American-made superconducting radiofrequency cavity makes the grade

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The U.S. Department of Energy's Thomas Jefferson National Accelerator Facility marked a step forward in the field of advanced particle accelerator technology with the successful test of the first U.S.-built superconducting radiofrequency (SRF) niobium cavity to meet the exacting specifications of the proposed International Linear Collider (ILC).

The cavity was developed as part of a DOE-funded R&D effort focused on developing technologies that would be required for an ILC, a proposed next-generation electron-positron collider that would enable scientists to explore matter at higher levels of energy.

Superconducting radiofrequency accelerator cavities are crucial components of particle accelerators or colliders, harnessing the energy that the collider pumps into a beam of particles. If it were built, the ILC would require about 16,000 niobium cavities, and vendors worldwide are vying to produce test cavities that meet the ILC's stringent performance goals. Superconducting cavities are also found in a number of accelerator facilities supporting Office of Science programs, and improved performance will benefit these programs as well.

"This is the first cavity built and processed in the U.S. that exceeds the ILC gradient specification established by the ILC Global Design Effort," said Rongli Geng, a staff scientist at Jefferson Lab and group leader of the Global Design Effort (GDE) Cavity Group.

The cavity was manufactured by Advanced Energy Systems, Inc. (AES), located in Medford, NY, one of several North American companies attempting to manufacture test cavities for the ILC. The cavity was processed, underwent final assembly and was tested at Jefferson Lab.

During the test, the cavity was cooled to operating temperature (2 Kelvin or negative 456 degrees Fahrenheit) and its ability to harness radiofrequency energy was gauged. The test revealed that the cavity's accelerating gradient, its ability to impart energy to particles, was 41 megavolts per meter, far exceeding the GDE specification of 35 MV/m. The test was confirmed the following day with an independent measurement.

The cavity is owned by the Department of Energy's Fermi National Accelerator Laboratory (Fermilab) and is slated for installation in a cryomodule, which will be assembled at Fermilab. Dubbed AES8, it is the eighth ILC cavity built by AES to be tested by Jefferson Lab and the first to surpass specification. Another cavity, AES9, tested shortly before AES8, performed just shy of the specification, topping out at 34 MV/m.

"It is a major ILC superconducting RF milestone and it is good news for JLab, for AES, for the Department of Energy and for Fermilab," Geng said. "We believe an improvement in cavity treatment for material property optimization specific to AES cavities may have been responsible for these remarkable results. This is the fruit of the new temperature-mapping and the optical-inspection tools we introduced into the process about a year ago under the guidance of ILC GDE project managers."

Using these tools, Geng and his team have been trying to understand performance limits in ILC cavities. They found that new AES built cavities already had high-quality electron beam welded joints. That allowed the researchers to then look at cavity performance-limiting factors beyond processing and fabrication.

For instance, cavities require heat treatment to remove hydrogen from the cavities' material. Instead of following the old Jefferson Lab formula of baking a cavity for 10 hours at 600 degrees Celsius, AES8 and AES9 were baked for two hours at 800 degrees Celsius (1472 degrees Fahrenheit).

"Somehow AES-built cavities appear to be stiffer, we changed the treatment temperature primarily for optimizing its mechanical properties," Geng explained. "Now, it seems that there might have been other material property improvement."

In addition, AES8 was also subjected to an extra cleaning step called buffered chemical polish, where the cavity was exposed to a mixture of nitric acid, hydrofluoric acid and phosphoric acid. Geng said a more uniform starting surface was produced before the main surface treatment.

"We will follow this path of success and treat the next two cavities with this procedure," Geng said. "I anticipate favorable results will follow shortly and AES will soon be regarded as a high-quality source for ILC superconducting RF cavities."

Tony Favale, CEO and a director of AES, said that conducting vigorous scientific testing and incorporating improvements that boost cavity performance will help his and other companies reliably produce accelerator cavities that meet specifications.

"It's always the partnership between labs and industry that makes benefits for both," Favale said.

Source: Thomas Jefferson National Accelerator Facility