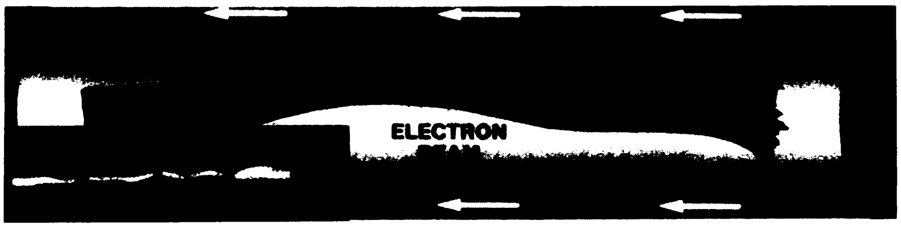
Star Wars: Lasers can guide electrons



Sandia

Magnetic forces set up by the electron beam's return current (flowing left in the channel walls) center the beam. Inset photo shows test beam controlled in this way.

The first conclusive demonstration that an intense electron particle beam can be laser-guided into a straight-line course through a gas has just been announced by researchers at Sandia National Laboratories in Albuquerque, N.M. The technique may prove useful in a number of areas, including controlling electrons in accelerators used for particle-physics studies and fusion research. It may also constitute an important step toward developing potent "Star Wars" weaponry for use against targets in earth's atmosphere. Under the Anti-Ballistic Missile Treaty (SN: 1/19/85, p. 39), the United States is prohibited from deploying such weapons, but is allowed to conduct research on beam weapons for strategic defense.

Particle beams have been called "the ultimate weapon." Not only do these beams of accelerated atomic particles have the potential to inflict more damage than lasers, but they also wreak their devastation virtually instantaneously.

Charged-particle beams are being developed for use in a gaseous environment, such as earth's atmosphere. Though like-charged particles, such as electrons, normally repel each other, the large electric currents in a beam moving through the atmosphere actually set up a strong magnetic field that pinches the electrons into a tightly focused stream. This keeps the beam from spreading. What it does not do is keep the beam from arcing and snaking unpredictably as it propagates through the gas. To do that, Sandia scientists have employed a low-power laser.

The laser's light is beamed for a few billionths of a second along the straight-line path the particle beam is to follow. Energy deposited by the laser's light strips electrons off gas atoms along the entire beam path. Because the laser has an annular beam (in cross section its light forms a ring), it creates a conducting plasma tunnel. When the electron beam is then pulsed down the core of this channel, a magnetic current is set up inside the tunnel's "walls." This magnetic field, caused by the return flow of the electron beam's current through the plasma, repels the electron beam from all sides, confining it along the path created by the laser.

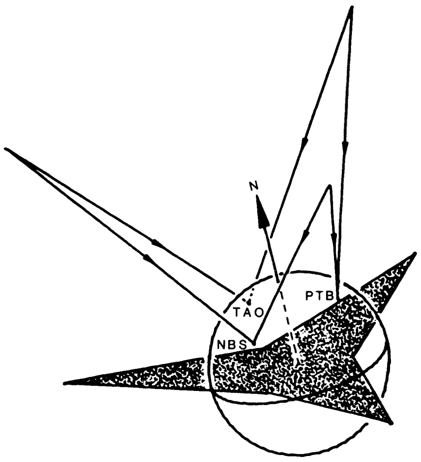
In Sandia's experiments, partially funded by the Department of Defense, a krypton-fluoride infrared laser provided between 1 and 100 millijoules of energy to ionize a small amount of the organic compound diethylaniline (DEA) that had been "seeded" into a low-pressure nitrogen atmosphere. Immediately afterward, a 1.5-million-volt electron beam was directed along the laser-ionized channel. Tests showed the electron beam was both stable and efficient — 80 percent of its injected current reached the target 5 feet away.

Even over kilometers-long distances, however, the researchers expect little additional current loss. Explains J. Pace VanDevender, director of the laboratory's laser and particle-beam research program, some of the electrons coming from the electron generator are not heading directly into the channel and will become lost to the system quickly. However, he says that of the remaining electrons, those successfully injected into the channel should just keep on going until they hit the target, regardless of the distance they're made to travel.

Moreover, VanDevender says, because the guidance lasers need only contain a millionth of the energy density in the particle beam, it's unlikely they would fall prey to the beam-spreading instabilities and energy losses that plague high-power laser beams directed through gases as dense as earth's atmosphere.

Other beam-guiding strategies are under study elsewhere, VanDevender notes. One electrostatic technique would use a solid-core laser beam to pave the way to a target by setting up an electric attraction between the coming particle beam and ions along its route. VanDevender believes that "for very low current [electron beams], probably the electrostatic mode is best; for higher current, the magnetic control would probably be best." However, he adds, "Right now it's not clear which would make the best weapons system." —*J. Raloff*

As the world turns, time flies



Allan/SCIENCE

This diagram shows the route of the three Global Positioning Satellites' signals to the earth timing stations: National Bureau of Standards (NBS) in Boulder; Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig; and Tokyo Astronomical Observatory (TAO).

One of the more interesting consequences of the theory of relativity is that moving clocks record a different time than stationary ones. It makes for a fun exercise for the imagination, but presents a problem when it comes to synchronizing clocks around the world to subnanosecond accuracy. This is the subject of a report in the April 5 SCIENCE by David W. Allan and Marc A. Weiss, both of the National Bureau of Standards in Boulder, Colo., and Neil Ashby of the University of Colorado in Boulder.

The synchronization problem is partly a result of the Sagnac effect, a phenomenon that causes clocks in a rotating system (in this case, the earth) to be out of sync with one another when viewed from a stationary frame. Theory predicts, and experimental data show, that when an eastbound clock completes a circle around the earth it will lag behind an earth-based clock, whereas one traveling west will lead that clock. In an experiment performed in 1971, researchers J.C. Hafele and R.E. Keating verified the theory by transporting atomic clocks by commercial jet around the globe in each direction.

In the recent experiment, rather than physically moving clocks, the Boulder researchers took earth-based clocks located in Boulder, Tokyo and Braunschweig, West Germany, to be the rotating frame of reference. Pairs of these earth stations simultaneously viewed electromagnetic signals from Global Positioning Satellites. Depending on the sequence in which they were observed, the signals in effect circumnavigated the globe in either an eastward or westward direction, and the time differences were recorded.

The results not only confirmed the theoretical prediction but, Allan asserts, had a higher degree of accuracy than any such experiment to date. The researchers conclude that "this measurement technique allows one ... access to the most accurate clocks in the world at any other site without being limited by measurement uncertainties." —*S. Welch*