SNS accelerator celebrates 10 years of leading the way

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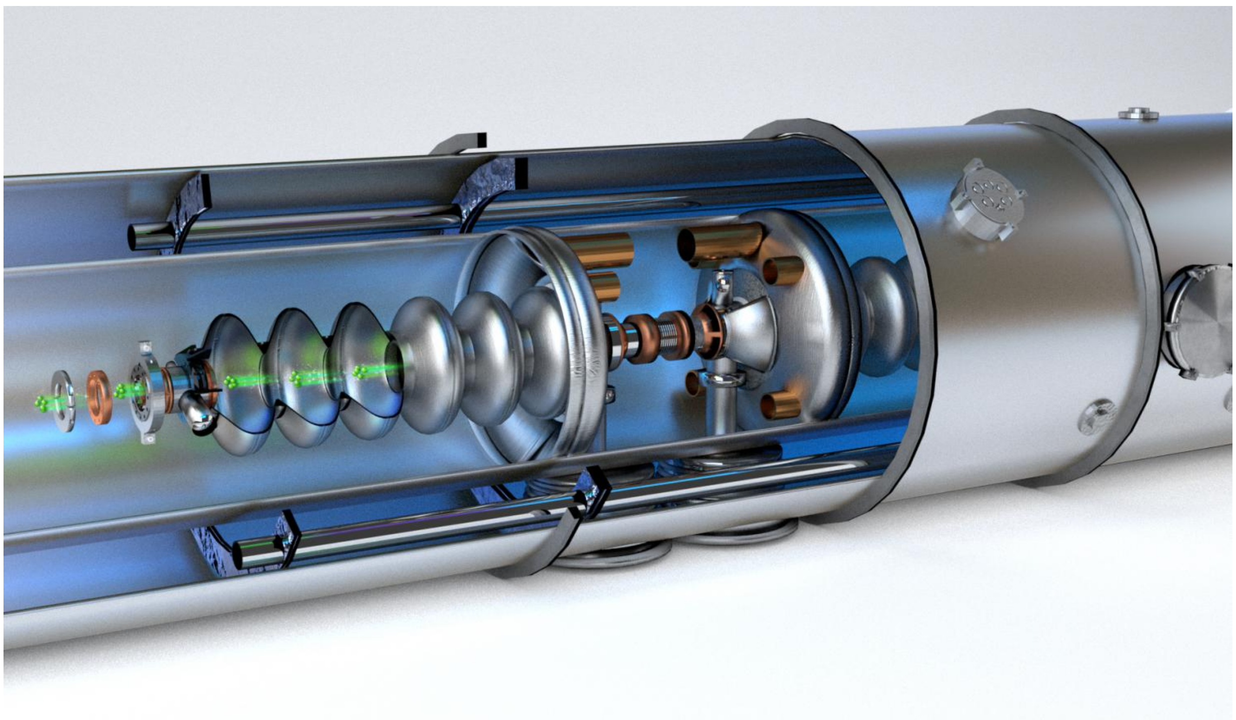

The SNS LINAC is the most powerful proton-pulsed accelerator in the world. Stretching the length of nearly three football fields, the LINAC is responsible for focusing and propelling protons to roughly 90 percent the speed of light just before they smash into a liquid mercury target, releasing about 25 neutrons for every proton to be used for scientific discovery. Credit: ORNL/Jill Hemman, et. al.

The first of its kind superconducting linear particle accelerator (LINAC) built for the Spallation Neutron Source (SNS) at the Department of Energy's Oak Ridge National Laboratory is now celebrating 10 years of successful operations.

The world-leading machine, which took 7 years to build, is the first mega-watt class hadron linear superconducting accelerator and proton accumulator ring. In operation since 2007, the SNS accelerator delivers a reliable medium-energy proton beam to a mercury target. Neutrons released from this collision are then delivered to a variety of science experiments.

"The SNS accelerator has proved to be a real game changer, with the first use of superconducting radio frequency (SRF) technologies in a high-power hadron LINAC," said ORNL Research Accelerator Physicist John Galambos. "Other accelerator projects around the world in support of nuclear physics like the Facility for Rare Isotope Beams in Michigan, the high-energy physics Proton Improvement Plan-II at Fermilab, and materials science at the European Spallation Source are following the successful SNS deployment of SRF for megawatt hadron beam operation."

The SNS machine—a DOE Office of Science User Facility—reflects the evolution of particle accelerators: While the first portion of the facility uses room temperature copper structures similar to many of the world's accelerators, the rest of the machine takes advantage of superconducting materials to deliver a high energy beam more efficiently and with fewer losses. Accelerators began incorporating superconducting cavities in the 1970s, but the SNS LINAC is the first large-scale hadron accelerator to use superconducting cavities.

"When the decision was being made to go superconducting with the second part of our accelerator instead of a room-temperature accelerator, everything looked good on paper," explained Research

Accelerator Physicist Sarah Cousineau. "No one had ever done it before with hadrons, though, so it was somewhat of a gamble in technology that has really paid off."

The advantage of superconducting cavities is that 99 percent of the RF power is actually transported to the beam. At SNS, once the particle beam gets to approximately 40 percent the speed of light, the superconducting part of the SNS accelerator takes over, allowing for more efficient conversion of power and permitting more rapid acceleration of ions per meter of accelerator than a room-temperature copper structure, as well as much greater operational flexibly. Other accelerators are following in the SNS accelerator's footsteps; the European Spallation Neutron Source, now under construction is Sweden, is being built almost entirely out of superconducting accelerator structures.

The science and engineering teams at SNS have also enabled a number of other "firsts" in accelerator physics and technology, including:

- The highest ever beam power to a neutron production target by any accelerator complex,
- The highest intensity proton ring on a charge per pulse basis, and
- The first use of a liquid mercury target in a neutron production environment.

The SNS accelerator also has best performing negative hydrogen ion source and the first production laser-based beam diagnostics system. The machine also demonstrates the first large-scale deployment of a specific type of high voltage converter modulator technology, crucial for pulsed high voltage sources. All of these achievements combine to situate the SNS team at the leading edge of accelerator performance.

A significant discovery was made by SNS scientists about hydrogen (H-)

ion intra-beam stripping, which started as a problem of unexpected beam loss.

"Once the electron is knocked off an ion inside the beam bunch, it's not affected by accelerating fields or magnetic fields," explained Cousineau. "When that happens we can't do anything with it, and it becomes beam loss. Being the first superconducting accelerator, there was no precedent so we didn't expect it."

An SNS visitor was the scientist that first identified H- intra-beam stripping as a source of beam loss in the linear accelerator, and SNS staff began to test the theory and find out if it was the culprit. After performing an experiment running protons down the accelerator instead of H(-), they found the beam loss went down to near zero. Later on they discovered that other labs, such as Los Alamos National Laboratory and the Japan Proton Accelerator Research Complex, have had the same beam loss mechanism.

The SNS team has since performed the first demonstration of laser-assisted H- ion strip ping to aid ring injection and reduce beam loss.

SNS staff developed a novel technique known as in-situ plasma processing to remove contaminants from the surface of the high-beta superconducting accelerating cavities. This technique has potential applications to superconducting accelerators of all sizes and types. By using hot plasma to burn off hydrocarbons on and just below the surfaces of cavities without removing the cavities from the accelerator, the SNS team was able to reduce the processing time from a complex, high risk 6 to 8-month procedure to one that can be completed in weeks.

"When the neutron users arrive to do their experiments, they've already made a significant investment in time, travel expenses, and sample preparation," Cousineau said. "We need to deliver beam when we promised to have beam, so that world-class science can happen. We promise 90 percent or more reliability on the average, and, we can go well over 90 percent for shorter periods."

The SNS LINAC was built with room to grow, and right now researchers, engineers and designers are working on a plan to boost power even further with a proton power beam upgrade from 1.4 megawatts to 2.8 megawatts. This performance upgrade will provide a platform for a Second Target Station adjacent to the existing facility.

"From computation talents to software development, particle simulation and beam instrumentation, we have real expertise here for understanding high-intensity beam dynamics," Cousineau said. "We're excited to see what the future holds."

Provided by Oak Ridge National Laboratory