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Until 8 a.m. CDT, Monday, November 2, 2026
MEDIA CONTACTS
Saralyn Stewart
(512) 694-2320
stewart@physics.utexas.edu

Heavy Water Boosts Laser-based Medical Isotope Production

Laser-plasma accelerators demonstrate scalable production of medical radioisotopes; using heavy water makes the process more efficient.

CHICAGO—Researchers from Stanford University used an intense laser and a thin sheet of flowing water to make carbon-11, a radioactive form of carbon used in medical imaging. This is the first time a laser-plasma accelerator—a device that uses laser light to speed up particles—has produced a radioisotope in a way that can scale up to quantities practical for medical applications.

Positron emission tomography, or PET, scans follow tiny amounts of radioactive material through the body to reveal cancer and track bodily functions like brain activity and metabolism. Some of the most useful and versatile PET scans use the radioisotope carbon-11. Because carbon is the backbone of life's molecules, chemists can put carbon-11 into drugs and natural compounds without changing the way they behave [1]. The problem is that carbon-11 disappears very quickly; half of it decays every 20 minutes. Its short lifetime means it must be produced very close to where it will be used. This limits the use of carbon-11 to facilities with a nearby particle accelerator, which is usually a bulky cyclotron that can cost over $10 million and needs a dedicated concrete bunker. Most community hospitals can’t afford or don’t have space for one. Laser-driven

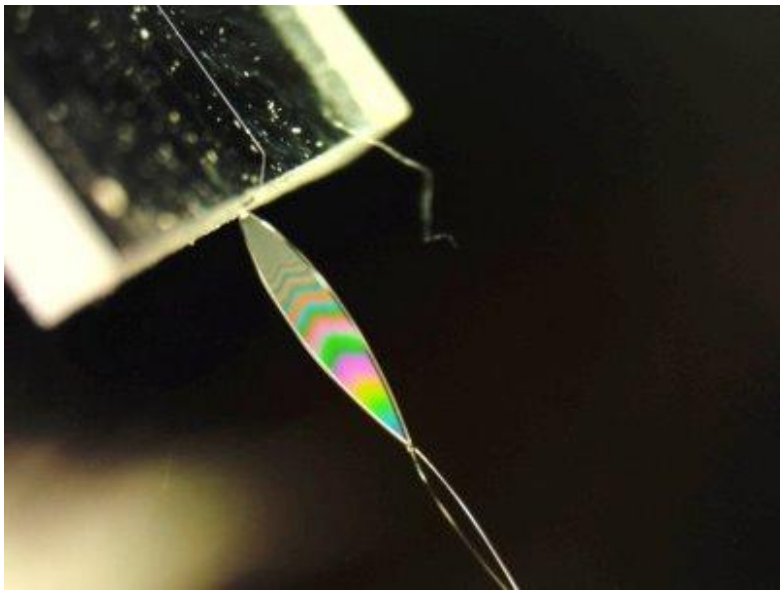


Figure 1: Continuous flow of sub-micron water sheet from micro-nozzle used for laser-driven radioisotope production at ALEPH Laser. Image courtesy of C. Hampton, SLAC.

accelerators could one day offer a more compact and affordable alternative, but only if they can fire rapidly for long periods of time.

Researchers performed experiments at Colorado State University's Advanced Laser for Extreme Photonics (ALEPH), one of the most powerful lasers in the world [2]. ALEPH compresses laser pulses to deliver a huge amount of energy in just 45 femtoseconds (less than the amount of time it takes light to travel the width of a human hair). The laser hits a thin sheet of water, about 100 times thinner than a piece of paper, that flows continuously from a tiny nozzle (Figure 1) [3]. Each pulse turns the water into plasma. The enormous electric fields in the plasma fling out a beam of hydrogen nuclei, or protons. The protons strike a boron sample, transforming some of the boron atoms into carbon-11.

At the annual meeting of the American Physical Society's Division of Plasma Physics, researchers will present, for the first time, results showing that switching to a sheet of heavy water increases carbon-11 production. Heavy water is chemically almost identical to ordinary water, but each of its hydrogen atoms has an extra neutron. When the laser hits the sheet of heavy water, it launches a beam of these heavier hydrogen nuclei, called deuterons, instead of protons.

Most particles from a laser-plasma accelerator, whether protons or deuterons, are relatively slow. Protons must be moving fast to make carbon-11, so many of the protons in the beam go to waste. Deuterons, however, can make carbon-11 even at low speeds, so more of the beam goes to work.

The results indicate that a much smaller laser than ALEPH—one that could fit on a table and cost an order of magnitude less than a cyclotron—could produce sufficient quantities of carbon-11 for PET scans. Lasers like these often fire over 1,000 times a second, which the team's flowing heavy water target can handle. One day, this approach could bring carbon-11 to hospitals and research centers that otherwise would not have access.

This work was funded by NSF Grant No PHY-2308860 and the DOE Office of Science, Fusion Energy Science under FWP100182. S. Popa and D. Ursescu acknowledge funding from project "Medical applications of high-power lasers - Dr. LASER" - SMIS Code: 326475 funded by the European Union, the Romanian Government and the Health Program; Projects ELI−RO/DFG/2025−013 IATP-NP 2.0 and ELI RO/RDI/029/30.10.2025 - AMIPulse funded by the Institute of Atomic Physics, Romania. J. Kennedy and C. Palmer acknowledge support from EPSRC grant number EP/Y001737/1.

Contact:
Matthew Ricks, High Energy Science Division, SLAC National Laboratory, California, USA, mttricks@stanford.edu

Co-authors: G. Jain, G. Glenn, S. Faubel, A. Dawes, C. Palmer, J. Kennedy, S. Popa, D. Ursescu, F. Treffert, J. King, G. Zeraouli, S. Zahedpour Anaraki, R. Hollinger, J. Rocca, M. Gauthier, S. Glenzer

Abstract

CO08/5 Scalable Production of Carbon-11 with Liquid H2O and D2O Jet Laser-Ion Accelerators

Session CO08: Ion Acceleration

2:00 PM–5:00 PM, Monday, November 2, 2026

Room: Hilton Chicago, Salon C 5 & 6, Lower Level