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Bill Andrews
(310) 206-0540

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# HIGH-ENERGY ELECTRONS MADE TO "SURF" PLASMA WAVE IN UCLA DEMONSTRATION OF FIRST SUCCESSFUL LASER ACCELERATOR

In the first-ever demonstration of such a device, UCLA researchers have successfully tested a plasma "beat wave" accelerator that boosts the energy of charged particles to more than 9 million electron volts.

Using a miniature prototype system, a team from the Electrical Engineering department led by Professor Chan Joshi has shown the possibility of producing, in the next 30 years, a machine that will not only accelerate electrons to incredible energy levels required by high-energy physicists, but do so in the space of just a few hundred feet. The research, titled "Ultrahigh-Gradient Acceleration of Injected Electrons by Laser-Excited Relativistic Electron Plasma Waves," was published in Vol. 70, No.1 of Physical Review Letters, the journal of the American Physical Society.

According to Joshi, the breakthrough demonstration could result in smaller, cheaper accelerators that could not only cut high-energy physics down to size, but also open the way to compact x-ray sources for medical therapies, biological studies, materials analysis, and semiconductor processing.

"If the same acceleration rate that we have demonstrated across a distance of a centimeter could be maintained over a meter or so, a beat wave accelerator conceivably could reach a gigaelectron volts, which would open up many practical possibilities for the device," said Joshi.

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"Yet, at this point, all we're trying to do is see if it works at all. By 30 years from now, physics machines will be getting too costly, too big, and some kind of new revolutionary approach will be required. This is what we're aiming at," he said.

Smashing charged particles together at nearly the speed of light in high energy accelerators and studying the resulting subatomic shrapnel has allowed physicists to advance understanding of the structure of matter, the fundamental forces of nature and the origin of the universe. In order to test cosmological theories, physicists have used particle accelerators to try to re-create the conditions that prevailed just after the Big Bang. Unfortunately, as physicists get closer and closer to the secrets of creation their equipment gets larger and more powerful. As a result, many scientists around the world are actively engaged in researching new ways of accelerating electrons.

One of the first to look seriously into plasma accelerators was Professor John Dawson of the UCLA Physics department. Beginning in 1958, Dawson investigated ways to harness the energy released in the fusion of plasmas, and then toyed with plamsa's wave-propagating ability to develop a new type of accelerator. In 1979, Dawson, primarily a theoretician, inspired Joshi and others into developing a working prototype plasma accelerator.

The UCLA "beat wave" accelerator is based on principles that begin with the fact that a laser beam fired into a cloud of hydrogen will superheat the gas, stripping the electrons from their nuclei, and create a plasma.

The process begins with two laser beams of different frequencies bounced through an array of amplifiers to boost their power to a trillion watts. The laser beams, now powerful, are then focused by mirrors down to the size of about 1/50th of an inch and fired through two centimeters of hydrogen gas enclosed in a sealed chamber. Plowing through the gas, the laser pulses rip the electrons right off their

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atoms, creating the plasma -- gaseous nuclei with no orbiting electrons.

Through this process, a pulsing wave is created by the overlapping laser frequencies, which alternately magnify and cancel each other. These alternating peaks of high and low intensity are like the peaks and valleys of a wave. As the thousands of peaks and valleys in a single laser pulse pass through any given region in the plasma, more and more electrons from that region are recruited into this "beat wave" movement -- the effect is that of a steadily increasing wave of charge, moving through the plasma along with the laser. Finally, once the wave effect is created, a fresh cluster of electrons is shot into the plasma behind the laser beam to "surf" the wave, following the laser at near light speed, picking up energy.

"At the moment, although we have demonstrated a prototype machine, even a relatively modest plasma accelerator is still physics fantasy," Joshi conceded. "What we learn during development of such an accelerator, could be used to develop low-energy and medium-energy systems. These could be used by universities and other private groups who don't have access to expensive accelerators," he said. Joshi's next step is to build a one hundred million volt laser-plasma accelerator, scaling-up the current machine.

In addition to the goal of devising new means of accelerating particles, the ongoing research holds promise for other areas of investigation. It may contribute to an understanding of particle-acceleration processes in nature. Pulsars, for example, are thought to generate intense waves in plasmas that accelerate particles to extremely high energies in a relatively short distance. Plasma-wave technologies will also provide new opportunities to study the interaction of electromagnetic fields with plasma.

Additional members of Joshi's team at UCLA include physicist Chris Clayton, chief

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experimentalist, and Ken Marsh, both of the Electrical Engineering department.

Joshi has been a member of the UCLA faculty since 1988. He received a bachelor's in Nuclear Engineering from London University in 1974, and a Ph.D. in Applied Physics from Hull University, England, in 1978.

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