

the magnetic field. With the new FFAG magnets an arbitrary frequency modulation program may be used. Since the magnet is always able to receive particles, a pulse of particles can be injected as frequently as the radio-frequency modulation cycle can be repeated. Thus the average beam current can be much higher than that from a conventional machine, whose magnet is pulsed.

About six different types of FFAG accelerators have been worked out. Some involve reverse field sectors and some involve ridges on poles or prismatic edges on magnet sectors. A unified theory which describes all the types so far imagined and suggests other types has been developed, so it may soon be possible to determine the optimum physical design for an ultra-high-energy machine.

It will require more theoretical analysis in order to determine whether or not the FFAG magnet will have an over-all advantage over existing designs in the 20 Bev range; however, it has already become clear that there will be important applications of the FFAG principle to the better-known accelerators at lower energies. For example, betatron acceleration with an FFAG ring magnet used for the guide field will make possible an intensity increase of several orders of magnitude, and existing FM cyclotrons can be changed to give higher current by the application of the spiral ridge form of FFAG poles. An early experimental test of the FFAG principle will therefore be of great importance to several branches of nuclear physics. The MURA group is laying plans for such a test in the very near future at the University of Illinois, using one of the betatrons.

Another activity of the study group which deserves special comment is the development of new computational methods, which make possible rapid experiments on orbit stability, using the Illiac electronic computer. Transformations have been discovered which have not only greatly accelerated the digital computer work, but which have made it possible to explore the more general nonlinear cases which are practically inaccessible analytically. Orbits can now be run through so quickly that the results can actually lead, rather than follow, the conjectures and speculations on modifications of design. Analytical work supporting, and feeding into, the digital computer program is carried out at the Universities of Iowa, Illinois, Wisconsin, and Indiana, and at Wayne University. This theoretical work is putting MURA in a position to answer some of the difficult questions about general (nonlinear) forces which arise in the conventional AG machines as well as in some of the especially interesting machines recently devised by the members of the MURA group.

(d) *Financial support.* The matter of financial support for the MURA objectives has been pursued continuously. So far no support for the construction of a laboratory has been obtained, but adequate support for the study group has been made available from several sources. In the early months of the study program, support was provided by the Atomic Energy Commission through its contracts at Argonne and Brookhaven, and by both the Atomic Energy Commission and the Office

of Naval Research through their contracts at some of the universities. Since the spring of 1954 the outside financial aid has been provided entirely by the National Science Foundation.

The member universities have contributed substantially from the time of the early stage of the organization. Faculty members' time has been released freely and in many instances travel expenses have been paid by the universities. The University of Illinois has provided services of its electronic digital computer, Illiac, which has by now amounted to a very large number of hours. The University of Michigan, through its Phoenix Project, has provided a special fund to cover the expenses of its scientific participants and for experimental work at Michigan. To provide for business expenses of the Corporation each of the eight-member universities has contributed \$5000 and has pledged another \$5000.

Science Education

OVER the past half-century, the number of science students among college graduates has dropped from about seventeen percent of the total to ten percent, a matter of steadily increasing concern to those who must deal with the realities of a shortage of trained manpower. Atomic Energy Commissioner Willard F. Libby addressed himself to the general subject at the Fall Convocation of the University of Chicago on December 17th.

Noting that a large fraction of the nation's ablest students "do not choose to become scientists", Libby indicated that a prime cause is the fact that "the pickings apparently are not as green for the young student as they were in our school days" because the sciences "have been so thoroughly and dramatically explored by the greatest men of science the world has known—men who still are with us in spirit and sense and memory. They have set a pattern and stride proper to giants and geniuses but most frightening to ordinary mortals. They have left few obvious opportunities for easy attack and apparently cleared the fields of physics and chemistry, so little undiscovered remains. Of course, one realizes that similar situations apparently have existed before in science and, much to the embarrassment of the prophets of the time, have been shown to be purely temporary in character. In each instance, a few years later new opportunities have been revealed which have greatly increased the scope and range of the particular fields. We can well imagine that this may happen again but until it does happen, we must understand that a young man contemplating studying physics or chemistry looks around him and observes with considerable discouragement that the obviously important fields are being well tilled. This is unfortunate for, of course, it is not entirely true. The principle of research is such that it leads to new research, to new investigations and to new queries, to new understanding and to new thought. We cannot imagine that fruitful research will ever lead to a satiation or to an exhaustion or termina-

tion of the fields of physics and chemistry. However, it is not obvious to the prospective student that this is so."

Other factors suggested by Libby as causes for decreased enrollment in the basic sciences are "the rather unsatisfactory salaries" which are paid men of real competence in the sciences; the quality, and especially the insufficient quantity, of instruction in secondary schools; and the quality of science instruction in colleges and universities.

Concerning the last point, said Libby, no university now offering mediocre introductory courses in the sciences can rest easily. "The beginning courses in physics and chemistry are an opportunity to enlist students in the fields. It is of extreme importance that these courses be well taught, that the subject be presented in an interesting and understandable way, not in any way ignoring the basic difficulties, but not with such a mass of detail that the beauty of the basic principles is obscured. It is vital that the better teachers in the whole of the university faculties be asked to teach the beginning courses. It is essential that the laboratory experiments used in the instruction be wisely chosen and well equipped so that the ordinary difficulties of experimentation may not mask the attractiveness of the subjects. It is also important that the teacher of the beginning course in physics or chemistry seriously consider his counselling responsibilities so that students who are interested in the sciences will be encouraged and that the students who are having difficulties of a temporary character will be led to persevere. He should see that the brilliant students be led to pursue the subject matter beyond the general level of the class so that boredom and frustration will not divert them into other fields. The freshman science teacher is certainly one of the vital cogs in the machinery which trains and insures the supply of basic scientists. It is clear at the present time that this job is not being very well done. It is clear that this is one of the principal factors which needs serious consideration in remedying the situation."

His conclusion: "The supply of physicists and chemists will be restored when the problem becomes sufficiently serious to command general attention. But it seems that the universities have a responsibility to recognize the situation early and to do all in their power to remedy it quickly. All of us should worry and consider this problem and try, with our best efforts, to implement any suggestions for improvement which seem sound and thus protect our society against a manpower shortage of the most critical kind."

Research Corporation Award

THE 1954 Research Corporation Award, consisting of an honorarium of \$2500, a plaque, and a citation, was presented on January 18th to Willis E. Lamb, Jr., professor of physics at Stanford University, in recognition of his major contributions to the understanding of atomic structure and quantum electrodynamics.



Willis E. Lamb, Jr., recipient of the 1954 Research Corporation Award for Contribution to Science.

He was cited particularly for having executed "a number of brilliantly conceived and bold experiments" by which the shift in the energy levels of hydrogen atoms was demonstrated and measured, thus providing experimental results leading to "an extension and reformulation of quantum electrodynamics which has greatly increased our understanding of the forces between charged particles . . . and opened new fields of theoretical and experimental investigation into the nature of matter and radiation".

In accepting the award, Lamb noted that much of the work mentioned in the citation had been done in collaboration with Robert Retherford, now of the University of Wisconsin, and with others who had participated in the research. He recalled that construction of the apparatus with which he and Retherford investigated the fine structure of hydrogen was begun in the summer of 1946 at Columbia University. Their first success came in the following year when, through spectral measurements in the microwave region, they observed a minute displacement of the $2s_{1/2}$ energy level from its accepted position as then predicted by Dirac's quantum theory of the electron. This effect (the "Lamb shift") has since been accounted for by Bethe and others as being a result of the interaction of the electron with the radiation field.

Research Corporation, a foundation created more than forty years ago "to provide means for the advancement of scientific investigation by contributing to educational and scientific institutions", established the award in 1925.