CONFERENCE SUMMARY

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The 1981, eleventh Linear Accelerator Conference was held from October 19 to 23, in Santa Fe, New Mexico, sponsored by the Los Alamos National Laboratory. This meeting can be termed a great success, thanks to the organizers in the Accelerator Technology Division of Los Alamos. I will single out here Bob Jameson and Jim Stovall, who as chief cooks, did most of the organization, and also Sue Nicol who carried the brunt of the work for them. The choice location for the conference helped a great deal. Bishop's Lodge, despite some trepidations about sufficient accommodations, proved to be the most congenial Shangri-la, providing just the right amount of spice to the meal. However, success would have been impossible without first class meat and potatoes; these were provided in 95 good technical papers presented during the conference. Thanks to all participants who made it possible.

Linear accelerator conferences have been held since 1960. First started at Brookhaven at a time when large proton linear accelerators were being planned, these meetings gained impetus with the design and construction of LAMPF, and the linac injectors for the BNL-AGS and FNAL synchrotrons. In the 1970s interest remained high. Transfer of information on experience gained in machine operation, and proposals for new linear accelerator facilities kept attendance up. In fact, attendance at linac conferences has grown. From about 50 attendees in the early 1960s, it reached about 150 in the 1970s. The 1981 conference gathered 230 participants. Foreign participation was especially strong, with good representation from Japan and Western Europe. This record attendance is a good indication of the continuing interest and excitement in the field of linear accelerators. Better understanding of the theory and new technologies are opening up new applications that may be promising for solving long-term energy needs, as well as providing radical improvements in accelerators being designed or under construction.

The meeting opened with a remarkable reminiscence on the MTA project by P. Livdahl. Although classified for many years, this project, which was terminated after a few years of intense accelerator development, has had long-lasting fruit in the training of a generation of accelerator builders, particularly linear-accelerator builders. This was a time when new ideas could be tested, even if it meant the construction of a 12-MHz, 60-ft-diam drift-tube linac, with drift tubes weighing forty tons, having bore holes large enough for a man to crawl through. This was a time when things could get done; over a 5-year period the group under Lawrence's direction actually built four large accelerator prototypes, from the so-called MTA to the A-48, 7.5-MeV working deuteron linac. This was a time when machines could be built successfully without fancy computer programs, and especially without environmental impact statements. Well, so much for that. Now, to the highlights.

Although it is difficult in a few words to relay the tone of the conference, we can classify it as forward looking: very few papers dealt with existing operating machines; on the other hand, a number of ongoing projects and proposals were presented, pushing the state-of-the-art in all aspects of machine development.

A number of papers reported on the progress of FMIT (a 35-MeV, 100-mA, 100% duty factor deuteron linac being developed for Fusion Materials Irradiation Testing). It is the first attempt at continuous-wave (cw) linacs since the now famous MTA project, almost 30 years ago. The development of this accelerator is important to future applications of linacs. The last few years have seen a renewal of interest in the United States and Canada in the use of accelerators for production of nuclear fuel. These would require proton or deuteron beams in the gigaelectron volts energy range and several hundred milliampere continuous currents. The success of FMIT could therefore strongly influence the future of cw linac applications. It is viewed as a proof-of-principle demonstration of the ability to handle large beam currents and manage the problems associated with continuous radio-frequency (rf) power. The unique problems concerning continuous beams were discussed with respect to ion source design, nondestructive beam diagnostic, etc. Of course the major machine development sparked by the FMIT project has been the RFQ (radio-frequency quadrupole).

The RFQ, first proposed in this country in 1978, owes its success to the Los Alamos group who enthusiastically pushed its development for its application for FMIT and other projects. In principle, the RFQ offers enormous advantages over presently used linac-injector schemes; it replaces very high voltage Cockcroft-Waltons, choppers, and conventional bunchers while offering simplicity and close to 100% bunching efficiency. In only 3 to 4 years, laboratories around the world have joined the RFQ development effort. No less than 14 papers from 7 institutions were presented on the subject (out of 95 papers).

Specific plans are already being made to apply RFQs as integral parts of new or retrofitted injectors for several heavy ion and polarized proton-accelerator projects.

Another important technological advance that will greatly influence the design and operation of future linacs is the development of rare-earth permanent magnets. The importance of this development was evident by the number of speakers on the subject. After a modest beginning (the use of permanent-magnet-focusing quadrupoles was first proposed at Los Alamos for their PIGMI project) and a fear of losing the ability to adjust quad fields, New England Nuclear Corp. took a bold step of faith in adopting this technology for their 40-MeV proton linac constructed for the production of radiopharmaceuticals. This has given the impetus to develop an entirely new technology of permanent-magnet designs from dipoles to quadrupoles and sextupoles, as well as designs of adjustable field-magnet systems. Papers dealing both with the theory of design and with the engineering of these magnets indicate that the technology is maturing and will be used extensively on new linac designs. Even now, two commercial companies are in the business of producing and selling these components to the accelerator community.

The other high point of the conference was the very exciting development taking place in our understanding of beam dynamics. Ever since the classic work of L. Smith, R. Gluckstern, R. Chasman and others in the late 1960s, theorists have been at a loss to explain beam-emittance growth phenomena observed in operating linacs. Typically, factors of 2 to 3 emittance growth were measured, without obvious explanation for the growth. A number of workers have addressed the problem and, using somewhat different approaches, are shedding new light on the subject. In particular, L. Smith (LBL), R. Jameson (Los Alamos), I. Hoffman (Max Planck) and K. Mittag (KfK) presented papers on detailed treatment of beam-bunch behavior during acceleration, demonstrating the effect of space charge, mismatching, and tight coupling between transverse and longitudinal phase spaces resulting in the onset of instabilities within the bunch. These mismatches and instabilities lead to emittance growth that appears to be consistent with those observed experimentally. This work indicates that beam-emittance growth can be controlled by properly matching the transverse and longitudinal particle temperatures within the bunch, or, to use the newly coined term, by equipartitioning. It is encouraging to see a picture emerging that will help clarify these effects and possibly provide the means of beam-emittance-growth control. However, there is still much to do before we will have good quantitative prediction of bunch growth. Other effects also influence the beam behavior, for example, longitudinal rf coupling, image effects, etc. This beam quality parameter will be very important in future applications of linacs where high beam currents, or very small output emittances, are required.

Also worthy of highlight are papers dealing with ongoing accelerator projects and those dealing with development of future projects.

F. Cole (FNAL) reviewed the field of collective acceleration. Although collective accelerators are types of linear accelerators, they have never been an integral part of these conferences. Collective accelerators in principle hold the promise of very high acceleration gradients (>100 MeV/m), hence the interest. However, although the physics principles appear sound, practical working devices have never been demonstrated. Of the many collective accelerator concepts developed, the electron ring accelerator (ERA) received substantial support during the 1970s. It was abandoned in this country and in Europe a few years ago. The work on this accelerator is apparently continuing in Russia with some measure of success. Among the many other concepts, several are being pursued in the United States at modest rates.

Another technology, which in the 1960s and 1970s appeared very promising and generated many interesting conference papers, was superconductivity as applied to linear accelerators. Superconducting linac cavities have met with some success, particularly as beam separators and heavy ion post accelerators (for example, raising the energy of ion beams exiting from Van de Graaffs). In both cases, beam currents are very small. In this context it was gratifying to listen to the only two papers on superconducting linacs, both from Argonne, describing the successful commissioning and routine operation of their heavy ion superconducting linac booster. This success demonstrates the viability of the technology for certain applications.

Another paper described the very recent coming on-line of the 40-MeV New England Nuclear proton linac which, after a 4-year construction period, has just accelerated a proton beam. This is noteworthy on two counts: it is the very first proton linac built by industry for industrial purpose (production of radio pharamaceuticals) and, as mentioned earlier, it is the first proton linac that uses permanent-quadrupole-magnet focusing throughout the entire machine. It is still too early to assess the success of that technology; the linac community will be following the commissioning and operation of this facility with great interest.

At this time, a number of proposed linac projects are generating good developmental work, some of which was reported at the conference. The long-standing program at Chalk River, to develop electronuclear fuel breeding using a nominal 300-mA cw, 1-GeV proton linac, has led them to concentrate on the development of high-current ion sources, injectors, and the low-energy front end of the linac, as well as development of disk-and-washer (DAW) structures for energies >150 MeV. The papers presented described some of their experiments and the difficulties one has to face with cw accelerators dealing with high current densities, multipactoring, thermal effects, etc. A developmental project called ZEBRA was described; it will consist of a 300-mA, 10-MeV front-end linac for what eventually might become a demonstration electronuclear breeder.

In a similar vein the most ambitious linac project presently on paper, the SNQ from KfK (Karlsruhe), was presented. The project generated a number of good, original papers describing various parts of the design study. This proton linac, to be a spallation neutron source primarily for neutron scattering research, will be a 1.1-GeV, 100-mA, 10% duty-cycle machine. A. Citron (KfK), who presented the project, is mildly optimistic and hopes that it may be the next large German accelerator project. Most interesting to the community was the development of a 325-MHz, 1-MW klystron rf power source for this project. Tests to date indicate tube efficiencies in excess of 70%. This is impressive.

Two papers presented by commercial firms described some of the work done to improve rf power sources. This is a subject that is always of great interest to linac designers. When considering future applications of linear accelerators, for example, spallation sources, heavy ion fusion drivers, etc., one is struck by the fact that the driving cost for these facilities is the cost of rf power. For the case of a 1-GeV, 300-mA cw electronuclear breeder, for instance, the cost of rf power is estimated at 70% of total accelerator-facility cost. Thus, advances in the technology of klystrons and power tubes are of the utmost importance, especially as they apply to increased efficiencies and lower costs. Development of high-power, low-frequency, gridded tubes at EIMAC was described, as well as work taking place at Thomson-CSF on high-power klystrons. From these presentations, the SNQ work, and other papers at this conference, one is left with the feeling that this country is lagging in pushing development of new, better rf power sources, while Europe and Japan appear to be investing rather heavily in the further development of the technology.

Finally, portions of the conference were devoted to electron linear accelerators. Interest centers on two relatively new developments. On the one hand, a number of technically interesting papers dealt with pushing the state-of-the-art in microtrons, and especially racetrack microtrons. A number of ongoing microtron projects generated some fresh ideas on the subject. At the other end of the spectrum, SLAC participants described the development work taking place for the Single Pass Collider. This experiment presents some unique accelerator control problems dealing with the handling of a single, intense electron bunch.

Now, it is impossible to do justice to all papers presented during a week-long meeting, and many interesting presentations are not discussed here, such as the ongoing development of induction linacs for heavy ion fusion, the rather interesting medical electron-linac design discussed by Benguang (Republic of China), the status of ion source technology, advances in computer codes such as SUPERFISH evolving to ULTRAFISH, various computer control and diagnostic instrumentation schemes that always have a touch of home cooking, etc. Nor does this review do justice to the real value of holding the 1981 Linac Conference in a congenial, secluded spot conducive to discussions and the exchange of information and ideas.

Overall, it remained (as have all linac conferences to date) a highly technical meeting continuing the tradition of excellence in this somewhat specialized and eclectic field. Ongoing work and development on existing machines, as well as plans for future projects, promise an even better fare for the next Linear Accelerator Conference to be held in 1984.