Building a Cyclotron on a Shoestring

Starting when he was an undergrad, Tim Koeth built a 12-inch cyclotron. Now he is in grad school and his creation is used in a senior-level lab class.

"I was immediately obsessed," says Timothy Koeth, who, as a sophomore in physics in 1995 at Rutgers University, got the bug to build a cyclotron. "I was sitting in Tom Devlin's modern physics lecture," recalls Koeth. "He described the principle of the cyclotron. He said it required a lot of RF power. I was—and am—a ham radio operator, so RF was no problem. It needed a big magnet; I knew I could find one of those. How tough could a vacuum system and chamber be?" Some six years later, Koeth's 12-inch machine became part of an undergraduate lab course.

Building the cyclotron required a combination of hands-on and theoretical skills, says Mark Croft, Koeth's undergraduate adviser. "High-voltage engineering, vacuum systems, machining skills, computer programming—the whole gamut. To have one person who could do all that, and dedicate so much time, is unheard of." Adds particle physicist Mohan Kalelkar, head of Rutgers' undergraduate physics program, "Tim has such creative ideas and puts them into play. Even though I myself am an experimentalist, I don't know the inner workings of a cyclotron. To actually construct one—Tim is a very remarkable individual."

Teaching tool

Koeth is now in Rutgers' PhD program doing research in accelerator physics at Fermilab. When he started graduate school, he had to find a new home for the cyclotron—which by then had migrated from his parents' garage to a warehouse on campus. "I sold the idea of using the cyclotron in the senior lab," says Koeth. "It may be the only fully functioning 1-MeV cyclotron dedicated to teaching in the US, or the world."

The first students to work on the cyclotron in the lab setting modified the magnet to better focus the proton beam. Others have worked on improving the ion source and, most recently, on a robotic measuring device to map the magnetic field in two dimensions. "We expect there is an azimuthal distortion," says Koeth. "We think we might have to further adjust the shape of the pole pieces."

The cyclotron is much more complex than "a typical experimental setup in the class—the photoelectric effect, lasers, and so on," says Michael Gershenson, who has taught the class. "Having it in the lab demonstrates to students that somebody can do this." So far, he adds, working on the cyclotron has counted either as multiple experiments or as independent study. Either way, Gershenson says, the students "have been in permanent contact with Tim."

But Koeth plans to phase out his own involvement. The aim, he says, is to have a standalone experiment "where students can turn on the machine and do canned experiments, such as measuring the charge-to-mass ratio of the proton or the mass of a neutron." To that end, Koeth and his friend Stuart Hanebuth, who has worked on the cyclotron from the start, are writing a user's manual. At Hanebuth's initiative, they are also exploring rigging the cyclotron to be remotely operable by high-school classes.

Free labor, cheap parts

The cyclotron was Koeth's brainchild, says Hanebuth. "I was his free labor. I fabricated the table, tested software, tightened screws. I must have crimped a thousand terminations. At one point, I had a full working duplicate of the control rack in my bedroom."

The two friends met when Koeth responded to Hanebuth's online ad for used Geiger counters. They discovered not only that they shared a love for surplus goods, but that Koeth was the guy Hanebuth had been wanting to meet for about six years: As a high-school student in Minnesota, Hanebuth had read in *Science World*, a publication for teens, about an eighth grader who discovered a radioactive source in a New Jersey school.

"That was me!" says Koeth. "I had


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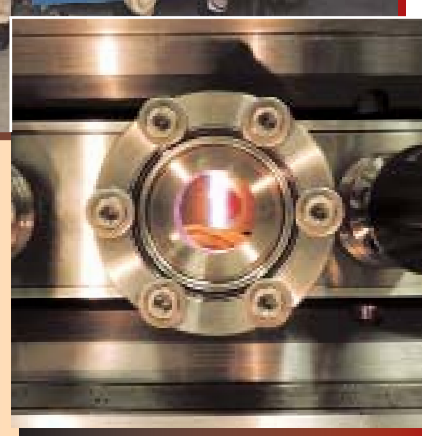
TIMOTHY KOETH

The cyclotron built by Timothy Koeth (above, left) and Stuart Hanebuth is now part of an undergraduate lab course. The dark brown cylinders are the coils that excite the 12-inch magnet (beige central cylinder). The ion beam, visible through the small central window (inset), can consist of pure protons from hydrogen gas (blue tank) or protons and neutrons from deuterium (green tank).

borrowed a Geiger counter and was measuring everything." He found a hot spot in his former school. It turned out to be radium on a nasopharyngeal applicator—a device for treating nasal tumors. It was never explained why the device was in the school, but within about a half hour, Koeth had convinced a teacher to let him take the source home, gotten his parents scared that their house had become contaminated, and been exposed to 275 millirem—or nearly a year's worth—of radioactivity. "It was a pivotal moment," says Koeth. "I was a born scientist."

Like Koeth and Hanebuth's meeting, every aspect of the cyclotron has a story behind it. "Nothing was just purchased, right down to the red light on top of the machine, which we bought from US military surplus before we knew what we would use it for," says Hanebuth. Take the 200-amp, 40-V power supply. Says Koeth, "I called around, and found one for $1000. So we made a list of all the surplus we had and asked if we could trade." In exchange for some frequency counters and plug-in modules for oscilloscopes, they got the power supply. On the way home, adds Koeth, "my girlfriend started screaming that [the power supply] was falling through the car." It turned out that the 400-pound box was safe, but it crushed the jump seats in his mom's car.

The first magnet Koeth and Hanebuth scrounged up was only 9 inches in diameter. They got their first proton beam in September 1999. Says Koeth, "It was during Hurricane Floyd—I got off work early. The needle pegged, showing I had a beam." They worked on the 9- and 12-inch versions in parallel. With the 9-inch magnet, says Koeth, "I could only get 600 keV [protons]. You can demonstrate the principles at lower energies, but you need 1 MeV to do real experiments." Besides, he adds, he wanted to emulate Ernest Lawrence, who was the first to get 1 MeV and who received the Nobel Prize in Physics.

Later, Koeth found a 12-inch magnet at Argonne National Laboratory. It weighed two-and-a-half tons and had been the steering magnet for a 60-inch cyclotron that was scheduled for demolition. "Stu flew out and we rented a truck and drove it back to New Jersey," recalls Koeth. "The magnet came to us ugly," Hanebuth adds. "We stripped it and repainted it. It was a full-time job for us for quite a while." They swapped magnets and had the more powerful cyclotron working by early 2001.

The pair spent perhaps $15 000 on their creation. Koeth estimates that, had they bought new parts and "paid real money to the machine shop," it would have cost about $250 000.

Plans and projects

Relentless scroungers, Koeth and Hanebuth have already started collecting parts for their next project: a Farnsworth Fusor. Says Koeth, "It's a curiosity. It has no magnetic field, no superconducting coils. The idea is to use electrostatic confinement to produce fusion on a tabletop." The fusor was first proposed decades ago by Philo T. Farnsworth, a pioneer in developing television. But, says Koeth, "there are problems in making one. We think we have some technological innovations."

They began working on the cyclotron as undergraduates—Koeth in physics and Hanebuth in environmental science—and continued after Hanebuth went to work for the Con Edison electric company in New York City and Koeth became a health physicist and then an accelerator engineer for Rutgers. Koeth took graduate classes part time, but after returning to Rutgers from a stint at Fermilab and being hired on a project that required trips to CERN in Switzerland, Koeth says, "I realized that my course schedule was not conducive to traveling. I had an epiphany that I wanted to go back to graduate school full time." He started back in 2002. When he finishes, he says, he'd "like to pursue a career in accelerator physics, perhaps at a national lab like Los Alamos. But I'd prefer it not be weapons related." **Toni Feder**

LANL Resumes Work, Morale Stays Low

In response to a safety violation and a supposed security breach this summer, Los Alamos National Laboratory has fired four people and punished eight others. In a 15 September memo to lab staff, LANL Director G. Peter Nanos wrote, "It is now time to begin conscientiously moving forward in a safe, secure and compliant manner. The period of the last several months marks a new beginning for this institution." But many lab scientists, bitter about Nanos's handling of the safety and security lapses, are skeptical about how new the beginning really is. "Nanos sowed the seeds of discontent, and there is now a lush garden," says Rhonald Keinigs, a longtime LANL weapons scientist.

Nanos halted work across the lab in July, after two electronic storage devices containing classified data reportedly went missing and a student's eye was damaged by a laser (see PHYSICS TODAY, September 2004, page 32). Later in the summer, reports surfaced that the storage devices had never existed; the real error, it seemed, was one of inventory, not of mishandling sensitive information. By press time, LANL had completed its own investigation, but lab officials would neither confirm nor deny the existence of the storage devices. External investigations were still under way; David Cremers, a laser physicist, was preparing to appeal his firing in connection with the eye injury and an alleged cover-up; and lab staff were passing the hat for legal funds for other scientists.

As of early October, administrative tasks, much theoretical work, and some experiments at the lab had resumed. A lab spokesman said most activities would be back to normal by mid-October, and everything should be running by year's end. The work stoppage cost taxpayers $4–5 million a day; or, as the spokesman put

LANL

G. Peter Nanos, the director of Los Alamos National Laboratory, addresses employees at a lab-wide meeting.