update

A Chip-Scale Particle Accelerator

Zipping ions down a MEMS racetrack could lead to portable particle beams

TIGHT TURNS: A MEMS particle accelerator drives argon ions.
IMAGE: YUE SHI

FORGET FOR a moment about the quest to build bigger high-energy particle accelerators. At the IEEE MEMS 2011 conference in January, researchers instead explained their efforts to create a smaller one.

Their chip-size cyclotron can guide argon ions with around 1.5 kiloelectronvolts of energy down a 5-millimeter accelerating track before whipping them around a 90-degree turn. The system boosts the ions' energy by 30 electronvolts. That's certainly not a world record; the Large Hadron Collider, the biggest and most powerful particle pusher in the world, would have it beat by some seven to 10 orders of magnitude. But unlike its larger cousins, this accelerator has no need for bulky magnets.

Instead it uses electric fields set up along electrode guide rails to accelerate and steer its particle beam. The device's designers at Cornell University, in Ithaca, N.Y., say that with more research, similar electrostatic mini-accelerators might be used in shoebox-size scanning electron microscopes or portable particle-ray guns for cancer treatment.

Funded by the U.S. Defense Advanced Research Projects Agency, Yue Shi, an electrical and computer engineering graduate student developed the accelerator-on-a-chip. She is working to create both a device that might accelerate ions to energies of hundreds of kiloelectronvolts on a chip not much bigger than a few square centimeters and a device capable of accelerating ions to hundreds of megaelectronvolts in a box the size of a suitcase.

Shi constructed three versions of the accelerator—two on silicon-on-insulator chips and one on a printed circuit board. Each had a straight, segmented acceleration track and either a 1-, 2-, or 4-mm turning radius. To test the design, she fired a stream of argon ions with around 1.5 keV of energy from a commercial ion source into each chip's tracks. Electric fields between four segments in each chip's acceleration track gave the ions a strong kick before they raced into the turn. Then another electric potential between two electrode curbs pulled ions around the bend.

If a small accelerator based on this design could bestow 1 MeV of energy to ion beams, it would have a broad range of applications, says Amit Lal, who worked with Shi and leads Cornell's SonicMEMS Laboratory.

Doctors already use particle beams to combat cancer. Such therapy requires devices that take up an entire room, but tiny accelerators might make treatments more feasible for smaller clinics or allow more localized beams to irradiate fewer healthy cells, says Lal. "Think of a scalpel with a proton beam coming out of it," he says.

Developing this proof-of-concept device into a commercial tool will take some work. Shi points out that the fastest ions that coursed through the accelerator during this initial research only had around 2 keV of energy, and that's three orders of magnitude lower than what she seeks. Having now shown that the ions can execute tight turns, Shi believes that future designs could navigate the ions repeatedly through accelerating strips to reach at least 1 MeV.

The Cornell device is not the only mini-accelerator in development, or even the smallest. Instead of electrostatics, Gil Travish, who is developing a micro-accelerator platform at the University of California, Los Angeles, wants to use the electric fields in laser light to speed particles on their way. Travish's group is starting to build a device that he describes as a 1-µm-thick "sandwich" with two mirrors above and below a gap that's only one wavelength of light high and several hundred wavelengths wide. As the light from a laser oscillates in that gap, an electron passing through the peak electric field will receive a tremendous boost—around a gigaelectronvolt per meter or a megaelectronvolt per millimeter. His team hopes to start beam tests in a prototype device in the next six months.

The UCLA team imagines that their particle beam might also one day appear in medical devices or in unmanned aerial vehicles that could examine suspicious buildings using X-rays. "I think that in the next half decade you'll start to see a real awakening," Travish says about the possibilities in particle accelerators' new realm. —JOSEPH CALAMIA

A version of this article appeared on http://spectrum.ieee.org in January.