

takes to drive the magnetization to the opposite saturation.

This is the inductive loading that keeps the reflected decelerating voltage at bay. The product of the accelerating voltage and its duration is given by the product of twice the saturation magnetization (the "flux swing") and the cross-sectional area of the ferromagnetic core. Although the beam sees only an electrostatic field during its brief transit through each gap, it is effectively the time-varying magnetic flux in the ferrite core that maintains the accelerating voltage. Hence the name induction linac.

High repetition rate. Non-ferromagnetic "air-core" linacs built in the Soviet Union and at Sandia have produced even higher electron-beam currents than the ATA. But in the absence of ferromagnetic loading they are restricted to beam pulses not much longer than 10 ns. (The Soviet linac has recently achieved significantly longer pulses by the use of water as a dielectric to increase the capacitance of its accelerating cavity.) The enormous power levels of such short-pulse accelerators, Keefe told us, present technological problems that have until now prevented sustained operation at high repetition rates. They have been basically "single-shot devices," he told us. The ATA, by contrast, is designed to operate for long periods at a steady 5 pulses per second. In its alternative "burst mode," the accelerator can also operate at kilohertz rate for 10-pulse bursts, each followed by a 2-second respite.

The unique importance of the ATA for accelerator technology, Keefe emphasizes, lies in the achievement of these sustained repetition rates in a high-current, high-energy machine. The ETA (experimental test accelerator), the ATA's immediate predecessor at Livermore, was able to achieve similarly high current and repetition rate in 1979, but this prototype only accelerated electrons to 5 MeV. The second generation Astron accelerator, completed a few years before Christofilos's untimely death in 1972, reached an 850-amp current of 6-MeV electrons, but in a much longer structure than the ETA. It achieved impressive repetition rates up to 30 pulses/sec.

An important function of the ETA and ATA, Briggs explained, "is to teach us how to build these pulsed power modules so that they can run all day without failing or wearing out." Running at several million pulses per year for nearly three years, the ETA has yielded much information about component lifetimes. "With the very high voltage and power levels in each module, the machine has found lots of ways to tear itself apart," he told us.

The 50-nanosecond, 250-kV pulse for each accelerating module is formed by

a Blumlein line (the corruption "Blumline" is inevitable). These special pulse-contracting coaxial lines have a third annular element between the inner and outer coaxial conductors that effectively serves as a capacitor plate as it is "slowly" charged up to 250 kV over 10 microseconds. At this point a spark gap is fired, discharging the third element to the outer conductor and sending a 250-kV pulse, now contracted to 50 ns, down the line. Thus the Blumlein, which feeds the transmission line to the accelerator, amplifies the power of the original 10-microsec pulse by a factor of 200.

The Blumlein spark gaps suffer a lot of wear and tear, Briggs told us. The ATA group is therefore pursuing the development of Metglas magnetic switching devices to replace the spark-gap switches in the pulse-forming networks of future induction linacs. Very few induction linacs have been built to date. "People have tended to use rf accelerators even for applications better suited to induction linacs," Briggs explained, "because induction linacs are a much less familiar technology. As we prove it out, they'll find many new applications where it will replace rf machines."

Applications. The experimental area into which the ATA fires its 10-kiloamp pulses of 50-MeV electrons will be used primarily to study beam propagation in air. In vacuum, the mutual coulomb repulsion of a charged-particle beam always wins out over the self-pinching magnetic attraction, breaking up the beam in the absence of an external focusing field. On the other hand, when a charged-particle beam traverses a gaseous medium such as air, the resulting ionization can play a focusing role. The ATA group will study the physics of this phenomenon, investigating the feasibility of propagating high-current, high-energy electron beams through air. The ATA is also eminently well suited, Briggs told us, to serve as an injector for high-energy free-electron-laser experiments.

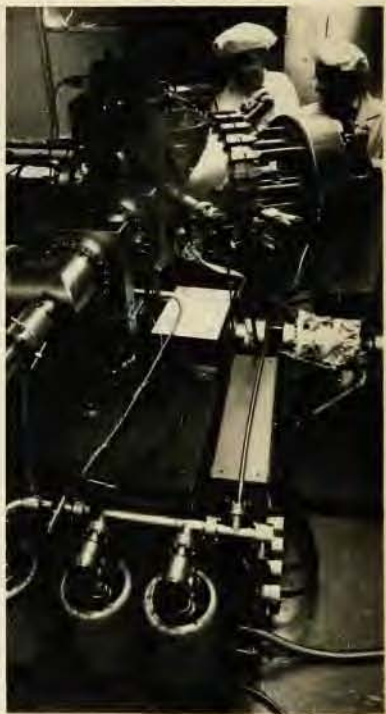
The Berkeley induction electron linac was built ten years ago to investigate the suggestion of V. I. Veksler (Dubna) that protons could be accelerated cheaply to very high energies by imbedding them in "smoke rings" of electrons. When it became clear this scheme would not be suitable for accelerating protons to extremely high energies, the Berkeley project was terminated in 1975. But Keefe told us that the Soviets have recently reported remarkable success in applying Veksler's idea to the acceleration of heavy ions. The Berkeley group is currently working on the direct acceleration of heavy ions in a linear induction accelerator, primarily for inertial-confinement fusion. Electron beams from induction linacs

are being considered as a means of heating the plasma in magnetic-confinement fusion devices, either directly or through the generation of intense microwave (or mm-wave) radiation.

Flash radiography is another potential application of the ATA. The electron beam could generate intense short x-ray pulses that would serve for high-time-resolution x-ray photography of rapidly varying dense materials. This technique is useful for the investigation of weapons implosion and for the study of equations of state in solids. Flash radiography has been used, for example, to look for the metallization of quartz and hydrogen at ultra-high pressures.

The ATA facility has been dedicated to the memory of Christofilos. Leaving aside its many contributions to magnetic-confinement fusion, Christofilos's Astron project was seminal for the development of induction-linac technology. —BMS

National Submicron Facility



The National Research and Resource Facility for Submicron Structures was dedicated at Cornell University in mid-October. Although the facility was established at Cornell in 1977 with a \$5-million grant from NSF, it has only recently moved to a new building, named for Lester Knight.

Shown in the photograph above are Lester Eastman and Colin Wood operating a molecular beam epitaxy system.

The facility is directed by Edward D. Wolf. (He described the capabilities of the submicron structure facility in *PHYSICS TODAY*, November 1979, page 34.)