



DOE SBIR/STTR Success

ADELPHI TECHNOLOGY INC.

Over the course of its 20 years of operation, Adelphi Technology, Inc. has pioneered and perfected the design and production of state of the art, compact, and safe neutron generators. The production of a neutron beam might seem like an activity strictly reserved to government and regional sponsored facilities and not something to be manufactured in parallel. That is precisely what makes Adelphi special. Thanks to their impressive technical ability, Adelphi's scientists have been able to shrink neutron generators to the point of making this technology available to modest-sized research laboratories and businesses, opening up an entire class of applications impossible before.

FACTS

PHASE III SUCCESS

30 customized neutron generators sold for a revenue of \$ 8 Million.

3 R&D100 Awards

Reached a total revenue of \$4M/year in 2017.

IMPACT

High flux, compact neutron generators are an economical and practical replacement for expensive research reactors or national facility neutron beamlines.

DOE OFFICES

Office of Basic Energy Sciences (BES); Office of Nuclear Energy (NE); Office of Nuclear Physics (NP).

Neutron generators provide non-destructive materials analysis with applications in many industries: medicine, cancer therapy, homeland security, geology, environmental monitoring and forensic science. For example, neutrons can be used to determine the concentration of trace elements in materials, and to create medical isotopes.

Neutrons can also provide chemical information that is hard to obtain using other probes such as X-rays and electrons, especially image contrast and chemical concentrations in materials containing light elements such as hydrogen and organic materials in general. However, because neutrons are typically produced in research-grade particle accelerators, nuclear reactors, or by using significant amounts of radioactive materials, their application has been limited. This has created a tremendous opportunity for the development of compact, safe-to-use neutron sources, which Adelphi was able to fully leverage. Today Adelphi produces neutron generators without the radioactive element californium, small enough to fit on a desk or be easily carried in a small vehicle, and powerful enough to provide thermal fluxes approaching those obtained at research facilities.

From early prototype development in 2005 to 2016 Adelphi sold 30 neutron generators to private customers for a revenue of \$ 8 Million, and commissioned three generators for government use. Adelphi's generators have earned the company three R&D 100 Awards and have been recently employed in projects that span from medical applications to transportation and mining industry solutions, and even to exotic physics experiments to test dark matter detection. For the latter effort, one of Adelphi's neutron generators, the DD108 model, was sold to Brown University and installed one mile under the earth at the Sanford Underground Research Facility in the Black Hills of South Dakota. The generator was used successfully to test the sensitivity of the Large Underground Xenon (LUX) dark matter detector. As dark matter particles are extremely elusive, dark matter detectors have to be able pick out a few events per year in hundreds of kilograms of material. Given its extreme sensitivity, testing the LUX dark matter detector is a big endeavor and neutrons are used because they easily pass through the detector thanks to their neutral electrical charge, mimicking the non-interacting dark matter particles. The experiment was conducted in 2013, and the results have been published in the peer review journal Nuclear Instruments and Methods in Physics Research B¹.

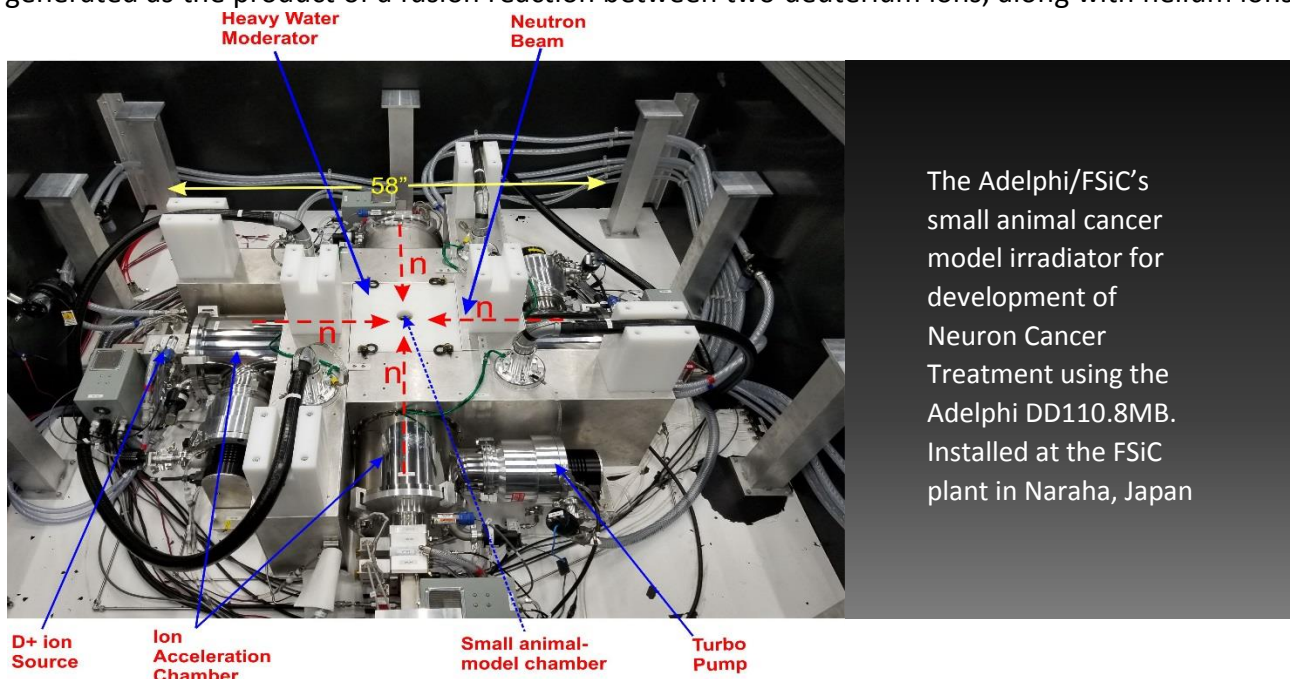
Another application, for which Adelphi neutron generators were purchased by medical facilities, is the production of the isotope Molybdenum-99 (Mo-99). This is done by shining neutrons on an enriched target of Mo-98. Mo-99 is the most in demand medical isotope because its decay product, Technetium 99m, is used as radioactive tracer in 85% of all nuclear medicine diagnostic examinations. Typically Mo-99 is shipped from a nuclear reactor where it is created as a fission product. Because the majority of Mo-99 generating nuclear reactors in the US have reached or are nearing the end of their service life, Mo-99 is often imported from Canada, which generates various supply-chain problems. Adelphi technology provides a solution to this problem in the form of a local source that most medical facilities in the country can afford.

Adelphi's neutron generators are used also in the mining industry, where they can be placed under conveyor belts carrying ores of coals cement or other mined minerals to perform neutron activation analysis, which can determine the concentration of sulfur, moisture, and other elements of interest.

According to Dr. Melvin Piestrup, Adelphi's VP of Research and Marketing, and Dr. Charles Gary, Adelphi's CEO, Adelphi's compact generators simply "would not exist without SBIR funds". Adelphi was initially founded by Dr. Piestrup when he was a Research Associate at Stanford University working on a replacement for synchrotron X-ray sources. Later on, Dr. Gary joined the company first as a Stanford graduate student, and then later, became its CEO. "The research we were doing back then in close collaboration with Stanford and Lawrence Berkeley National Laboratory was also funded by SBIR, and is still very relevant today", explains Dr. Piestrup. "In fact," Dr. Gary continues, "it is presently conducted at Fermi Lab and other national facilities using ideas and models very similar to those developed here at Adelphi. However, we soon realized that our project was too big for a small business, requiring considerable investment and lacking commercialization potential."

Funding for developing a compact neutron generator came mainly from DOE SBIR awards starting around 2002. The SBIR funds were awarded to develop components for DOE beam lines, such as X-rays and neutron lenses in various government accelerator facilities. Dr. Gary recalls that the core technology for Adelphi's neutron generators was mainly developed in response to one particular DOE SBIR Phase II award in 2005 from the Office of Nuclear Energy (NE). Subsequent SBIR grants were awarded to Adelphi for developing components of beamline facilities and technology needed to calibrate beamline detectors. The latter project was devoid of any commercial promise because there is no private market for calibrators of beamline detectors. "Nonetheless," Dr. Gary explains, "the work we did on that project expanded our ability to make better generators, and ultimately contributed to our final prototype."

Shrinking the size of all components in order to produce even smaller generators has been an ongoing push for Adelphi. Recently, Adelphi has leveraged a contract with the Defense Advanced Research Projects Agency (DARPA) to make significant advances in reducing generator dimensions. The main achievement was reducing the dimensions of the ion source, which produces ions of deuterium, an isotope of hydrogen with one proton and one neutron in the nucleus. The deuterium ions are accelerated into a metal hydride target also containing deuterium. Neutrons are then generated as the product of a fusion reaction between two deuterium ions, along with helium ions.



The ion source uses a magnetron like those used in commercial microwave ovens, which is essentially a vacuum tube energized by a high voltage power supply. As Dr. Gary explains, “Adelphi’s innovation consisted in replacing the magnetron tube with solid state components, which are much smaller and require much lower voltages. This is analogous to replacing old vacuum tube transistors with Si chips in modern computers, and precisely what industry is now proposing to do in commercial microwave ovens. This new development was possible thanks to chips that became available commercially only in March 2016. This latest innovation, together with the entire technology developed through five Phase II DOE SBIR and STTR awards, with the last one ending in 2015, have culminated in the production of the latest generator, the DD110MB Multi Beam Neutron Generator, which is the most powerful neutron generator produced by Adelphi Technology, yielding a thermal flux of 5×10^7 neutrons/cm²/s, comparable to those obtained in nuclear reactors².

Two versions of this generator have been built: One has been installed at DOE’s Savannah River National Laboratory (SRNL) and another at the Fukushima SiC Applied Engineering Corporation (FSiC) plant in Naraha, Japan. The SRNL generator is designed to irradiate samples for nuclear identification, while the model DD110.8M is for the irradiation of small animal models (mice) to test boron carrying drugs for Neutron Capture Therapy (NCT).

Previously, DD fusion generators had not been used for any pre-clinical small animal studies. To accelerate the research and demonstrate the efficacy of using DD fusion generators, FSiC has contracted Adelphi to fabricate a multi-beam neutron source that will have a large enough neutron flux to deliver an adequate neutron dose to small animal cancer models. Early experiments will include the implantation of the tumor cells in the mice, monitoring intracranial tumor growth using bioluminescence imaging, delivery of BNCT drugs systemically or locally, and monitoring of tumor growth and the response to the BNCT in the mice.

Adelphi’s current objective is getting ready for production and sales of generators in larger markets, in order to be able to accept larger contracts like the one mentioned above. Getting to this step has required many years of hard work by Adelphi. Any product needs to be de-risked and validated before production can be scaled up. This means that, in absence of external funding, many years have to be spent in order to prove the product in smaller markets and to build a record of performance.

For the purpose of scaling up production, Adelphi recently hired 10 full time employees including 2 technicians and a machinist, bought additional mechanical equipment and added a stock room to keep needed commercial electronic parts.

Written By Claudia Cantoni, Commercialization Program Manager, DOE SBIR/STTR, February 2018.

¹ D.S. Akerib *et al.*, “Improved Limits on Scattering of Weakly Interacting Massive Particles from Reanalysis of 2013 LUX data” <http://slac.stanford.edu/pubs/slacpubs/16500/slac-pub-16559.pdf>.

² Jaakko H. Vainionpaa, Allan X. Chen, Melvin A. Piestrup, Charles K. Gary, Glenn Jones, and Richard H. Pantell, “Development of high flux thermal neutron generator for neutron activation analysis” *Nuclear Instruments and Methods in Physics Research B* 350 (2015) 88–93.