Last year I. J. Good,[6] extending ideas of Sir Arthur Eddington, came up with the same formula.

Although some theorists believe that the fine-structure constant may have something to do with a geometrical calculation, most would argue against a geometrical interpretation of the proton-to-electron mass ratio. Most theorists would argue that the ratio would certainly involve strong-interaction dynamics. —GBL

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Livermore's new linear accelerator

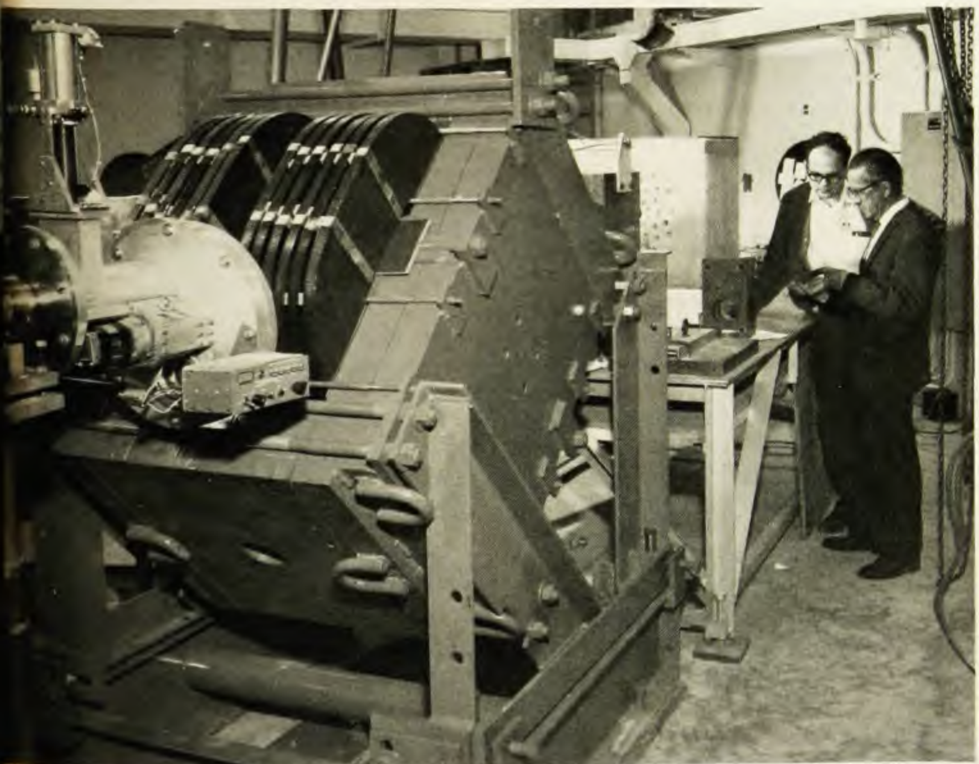
A linac that can accelerate either positrons or electrons is now operating at Lawrence Radiation Laboratory, Livermore. The accelerator can produce variable-energy beams of up to 100-MeV electrons or 80-MeV positrons. The positrons are used to produce a high-intensity monochromatic photon beam that will explore photonuclear processes over a wide energy range. The electrons will primarily be used for neutron-physics studies through creation of a pulsed neutron source.

The 100-MeV electron accelerator is a five-section pulsed traveling-wave machine that can operate with beam pulses as short as 5 nanosec and as long as 3.0 microsec. It has a duty cycle of 10^{-3}. In the short-pulse mode the instantaneous current is 10 amps.

To produce positrons, electrons are accelerated through the first three sections and then strike a target such as tantalum to produce positron–electron pairs. The positrons are then accelerated through the final two sections. The positron beams are energy analyzed and then pass through thin targets of low atomic-number material (such as beryllium), where the positrons annihilate in flight with bound atomic electrons; this process produces a stream of annihilation photons. By using a small solid angle in the forward direction, one obtains a narrow spectrum of photons (less than 1% wide) of adjustable energy. The equipment has an extensive beam-handling system that can direct the charged-particle beams to seven different target locations.

To produce neutrons the pulsed electron beam is stopped in a thick target of high atomic-number material, either through a (γ,n) reaction or (γ,n) plus (γ,f), if fissionable material is used. Neutron yield is about 10^{14} per sec in a 4π distribution at the target. The spectrum obtained contains a range of neutron energies from thermal to as high as 50 MeV. There are several underground neutron drift tubes radiating from the target area and leading to permanent detection stations.

The accelerator, built with funds from AEC's Division of Military Applications, cost \$1.9 million, and associated buildings and equipment cost \$2.6 million. Stanley Fultz, operations manager of the accelerator, and Clifton Whitten, have played major roles in planning and designing the machine. The research program manager is Charles Bowman.



Experimental cave at Livermore linac. The positron beam passes through a horizontal tube (left), strikes a target, thus creating monochromatic gamma rays. "Waste" positrons are bent downward by a magnet and absorbed in a particle "dump." The gamma rays go to the white rectangular apparatus (next to Raymond Alvarez and Stanley Fultz), where the gammas generate neutrons.

Other electron linacs. At Oak Ridge ORELA produces 140-MeV electrons with an instantaneous short-pulse current of 15 amps. Its longest pulse length is almost 1 microsec; its shortest is 3 nanosec. The machine is used primarily to produce neutrons for time-of-flight measurements.

At the National Bureau of Standards the 150-MeV electron linac has an instantaneous short-pulse current of 4 amps. Its longest pulse length is 6 microsec and its shortest, 1 nanosec. The machine has extensive beam transport, sending the energy-analyzed beam into many isolated experimental areas. Emphasis is on electron-scattering experiments, photonuclear physics and nuclear and radiation-standards development. This summer the Bureau is installing an adjustable positron source that will produce up to 40 MeV; it will primarily be used as a monoenergetic-photon source.

At MIT a 400-MeV electron linac is nearing completion; it is expected to be at full energy late next year. Average currents of over 100 microamps are expected. At high energies, it will have a duty ratio of almost 2%, and at about 200 MeV a 6% duty ratio. Experimental emphasis will be on electron-scattering experiments; for that purpose MIT is developing an energy-loss spectrometer whose resolution is expected to be better than 10^{-4}. —GBL

Space-science study group recommends soft pedal

If NASA follows the recommendations of a study group of National Research Council and National Academy of Sciences Space Science Board, expensive unmanned missions such as the "Grand Tour" of the solar system will be deferred and the space agency will concentrate its efforts for the next decade on relatively small missions. The results of the study, published as *Priorities for Space Research 1971–1980*, is primarily concerned with the unmanned programs of the NASA Office of Space Science and Applications.

The study recommends that at the current budgetary level, highest priority should be given to a series of small Venus atmospheric, landing and orbiting probes to begin in 1975 and Jupiter probes; completion of the remaining Apollo missions and a series of fully automated unmanned landers and roving vehicles for further lunar and planetary exploration; a series of large High Energy Astronomical Observatories and Small Astronomy Satellites as well as a substantially increased program in balloon and rocket astronomy and the development of a mirror for the Large Space Observatory.

To maintain progress in gravitational research, it is recommended that studies of an earth-orbiting gyroscope underway at Stanford University and the European Space Research Organization's sun-orbiting satellite should be continued. The study group recommends the launching of a pair of satellites for the examination of the interaction of the earth's magnetosphere and the solar wind. Three new satellite programs to gather additional meteorological and earth resource data are recommended, as well as a continuation of ground-based life sciences research in support of the Viking project's Martian softlanders.

If funding levels increase 25%, a 60-inch space telescope, additional orbital solar observatories, atmospheric explorers and earth resources satellites can be considered. The Grand Tour mission should be undertaken only if the budget can be increased still further.

Herbert Friedman of the Naval Research Laboratory was the chairman of the study group. More than 90 scientists participated in the panel. Copies of the report can be obtained at $4.50 each from the Printing and Publishing Office, National Academy of Sciences, 2101 Constitution Avenue, N. W., Washington, D.C. 20418.

Improved Lamb-shift experiments

Precise measurement of the Lamb shift, the difference δ in energy between the $S_{1/2}$ and $P_{1/2}$ levels in single-electron atoms and ions, is a basic test of quantum electrodynamics. Several factors limit the accuracy of experimental determinations of δ; the most important are difficulties of measuring the resonance-line center, uncertainty about the velocity distribution of the atoms, and systematic errors, such as Stark-effect shifts, caused by the applied electromagnetic fields.

Now an experiment done at Harvard by Christian Fabjan and Francis Pipkin,[1] using a variation of a double oscillatory-field method suggested over ten years ago by Vernon Hughes[2] (Yale), has apparently succeeded in substantially narrowing the linewidth. Fabjan and Pipkin report a value of (314.810 $\pm$ 0.052) MHz for hydrogen in the $n = 3$ state; their result, which they state is eight times more precise than the best previous measurement of δ for $n = 3$,[3] indicates to them that the method does not introduce unmanageable systematic errors, and encourages them to include "uncertainty-principle narrowing," as well as "interference narrowing," in their next experiments, by physically separating the two oscillatory fields. Hughes, with James Bayfield, has been designing similar experiments.

Fabjan (who is now at CERN) and Pipkin formed a fast hydrogen beam by charge transfer of a 19.5-keV proton beam incident on a nitrogen gas target at 5×10^{-3} torr. The atomic beam is sent through a spectroscopy chamber consisting of two consecutive rf cavities whose frequency can be varied through the resonance frequency of the $S_{1/2}$–$P_{1/2}$ transition. By switching the rf field in the cavities on and off and detecting the resulting signal with a photomultiplier sensitive to Balmer α photons (photons at the energy of the $n = 3$ to $n = 2$ transition), they determined the frequency of the $S_{1/2, F=0} - P_{1/2, F=1}$ transition. Those species that were excited to the $P_{1/2}$ state decay rapidly to the $n = 1$ or $n = 2$ state and are not sensed by the detector. A third rf cavity serves as a hyperfine state selector to remove $S_{1/2, F=1}$ atoms from the beam, so that only $S_{1/2, F=0}$ atoms pass in front of the detector.

The improvement here over past rf spectroscopy by the same group is due to the double rf cavities, whose relative phases can be modified to be either 0 or π. For the initial experiment, there was a very small separation between the two rf cavities. With the cavities in phase, the rf region is identical to a single-field spectroscopy region, and the resonance curve has the natural linewidth. The natural linewidth is determined by the lifetime of the excited states and the time spent in the rf field.

The difference between the counting rates with the rf fields in phase and 180 deg out of phase gives an interference pattern whose linewidth equals one half the natural linewidth.[4] This decrease in linewidth is often referred to as "interference narrowing." It is analogous to the reduction in the central width of a diffraction pattern when a single slit is replaced by two slits whose separation is equal to the width of the single slit.

Certain kinds of systematic errors are minimized with this method. In earlier work, Fabjan and Pipkin had used a foil rather than a gas target to produce the fast hydrogen. They switched to a gas target, Pipkin told us, to get a more intense beam and to ensure more uniform velocities for the beam. Because he is working with a zero magnetic field and varying the frequency of the rf field, Stark-effect errors are less than in the more conventional variable magnetic-field experiments.

The next step for Pipkin, now that the interference experiment is done, is to measure the resonance frequency when the two rf cavities are separated by a variable distance. Under these conditions only those atoms that live long enough to travel between the two cavities are detected. In other words the natural spectral linewidth of the transition, set by the uncertainty principle, is narrowed by looking only at those P states that live longer than the average P-state lifetime. Fabjan and he have done measurements with separated fields, but they did not consider the resulting data accurate enough to include in their Lamb-shift calculation.

Hughes and Bayfield, as well as Pipkin, plan to study transitions in the $n = 2$ state of hydrogen with the separated-field method. The $n = 2$ state is much more stable than the higher states. This relative stability, Bayfield pointed out to us, means that uncertainties due to rf-induced transitions that decay at the detector and are included in the Balmer α signal, would be negligible.

The more precise values for the Lamb shift that we can eventually expect from separated-field studies should spur attempts at refining the theoretical value; the most recent value for the $n = 3$ state, (314.894 $\pm$ 0.009) MHz, has been calculated by Thomas W. Applequist and Stanley J. Brodsky.[5]

—MSR

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