Accelerating ions collectively

Accelerated subatomic particles, such as electrons, protons and various ions, are fundamental research tools in physics and, for some applications, in chemistry and biology. Lately they have also become therapeutic agents in medicine (SN: 6/29/85, p. 408). The accelerators that energize these particles are both expensive and space consuming. For a long time physicists and engineers have worked to find new methods of acceleration that would save money and space.

At the Sandia National Laboratories in Albuquerque, N.M., two experimental versions of what is called a collective ion accelerator have now accelerated ions successfully in a manner that promises to be cheaper and on a smaller scale than methods now in use. For more than two decades researchers have looked for a way of accelerating a bunch of electrons so that they would carry some trapped ions along for the ride. This is what the term "collective" means, and it is what the Sandia researchers, under the direction of Craig L. Olson, have done.

A conventional linear accelerator operates by establishing a voltage difference between two electrodes. Particles to be accelerated fly from one electrode to the other, and in doing so gain an amount of energy determined by the voltage difference (a certain number of electron-volts of energy for the same number of volts in the voltage difference). The minimum size of such an accelerator is governed by the highest voltage that can be put across two electrodes a given distance apart (say, 1 meter) without breaking down the system electrically.

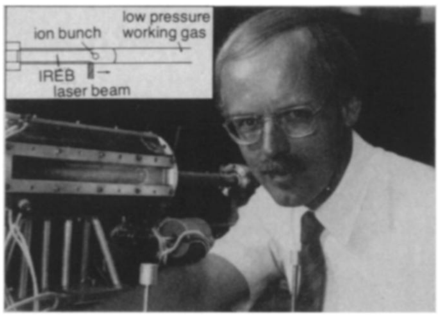
The Sandia concept, called the Ionization Front Accelerator (IFA), does not suffer this disadvantage. A conventional accelerator needs a length of ½ mile to reach 1 billion electron-volts. "We would hope," says Olson, "to do it in 1 meter to 10 meters." The IFA starts by injecting an intense relativistic electron beam into a tube. The electrons have 1 million volts of energy and a current of 30 kiloamperes. This current is very nearly at what physicists call the space-charge limit. That is, the electrons are so dense that the repulsive forces among them due to their negative charge will stop and even reflect the motion of the beam. The electron beam would like to go down the tube, but the space-charge limit stops it, and it just sits in the end of the tube, blowing up laterally and going to the walls of the tube.

The end of the electron beam inside the tube has the conditions desirable for a collective accelerator: At the center of this end or front of the beam is a potential well, a spot to which positively charged ions of, say, hydrogen or helium will be attracted and trapped. At this point there is also a very strong electric field in the forward direction, which will carry the trapped ions along if the electron-beam front can be made to move.

To move the electron-beam front, the space charge has to be neutralized. The Sandia physicists do this by having in the tube a heavy working gas — in the actual case, cesium — which can be ionized. The electrons from the ionized cesium go to the wall; the ions remain, and, being much heavier than the hydrogen or helium to be accelerated, they do not interfere with the trapping of the lighter ions. The cesium ions neutralize the space charge of the electron beam, and the beam front will then move down the tube as far as the cesium is ionized.

To accelerate the electron-beam front, the physicists provide an accelerated, moving ionization front in the cesium. A sharply defined laser beam comes in from the side and photoionizes the cesium. The beam swings from one end of the tube to the other, and the front of the electron beam moves down the tube with it. To accelerate the electron-beam front and so accelerate the trapped ions, the laser beam must swing in an accelerated way.

Making the laser beam swing sidewise in an accelerated way is one of the key tricks to making the IFA work. Actually two lasers are used. One pre-energizes the cesium, lifting it almost to the ionized state. The other, the swinging laser beam, then has less work to do in the final ionization. To make the laser beam swing, the researchers put it through a series of electro-optic crystals. As the voltage across them changes, these crystals change their index of refraction, which measures how much the light beam bends as it goes through the crystal. As the bend increases, following a programmed voltage pulse, the far end of the beam swings. It goes down the acceleration tube, 30 centimeters in 20 nanoseconds. At the moment, the laser has to be 50 meters to the side of the acceleration tube, but there are ways to shorten that. One way is to use telescopes.



Sandia

Olson. Inset: How IFA works.

The present experiment achieves an acceleration of about 100 million electron-volts per meter. In the future, Olson says, they expect to scale that to 1 billion electron-volts per meter (1 GeV/m). Particles with 1 GeV energy move at 0.87 of the speed of light. In the farther future there is a possibility of a relativistic IFA, which would accelerate particles much closer to the speed of light. In this case the laser beam could come from the same direction as the electron beam, as it would be leading the electron beam at very nearly its own speed of forward propagation.

—D. E. Thomsen

Plan unveiled to save tropical forests

Each year more than 11 million hectares of tropical forests — an area larger than Austria — are lost to agriculture, firewood collection, rural development and logging. That loss, besides wiping out 500 to 1,000 plant and animal species per year, affects more than 1 billion people by reducing the long-term agricultural productivity of the land, contributing to deadly floods, to soil and water degradation, to fuel wood scarcity and ultimately to greater poverty, according to the United Nations Food and Agricultural Organization (UNFAO). And that explains the excitement engendered within the international-development community this week by a new five-year action plan to arrest and ultimately reverse this growing destruction of tropical forests.

An international task force convened by the World Bank, United Nations Development Programme (UNDP) and World Resources Institute authored the plan. A report of their recommendations lists specific projects addressing the most critical individual needs of the 56 nations most affected by tropical deforestation; it includes the estimated cost of achieving these goals in each country. A 55-page appendix of case studies highlights successful small-scale projects that might serve as examples for plan implementers.

According to the plan's authors, tropical reforestation and forest management must become essential components of any long-range plan to "alleviate [the region's] hunger and deprivation, arrest dangerous assaults on the planet's environmental support system and provide the basis for sustainable economic growth."

World Bank President A.W. Clausen says the action plan "carries the Bank's full support"—despite its $8 billion price tag. The U.S. Agency for International Development, UNFAO and UNDP have also pledged to support the new action plan. Already under discussion as one of the first steps to implement the plan is a 1986 "summit" meeting of world leaders to iron out specific funding and political priorities.

—J. Raloff