New Ways to Accelerate?

Even as physicists are completing one new generation of particle accelerators, they are drawing up plans for the next (*Science*, 20 May, p. 809)—yet with a disquieting sense that things cannot go on as they have. In the quest for higher and higher energies, their machines get bigger and bigger. The next generation of machines will be extrapolations of current accelerator technologies, such as the synchrotrons employed at Fermilab in this country and at CERN in Geneva, or the linear accelerator approach taken at the Stanford Linear Accelerator Center. But it is clear that these designs are beginning to strain the limits of practicality.

LEP, for example, the 100-billion-electron-volt (GeV) electron-positron collider scheduled for completion at CERN in 1987, will be some 27 kilometers in circumference and will cost $400 million. It will consume as much electricity as a city of 150,000. The ultrahigh-energy accelerator, a hypothetical 20-trillion-electron-volt (TeV) collider being contemplated for the 1990's, would have a main ring some 100 kilometers in circumference and would cost well in excess of $1 billion. In principle the physicists could continue in this same vein indefinitely, until their machines encircled the earth. In practice, they will have to find another way.

As it happens, there are other ways to accelerate particles, and in the last year or two these new approaches have begun to receive increased attention. "I doubt that any of them will be brought to the point of being a practical accelerator by the turn of the century," says Andrew M. Sessler, former director of the Lawrence Berkeley Laboratory. "But one can hope they will pay off in the next century."

In conventional accelerators, the particle beams are accelerated by electric fields and guided by magnetic fields, both of which are produced in external conductors. Thus, the field strengths are limited by the properties of materials. Too high an electric field, for example, and the accelerator will begin to short itself out by internal sparking.

One obvious alternative is to use the intense electric fields available in a laser beam. In fact, much of the current interest in alternative technologies stems from a conference on laser acceleration that Sessler helped organize at Los Alamos Scientific Laboratory in February 1982. "We recommended that the Department of Energy should spend about $5 million per year on these ideas," he says, "and the department is making an effort to do just that. But proposals are only just now getting written."

In a laser, the electric and magnetic fields lie perpendicular to the beam direction and oscillate hundreds of billions of times per second. The trick is to harness these fields into an effective accelerating potential. One possibility, explored by Robert Palmer of Brookhaven National Laboratory, is to shape the beam by passing it through a diffraction grating. He estimates that such a system could achieve acceleration gradients of 10 GeV per meter (versus 15 or 20 MeV per meter at SLAC).

Unfortunately, there are severe problems in practice: a laser beam of the required intensity would vaporize the grating; worse, the beam would have to travel within a few micrometers (a wavelength of light) of the grating surface.

Other approaches are possible, says Sessler—the inverse free-electron laser, for example, or the inverse Cherenkov effect accelerator—but probably the most exciting is the Plasma Beat-Wave accelerator first proposed in 1979 by Toshi Tajima of the University of Texas and John Dawson of the University of California at Los Angeles.

The idea is to illuminate a plasma with lasers of two slightly different wavelengths. The interference between the two beams—the "beats"—will tend to bunch the charges in the plasma. If the beats happen to come at the plasma's own natural oscillation frequency, the bunching will be very strong. In fact, numerical simulations suggest that the plasma separates completely, forming parallel sheets of charge running along the beam direction at virtually the speed of light. In between the sheets the electric field would be intense, and in principle charged particles could ride the waves like a surfer, picking up energy at the rate of some 10 GeV per meter. Although it is not clear how well this approach will work in practice, says Sessler, physicist Chan Joshi and his colleagues at the University of California at Los Angeles have done some very preliminary experiments that do demonstrate particle acceleration.

Actually, says Sessler, the plasma wave accelerator can be viewed as a hybrid between laser acceleration and a totally different class of approaches: collective effect acceleration, in which a carefully shaped plasma generates the accelerating field. A pure example of the latter is the Ionization Front Accelerator technique proposed by Craig Olsen of Sandia Laboratory: particles would be accelerated by the fields on the face of an intense, sharp-fronted, relativistic electron beam.

To date, emphasizes Sessler, none of these concepts have been much more than tabletop toys. "But it would have been wrong to have dismissed Lawrence's first cyclotron (5 inches in diameter) or—for that matter—most anything when it was first realized, such as Edison's light bulb or Bell's telephone. It is terribly important to do the R & D."

And that is a problem, he adds. Even though interest is picking up, the particle physics community as a whole still seems reluctant to make a committment. Cornell's Maury Tigner, a member of the DOE's advisory panel on new accelerators (the "Woods Hole" panel, *Science*, 20 May, p. 809), agrees on this point and it worries him.

"People are reluctant to devote their lives to something that might not pan out," says Tigner. "But more importantly, this kind of work can't be done by one individual working in the corner with one student. It requires advanced instrumentation and facilities. One obvious place for it is the big national labs, but for the past several years the big labs have had their plates full with work on the current machines.

"We should be ashamed of this," he says. "It's not a matter of money. It's a lack of commitment on the part of the people in the field to get in there and start slugging away. The development of new accelerator technologies should be a burning issue. It requires the best minds, and the most ambitious people."—**M. Mitchell Waldrop**