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UCLA Team Seeking New Keys to Atoms' Inner Secrets

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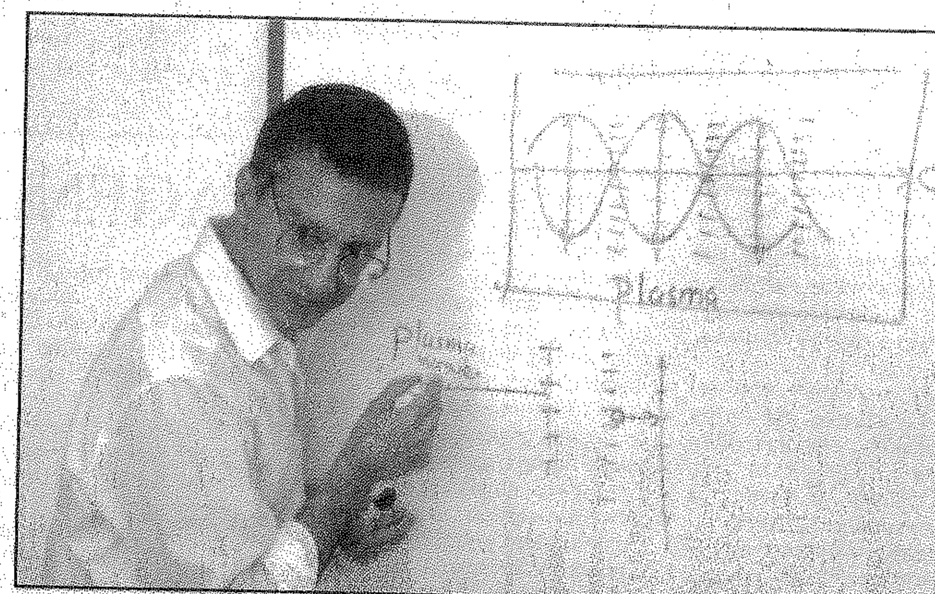

MICHAEL EDWARDS / Los Angeles Times

UCLA professor Chan Joshi shows functions of new type of particle accelerator.

Chan Joshi swiftly navigated the labyrinth of Boelter Hall, heading toward his laboratory on the first floor of the UCLA engineering building. The cluttered, windowless room was dominated by a carbon-dioxide laser and odd paraphernalia such as skillet-like copper mirrors and portholes sliced from pure salt crystals.

Off in one corner was a stainless steel chamber the size of a vacuum cleaner. Joshi and his graduate-student assistants posed behind it. This is where they taught electrons to surf.

In Texas, workers only recently began constructing the Superconducting Super Collider, and years will pass before the 54-mile-long, $10-billion device can be switched on to try to answer some fundamental questions about atoms and the universe.

But Joshi and a handful of other scientists already are looking beyond the SSC and asking: What next?

Like superior chess players, these scientists are scrambling to stay several steps ahead of themselves. Their goal is to anticipate the methods and machines that will be needed to solve subatomic riddles no one has yet uncovered—riddles with solutions beyond the reach even of the mighty super collider, the

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biggest and costliest scientific device in history.

In his cramped laboratory, Joshi has demonstrated the feasibility of one of these machines, a new kind of particle accelerator. Unlike the super collider, which uses electrical fields to crack open relatively heavy protons, Joshi's device uses plasma waves to slam together lighter electrons.

His "beat-wave accelerator," based on a theory by fellow UCLA professor John Dawson, uses exquisitely timed laser pulses lasting a few trillionths of a second to push electrons almost to the speed of light in a fraction of the space required by today's best particle accelerators.

With this technology, better particle accelerators would not necessarily have to be bigger. That is welcome news to policymakers still trying to sell a skeptical Congress on the value of completing a super collider the size of an entire county.

The laser pulses in Joshi's device create an electrically agitated gas, or plasma, rippling with very orderly waves. Electrons added at precisely the right instant tend to "surf" on these waves, picking up speed the way people do when they ride ocean waves.

It is a delicate and complicated process that relies on notoriously unstable plasmas, Joshi conceded. But the experimental machine in his laboratory, while complex enough to be worthy of Rube Goldberg, shows that the idea works—indeed, he said, "it worked just as advertised."

And, Joshi added, the beat-wave accelerator has the ability to speed up electrons more quickly than any other device, so a production model eventually may match the power of some of today's more powerful accelerators in a fraction of the space.

Whether this technology ever leaves the lab depends on whether Joshi and other researchers—beat-wave accelerators also are being developed in Japan, France and Britain—can increase both the size and power of their machines at a reasonable cost.

But even if they prove unable to do the kind of cutting-edge research expected of the super collider, beat-wave machines still can be useful, Joshi and Dawson said. The relatively compact devices would be easier to fit on college campuses, making them more accessible.

Instead of one giant machine accommodating a few collaborative experiments—a process that forces many scientists to compromise their work—dozens of machines could let individual researchers pursue their own theories. Accelerator time could be as accessible as computer time became when personal computers supplanted bulky mainframes.

In addition to benefiting researchers, powerful accelerators could be accessible to more hospitals, where cell-killing particle beams from a number of conventional machines already are used to combat cancer. Beat-wave machines also can be used to generate tiny bursts of light or X-rays that would permit better medical images using only a fraction of the radiation.

These electromagnetic "microbursts" also could allow scientists to make slow-motion movies of chemical reactions, which have never been seen before.

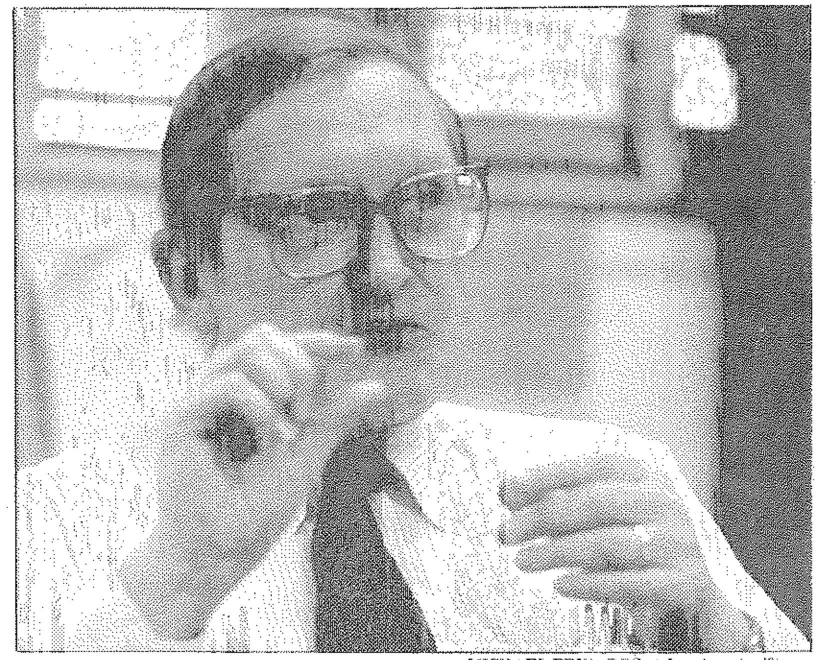
None of this occurred to Dawson when he dreamed up the idea of beat-wave particle accelerators while working at Princeton University in the 1970s. At the time, he was trying to use the coherent amplified light in laser beams to trigger temporary nuclear fusion reactions, but was frustrated when the laser created turbulence in the reactor's plasma fuel.

Once he worked out how the turbulence could be harnessed to accelerate electrons, potential applications were easy to think up, he said.

Accelerator physicist Andrew Sessler of Lawrence Berkeley Laboratory said the demonstration by Joshi was a "significant step forward" in efforts to develop a new generation of accelerators.

When the super collider eventually uses its unprecedented energy to crack protons, the debris should tell physicists a lot about atoms: what holds them together, what causes some to decay radioactively, and how those processes are related.

But the field of particle physics will not come to an end when the super collider completes its work, even if its powers help scientists map out the grand-unification theory—the so-called "theory of everything" that would prove a common basis for all the basic forces in nature. Achieving this, which stumped Einstein, is the most hotly pursued goal in physics.



MICHAEL EDWARDS / Los Angeles Times

UCLA's John Dawson explains his early research that led to development of a device that uses laser pulses to accelerate electrons.

Scientists have learned that discoveries made by the SSC are likely to raise a new set of questions.

When the Greeks, for example, first tried 2,400 years ago to divine the most basic building blocks of nature, they suggested that matter was made up of indivisible parts called atoms.

Savvier scientists later asked what atoms were made of, and then asked the same question about the protons, neutrons and electrons they found inside. This led to the discovery of exotic new particles called leptons and quarks, as well as bosons, gluons and other particles binding them together.

At each step, the discovery of new "elemental particles" led to a fuller understanding of nature and significant advances in electronics, chemistry and the development of new plastics, metals and other materials.

Some of the particles described in the "standard model" of atomic structure exist only on paper because no one has a machine powerful enough to thoroughly smash protons and find them. No one, for example, has confirmed the existence of the "top quark" (an arbitrary name chosen by whimsical physicists) or the "Higgs boson" (named after a British physicist).

The super collider is designed to discover these missing pieces. But researchers suspect it cannot answer all their questions about how these particles interact, and it may turn up unexpected phenomena, such as new types of subatomic particles.

To answer such a new set of questions, the next generation of physicists would need a new, more powerful generation of accelerators.

A bigger version of the super collider is not an option, scientists agree. The nation could not afford it, they said, and engineers might not even be able to build it.

Moreover, speeding up protons—as the super collider does—requires far more room and energy than accelerating lighter electrons, so scientists around the world have been concentrating on designing electron accelerators. But to reach speeds they desire, a machine using conventional technology would have to be prohibitively big—from 4 to 18.6 miles long—and costly—about $4 billion.

In principle, beat-wave technology may be an alternative. Dawson estimated that a beat-wave accelerator could push particles to desired speeds in a little more than three miles—one-sixth the distance needed by some of the more conventional colliders.

Joshi conceded that no one can estimate the cost of a beat-wave machine that size, and it's not known if anyone could create a pencil-thin plasma beam three miles long. He said much work also is needed to boost the "luminosity," or density, of the electron beam created by plasma accelerators.

For the record, Joshi stresses that he is content counting and clocking the electrons streaming out of his device, and trying to stay a step ahead of friendly competitors at the University of Osaka in Japan, Ecole Polytechnique in France and Rutherford Laboratory in Britain.

Privately, however, he and Dawson wonder about the ground-breaking medical diagnostic devices, mind-boggling microscopic movies and world-beating particle accelerators that may wait just a few experiments down the road.

"We aren't pretending to be in competition with [traditional] accelerators—yet," Dawson said. "They're building on a design developed in the 1930s, so they have a lot of history and experience when it comes to making them bigger and better.

"But if we can continue overcoming technical problems the way Chan has so far, it opens up some real possibilities—oodles of ideas that we are only just now beginning to imagine."