron," Polyakov says. "If we can better understand how quarks bind in tetraquarks, we will have a deeper insight into how this interaction happens inside atomic nuclei."

Polyakov and his US colleagues on the LHCb experiment are funded by the National Science Foundation. They are hoping to find even longer-lived exotic hadrons – ones that could travel up to a centimeter before decaying – in the not-so-distant future. "We're hoping that with the new upgrades to our detector, we'll be able to get to that level," Stone says. ■

Scientific Publishing Organizations, 17 National Laboratories Partner on Name-Change Process for Published Papers, Embrace Transgender Inclusivity

All 17 US national laboratories and many prominent publishers, journals and other organizations in scientific publishing announced the beginning of a partnership to support name change requests from researchers on past published papers. This agreement will allow researchers who wish to change their names to more easily claim work from all stages of their careers; it specifically addresses the administrative and emotional difficulties some transgender researchers have experienced when requesting name changes associated with past academic work.

Previously, individual researchers shouldered the burden of initiating name change requests, both administratively and emotionally, with each publisher of their past papers. While many publishers have been independently updating their own policies to address an increasing number of name-change requests, this partnership streamlines these processes and offers an official validation mechanism to all involved by enabling researchers to ask their respective institutions to pursue name changes on their behalf directly with the publishers and journals.

Image: Jenny Nuss, Berkeley Lab

For researchers of all genders – and transgender researchers specifically – the new process ensures they can rightfully claim ownership of prior work under their former name without fear of reprisal and be known in their respective fields primarily through their merits as published authors. As several researchers have attested, having their names updated on previous publications allows them to best represent their full suite of accomplishments. The ability to claim the volume of their work over time has significant implications for maintaining prominence in their area of research and for receiving credit for their academic impact.

The partnership between the national laboratories, major scientific publishers, journals and other organizations represents a commitment to creating a more inclusive culture in STEM fields and STEM publishing in particular. The national laboratories will facilitate requests for name changes for any reason, including religious, marital or other purposes where supported by the policies in place at publishing partners.

The 17 national laboratories across the US are pursuing this work in alignment with their respective diversity, equity, and inclusion initiatives, not as a result of any federal policy changes, and welcome new partners as the effort advances. Lawrence Berkeley National Laboratory (Berkeley Lab) is coordinating the effort. ■

DUNE Experiment Progresses in Drilling, Continues towards Space for 68,000 tons of Liquid Argon

by Mary Magnuson, Fermilab, mmagnuson3@wisc.edu

Right now, nearly a mile below ground in South Dakota, there's a flurry of activity. Three shifts of 30 construction workers each labor around the clock, carving out subterranean space for science. It's a huge effort centered around one of the tiniest things in nature: the neutrino. Trillions of them pass through you every second without a trace. They're produced by almost everything: Earth, the sun, supernovae, bananas and people, to name a few. These bizarre building blocks could hold the key to understanding why matter exists in the Universe, rather than antimatter – or nothing at all.

Drilling the ventilation shaft. Fermilab's Syd Devries (left) and James Rickard stand with the reamer.
Image: Andrew Hardy, Thyssen Mining

To better study these elusive particles, an international collaboration of more than 1,000 scientists are building the Deep Underground Neutrino Experiment, or DUNE, hosted by the US particle physics laboratory Fermilab (CSA CSM). Researchers will study a beam of neutrinos as it leaves the PIP-II accelerator in Illinois (Page 18 to PIP Story) and again when it reaches the Sanford Underground Research Facility in South Dakota. The particles will travel 800 miles (1,300 kilometers) straight through the Earth to go from lab to lab, with no tunnel needed.

Space for four jumbo jets

The DUNE detector will be the largest neutrino detector of its kind ever made. Each of the four detector modules will hold 17,000 tons of liquid argon, in which neutrinos will interact and leave their signature traces. Making space for these massive instruments and their support equipment is part of the work to create the Long-Baseline Neutrino Facility. It will require moving roughly 800,000 tons of rock, creating caverns big enough to hold the bodies of four jumbo jets.

Thyssen Mining, the company carrying out the excavation, is one of two major contractors that are supporting the excavation phase of work. "It's our first federal contract. We were interested in it because we do large-cavern excavation in hard rock, so we are well qualified for it," Andrew Hardy of Thyssen Mining said. "It's very exciting for us to be part of this massive team that will contribute towards the success of this project. We're part of a great on-site team."

Before large cavern excavation can begin, there is some prep work to do. The first step is widening existing underground tunnels, called drifts, and creating a quarter-mile-long vertical ventilation shaft. The opening will improve the flow of air needed for excavation a mile underground at the 4,850-foot level, where the main construction work will take place. The excavation of the main caverns will begin this fall.

Excavating with precision

To create the shaft, Thyssen is using a technique called "raise-bore drilling." In June, construction workers drilled a 1,200-foot-long pilot hole about a foot in diameter from the 3,650-foot level down to the 4,850-foot level. The drill bit used sensors called inclinometers to detect any deviation from vertical, sending real-time data to a computer that issued corrections to the steering mechanism. The pilot hole was completed on June 30, with the drill emerging mere inches from its target in the cavern at the 4,850-foot level.

With the pilot hole complete, workers at the 4,850-foot level replaced the drill bit with a large reamer. This circular tool is about 12 feet wide and spins as the construction crew pulls it up through the ceiling, chewing out rock as it goes. The debris falls down to the 4,850-foot level, where it is scooped up, transported to the Ross Shaft and taken for a mile-long ride to the surface. A conveyor system then brings the rock another three-quarters of a mile to a former open-pit mining site called the Open Cut. Crews expect to complete the ventilation shaft in the fall.

The raise-bore technique "is probably the best method to build circular shafts," said James Rickard, the Fermilab resident engineer managing the excavation. "And it's very good for hard rock," the type present at the facility.

Along with excavation of the main caverns, crews will enlarge some of the drifts and the area around the Ross Shaft to create more space for transporting the DUNE equipment. For this excavation as well as the eventual excavation of the main caverns, the teams will switch to the "drill and blast" technique, using explosive charges placed in small holes.

Working underground isn't always easy, but the crews are highly trained and work with state-of-the-art equipment. "It can be dark; it can be dirty; it can get hot," Rickard said. "But it's a way of life that these workers are used to. And we have everything modern — we've got modern equipment and good ventilation."

Driven by science

When the space is ready, researchers will begin bringing all of the components needed for the massive experiment underground and assembling the detector, like a ship in a bottle.

The raise-bore drill rig stands at the ready. *Image: Nathan Strasbaugh*

DUNE will address three major science goals: determine why matter exists in the Universe; watch for neutrinos from a supernova in our galaxy; and look for unexpected subatomic processes, such as proton decay — a phenomenon that has never been observed before.

Fermilab's Elaine McCluskey, the project manager for LBNF/DUNE-US, said while the excavation process may take years, keeping the future science goals in mind helps her stay excited. "It feels like we're actually accomplishing the goal that we all want to get to, which is to enable the scientists to take data," McCluskey said. "Neutrinos will help us understand more about our universe and ourselves. People want to know why we're here, why we exist. DUNE will bring us closer to the answers to these questions." ■

Successful Tests Pave the Way for Fermilab's Next-Generation Particle Accelerator

by Diana Kwon, diana.kwon89@gmail.com

A highly anticipated particle accelerator project at the US Department of Energy's Fermilab (CSA CSM) is one step closer to becoming a reality. This spring, amidst the pandemic, testing wrapped up at the PIP-II Injector Test Facility, or PIP2IT (***Cold Facts***, Vol. 36, No. 4). The successful outcome paves the way for the construction of a new particle accelerator that will power record-breaking neutrino beams and drive a broad physics research program at Fermilab over the next 50 years.

The feat was a culmination of over eight years of work on the Proton Improvement Plan-II, or PIP-II, by a dedicated group of scientists, technicians and engineers. "I'm very proud, first and foremost, of how the entire team came together in the middle of the pandemic and achieved so much under such adverse circumstances," said Lia Merminga, Fermilab PIP-II Project Director.

In February 2020, PIP-II Engineer Lidija Kokoska (left) and Project Director Lia Merminga in the PIP-II Test Injector Facility. In spring 2021, the PIP-II team successfully completed testing of the front end of the new particle accelerator.
Image: Al Johnson, Fermilab

Prototyping a next-generation accelerator

Once complete, PIP-II will be one of the highest-energy and highest-power linear particle accelerators in the world. It is the first accelerator project in the US with significant international contributions, with partner institutions in France, India, Italy, Poland and the United Kingdom.

PIP-II will provide the international particle physics community with a world-class scientific facility that will enable discovery-focused research using neutrinos, muons and protons. It will power the international Deep Underground Neutrino Experiment (DUNE, page 16), as well as many other particle physics experiments at Fermilab that aim to transform our understanding of the universe. Along the way, it strengthens the connection between advances in fundamental science and technological innovation.

The PIP-II accelerator will be 215 meters long and propel particles to 84% the speed of light. It will have the unique ability to deliver particle beams in either a steady stream or a pulsed mode. The machine will comprise 23 cryomodules — large vessels that house and cool structures known as superconducting cavities. These cavities will provide the bulk of the particle acceleration in PIP-II.

PIP-II's ambitious specifications come with many technical challenges. For example, PIP-II will feature five different types of superconducting cavities. Each type needs to be separately prototyped and tested. "Some of the capabilities that are embedded in the design of PIP-II are encountered by the international community for the first time, therefore intense development and technology validation is required," Merminga said. "Since PIP-II is built with components from around the world, ensuring that all these systems integrate seamlessly is of paramount importance."

PIP2IT was conceived, constructed and operated to serve as a proof-of-concept for the front end of PIP-II. It comprises the particle source and the first section, which is approximately 30 meters long. "We wanted to build this because it is one of the most complicated parts of PIP-II," said Eduard Pozdeyev, PIP-II Project Scientist and Commissioning Manager. "The main idea behind PIP2IT was to prototype the critical systems of the main accelerator."

Two stages to success

The construction and testing of PIP2IT took place in two stages. The first phase, which began in 2013, focused on building the room temperature portion of the machine. This included three parts: an ion source that generates the hydrogen ions; a radiofrequency quadrupole module, or RFQ, designed and built by DOE's Berkeley Lab, which focuses and accelerates the particle beam; and a transport line for carrying the beam to the superconducting section of the accelerator.

The team then carried out stage-one tests from 2016 to 2018. Testing ended with the generation of a beam that reached the goal of 2.1 million electronvolts of energy. The successful testing of all room temperature components was a key step necessary to progress to the project's next stage. "The ion source puts out these H-minus ions at 30,000 electronvolts, which is comparable to the energy that old-fashioned cathode-ray tube televisions used to produce," said Fermilab Engineer Curtis Baffes, the linac installation manager for PIP-II. "Then the RFQ takes that up to 2.1 million electronvolts — that's a very significant energy increase."

During the second stage, which began in 2019, the PIP2IT team installed and tested the first parts of the cold section of the machine, which uses superconducting radiofrequency technology. They installed two cryomodules known as HWR, contributed by DOE's Argonne National Laboratory (CSA CSM, ***Cold Facts***, Vol. 36, No. 1), and SSR1, designed and constructed at Fermilab.

SSR1 also integrated a new feature called the strongback technology. Typically, technicians link the cavities within a cryomodule to one another. The strongback technique connects the cavities to a common frame instead. This reduces vibration and enables easier alignment and assembly.

Meeting all goals

Cooling down these two cryomodules with liquid helium, then demonstrating that they could accelerate beams was "a big accomplishment," Baffes said. "When the two cryomodules were cooled down, powered up and validated, they were individually big milestones. Then the final milestone was putting everything together and operating it with a particle beam."

Despite the global pandemic, the PIP2IT team managed several novel feats for Fermilab. That included the first acceleration of a proton beam using superconducting technology; the completion of SSR1, the first cryomodule entirely developed and built in-house; and the employment of the novel strongback technology. The Bhabha Atomic Research Center in India, an international partner of PIP-II, supplied one of the SSR1 cavities, meeting the stringent specifications for the component. BARC also provided the radio frequency power amplifiers that powered the SSR1 cryomodule and successfully enabled beam acceleration in PIP2IT.

The test accelerator met the team's goals. The machine reached the beam parameters needed for the Long-Baseline Neutrino Facility, which will generate the neutrinos for the DUNE. PIP2IT achieved a beam energy of 16.5 million electronvolts, a current of 2 milliamps with 550-microsecond-long pulses and a 20-Hertz repetition rate. It also demonstrated the seamless integration of national and international partner deliverables.

Bringing the many pieces of PIP2IT together and making sure that they met all the operational requirements was no easy feat. It was one that took years of painstaking effort by a dedicated team, Pozdeyev said. "Once we demonstrated that this whole complex system operated, we breathed a big sigh of relief."

On top of the technical challenges posed by the project, working during a pandemic brought additional obstacles. The PIP2IT team had to temporarily shut down activities and introduce all the necessary precautions – such as setting up plexiglass barriers and establishing strict social distancing rules – before restarting.

"We achieved all the main goals and milestones, even with all those difficulties," said Lionel Prost, the manager for the warm front end of PIP-II. "It is gratifying that we were able to do it during those times."

Testing novel features: beam chopping and artificial intelligence

The PIP2IT team also tested a novel technique for PIP-II: bunch-by-bunch chopping.

Accelerators typically propel and deliver particles in bunches – parcels that hold trillions of particles each – that are mere nanoseconds apart. A so-called chopper system within PIP2IT enables operators to eject bunches of particles at controlled intervals. This enables the machine to deliver unique beam patterns catered to the needs of a given experiment.

"One particularity of this chopping system is that it should be able to take any of the bunches that come out of the RFQ and be capable of kicking them to the absorber or letting them pass," Prost said. "That has been a tricky and difficult technical achievement, because this technology doesn't exist anywhere else."

The team also demonstrated the implementation of artificial intelligence in PIP2IT. They used machine learning algorithms to align the beam trajectory within the cryomodules. The eventual goal is to use such AI/ML technology more broadly in PIP-II and beyond. "The ultimate vision is an autonomous accelerator," Merminga said. "A scientist comes in, dials in the beam parameters that they want for an experiment and then the software tunes the machine to deliver them. Minimal to no human intervention."

A new beginning

PIP2IT completed its final run in April. Now, the team is working on disassembling the machine. They will store the cryomodules and other components until the construction of the PIP-II building is complete.

Meanwhile, the project team will convert the cave that currently houses PIP2IT into a PIP-II cryomodule test facility. Before installation, each of PIP-II's 23 cryomodules needs to be cooled down to cryogenic temperatures and tested.

PIP2IT was an important learning experience, teaching the team important lessons about the operation of the machine's complex components such as its cryomodules. It also demonstrated the coordination that is necessary to integrate the numerous systems that come together.

"All these lessons learned are going to be used to improve, update, modify and test designs for PIP-II," Pozdeyev said. "When you start commissioning a new machine, sometimes you don't know what's going to happen. The test results obtained from PIP2IT significantly reduce the risk of future operations."

While PIP2IT is now complete, PIP-II's journey continues. "Demonstrating that the front of PIP-II can meet its requirements is certainly a great milestone for the project," Baffes said. "But it's definitely not the end of the story." ■

Purdue-Designed Heat Transfer Experiment Arrives at International Space Station

On August 10, an Antares rocket launched from the Mid-Atlantic Regional Spaceport on Wallops Island VA. Atop the rocket was a Northrop-Grumman Cygnus spacecraft carrying 3,000 pounds of supplies for the astronauts aboard ISS, as well as the Flow Boiling and Condensation Experiment (FBCE) and three other science experiments. Cygnus docked with ISS on August 12 where the FBCE will soon advance the science of heat transfer in microgravity.

Issam Mudawar (far left) inspects one of the modules of the Flow Boiling and Condensation Experiment, which was recently launched to the International Space Station. Joining him at NASA's Glenn Research Center are (left to right) Purdue PhD candidate Steven Darges and NASA's Mojib Hasan and Henry Nahra. *Image: Issam Mudawar*

People who design spacecraft must prioritize two factors: reducing weight and managing extreme temperatures. This new experiment designed by Purdue University engineers addresses both problems. "Vehicles like the space shuttle used single-phase cooling, which circulates liquid through tubes to remove heat from the avionics," said Issam Mudawar, the Betty Ruth and Milton B. Hollander Family Professor of Mechanical Engineering and the principal investigator of the FBCE. "But these systems are complex and add a lot of weight to the spacecraft. What we've been exploring is using two-phase flow, which is more efficient and reduces the size of the cooling hardware."

Two-phase flow refers to two phases of matter – liquid and vapor – that happen during boiling and condensation. In a process known as "flow boiling," a specialized liquid flows by a heat source, which causes the liquid to boil and create bubbles. Those bubbles of vapor flow past the heat source, reject the heat and then condense back into liquid, which recirculates constantly in a closed system. It's a highly efficient and well-studied process, but one aspect remains unknown: is flow boiling in space as efficient as flow boiling on Earth?

To find the answer, Mudawar formed a research partnership with NASA's Glenn Research Center (GRC). His team designed and built an experiment to test flow boiling and condensation in microgravity, and in 2012 the team sent it on the "vomit comet," an airplane that simulates periods of 15- to 17-seconds of microgravity by flying up-and-down parabolas. "We discovered that at certain flow rates, microgravity actually did reduce the amount of heat flux by up to 50%," Mudawar said.

In collaboration with colleagues at GRC, Mudawar's team continued to tweak multiple factors in the process, and in the next few years, sent the experiment up several times on parabolic flights with Zero Gravity Corporation (ZERO-G). Purdue students were aboard to operate the equipment. "Our goal has always been to achieve design specifications for the experiment to actually be performed in space," Mudawar said.

"Teaming up with Glenn Research Center has been a perfect partnership. This will be the largest phase change experiment ever conducted in space. Hopefully, what we learn from this experiment can be used to make future spacecraft more efficient, and enable us to go to the moon, Mars and beyond."

- Professor Issam Mudawar

The researchers got their wish earlier this year. Mudawar and his colleagues at GRC had been working on a smaller version of the experiment to fit in a specific rack on the International Space Station. In March, they confirmed that this new experiment module – FBCE – had passed all of NASA's safety and readiness reviews and was ready to be launched. "This is no small task," Mudawar said. "Every single structural member needs to be optimized for weight and size. Every single screw has to be evaluated and certified. It's actually good preparation for trying to make future spacecraft lighter, which is what we're trying to accomplish!"

Astronauts will soon run the science equipment through operational readiness reviews and, later this year, will begin to conduct the experiment.

"This is truly a milestone for Purdue's space research," Mudawar said. "I've had 14 PhD students and one Master's student work with me on this project over the past decade. Teaming up with Glenn Research Center has been a perfect partnership. This will be the largest phase change experiment ever conducted in space. Hopefully, what we learn from this experiment can be used to make future spacecraft more efficient, and enable us to go to the moon, Mars and beyond." ■

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Space Cryogenics

by Wesley Johnson, NASA Glenn Research Center, wesley.l.johnson@nasa.gov

Cryocooler Integration Options for Large-Scale Space Systems

The integration of the cryocooler to a load is an important detail in the use of any cryocooler or refrigeration system. Many system designs and tests have gone awry when attention to detail is not paid to the integration aspects. Unaccounted for thermal resistances or heat loads can leave a cooling system underpowered and significantly degrade system performance, enough to impact the mission. Often for terrestrial applications, the simplest approach is to install the cold head directly into the top of the tank, using it to induce natural convection and reliquefy any boil-off (Figure 1). However, for in-space applications, the structural mass implications of such an attachment method, the lack of a tank at all and the lack of natural convection to distribute the cooling within a tank lead to the need for other integration methods.

Figure 1: Cryocooler mounted on top of a tank. *Image: NASA*

For many space cryocooler applications, the surface to be cooled is a small set of optics that are on the scale of a few square centimeters. These small area cooling devices can easily be cooled by point cooling devices typically seen on a Pulse Tube or Stirling type cryocooler or a thermal strap (Figure 2). However, thermal straps or direct mounting require the warm and cold surfaces of a spacecraft to be in close proximity to each other, increasing the thermal challenges of the system. Many spacecraft in development continue to be these small systems where thermal strapping approaches work; however, several examples of large systems require different cooling integration approaches.

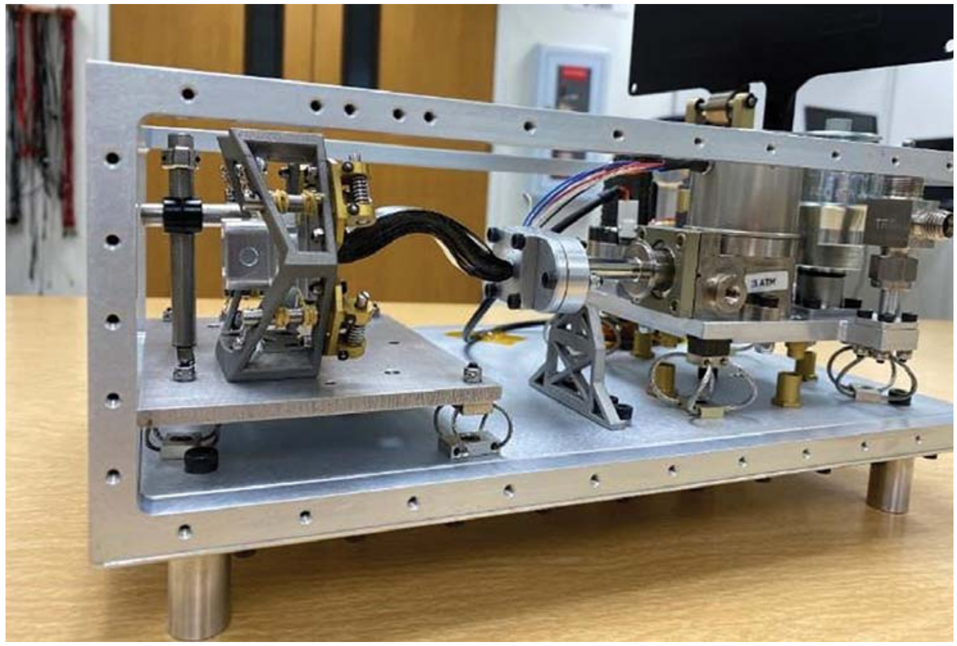

Figure 2: Optical plane mounted via flexible thermal strap to a cryocooler cold head. *Image: NASA/JPL*

The James Webb Space Telescope (JWST), which is currently planned to launch in late 2021, uses several meters of small gold-plated tubing to distribute cooling from a Joule-Thompson (JT) refrigeration system to the Mid Infrared Instrument (MIRI). [1, 10] This allows the cryocooler compressors to be packaged farther from the instrument. While the large sunshades encompassing the telescope preclude the need for cooling large areas, the proposed Origins Space Telescope has wider distribution networks required for cooling than JWST. Origins is proposing cooling four instruments similarly to the way that MIRI was cooled with the JT refrigeration system as a cooling distribution loop that is precooled by pulse tube cryocoolers. [10]

While most of the other integration methods are passive (they are generally always on or always off), the gas-gap or mechanical heat switch can be used for either passive or active control or isolation of the cryocooler. [12] The gas-gap heat switch uses a conductive gas over a small gap and relatively large surface area to conduct heat between the two sides of the gap. If one side gets too cold, the gas is collected by a getter, greatly limiting the conduction. These can be used to help not only connect cryocoolers to instruments, but also to behave as temperature control units, preventing the system from getting too cold.

For cooling of large propellant tanks, the cooling of large areas is required. To this effect, it was recently demonstrated that local cooling with large cooling loads can drive large unwanted temperature gradients in the system. [2] Multiple different approaches have been used to get around this challenge. Researchers from NASA's Marshall Spaceflight Center and Glenn Research Center demonstrated a forced pump cooling loop that interfaced with a thermodynamic vent system for cooling a tank. [3] While this does require the addition of heat to the system through running the pump, it does allow for integration of a more compact heat exchange area into a large volume system. Salerno and Feller developed the concept of broad area cooling, where a tubing network is attached to the exterior of the tank wall (Figure 3), the refrigeration system working gas flown through it to provide direct cooling to the tank wall. [4] This approach was used for demonstration of both tank cooling and intermediate temperature cooling [13] and is currently being extended to higher heat removal cases such as liquefaction. [14] This system attempts to intercept most of the heat before it gets into the tank and uses the tank wall as an expanded heat exchanger area.

This type of approach can work well with cooling cycles such as a Brayton cycle or Collins cycle where the working fluid of the refrigeration cycle goes directly through the tubing network on the tank wall. It can also work well with pulse tube and Stirling type cycles; however, a secondary circulation loop is required to move the heat from the tubing network on the tank wall to the cold heads. [5] Heat loads on any cold tubing that is not mounted in contact with the tank must be accounted for and carefully designed out. CERN has also recently explored this method for cooling resonating cavities in their cryomodules. [6] Notardonato developed a system with the heat exchanger inside the tank for direct cooling of the fluid. [7] While this has the advantage of interacting directly with the fluid, for spaceflight applications, it must structurally be attached to the tank in a manner that allows it to survive launch,

Figure 3: Tank with tubes welded to the tank wall.
Image: NASA

so it is less easily accessed if a problem occurs. This does however work very well for ground tanks, and NASA recently installed a heat exchanger inside their new 4,700 cubic meter sphere at the Kennedy Space Center. [11]

More recent developments such as pulsating heat pipes are showing promise for delivering cooling to distant locations with conductance values two orders of magnitude higher than that of traditional copper thermal straps. [8] Currently, efforts are underway to explore how long these pulsating heat pipes can be made without degradation in their performance. [9] With multiple cooling locations possible on a single cooling source, these may allow for even further simplification of cooling chains for large scale applications in space.

There is a wide array of methods of integrating cryocoolers into a system, with each method having its benefits and drawbacks. A careful evaluation of options must be performed when assessing a new application to identify any additional thermal heat loads that serve as parasitic loads or temperature differences on the cryocooler or refrigeration system.

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Cryo Bios

by Dr. John Weisend II, European Spallation Source ERIC, CSA Chairman, john.weisend@esss.se

Laszlo Tisza

Laszlo Tisza was an early researcher in the field of quantum mechanics who developed the two-fluid model of He II.

Tisza was born in Budapest, Hungary, in 1907. His original interest from a young age was mathematics. He studied mathematics for two years at the University of Budapest and then moved to the University of Göttingen to continue studying mathematics. While at Göttingen, he became interested in the subject of quantum mechanics and attended the very first formal class on the subject. This class was developed by Max Born, one of the pioneers of quantum mechanics.

Tisza found quantum mechanics fascinating and as a result decided to change his field of study from mathematics to physics. He took a number of other physics courses in Göttingen, including one on thermodynamics that was also taught by Max Born. Tisza would make thermodynamics his principal field of study later in his career.

He was good friends with the physicist Edward Teller (also from Budapest) who suggested that Tisza study with Werner Heisenberg at the University of Leipzig. After working in Heisenberg's group for three months, Tisza returned to Budapest and was awarded his PhD from the University of Budapest in 1932. Shortly thereafter, however, he was arrested and sent to prison for 14 months due to his participation in the communist party.

After his release from prison, he joined Lev Landau's theory group (***Cold Facts*** Vol. 36, No. 3) at the Ukrainian Physico-Technical Institute in Kharkiv in 1935 where he started work on a theory of liquid helium. However, Stalin's purges and general oppression disillusioned

Portrait of Laszlo Tisza at age 18 in Budapest.
Image: Laszlo Tisza's personal collection

Tisza of both the Soviet Union and communism and, in 1937, he moved to the College de France in Paris. Here he started to collaborate with the theorist Fritz London who was also in Paris at the Institut Henri Poincaré.

Shortly after his arrival in Paris, the discovery of superfluidity in He II was announced by Allen (***Cold Facts*** Vol. 36, No. 4) and Meisner in Cambridge and Kaptiza (***Cold Facts*** Vol. 34, No. 5) in Moscow. London and Tisza immediately started to work together on theories to explain this behavior. London proposed that superfluidity in He II could be explained if a certain fraction of the helium atoms had undergone Bose-Einstein condensation. Tisza realized that this would mean there were two velocity fields in He II, one (vn) with normal viscosity and finite entropy and another (vs) with zero viscosity and zero entropy.

This is the basis of the two-fluid model which Tisza published in ***Nature*** in 1938. The two-fluid model was very successful in explaining He II behavior including superfluidity when flowing through narrow channels, internal convection heat transfer within He II and the fountain effect discovered by Kapitza. The model also predicted the existence of second sound, which wasn't

Laszlo Tisza

Born July 7, 1907

Died April 15, 2009
Cambridge, Massachusetts

seen in experiments until 1946. The two-fluid model remains today a very useful way to explain He II behavior, particularly transport properties.

When Germany invaded France at the start of World War II, Tisza left Paris and moved to the USA, where he became a professor at MIT in 1941. There he switched his emphasis to thermodynamics and the philosophy and history of science. He was a well-liked and respected professor; his lectures on thermodynamics were very popular with both students and faculty. He wrote a book, *Generalized Thermodynamics*, on the subject. Tisza retired from MIT in 1973.

In retirement, Tisza was interviewed by Andor Frenkel and this produced the two-part memoir "Adventures of a Theoretical Physicist" published in ***Phys. perspect***. 11 (2009). This highly recommended memoir describes Tisza's life, research, his interactions with many of the leading scientists of the 20th century and the impact of both communism and fascism on his life. ■

Cool Fuel

by Dr. Jacob Leachman, Associate Professor, Washington State University, jacob.leachman@wsu.edu

Bias and Green versus Blue Hydrogen

I was ready to write about the awesome green beauty of a 454.6 nm argon laser and what it does to the hydrogen molecule when a friend sent me an article from the ***New York Times*** by Hiroko Tabuchi, "For many hydrogen is the fuel of the future. New research raises doubts." The article is "based" on a recent journal publication, "*How green is blue hydrogen?*" by Robert Howarth and Mark Jacobson, who are researchers at Cornell and Stanford Universities, respectively. As the title suggests, the ***New York Times*** piece (unlike the underlying journal publication) is generally negative about hydrogen, just as multiple federal legislative bills concerning hydrogen are in the final touches of Congress. If I took the time to respond to every negative hydrogen opinion in the press, I wouldn't have time for research anymore. But this is the first time in my career I have seen an article emphasize so many of the negative biases at once, in such a high-profile venue, at such an inopportune time. So, we need to have a talk about bias and the colors of hydrogen.

Many of you may be confused about this talk of hydrogen "colors." No worries. Hydrogen is still the same colorless, odorless, tasteless gas that comprises 74% of the universe. But not all hydrogen is created equally. A color designation scheme was invented a few years ago to color-code hydrogen based on the quantity of carbon dioxide (CO_2) emissions during production:

- "**Black**" hydrogen is produced from coal or oil with the highest associated CO_2 emissions.

- "**Gray**" hydrogen is produced from methane with steam reformation resulting in approximately 7.2 kg CO_2 for every kilogram of hydrogen produced (this is the color associated with the vast majority of industrial hydrogen produced over the years, which nearly entirely go to petroleum refining and ammonia fertilizer production).

- "**Blue**" hydrogen is produced with CO_2 emissions, but those emissions are captured and sequestered in some way – like geological storage or concrete.

- "**Pink**" hydrogen is produced with no CO_2 emissions but from a nuclear reactor and the associated nuclear waste (for what it's worth, hydrogen will fluoresce a beautiful pink in an arc lamp, just about the only color hydrogen ever actually is).

- "**Green**" hydrogen is produced with no CO_2 emissions, typically from electrolyzing water via renewable energy like wind or solar.

"Turquoise," "brown," and an entire rainbow of other colors are out there; you get the point.

Howarth and Jacobson's much needed research article considers the practical global warming emissions associated with blue hydrogen that would otherwise allow this form of hydrogen to be comparable to the zero CO_2 emissions of green hydrogen. They found that – no surprise – sequestering the CO_2 produced with gray hydrogen is challenging, and that methane leaks from the processes generally offset the net global warming improvements. Although critical of blue, this is by no means a general rebuke of hydrogen as a fuel. The authors specifically say in the conclusions, "Society needs to move away from all fossil fuels as quickly as possible, and the truly green hydrogen produced by electrolysis driven by renewable electricity can play a role."

Hiroko Tabuchi's ***New York Times*** piece, however, uses the small truths from the journal article to weave a tail against hydrogen in general that a friend who is an editor described as a "hit job." Here are some of the embedded biases used in the article that are common in anti-hydrogen groups:

- The article generalizes hydrogen, with almost seeming intent to conflate the different colors. "Blue" hydrogen isn't specified until the fourth paragraph before quickly shifting back to hydrogen generally.

- "Green" hydrogen, which is a primary focus of the journal article, current legislation and most (in my experience) gas company efforts, isn't mentioned until the 17th paragraph.

- When discussed, "green" hydrogen is placed in a negative light: "Today, very little hydrogen is green, because the process involved – electrolyzing water to separate hydrogen atoms from oxygen – is hugely energy intensive." Thermodynamics, my passion to teach, shows us that energy conversion requires energy for starters, and since hydrogen has a lot of energy it is therefore intensive. That's why hydrogen has value, it is the primary energy driver of chemistry. This certainly sounds like a bad thing when said the way the author's bias intended.

- "For the foreseeable future, most hydrogen fuel will very likely be made from natural gas through an energy-intensive and polluting method…" Green hydrogen electrolyzers are following similar growth trajectories as wind and solar, just two decades later. Underestimating the pace of technological change was emphasized in the journal article for prior dismissals of green hydrogen but seems to have been ignored by the ***New York Times*** reporter.

- "In most places, there simply isn't enough renewable energy to produce vast amounts of green hydrogen." I live in the heart of a place that does have enough renewable energy: the Pacific Northwest. While not "most places" in a traditional sense, the entire surface of the ocean is "most places" and has enough renewable energy to produce vast amounts of green hydrogen from floating wind turbines, as one example.

• Falsely associating a leading hydrogen advocacy group, the Hydrogen Council, with oil companies, "The Hydrogen Council, an industry group founded in 2017 that includes BP, Shell, and other big oil and gas companies, did not provide immediate comment." By my count nine of the 41 steering members of the Hydrogen Council are based in the oil and gas industry. 3/4 of the Hydrogen Council steering members not being oil and gas companies sure sounds like a different story.

What is clear is that the ***New York Times*** piece is trying to lead people away from all hydrogen, even green, at a critical time. Why reporters and editors would feel the need to gatekeep and construe the hard efforts of many researchers and organizations like this is beyond me. We will not solve the climate crisis without clean molecules. We will not have clean molecules without clean hydrogen. It's a universal law.

Regardless, the damage is done. Most of my friends on the fence about hydrogen shared this, or a derivative of the journal article, with me within days of publication. Many, even those in academic spheres, didn't read beyond the press title or the journal article carefully to see the bias, as we're all in a hurry these days. The irony is that if you replace "hydrogen" with "electricity" in the press article, it could've been straight out of the 2000's regarding the greening of our electric grid.

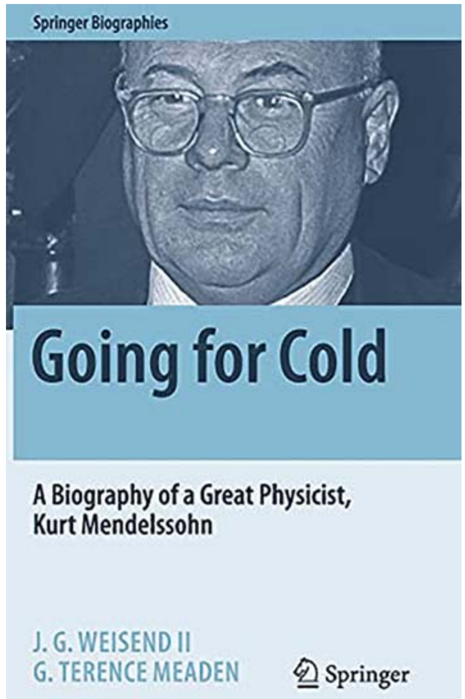
For what it's worth, all you'll see is green hydrogen in my CSA short course or on my blog, because that is the future for which I'm training professionals. But you won't see me slamming the door shut on "blue" hydrogen either. The green hydrogen route with liquefaction that I've been pushing for over a decade now was long ridiculed, using many of the same arguments as those against blue hydrogen above. Both the press and journal articles make the same mistake of casting as absolute extrapolations of the status quo without consideration for the limits of physical law. Those limits of physical law mean that if something is not forbidden, we will eventually find a use for positive means. What we really need is more research on ways to produce hydrogen (of any color) more efficiently with less global warming. Until we finally fund hydrogen research equivalently with batteries and electricity, all of this negative bias about hydrogen is turning my hair gray; no, let's call it silver. ■

Book Review: Going for Cold

by John Vandore, john@vandore.com

Two days after the Tokyo Olympics closing ceremony, what an inspired book title to appear through my letter box. Google "Mendelssohn" and you likely arrive in the classical music world of Felix. This [Kurt] Mendelssohn would more likely be known to attendees of the normally biannual International Cryogenic Engineering Conference, alternating between Europe & Asia, and in which Mendelssohn played a founding role. The Mendelssohn Prize is presented today for Lifetime Achievement in Cryogenics. At the ICEC 27 Conference in Oxford in 2018, delegates were given insight to the man whose name is on the Award in a presentation by Professor Stephen Blundell, making the connection with Mendelssohn's time in and association with Oxford and giving an appetite to learn more about the man in this excellent book (read mostly by the reviewer over a glass of beer taken not far from Oxford, and the last few pages at the Magdalen Arms, in Iffley Road, just yards from Mendelssohn's house).

The book brings out several strands of value for the reader. It explains how pursuit of the Third Law of Thermodynamics (associated with Nernst) was concerned with entropy, leading to examination of the lowest energy states – requiring the lowest temperatures – hence the focus by Mendelssohn and others on… cryogenics. Saying "Mendelssohn and others" goes straight to another theme – the power of *networks*: Mendelssohn and his connections remaining in touch and migrating from Berlin to Breslau (later called Wroclaw) and Oxford. Some connections were relatives, such as cousin Franz Simon (and Felix the composer!).



In chapter 3, the authors navigate a fascinating journey of families, relationships and wartime politics. Oxford was fortunate to find itself home to Mendelssohn and the connections including Simon, Nicolas Kurti and others. Mendelssohn is depicted as a scientist of exceptional caliber, one who cared for his students and for communication of his work, and a man of broader interests too. The book avoids dumbing down the science explored by Mendelssohn – and indeed gives valuable insight for non-scientists on the things that count in the life of a scientist.

Mendelssohn was clearly an internationalist – keen to travel and connect, but also in his responsibility for a diaspora of foreign students whom he nurtured in Oxford and who went back to different points on the planet to start new institutes and carry forward the low temperature work they began under Mendelssohn's tutelage. One delight for the reviewer was to see the reference to Vinod Chopra, one of Mendelssohn's last students, who came to study in Oxford under a Nehru scholarship from India. As the reviewer knows separately, Chopra worshipped his time in Oxford with Mendelssohn. He would so applaud this book.

Not many books combine cryogenics and the pyramids! Yet early exposure to Egyptology during Mendelssohn's youth in Berlin, together with his penetratingly enquiring mind, led to him devoting one of his books to the pyramids and his theories on their purpose and their construction, providing yet one more bonus for reading this book. The reviewer has no hesitation in commending it to anyone with an interest in science, particularly low temperature science, and science in Oxford. ■

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Photo caption: Two welders from MAN Energy Solutions, working in parallel on opposite sides of the component's skin, produced the "first arc" of a welding campaign scheduled to last four to five months. *Image: ITER*

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QUB Experts Call for International Collaboration for Quantum Experiments in Space

Experts at Queen's University Belfast are calling for scientific, engineering, industrial and political communities to join forces and take quantum experiments to space. Scientists in the areas of quantum physics and space currently work separately. However, experts now believe that by joining forces they could make many more discoveries. Professor Mauro Paternostro, Head of the School of Mathematics and Physics at Queen's, Research Fellow Dr. Matteo Carlesso and Visiting Research Scholar Dr. Alessio Belenchia from Universität Tubingen, have published an article in ***Nature*** outlining their vision, which they say could revolutionize science as we currently know it."Scientific legacy of the 20th century is twofold – on one hand there is quantum mechanics, which has helped us to explain the fundamental principles of the microscopic world," said Paternostro. "On the other hand, we have the space program, which has made space exploration a reality. If scientists in these two areas were to join together, we could work towards truly unforeseen possibilities."

At present, quantum experiments are mainly performed in labs, and it can be difficult to create the correct conditions to test the fundamental principles of nature. Dr. Carlesso explains, "Meeting the right experimental conditions such as low pressure and temperature, or isolation from external noise, all the way down to being able to test the very fundamental principles underpinning nature – the holy grail of every quantum physicist – is very demanding. Carrying out the experiments in space would offer an efficient and exciting way forward. Onboard a satellite – free-fall, high vacuum and no ground-related vibrations – would make quantum experiments more robust. This would allow for the test of those tiny, elusive effects that are so difficult to unveil on ground."

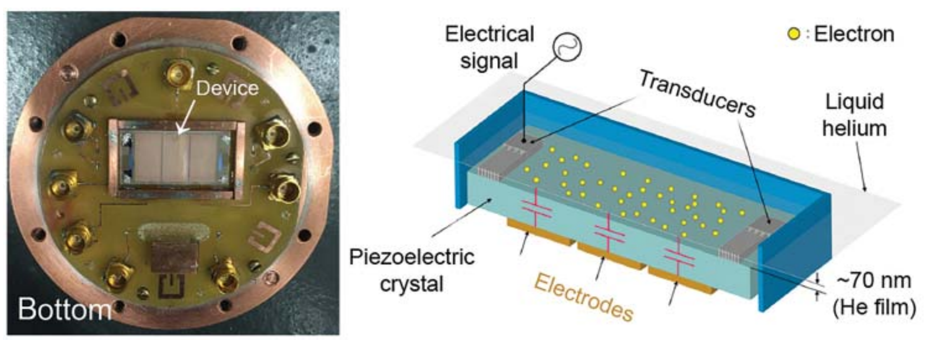
While the plan to take the experiments to space could transform science, it would also be costly. Therefore, Paternostro and his colleagues are calling on the efforts of the entire science community to turn the dream into a reality. "Dr. Carlesso and I have been working with Dr. Belenchia in Tubingen, and colleagues from the University of Southampton, Universita' degli Studi di Trieste and Universitat Autonoma de Barcelona, to set out the pathway for achieving the goal," he said. "We have identified the challenges ahead and are now making the case for an international effort. This would mean that scientists, quantum industry and policy-makers would work together towards the exploration of a new space frontier. This time, a quantum one!"

The next step will be to initiate a transnational dialogue among quantum and space stakeholders to map out a plan for the work. ■

Michigan State Researchers Introduce New Technology for Quantum Computing

by Matt Davenport, Strategic Science Storyteller, Michigan State University, daven150@msu.edu

Johannes Pollanen stands with the equipment his team uses to test and characterize its devices. *Image: MSU*



The photograph on the left shows the new quantum device (a light copper-colored rectangle in the center of a metal holder). The illustration on the right shows a close-up of the device. Electrodes underneath the device help researchers trap electrons, which float above a thin layer of liquid helium. Transducers on top of the device create waves or vibrations that let researchers precisely manipulate electrons. *Image: Nature Communications/Laboratory for Hybrid Quantum Systems*

Researchers led by Michigan State University's Johannes Pollanen have developed a new device to help future quantum bits, or qubits (pronounced "Q bits"), take flight. Using liquid helium and readily available modern telecommunications technology – based on so-called "surface acoustic wave" devices – the Spartan team has created a new way to precisely manipulate electrons. With this capability, scientists can envision building what are known as trapped-electron quantum computers powered by processors whose quantum bits are free to move – or fly – around. The team showcased its new tech in the journal ***Nature Communications*** (July 6, 2021).

"We're developing tools to grab single quantum particles and control them. It's very exciting work," said Pollanen, a Jerry Cowen Endowed Chair of Experimental Physics in the College of Natural Science. "This work really opens up new possibilities for moving these electron qubits around, and there are lots of fun experiments one can imagine now that we demonstrated these proof-of-concept devices." Pollanen is also an assistant professor in the Department of Physics and Astronomy and the associate director for MSU-Q, the Center for Quantum Computing Science and Engineering.

Thanks to the arcane workings of quantum mechanics, quantum computing stands poised to solve problems that are very messy or impossible to solve with conventional computers. Because of that, there's no shortage of interest in quantum computing technologies from the areas of science, finance, cybersecurity and others. Still, quantum computing faces major hurdles before it can make meaningful contributions to these applications. One of these hurdles is that current quantum computing technologies are noisier or more error-prone than their classical counterparts.

Classical or conventional computers, like your smart phone or laptop, have a staggering number of bits at their disposal to store and process information. In the binary language of bits, this information is represented as 1s and 0s. Any given bit can be only a 1 or a 0, not both. But errors happen. Sometimes bits get flipped: what should be a 1 is instead a 0, or vice versa. Because a bit can be only one or the other, though, it's relatively easy to correct this error in conventional computers, Pollanen commented.

Quantum bits aren't so straightforward. A qubit isn't either/or, but rather some combination of a 0 and a 1. The states that are mutually exclusive in classical computing can coexist in a qubit. This is one reason why quantum computers can handle much more complex information than conventional computers using far fewer bits. With a fairly modest number of qubits, quantum computers would be able to do things that classical computers simply can't. "One of the things I love about quantum computers is that, if we could build a 100-qubit machine, we couldn't directly verify what it does with a classical computer," Pollanen said. "There's just no way."

On the other hand, moving from the clarity of a 0-or-1 system to the murkiness of quantum introduces far more complexity when it comes to noise, random changes or fluctuations in the system that can lead to errors. Flying qubits might offer a way to simplify that. "If you can move the qubits around, you can essentially cancel out some of the errors," Pollanen said.

His team has now introduced a device that could one day help build flying qubits. The Spartans start with what's known as a piezoelectric crystal. This may sound exotic, but these materials are widely used in today's telecom devices. Coating the piezoelectric is a thin layer of liquid helium, just a little warmer than absolute zero. The researchers can then float electrons – particles that naturally store quantum information – above that pool. "We drop the electrons in and they get stuck there, literally floating like 10 nanometers above the surface," Pollanen said. "And this liquid helium surface is pristine. You don't have to worry about defects like you would with semiconductors used in some quantum computing devices."

By sending an electrical signal to the piezoelectric, the researchers set it vibrating in a very precise way, creating finely tuned waves to control the hovering electron. "With this work, we showed that we can grab ahold and manipulate these quantum particles with modern telecom devices," Pollanen said. "The next question is: can we create flying qubits with this type of device? I think the answer is ultimately yes but there's lots of cool experiments to do to get there."

For years, experts at MSU and elsewhere have hypothesized that approaches like this would work for building floating qubits. Now, with increasingly refined and accessible technologies, scientists are starting to put these approaches into action.

Because of this increased accessibility, more scientists from more backgrounds can contribute to quantum computing research, a fact on display at MSU-Q. The center boasts nearly 30 faculty from a breadth of disciplines – physics, chemistry, computer science and more – working to bring the promise of quantum computing to the real world.

"A big part of that is limiting error rates and noise. We have experimentalists and theorists working to attack that problem," Pollanen said. "Flying qubits are one way that we can do that." ■

Helion Energy Breaks Ground on Next-Generation Fusion Facility Site in Washington

Helion Energy (Helion), a clean energy company committed to creating a new era of zero-carbon electricity through fusion, broke ground on the next iteration of its fusion facility in Everett, Washington, on July 27. The new facility will accelerate Helion's efforts to build the world's first commercially viable fusion power plant known as Polaris. Helion is developing a cost-effective, zero-carbon electrical power plant using its patented pulsed, non-ignition fusion technology. The fusion power plant will provide flexible, scalable, baseload power that is affordable, providing the world a new path to full decarbonization of electricity generation. The facility will also produce helium-3 and extract tritium.

The groundbreaking ceremony for Helion's new facility. *Image: Helion Energy*

"Washington is proud to be the home of world-leading pioneers developing affordable clean energy solutions," said Governor Jay Inslee. "It's a great milestone that Helion is now ready to commercialize their innovative technology. With this new facility, Helion and Washington are taking game-changing action to address the climate crisis."

Helion's new facility will bring over 150 high quality, long-term jobs to Everett and the surrounding communities, positioning Washington and Snohomish County at the forefront of the world's efforts to transition to a clean energy future. The new jobs created by Helion's fusion facility also align with Everett's efforts to create more opportunities in science, technology, engineering and mathematics (STEM) and draw from the extensive STEM talent pool already in the community.

By applying proven and patented technologies, Helion is working towards building the world's first commercially viable fusion power plant which runs on a fuel that can be derived from water. Their zero-carbon solution is capable of low cost 24/7 power generation that replaces the energy sources the world currently relies on, enabling a future with limitless, reliable and affordable clean electricity.

"At this facility, Helion will close in on its goal of breaking the fusion barrier and pushing the world towards the end of the fossil fuel era," said Dr. David Kirtley, founder and CEO of Helion Energy. "Helion has deep roots in Washington, having spent the last eight-plus years here researching and developing a technology with unparalleled implications for reshaping how the world obtains its energy. We are enormously proud to have Governor Inslee and Mayor Franklin, leaders and advocates of climate action and STEM innovation, in attendance today at the groundbreaking of our facility's construction." ■

Researchers Work to Drum Up Dark Photons

by Mara Johnson-Groh, symmetry magazine, mara.johnson-groh@nasa.gov

In the cryogenically cooled silence of an empty lab, a group of cosmologists, engineers and theoretical physicists hope to someday hear drumbeats. The group, comprising individuals from the Universities of Arizona and Delaware, is searching for a type of theoretical particle called the dark photon – and they're doing it by listening for the particles to tap out a rhythm on a tiny glass drum.

Dark photons, if they exist, are thought to be force-carrying particles, similar to the regular photons the Earth interacts with every day that carry the electromagnetic force. But unlike massless photons, these dark matter particles would have a mass, albeit a very small one. If they exist in the quantities needed to account for all the dark-matter mass in the universe, dark photons would be so ubiquitous that they would move together like a wave. Individually, dark photons hardly interact with normal matter; but as waves, they would exert a very weak force, theoretical physicists predict.

The effect would be noticeable only on the smallest scales, but a growing class of nano-instruments specialize in detecting such ultrasmall forces on the cusp of quantum limits. Known as optomechanical membrane accelerometers, these devices have previously been used to detect quantum back-action, a weak force important in taking quantum-limited measurements.

Now, scientists hope to use them to detect the beat of a dark photon wave.

Drums for dark matter

Dark matter searches aren't for pessimists. Despite more than 30 years with no direct detections, physicists are still coming up with new ideas – for both experiments and dark matter candidates. Today, the list of particles is full of superhero and supervillain names like MACHOs, axions, WIMPs, gravitinos and neutralinos. Some models invoke supersymmetry, others superfluids. "Right now, the field is in a position where we should leave no rock unturned, because we've been looking for years and we haven't found anything," says Dalziel Wilson, an assistant professor at the University of Arizona and experimentalist involved with the new search. "So that's what we're doing."

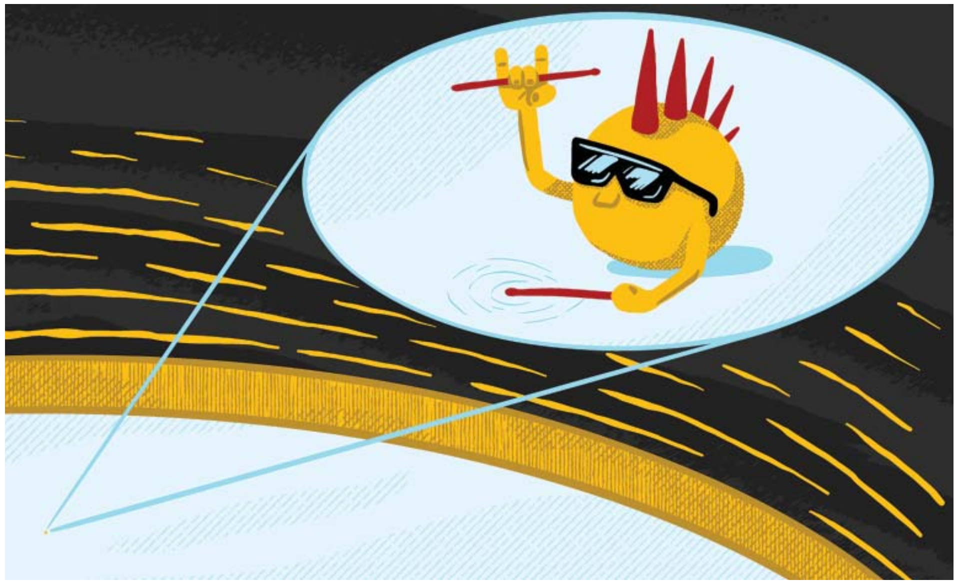


Illustration of a particle tapping a rhythm on a tiny glass drum. *Image: Sandbox Studio, Chicago with Steve Shanabruch*

The idea for using optomechanical devices to detect dark matter was initially suggested by Swati Singh, an assistant professor at the University of Delaware who is currently researching the use of quantum systems as sensors to search for new physics. After reading proposals to repurpose gravitational wave detectors to look for dark matter, Singh drew the connection to her previous work with gravitational-wave-sensing mechanical systems. "A lot of things we don't know about – things beyond the Standard Model of particle physics – have signals that are sometimes a very weak force," Singh says. "As we control more and more devices down to single quanta of motion, we can probe these things and the rest of the universe."

To bring her idea to life, Singh formed a multidisciplinary collaboration. Along with her graduate student, Jack Manley, Singh approached Wilson, who has worked with optomechanical resonators for over a decade, and cosmologist Daniel Grin, who specializes in dark matter candidates.

Initially, the group wanted to use mechanical detectors to target another type of dark matter, called scalar dark matter. They then realized that dark photons would also affect mechanical detectors, albeit in a different manner.

A dark photon interacting with a normal atom should slightly alter the position of the atom's center of mass. So, if a wave of dark photons passed, an atom would subtly oscillate back and forth. This effect, though small, could be amplified to the detectable range with optomechanical devices. Unlike most dark matter searches, these detectors are relatively inexpensive and fit on a tabletop. "It turns out, the devices I have in my lab are perfectly capable of searching for this type of dark matter," Wilson says.

The materials used for the drum were specifically chosen, as dark-photon interactions depend on the density of neutrons in the drum's atoms. For their first prototype, the group proposed a detector with a membrane made of silicon nitride, less than a micrometer thick, and stretched over a mirror made of beryllium. Immersed in a vacuum and cooled down to just 0.01 Kelvin, this type of detector would identify almost no vibration other than that coming

▶ ***continues on page 32***

from the very tiny dark-photon force, making for a clean signal.

The detector they designed looks like a drum, but alternative shapes, such as cylinders, cantilevers or balls could work in a similar manner. “In our laboratory, we already have some devices which we think might be more promising,” Wilson says.

To resonate with dark matter, an opto-mechanical drum would need to be tuned to the frequency that corresponds to the mass of the dark photon. The trouble is, no one knows exactly what that mass should be. “It's a needle in a haystack. It's a really, really tiny needle,” says Mitul Dey Chowdhury, a graduate student in Wilson’s lab.

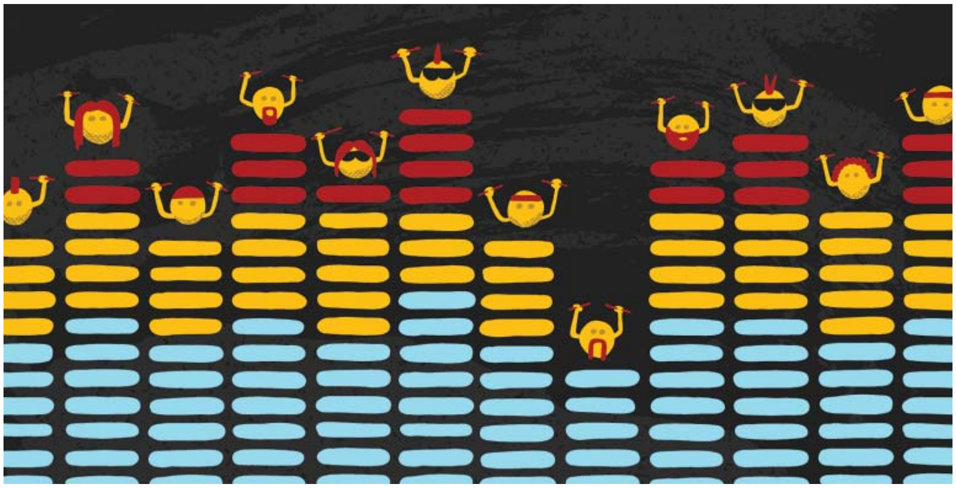


Illustration of an equalizer display. *Image: Sandbox Studio, Chicago with Steve Shanabruch*

For now, the group is working to build two detectors. In the coming year or two, they hope to lock their devices away in a quiet room for month-long runs, during which they will continually listen for the beat of the drum. The proposed detector is designed to scan dark-photon frequencies across a large range: from 1 to 100 kilohertz. But it can monitor only a small fraction of that – 1/10,000th – at a time.

Wilson says he hopes their work will inspire other researchers to find opto-mechanical devices that could be suitable for searching for dark matter. The group has published two peer-reviewed papers, led by Manley, that they hope will interest other groups to join the search. Ideally, a fleet of experiments worldwide, each tuned to a different frequency, would work together to search for dark photons. “Right now [this field] is the Wild West,” Wilson says. “I would say maybe in three years we will have some initial results, but it's very much in its infancy right now.” ■

Rigaku Acquires Life Science Imaging Equipment Manufacturer MILabs

Rigaku Corporation in Akishima-shi, Tokyo, a leading manufacturer of X-ray analysis equipment, has acquired all issued shares of MILabs B.V. in Houten, The Netherlands, on August 2, 2021, as part of their full-scale effort to enter the life sciences business.

Through this acquisition, Rigaku will expand its life sciences modality business globally by combining MILabs' multi-modality businesses, including PET (Positron Emission Tomography), SPECT (Single Photon Emission Computed Tomography), Optical Imaging, and CT (Computed Tomography) equipment for animals, with Rigaku's original X-ray imaging business for animals.

Founded in 2006, MILabs has provided high performance SPECT and PET equipment with higher efficiency and accuracy than conventional alternatives and unique capabilities to image nuclear therapeutics and multiple tracers simultaneously. This leverages the company's proprietary collimation and data acquisition technologies developed by Dr. Frederik Beekman and his colleagues.

Furthermore, MILabs has developed a unique multimodal system that enables fully integrated high performance X-ray CT, PET, SPECT, and Optical Imaging, which addresses customer needs in terms of flexibility at lower costs. The company has experienced rapid growth in sales across various imaging modalities over the past few years.

Rigaku has played a leading role in supporting the advancement of science, technology and related industries, alongside universities, research institutions and major industry players across the globe. The company's business areas include nanotechnology and new materials, resources, energy, environmental management, semiconductors, electronic materials and life sciences, for which Rigaku has accumulated vast knowledge and technologies over the last 70 years. Through this acquisition, Rigaku aims to strengthen its preclinical imaging business within the life sciences field by incorporating MILabs' radiation imaging and optical imaging technologies, a new initiative for Rigaku, while simultaneously building its existing X-ray imaging business.

Rigaku believes that preclinical imaging will become increasingly important in the life sciences field. As innovative technologies such as gene editing are developed, it will become necessary to verify the effects and functions of edited genes through in vivo analysis, for which preclinical imaging is expected to contribute greatly. Furthermore, in the field of drug discovery, it is necessary to observe how drug candidates behave in vivo in the development stage, and preclinical imaging is expected to greatly contribute to the elucidation of the drug efficacy mechanism. ■

Plug Power Breaks Ground on Green Hydrogen Production Plant in Georgia

On August 10, Plug Power Inc., a leading provider of turnkey hydrogen solutions for the global green hydrogen economy, broke ground on the site of a green hydrogen production plant in Camden County GA, where 15 tons of green liquid hydrogen will be produced per day. By investing $84 million in the facility, Plug Power affirms its continued commitment to establishing the first North American green hydrogen supply network. The plant, which will serve customers in the southeastern US, will produce green liquid hydrogen using 100% renewable energy with the help of at least 24 full-time, local employees.

Plug Power is already the largest buyer of liquid hydrogen globally and has built more hydrogen refueling stations than any other company in the world. Experts forecast that green hydrogen will play an essential role in meeting targets for greenhouse gas emissions worldwide, particularly in the transportation and logistics sectors. Exponential growth in the hydrogen economy is expected to accelerate, reaching up to an annual usage of 500 to 800 million tons by 2050 and supplying 20% of global energy demand.

Andy Marsh, CEO of Plug Power, said the location of the plant is a part of the company's larger strategic plan to offer green hydrogen that is cost-competitive with fossil fuel energy to its customers looking to meet their sustainability goals. "Green hydrogen is the environmentally conscious solution companies need and want," Marsh said. "Plug Power's investment in this facility is an investment in Georgia – and an investment in our customers and the future world we want to live in."

Sanjay Shrestha, general manager of energy solutions and chief strategy officer for Plug Power, said the Georgia production plant signifies the company's deep commitment to the region and its customers. "Plug Power's newest production plant is a result of increasing customer demand," Shrestha said. "More and more, customers are expressing their commitment to green hydrogen solutions. This Georgia plant is an important step for developing North America's first force-majeure resilient green hydrogen supply network. This helps Plug Power, our customers and, more importantly, the broader hydrogen economy."

The groundbreaking of the plant also serves as a milestone for local and state officials who have worked to attract more innovative jobs to the region. The Camden County plant joins previously announced green hydrogen facilities in South Central Pennsylvania and the Western New York Science, Technology and Advanced Manufacturing Park (STAMP), all of which contribute toward Plug Power's goal of producing more than 500 tons per day of green hydrogen by 2025.

Together with Plug Power's existing plant in Tennessee, acquired in 2020, and its PEM stack and electrolyzer Innovation Center in Rochester NY, this plant further strengthens the company's position as a leader in advancing the green hydrogen ecosystem. The Georgia gas production plant is expected to be completed by the end of this year. ■

Look who's NEW in the Cold Facts Buyer's Guide

Cold Facts Buyer's Guide is the place to find suppliers in every area of cryogenics and superconductivity. These are the new suppliers added to the Buyer's Guide since the last issue of ***Cold Facts***. Find it online at **csabg.org**.

A-Vac Industries

A-Vac Industries repairs and sells high vacuum pumps, helium leak detectors and associated equipment to commercial, government and nonprofit organizations.

Danclan Biotech Chengdu Co., Ltd.

Danclan Biotech is a manufacturer of solutions for cryopreservation and monitoring. This includes small liquid nitrogen containers and a monitoring system for LN_2 products. Systems are designed to meet the needs of customers' specific applications.

East Far Materials Co., Ltd.

Thermal control materials such as multilayer insulation (MLI), aerogels, vacuum insulated panel, state-of-the-art coating processes, as well as technical tapes and adhesives to serve the energy, electronics, cryogenic, aerospace and medical markets.

ILK Dresden—Institute of Air Handling and Refrigeration

ILK Dresden's Cryogenics and Low Temperature Physics department provides industrial and R&D services. It offers integrated solutions for complex projects, with expertise in technological installations, assembly and maintenance of cryogenic equipment.

M1 Engineering Ltd.

Manufacturer of cryogenic distribution equipment including semitrailers, microbulk rigid units and tank containers, with expertise in the safe and economic distribution of LIN, LOX, LAR, LNG, CO_2, Liquid Ethylene and Nitrous Oxide.

Midalloy

A full line of welding consumables to meet the needs of fabricators and manufacturers of cryogenic components. Welding forms available are: MIG, TIG, SUB-ARC, and FLUX-CORED wires along with SUB-ARC fluxes. Technical welding consulting is also available.

Rutherford & Titan Inc.

A nationwide cryogenic installation and servicing company that assists customers with needs ranging from selecting and installing a machine to performing ongoing maintenance and sourcing replacement parts. ■

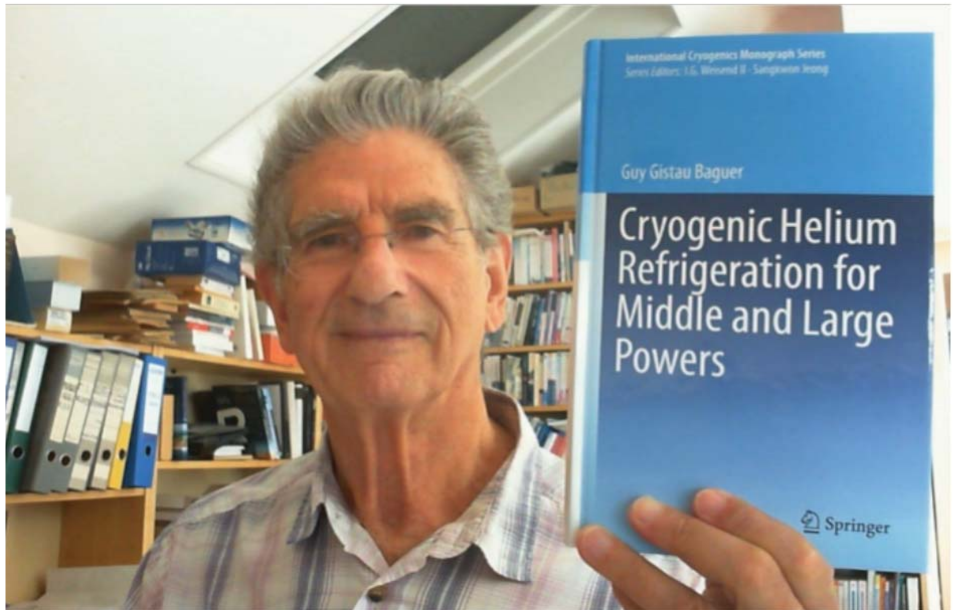
***CSA CSM**

“Cryogenic Helium Refrigeration for Middle and Large Powers”: A Book on Helium Refrigeration

by Guy Gistau Baguer, guy.gistau@orange.fr

Meet the Author, Guy Gistau Baguer

I have spent most of my working time dealing with helium refrigeration and liquefaction. I was hired by Air Liquide in 1965 for my first job in the “Centre d’Etudes Cryogéniques” in Sassenage, France, where I was in charge of building seven L/h helium liquefiers. Then, I helped operate an air separation plant and its distribution system, sold specialty gases, coordinated the activities of electronic gases and liquid helium among subsidiaries and, finally, in 1975, I came back to the Sassenage site where I dedicated myself again to helium refrigeration.



Author Guy Gistau Baguer proudly holding his new book. *Image: Guy Gistau Baguer*

As the team was very small, I had the opportunity (or, more exactly, the requirement!) to deal with all steps of a project: sales, design, construction, erection, tests, after sales, troubleshooting and, simultaneously, development. That was an incredibly efficient way to become familiar, or even intimate, with all aspects of helium refrigeration, since at the time there was no possibility to get such information from literature.

Of my various projects, a few stand out. In the beginning of the ‘80s, our team gave birth to the first fully automatic liquefier/refrigerator: HELIAL. The expertise that was acquired at this occasion, especially in automation of the process, later allowed us to deal with much more complicated systems. A few years later, the controlled thermonuclear fusion project Tore Supra needed 300 W at 1.8 K, a size of plant that had already been built, incorporating a lot of room temperature Roots machines. With the hope that fusion would progress, it was decided to develop centrifugal cryogenic compressors that were integrated into the refrigerator, making it the first one operating on such technology: the way to the modern large systems operating at temperatures lower than 4.5 K. Finally, when CERN required refrigerators for large power at 1.8 K, I was able to integrate my knowledge in helium refrigeration into the design.

During this period, I had the opportunity to write around 50 publications, mainly about the machines that were built, but also on topics dealing with helium refrigeration. A few patents on helium refrigeration were filed over the years, too. In 2011, the largest helium liquefier being built by my younger colleagues delivered 7000 L/h! Therefore, in my life, I had the opportunity to see the helium liquefier size increasing by three orders of magnitude.

Attending the usual cryogenic conferences led me to be a member of the International Cryogenic Engineering Committee for 16 years and finally to be the Chairman of the Committee for another 12 years.

When it came time to retire in 2000, I felt guilty to let such an amount of self-gained experience (mistakes, thinking, trying again, success sometimes...) to be lost. Therefore, I decided I would try to transfer this knowledge to other people who would need it, especially young ones. Up to now, I have held more than 60 sessions of education in cryogenics.

In 2012, I wrote a text for the French ***Techniques de l’ingénieur*** about helium refrigeration. All the material was to stay within 16 pages: what a challenge to stuff the subject into a rather compact digest! This exercise gave me the idea to write down the talks I give at each school. This is the idea that gave birth to the present book.

In 2020, I was awarded the Mendelssohn Award that should have been presented to me at the International Cryogenic Engineering Conference that was to be held in Hangzhou, China, in August 2020, but that has been shifted to 2022 due to the COVID-19 pandemic.

By the way, this book is kind of my “cryogenic testament”!

About the Work

A book on helium refrigeration has recently been released: “Cryogenic Helium

Refrigeration for Middle and Large Powers," written by me, Guy Gistau Baguer. In this book I have tried to concentrate on almost everything one needs to deal with helium refrigeration. I wanted this book to be a very pragmatic tool.

I split the work into various chapters, the first one dealing with theory of cycles. Prior to getting into the topic, short refreshers about cryogenics and heat exchangers are given. These basic cycles are considered: Joule Thomson, Brayton and Claude. They are calculated and discussed using the REFPROP software by NIST in conjunction with Excel®. They are followed by special cycles for high powers or colder temperatures. Some examples of possible connections between cold box and cryostat are introduced.

The technology chapter takes care of compression with oil lubricated screw compressors and the necessary oil management system, heat exchange, cryogenic expansion and cryogenic compression. Examples of typical refrigeration systems are discussed.

Prior to dealing with system control, I provide a glance at the behavior of a refrigerator in off-design operation. Helium purification, both by adsorption and cryofreezing, is discussed, followed by basic helium analysis.

In the everyday life of the plant, an operator has to deal with the important issues included in operation and maintenance. Some advice is given about points that must not be forgotten in writing a request for quotation and how to perform accurate commissioning tests.

The Cryo Tool Box explains how to perform a set of typical thermodynamic calculations with REFPROP and Excel, like heat exchangers or expansion turbines that are very useful in an operator's daily life. Finally, a quick trip through the "saga" of refrigeration is performed.

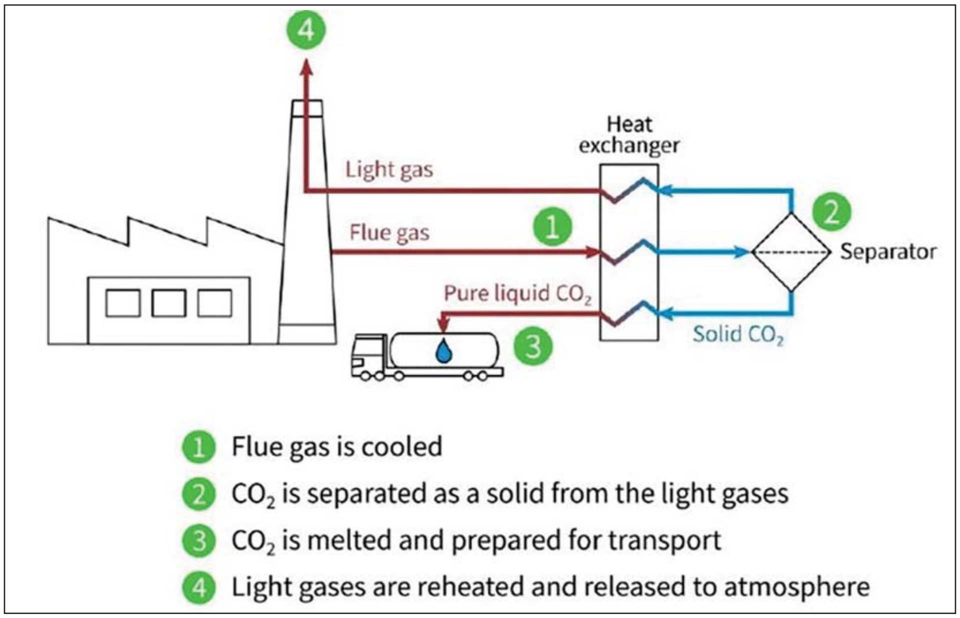
Thanks to Springer, the book is color-printed, which makes it rather attractive as well. I hope this book will be useful for the worldwide cryogenic community.

Cryogenic Helium Refrigeration for Middle and Large Powers is available at Springer Nature at: **www.springer.com/gp/book/9783030516765** ■

SPOTLIGHT ON A CORPORATE SUSTAINING MEMBER (CSA CSM)

Chart Carbon Capture Technology Recognized by International Consortium

Chart Industries, Inc., a leading diversified global manufacturer of highly engineered equipment for the industrial gas and clean energy industries, has been recognized for its Sustainable Energy Solutions (SES) Cryogenic Carbon Capture™ ("CCC") by researchers in a study in the journal ***Applied Energy*** that was co-authored by researchers at the MIT Joint Program on the Science and Policy of Global Change, MIT Energy Initiative and ExxonMobil.



CCC process diagram. *Image: Chart Industries*

This research analyzed the competitiveness of several types of carbon capture and storage (CCS) technologies in a global economic model with specific emphasis on ways to reduce greenhouse gas emissions from the manufacture of cement, which accounts for approximately 7% of annual CO_2 emissions. Coal-fired post combustion capture (PCC), natural gas-fired PCC and CCC were each separately evaluated using the Economic Projection and Policy Analysis model with their specific costs and inputs.

CCC was determined to be the most competitive CCS technology. In the analysis, it was determined that the cost to produce cement and capture CO_2 using Chart's CCC technology is 24% higher than producing cement with no CO_2 capture (not accounting for any value for the CO_2 being captured). This is compared to other capture technologies that range from a 38% increase to a 134% increase in the cost of producing cement and capturing CO_2 vs producing cement with no CO_2 capture. This has the potential to reduce carbon emissions from fossil fueled power plants by 95 to 99% with half the cost and energy of other carbon capture processes. In addition, CCC also removes harmful pollutants, such as SOx, NOx and mercury. Sustainable Energy Solutions (SES), the company that developed CCC, was acquired by Chart in 2021. **www.Chartindustries.com** ■

Qubit Measurement Systems Right Out of the Box?

by Russell Lake, Senior Scientist, Bluefors, russell.lake@bluefors.com

Necessity of mK-cryogenics

During past years, advances in both lithography and millikelvin cryogenics have supported and enabled vast improvement in the sophistication of experimental research on electrical circuits that display uniquely quantum mechanical behavior. It comes as no surprise that dilution refrigerator measurement systems have moved beyond basic physics research contraptions and into central focus in the new era of quantum engineering. Achieving millikelvin temperatures remains a prerequisite for many of the leading hardware candidates for quantum computing with solid-state devices. For example, superconducting quantum circuits need temperatures low enough to keep microwave thermal photon populations on the chip negligible. In addition, the amplifiers that are typically required to achieve high fidelity dispersive readout are also based on superconductors and operate at the lowest noise temperatures allowed by physical limits.

Enabling quantum technology

Since 2008, Bluefors in Helsinki, Finland has aimed to support sub-Kelvin measurement applications by providing well-engineered reliable systems that are easy to use. To continue technical leadership, Bluefors pursues several important developments aimed specifically at improving functionality for quantum measurement applications. These include scaled-up wiring infrastructure, coaxial infrared (IR) filtering, and advanced diagnostics for measuring noise temperatures (Figure 1). In immediate applications, high density wiring addresses the problem of sending control and readout tones to the largest quantum processor units currently available. The lines are thermalized at each temperature stage using matched cryogenic microwave attenuators. Signals are conditioned using high density filter banks realized using cryogenically compatible materials, that are installed at the base temperature stage. Bluefors also developed IR filters that are designed to protect superconducting qubits devices from photons with higher energy than typical superconductor pair breaking energies. The IR filter has low insertion loss in the spectral range where signals are sent to the qubit but it utilizes a microwave absorber material to dissipate high frequencies. Diagnostic tools such as the cryogenic variable temperature noise source also offer new ways to measure the quality of readout lines by implementing Y-factor analysis in the cryogenic environment. [1, 2]

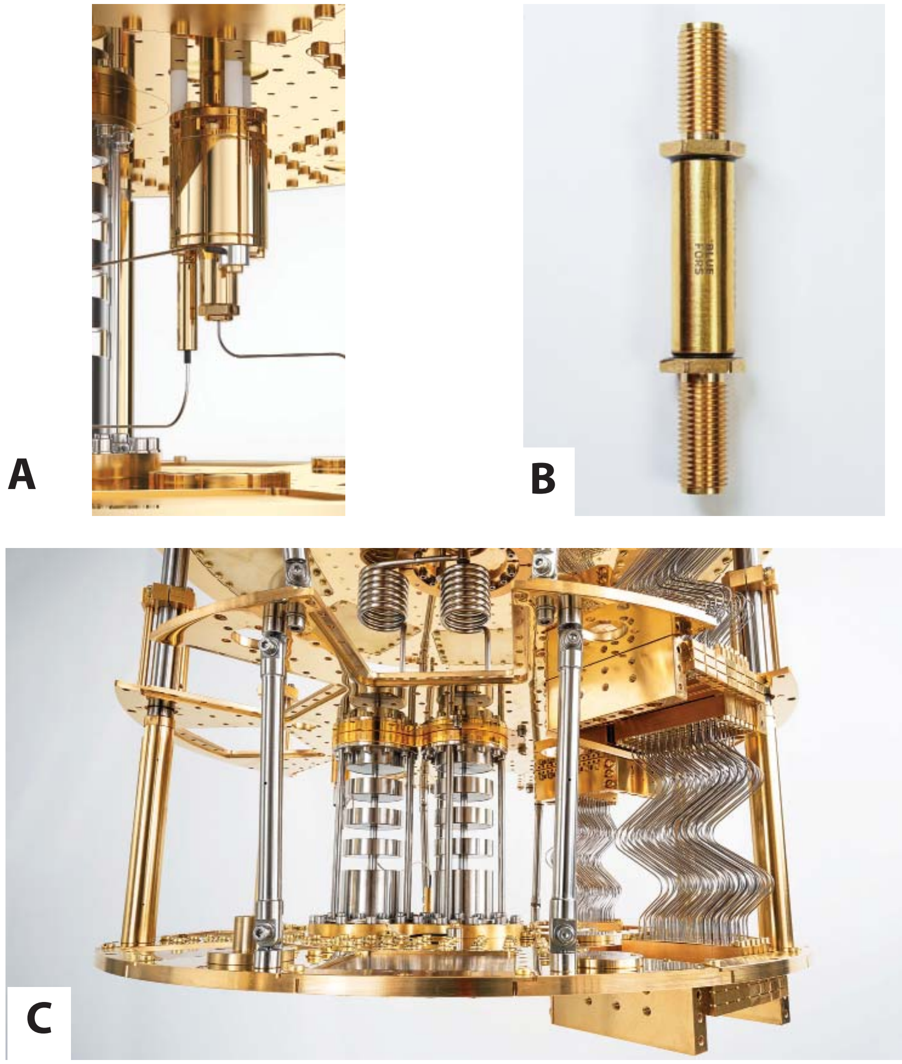


Figure 1: Recent developments enabling quantum technological applications at millikelvin temperatures: a) Cryogenic Variable Temperature Noise Source, b) Bluefors IR Filter, c) High Density Wiring in an XLDsl dilution refrigerator measurement system. *Image: Bluefors*

Application examples

In spring 2021, Bluefors published two application notes to provide working examples of quantum measurements from within the manufacturing environment. The first application note (in collaboration with Keysight Technologies) was a concise guide to setting up and running a single-qubit characterization measurement including integration of the room temperature electronics with the cryogenic system. The measurement results demonstrated the signal input-output, hardware-software interface, and a qubit measurement system capable of reaching long qubit energy relaxation times of order 100 µs. [3] The second application note (in collaboration with Zurich Instruments) reported statistics spanning 100 hours of measurement time of the qubit energy-relaxation times: a crucial system parameter for qubit applications. [4] In addition, the measurements enabled a comparison between Bluefors measurement systems installed at Chalmers University (Gothenburg, Sweden) and in the Bluefors factory itself. Interlaboratory comparisons are often performed in the context of international metrology but have not been commonly applied to the field of solid-state qubits. Can the cryogenics industry demystify the factors that lead to high performance quantum devices through benchmarking data, measurement examples and clear documentation? Building integrated quantum systems is a multidisciplinary pursuit that needs innovations in interconnects, room temperature and cryogenic electronics – and of course the cryogenic environment itself.

Outlook

Integrating the components required for a turnkey quantum measurement system is a major engineering effort that involves many partners around the world. Improving measurement setups and publishing the results promotes the utilization of cryogenics and will have a broad positive impact on quantum measurement science. Customers and stakeholders benefit from reduced time to bring up new systems, and the cryogenics industry can benefit from improved knowledge of the application of dilution refrigerator systems. **www.bluefors.com**

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[4] S. Simbierowicz, C. Shi, M. Collodo, M. Kirste, F. Hassani, J. Fink, J. Bylander, D. P. Lozano and R. Lake, "Qubit Energy-Relaxation Statistics in the Bluefors Quantum Measurement System,"2021. [Online]. Available: **https://bluefors.com/wp-content/uploads/2021/06/application-note-qubit-energy-relaxation-statistics-bluefors-quantum-measurement-system.pdf.** ■

International Cryogenic Research, Industry Leaders Meet for Virtual CEC-ICMC '21

CEC/ICMC 21
VIRTUAL CONFERENCE JULY 19-23
Cryogenics · Through · Collaboration

While the pandemic may have changed the approach, organizers and attendees of the 2021 Cryogenic Engineering Conference–International Cryogenic Materials Conference participated in a valuable week of presentations, discussions, posters, short courses and exhibitions. Held virtually via Whova® from July 17–23, CEC-ICMC hosted over 670 attendees from across the globe in a unique opportunity to reconnect with colleagues and friends while sharing information, news and ideas: a welcome change after a long period of uncertainty.

Saturday saw the first official event of the conference – a short course entitled "Quantum Information Science" – which was presented by Zlatko Minev of IMB and Matthew Hollister of Fermilab (CSA CSM). Organized by Eric Holland of Keysight Technologies, the two sessions covered superconducting qubit device design and dilution refrigerators for quantum science.

Sunday's course was presided over by Robert Walsh of the National High Magnetic Field Laboratory (NHMFL, CSA CSM) at Florida State University (FSU), Ignacio Aviles of CERN and Tim J. Horn of North Carolina State University. Entitled "Properties of Structural Materials and Introduction to Additive Manufacturing for Cryogenic Applications," the course covered each topic in separate sessions. Sunday also featured two welcome sessions, live-streamed six hours apart for attendees on opposite sides of the globe, that included an intro to the conference and the software with which it was being hosted.

Awards were given each day. Day one featured an opening ceremony and the ICMC's award presentation, hosted by Eric Hellstrom of the NHMFL. The Cryogenic Materials Award for Excellence was awarded to Mark Ainslie of the University of Cambridge to recognize excellence in advancing the knowledge of cryogenic materials over recent years. The Lifetime Achievement Award was presented to Shi Xue Dou of the University of Wollongong to recognize a lifetime's achievement in advancing the knowledge of cryogenic materials.

On day two, the CEC awards ceremony, hosted by Peter Kittel (CSA Fellow) was held. The Russell B. Scott Memorial Awards (one research and one application) to recognize the best papers published in ***Advances in Cryogenic Engineering*** were given to Ali Ghavami, Tao Fang and S. Mostafa Ghiaasiaan for the Best Research Paper while F. Micolon, T. Dijoud, H. Mainaud Durand, V. Parma, V. Rude and M. Sosin of CERN received the award for Best Application Paper. The prestigious Samuel C. Collins Award – awarded to an individual who has given outstandingly of himself/herself in the identification and solution of cryogenic engineering problems and has subsequently demonstrated their concern for the cryogenic community with their dedicated and unselfish professional service and leadership to this community – was presented to Jay Theilacker of Fermilab.

The CSA and Elsevier Awards were presented on day three and hosted by Dr. Chris Rey of Energy-to-Power Solutions and Shreyas Balachandran of the NHMFL. CSA's newly elected Fellows, Dr. John G. Weisend of the European Spallation Source (CSA Board Chairman) and Dr. Sastry Pamidi of Florida A&M University-Florida State University (FAMU-FSU) and the NHMFL, were announced first. After, the George T. Mulholland Memorial Award for Excellence in Cryogenic Engineering – given for notable engineering development in a particular area leading to a major contribution in the cryogenic field – was given to Dr. Jingyuan Xu of Imperial College London. The CSA Technical Award for Excellence in Cryogenic Operations and Support went to Benjamin Hansen at Fermilab. Elsevier's Best Paper Award Published in 2020 in the journal ***Cryogenics*** was awarded to Philippe Fazilleau, Xavier Chaud, Francois Debray, Thibault Lecrevisse and Jung-Bin Song and was presented by the editors of the magazine, B. Baudouy of the French Alternative Energies and Atomic Energy Commission Saclay Center, H.M. Chang of Hongik University in Seoul, Republic of Korea and Peter Shirron (CSA Fellow and Past President) of NASA Goddard Space Flight Center.

While no awards were presented on day four, day five saw the joint CEC-ICMC awards presentation hosted by Al Zeller (CSA President-Elect) of the NHMFL and CEC Scholarship Chair Eric Hellstrom. The Klaus and Jean Timmerhaus Scholarship Award for graduate students in US universities was awarded to Jonathon Howard of Michigan State University's (MSU) Facility for Rare Isotope Beams (FRIB, CSA CSM). The award includes a $2,500 prize. The Donna Jung Scholarship Award, intended to develop and foster increased interest and participation in fields of cryogenic studies and to encourage future engineers and scientists in these areas, was given to Hosna Rastegarpouyani from FSU. Meritorious Student Paper Awards – a long-standing practice of ICMC that present awards to students for outstanding work made on a competitive basis – were given to lead authors Srikar Telikapalli of FSU and S. Imam Hossain of the NHMFL.

Each morning began with a plenary session. Monday's plenary was given by Irfan Siddiqi and Tengming Shen (CSA Boom Award Recipient 2020), both of Lawrence Berkeley National Laboratory, and Michael Sumption of Ohio State University and entitled "The Promise of Superconducting Quantum Processing." Tuesday's plenary, hosted by Eric Hinterman of Massachusetts Institute of Technology (MIT) along with conference chairs Robbi McDonald of Westport Fuel Systems and Wesley Johnson from NASA Glenn Research Center, was called "The Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE)."

Day three saw session chairs Timothy Haugan from the US Air Force Research Laboratory and Sonja Schlachter of the Karlsruhe Institute of Technology preside, while Ludovic Ybanez of Airbus presented the plenary on "ASCEND – A First Step Towards Cryogenic Electric Propulsion for Aircraft?" Day four saw no plenaries while day five featured session chairs John Weisend and Jay Theilacker of Fermilab overseeing David Grillot of ITER giving a presentation entitled "ITER Cryogenic Systems – the Scale, Complexity, and Innovation."

Every day was jam-packed with oral sessions and focus sessions – nearly 50 in total. Sprinkled throughout the week were poster sessions in which researchers could digitally converse with individuals as they made their way through the virtual poster room. Participants could enter video conference rooms with presenters to get more information just like one would at an in-person event.

Exhibitors were given the opportunity to showcase their products and services in a virtual "exhibitor hall." Attendees could peruse the exhibitor hall whenever they were so inclined, but special times were set aside for representatives from each organization to "man" their tables and for teleconference rooms in which attendees could ask questions, get more information and network.

While the COVID-19 pandemic may have altered the landscape of the event, organizers, attendees, sponsors and exhibitors made the first virtual CEC-ICMC event a smashing success. Until we can all meet again, events like this show that the cryogenic community can overcome any obstacle to continue to advance the science that enables current applications and future necessities for so much of our world. ■

SPOTLIGHT ON A CORPORATE SUSTAINING MEMBER (CSA CSM)

Linde to Supply Green Hydrogen to the Semiconductor Industry

Linde announced it has signed a long-term agreement with Infineon Technologies for the on-site production and storage of high purity green hydrogen, alongside the supply of other industrial gases. It will be the first time green hydrogen is used in Infineon's semiconductor manufacturing process. The announcement was made August 18.

Linde will build, own and operate a two-megawatt electrolyzer plant at Infineon's Villach site in Austria. The plant will produce green hydrogen using Proton Exchange Membrane (PEM) technology from ITM Power, which Linde will then purify to meet the rigorous specifications needed in Infineon's manufacturing process. The use of this high purity green hydrogen is part of Infineon's plans to reduce greenhouse gas emissions at their Villach site.

Linde will also build, own and operate a compact air separation unit at the Villach site to deliver a reliable supply of nitrogen in addition to a bulk storage system to supply additional industrial gases to meet Infineon's expanding requirements. The new Linde facilities are expected to start up in 2022.

"Finding sustainable methods of manufacturing is essential to achieving our climate targets," said Thomas Reisinger, board member operations at Infineon Technologies Austria. "By introducing an electrolysis system at the Infineon Villach site, we are equipping ourselves for the future by securing the essential supply of high purity hydrogen while reducing our emissions."

"We are proud to work with Infineon to pioneer the use of green hydrogen in the semiconductor industry," said Veerle Slenders, President of the Western European Region at Linde. "Linde has supplied Infineon for over 20 years and we are pleased to support our customer's sustainability initiatives through the use of technology and smart solutions."

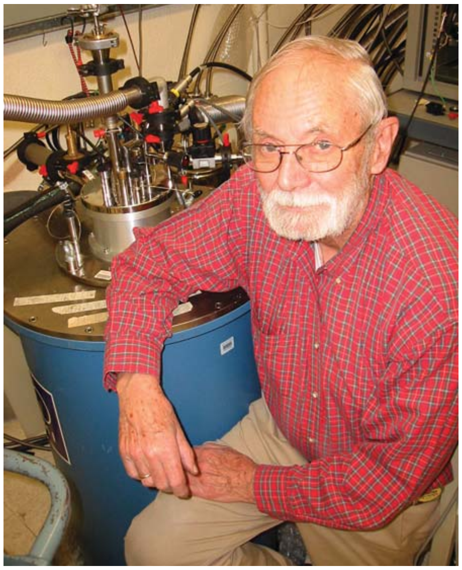
Linde is a global leader in the production, processing, storage and distribution of hydrogen. It has the largest liquid hydrogen capacity and distribution system in the world. The company operates the world's first high purity hydrogen storage cavern plus pipeline networks totaling approximately 1,000 kilometers globally, to reliably supply its customers.

Linde is at the forefront in the transition to clean hydrogen and has installed close to 200 hydrogen fueling stations and 80 hydrogen electrolysis plants worldwide. The company offers the latest electrolysis technology through the joint venture ITM Linde Electrolysis GmbH as well as ultrahigh purity hydrogen supply solutions for the semiconductor industry. **www.leamericas.com/en/technologies/deep-cryogenics/** ■

In Memoriam

Peter Mason

1928-2021



From left to right, Laurie Huget, Peter Mason, Doreen Mason, and John Pfotenhauer during the CSA Award Ceremony when Peter was made a Fellow of CSA in 2011. *Image: CSA*

We regret to report the passing of former Jet Propulsion Laboratory (JPL) leader, visiting associate at Caltech, CSA Fellow and ***Cold Facts*** Space Cryogenics columnist, Peter V. Mason. He passed after a short illness on May 30, 2021.

Peter was a dedicated supporter of CSA for decades. In addition to being a CSA Fellow, Peter was also a highly respected and eloquent contributor to the *Space Cryogenics* column in ***Cold Facts*** for many years, beginning in the first issue of 2005. Once retired from the column, he served on the Editorial Board where his expertise in cryogenics and space research were an invaluable resource for countless readers.

Peter received a PhD in electrical engineering from Caltech in 1962, where he taught physics for many years before moving to NASA's JPL as a low temperature physics research engineer. While there, he was in charge of designing the Infra-Red Astronomy Satellite's cryogenic systems and advised the Stanford team with the Gravity Probe 8 satellite. Peter served as a mentor for some of physics' top scientists on project Boomerang, the Antarctica-based study of radiation from the Cosmic Microwave Background.

Dr. Mason quaffs a Guinness at the South Pole. The photo was taken next to the official geographic South Pole sign. *Image: Courtesy of Peter Mason*

You can read Peter's work in past issues of ***Cold Facts***. Apart from his regularly published *Space Cryogenics* columns, some of Peter's notable work includes a special feature in Volume 30, No. 3, page 20 entitled "*BICEP2 and the Outer Edge of the Universe*." Peter spent some time in Antarctica at the US South Pole station, and he writes about his work in the article noted.

Peter also wrote "*Superfluid Helium in Space*," a feature publicly available on the CSA website that discusses the nuances of the behavior of superfluid helium in space and observations with instruments and millimeter-wave telescopes operating at liquid helium temperatures.

On behalf of the entire CSA organization, we extend our sincerest condolences to Peter's family and thank him for his years of contributions, support and influence.

Tribute

From Laurie Huget, *former CSA Executive Director*

We were privileged to know Peter Mason through CSA for many years. It was an honor to be among his friends. Peter was a long-time supporter of CSA and its goals to further knowledge and research in the realm of cryogenics. He was extremely generous to us and to the Cryogenic Society with his time and talents.

He not only wrote a long-term column for ***Cold Facts***, but he was on the Editorial Board and always available to help with technical questions and issues. Highly regarded and respected in his field, he shared his expertise and experience with us often. He led a very full and wide-ranging life and he and his wife Doreen shared many of their stories with us.

It is an understatement to say Peter will be missed! He left his mark on science and was an asset to Caltech and to all the other organizations he touched. As a Fellow of the Cryogenic Society of America, he holds a very special place in our hearts and our memories. ■

Product Showcase

This Product Showcase is open to all companies and related manufacturers offering new or improved products for cryogenic applications. We invite companies to send us short releases (75 words or fewer) with high resolution JPEGs of their products to editor@cryogenicsociety.org.

Princeton Cryo

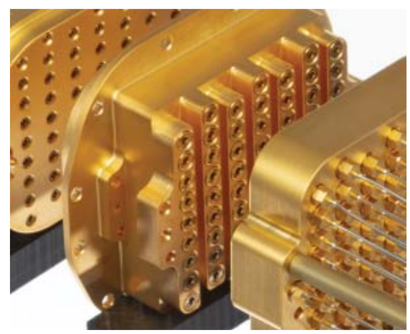
Labs 20K Cryogenic Freezer by Worthington

Princeton Cryo's 20K freezer stores up to 19,500 vials in liquid or vapor phase with high efficiency and very low LN_2 consumption and storage in either liquid or vapor phase. Near LN_2 temperatures are maintained at the top of the inventory storage system for overall sample viability while a single pivot point aluminum turntable design facilitates smooth rotation and ergonomic use while eliminating any mechanical component maintenance. Full height, segmented and labeled turntable provides easy inventory storage access and management and convenient access to measure LN_2 level. Hinged lid and stainless steel tabletop features include locking capabilities and activation of an automatic defog for quick viewing of inventory storage. The 20K features discrete thermistor level measurement and thermocouple temperature resolution within 0.1 °C plus capabilities for data collection, event scheduling and enhanced security settings. **www.princetoncryo.com** ■

The Phoenix Company of Chicago, Inc.

Microwave PkZ® Contact Housings

The Phoenix Company of Chicago develops complete PkZ Interconnect solutions for cryogenic-based quantum computing applications. While PkZ blindmate microwave contacts are the center of attention in these applications, PkZ housings which contain the contacts and support their proper functionality, are just as important. The housings protect the PkZs from damage and provide accurate mating engagement to ensure a repeatable and reliable connection.
www.phoenixofchicago.com ■



Hoffer Flow Controls

"ICE" Cryogenic Electronics

ICE (Integrated Cryogenic Electronics) is Hoffer's most advanced truck-mounted cryogenic flow metering system. ICE meets the requirements of Handbook 44 and has NTEP approval. It includes a full-color graphical display and electronic touchscreen ensuring a user-friendly operator interface. It is now available with Hoffer's smart phone app to give customers the ability to revolutionize the way they interface with their delivery systems. **www.hofferflow.com/cryogenic-flow-controls** ■

Scientific Instruments

SI-7000 LTD

The SI-7000 LTD is a very dependable solution for level, temperature, and density profiling in LNG & LPG storage tanks. Now on a smaller footprint, with built-in intuitive keypad display, it provides optimized performance, reliability and accuracy. The SI-7000 Probe has dedicated sensors for level, temperature and LNG density measurements, all embedded into a robust stainless steel housing. All components exposed to Zone 0 and 1 are constructed of stainless steel, offering superior corrosion resistance. The SI-7000 now features an entirely redesigned jam-proof vertical-gear-drive mechanism (VGD), combined with a robust stainless steel chain, resulting in trouble-free reliable profiling performance in LNG and LPG storage tanks. **www.scientificinstruments.com** ■

People, Companies in Cryogenics

Image: APS

Danielle H. Speller, a nuclear and particle astrophysicist and an Assistant Professor of Physics at Johns Hopkins University was awarded the 2021 Stuart Jay Freedman Award in Experimental Nuclear Physics by the **American Physical Society**. She was recognized for excellence in experimental research into the fundamental nature of matter and mass based on low-energy cryogenic detection techniques, in particular neutrinoless double beta decay and dark matter searches.

The US House and Senate both propose to increase funding for the **Department of Energy's Office of Science** in fiscal year 2022. Appropriators propose increasing the annual budget for the DOE's OOS by 4% and 7%, respectively. The Biden administration has requested a 6% increase in the budget, which currently stands at just above $7 billion.

Image: Catalent

In April, **Catalent** expanded capabilities at the 200,000 square-foot Philadelphia facility to include cryogenic handling and storage capacity to support sponsors developing cell and gene therapies. The facility houses an on-site pharmacy to support FlexDirect® direct-to-patient service for clinical trials, and it offers customers access to Catalent's FastChain® demand-led supply services, primary and secondary packaging capabilities, as well as a range of temperature options for storage and distribution, clinical returns and destruction services. **Harold A. Jenkins, III** will serve as General Manager.

The city of Winter Park FL has joined Orlando FL with a request for residents to conserve water in order to save liquid oxygen so it can be provided to hospitals to treat COVID-19 patients. Both the **Orlando Utilities Commission**, tasked with providing Orlando with its water, and **Winter Park Water & Wastewater Utilities Department** use liquid oxygen daily in treating water for customers' use in a process used to remove any odors or bad taste. As in many parts of the country, liquid oxygen is in short supply at Orlando-area hospitals.

Image: Fermilab

Fermilab's (CSA CSM) **Pedro Machado** builds theories and frameworks that push the lab's neutrino experiments to expand and accelerate their scientific advances. Machado won the 2021 Early Career Award from the Universities Research Association, an annual recognition of the most outstanding work for a researcher in the first leg of their career at or in collaboration with Fermilab. Through his neutrino expertise and theoretical models, Machado helps experimental physicists determine which neutrino questions could be worth exploring.

Galveston Wharves at the Port of Galveston and SEA-LNG Member **Stabilis Solutions Inc.**, a leading provider of energy transition services, including liquefied natural gas and hydrogen fueling solutions, have entered into a Memorandum of Understanding to facilitate the use of LNG as a marine fuel at the Port.

Image: Stabilis Solutions

On August 12, an **Indian Space Research Organization (ISRO)**-operated rocket, GSVL-F10, lost control and crashed five minutes after liftoff following a malfunction in the cryogenic upper stage, which failed to ignite. The reason for the malfunction is under investigation.

Cryonorm, a cryogenic systems and vaporizer supplier based in the Netherlands, has established a subsidiary in the United States. Headed by **Chasen Wendt** and **David Chicuorka**, managing director and global manager of engineering, respectively, the company has officially entered the US market.

Image: Cryonorm

Gulf Cryo, a cryogenic gas production plant servicing the liquefied natural gas terminal in Al Zour, Kuwait, received a Supply Achievement Award from Hyundai Engineering for the successful supply of 2,700 tonnes of liquid nitrogen to the facility. The operation took one week with a peak supply of 540 tonnes a day.

Scientists at **St. Jude Children's Research Hospital** compared cryogenic structures with those observed at room temperature. The findings, published in ***Chemical Science***, indicate that freezing can introduce errors, cause certain conformations (shapes) to be missed and lead to inaccuracies in computational models. Protein structures are essential to the drug development process because they provide a map indicating how targeted drugs should be designed.

When the **Maine Mineral & Gem Museum** opens in Bethel ME on September

1, it will include the largest intact Mars rock on Earth. The specimen weighs 32 pounds and measures 9" x 10" x 6.5". This specimen was acquired for the Museum by meteorite dealer **Darryl Pitt** in April 2021 from a Mauritanian meteorite and desert truffle hunter. For confirmation of his belief this could be Martian, Pitt sent a small sample to **Dr. Carl Agee** – the director of the Institute of Meteoritics at the University of New Mexico and one of the world's most renowned classification experts on Martian meteorites.

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The first piece of the Artemis rocket intended to take humans on a trip around the moon arrived at Cape Canaveral FL on July 28. **United Launch Alliance** built and delivered the interim cryogenic propulsion stage of the Space Launch System.

Image: NASA

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On August 24, **Voyager Space**, a global leader in space exploration, announced its subsidiary, **Altius Space Machines, Inc.** was selected by **Eta Space** (CSA CSM) to provide a cryogenic coupler for liquid oxygen (LOX) transfer in support of its planned nine-month LOXSAT cryogenic fluid management mission. Eta Space was selected by NASA to execute a flight demonstration of a complete cryogenic oxygen fluid management system. The system will fly as a dedicated payload on a Rocket Lab Electron launch vehicle and will collect critical cryogenic storage and transfer data in orbit for nine months.

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Proposals for a **Highview Power** cryogenic energy storage system at Hunterston Marine Construction Yard in Scotland have been announced. Highview Power has proposed development that will generate 49.9 MW of electricity. The cryogenic energy storage system will feature three main processes: a charging system, an energy store and power recovery using the company's cryobattery. It turns ambient air into liquid, stores the liquid air in tanks and, when needed, expands the liquid air into a gas which generates electricity.

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Nikkiso Cryogenic Industries' Clean Energy & Industrial Gases Group, a subsidiary of Nikkiso Co., Ltd (Japan, CSA CSM) has announced that they have completed the recommissioning of an Air Separation plant in Patancheru, Hyderabad, India. This project was done in coordination with the Telangana government and Greenko Foundation. Due to the ongoing Covid crisis in India, the Indian government initiated a directive to restart the operation and LOX production to meet the urgent demands for medical oxygen. The Greenko Foundation has taken the old shut-down oxygen plant on a rental basis from Air Water India Private Limited for a period of two years.

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On August 8, an experiment at **Lawrence Livermore National Laboratory's National Ignition Facility (NIF)** made a significant step toward fusion ignition, achieving a yield of more than 1.3 megajoules. This advancement puts researchers at the threshold of fusion ignition, an important goal of the NIF, and opens access to a new experimental regime.

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The **ITER Organization** has added a permanent virtual visit option to its visit program. Developed in reply to the COVID-19 pandemic and the necessary restrictions to in-person visiting, the virtual visit now co-exists alongside other options, including individual and group visits, on the ITER webpage dedicated to visitors. The virtual visit option will remain available to the public even after COVID-related restrictions end. ■

Meetings & Events

Superconductors for Fusion Webinar
August 25, 2021
Virtual
http://2csa.us/kl

15th European Conference on Applied Superconductivity
September 5-6, 2021
Virtual
http://2csa.us/kd

Gastech Exhibition & Conference
September 21-23, 2021
Dubai
http://2csa.us/jt

16th CRYOGENICS 2021 IIR INTERNATIONAL CONFERENCE
October 5- 7, 2021
Virtual
http://2csa.us/kj

European Cryogenics Days 2021
November 3- 4, 2021
Virtual
http://2csa.us/ki

Space Cryogenics Workshop
November 15-17, 2021
Virtual
https://spacecryogenicsworkshop.org

ICC 22
June 27- 30, 2022
Bethlehem, PA
http://2csa.us/kn

29th International Conference on Low Temperature Physics
August 15-24, 2022
Sapporo, Japan
http://2csa.us/ha

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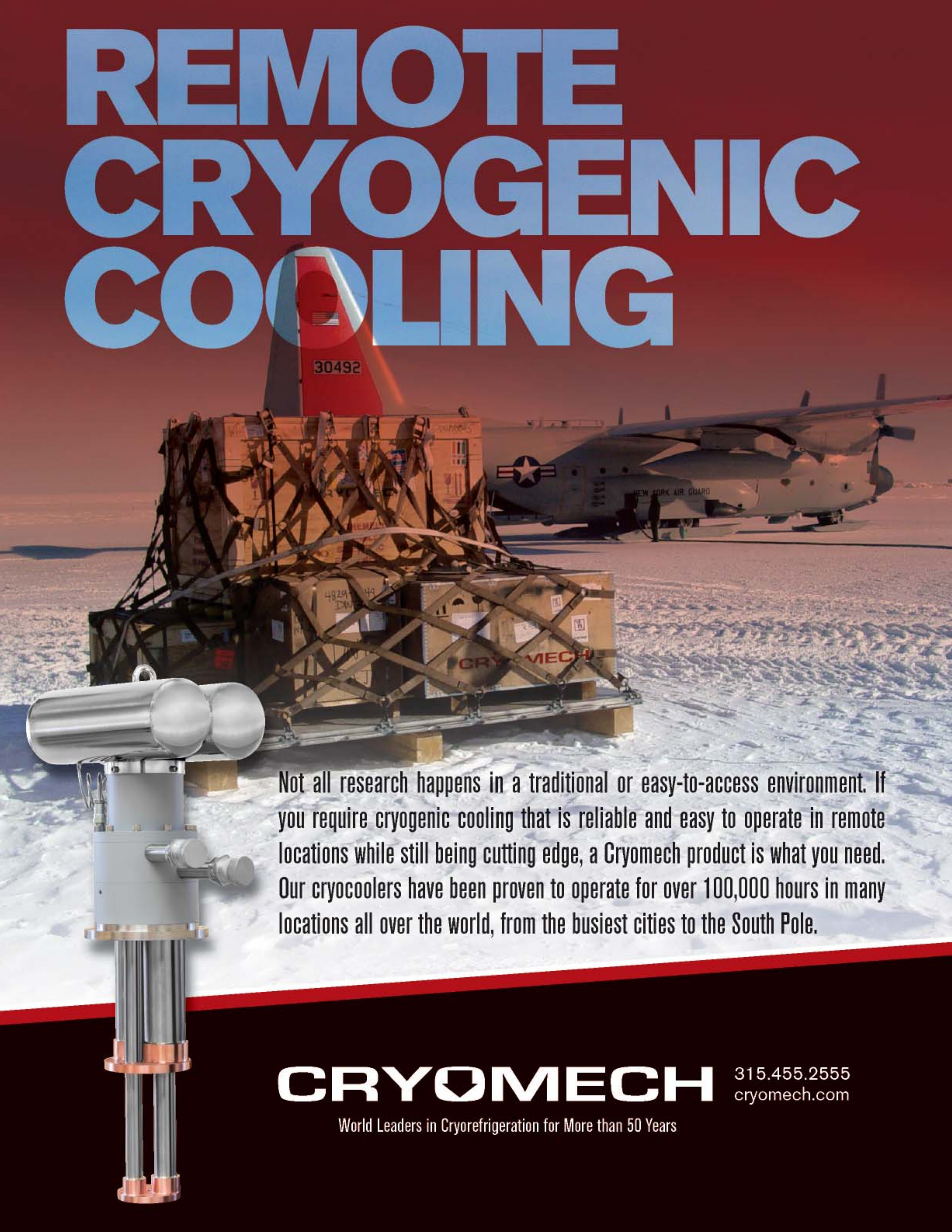
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