Photo: Paul Rivenberg

From cyclotrons to cancer treatment

The path from basic research to practical applications is circuitous, and researchers can never predict what their work might be used for.

This year marked the 75th anniversary of an important milestone—the 1932 publication reporting how E.O. Lawrence and M. Stanley Livingston used a circular machine, the cyclotron, to accelerate protons to an energy of 1,220,000 electron volts with only 4000 volts of input.

Their device was perhaps the first of the cyclotron models developed at Berkeley that could be put to practical use in research. Based on the magnetic resonant acceleration principle, identified by Lawrence in 1930, it was used for nuclear science studies; at the time it was a model of acceleration efficiency.

The device worked despite the fact that much of the theoretical basis for its stability was not understood at the time. Those details would follow over the course of the following decade or so, leading to many other possible forms of resonant acceleration. And the rest, as they say, is history.

Well, not exactly.

A 50-year-old relic from the early days of the cyclotron is now being resurrected as the basis for a life-saving cancer therapy. This nearly missing link is called the "synchrocyclotron." Built in the 1950s and 1960s, it was eventually supplanted by other technologies more suitable for high energy and nuclear physics.

But the synchrocyclotron has a distinct advantage: In a space the size of a doctor's treatment room, it could accelerate protons to the energies needed for cancer treatment. If it works, this will bring Proton Beam Radio-Therapy (PBRT), a well-tested and highly effective technology offered at just five locations in the United States, to medical offices across the country, and at much lower cost. Based on the prevalence of cancers that can be treated with proton beams, there could be a demand for roughly 150 facilities in the United States alone—one for every two million people.

As I scour yet another circa-1950s accelerator progress report for some read-between-the-lines detail that can be used to help validate a 2007 calculation, I smile yet again at the set of loosely related activities at accelerator laboratories and medical facilities that have led me to this task.

Let's start with the large set of efforts demonstrating the clinical value of PBRT at the Harvard Cyclotron, Loma Linda University Medical Center in California, Indiana University, and the Northeast Proton Therapy Center in Boston. Then add the development of the superconducting isochronous cyclotrons of Henry Blosser and colleagues at Michigan State University in the 1980s, which demonstrated the costs and benefits of scaling cyclotrons to higher fields using superconducting niobium-tin magnets.

Then we skip off to Lawrence Berkeley National Laboratory, where a set of experiments by the Magnet Division, beginning in the 1990s, reached magnetic fields of more than 15 Tesla with brittle niobium-tin superconductors. Those superconductors, in turn, were developed in a companion program managed by the national labs and sponsored by the Department of Energy's High Energy Physics program. At the same time, the development of a novel plasma fusion device, the Columbia/MIT Levitated Dipole Experiment, sponsored by the Department of Energy's Fusion Energy Science Program, required a high-performance niobium-tin conductor-based coil set. This resulted in a new design for a niobium-tin superconducting cable with important and scalable properties.

Finally, strong collaborative work in the multi-lab US Large Hadron Collider (LHC) Accelerator Research Program has shown how to engineer such conductors for stringent magnet requirements. Although these magnet studies are aimed at an eventual upgrade of the LHC at CERN, the European particle physics lab near Geneva, Switzerland, they are exactly what we need for our new application.

So where is this heading? Toward a commercial PBRT system, based on a compact niobium-tin superconducting synchrocyclotron that fits in a treatment room. That's why I was looking up old experimental data from the 1950s; these studies will serve as benchmarks for results we are getting from new beam simulations.

Lots of hard work remains and there are many challenges, but this 21st-century-style innovation, the result of so many developments in accelerator science and engineering, might first operate in 2008. That would be close to the 50th anniversary of Lawrence's death. Would Lawrence ever have imagined that his research could lead to such a big step in the technology for cancer treatment—a compact device 10 times higher in field and more than 100 times lighter than its predecessor? What would he make of all this?

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