SUMMING-UP OF THE LAST LINAC CONFERENCE

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Abstract

The last Proton Linear Accelerator Conference was held at the National Accelerator Laboratory from September 28 to October 2, 1970. This was a time of intense linac construction activity in the U.S. and three new U.S. linacs were coming into operation; the 200-MeV injector at BNL, the 200-MeV NAL linac, and the 800-MeV LASL Meson Facility accelerator. The major emphasis of the conference pertained to the first operation of the early stages of these linacs. The conference proceedings1) contains many papers describing the engineering details of these three linacs. Other conference highlights include the work on the helix structure, progress on superconducting rf cavities, heavy-ion accelerators, and experimental and theoretical measurements relating to collective effects in high-intensity beams.

Introduction

The last Proton Linear Accelerator Conference, the seventh in a series dating back to 1961, was held at the National Accelerator Laboratory from September 28 to October 2, 1970. This national conference has usually been held every two years, alternating with the International Accelerator Conference. It has previously been hosted by BNL, Yale University, Midwestern Universities Research Association, and Los Alamos Scientific Laboratory. Next year, in the fall of 1972, it will be held again at LASL.

The main emphasis of the conference has been directed toward proton linear accelerators, but the boundary conditions have frequently been enlarged by the organizing committee to include heavy-ion linacs, traveling-wave electron linacs, other linear acceleration devices, and special closely related areas of development. Engineering developments have been given prominence. The free exchange of information during this conference has had a large effect on the engineering similarities of the three new U.S. linacs. A large number of linac builders received early training and ideas from the conference before good published books and documents were available.

The NAL conference had 149 participants representing 27 laboratories. The sessions were held in the NAL conference hall, a barn that had been modified to provide the necessary requirements (the cows and other animals had been removed earlier). Figures 1 and 2 show exterior and interior views of the NAL barn.

Seventy-eight papers were published in the conference proceedings1); seventy-one of these were presented orally at the conference. The conference program committee chose to combine some papers rather than resort to scheduled parallel sessions.

Sessions were held to discuss the status and operation of new proton linacs (the BNL, LASL, NAL, Saclay, and the planned injector for the Japanese Proton Synchrotron), beam-diagnostic measurements, superconductivity, rf structures, controls, electrical and mechanical engineering, beam dynamics, heavy-ion and electron accelerators, ion sources and preaccelerators, and beam-transport and diagnostic methods.

Conference Summary and Highlights

The conference was held at a time of intense linac construction activity in the U.S. and after most design decisions had been made. The operating experience, although in most cases meager, was cause for great optimism and jubilation. Especially, engineers were willing to boast of their improvements and, in fact, the proceedings of this conference contain some of the best engineering descriptions of linac technology produced to date. At NAL, a documentary movie on linac-tank fabrication had been produced and was shown to those conferees who were willing to make do with an abbreviated luncheon.

BNL had been operating their first tank since March 24, 1970, while construction was proceeding on higher-energy tanks; the installation of tank 2 was delayed until the 10-MeV diagnostic system could be dismantled. By conference time, 215 mA of 10-MeV protons had been produced and extensive measurements were showing good correlation with computed results. The emittance growth had been measured and amounted to a phase-space dilution by a factor of 2 or 3 for different percentages of the beam, a somewhat higher value than the calculated value, which probably means that the phase-space match into the linac was not optimum. Good experimental results had been obtained on the emittance growth at 10 MeV as a function of beam current.

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The Los Alamos Meson Physics Facility was about halfway through the construction cycle and beam tests had been underway on the first 5-MeV tank since June 10, 1970. Unfortunately, a few problems, not basic, had limited the running time, so that beam emittance and energy spectra data were limited. Nevertheless, just prior to the conference an 8-mA proton beam had been accelerated at 6% duty factor to give an average power of 2.5 kW, enough to bore a hole in one minute in a water-cooled copper jaw and cause a water leak.

At NAL, the 10-MeV section, which had been operated as a prototype to test design features a year earlier, had been moved to its permanent building, equipped with a new preaccelerator and had again accelerated a 10-MeV beam on April 17, 1970. Three months later, the second and third cavities had been added to give a 66-MeV beam and by conference time, on September 25, three more cavities had been added to give a beam of 139 MeV, the highest energy from a proton linac up to that time. Emittance measurements at 66 MeV had indicated no significant growth beyond 10 MeV, although a growth of from 2 to 3 had been measured in the 10-MeV section for a 100-mA beam, Fig. 3. Cavity phases had been adjusted by measuring the total current passing through an absorber of adjustable thickness as the phase of the tank was changed, thus plotting out the rf bucket width, Fig. 4.

Other reports on operating linacs included the experiences with the 20-MeV injector for the 3-GeV Saclay synchrotron and the 3-MeV experimental cavity at CERN. The Japanese Proton Synchrotron project had been authorized and the injector for the 8-GeV synchrotron was to consist of a 500-MeV booster and a 20-MeV linac. After using a half-scale electron model of the first 10-MeV linac stage, a full scale prototype cavity 2.5 meters long was being constructed by the Japanese group using an electroplating technique. A report was also received from the Institute of Nuclear Research, Poland, describing the operational experience on a 10-MeV linac which had accelerated its first protons on January 15, 1970.

One impressive feature inherently contained in the papers describing the operation of the new U.S. linacs was the rapid data-collection techniques and displays using digital-computer-controlled equipment. Such a display is shown in Fig. 5 which is a measured emittance plot at 200 MeV taken from the NAL display scope. Even though operating periods had been brief, the vast amount of data collected by these systems had allowed a better analysis of the operation to be procured than ever before. Some rather positive statements could be made relative to the problems of beam growth and collective effects. By closing control loops, better regulation and controlled conditions could be obtained for measuring beam properties and for providing more stable injector beams.

The 1968 linac conference had left unanswered problems relative to the operation with beam of linac cavities stabilized by using either the post-coupler system (LASL) or the multiple-stem system (BNL). By 1970, it was clear that both systems work as predicted by their proponents and that, if transverse field components were present, they had little or no effect on the beam. The virtues of each system continue to be debated by the proponents of each system, but it is recognized that the stabilization devices have had much to do with the success of the current designs and constitute a notable extension in the technology.

Another advance in rf structures has come from the development work on the helix structure by the Frankfurt, Germany group. They hope to solve the problems of the low-velocity sections of the conventional linac by lowering the frequency, which ordinarily would result in an increase in the structure dimensions. The helix structure, due to heavy loading, results in small dimensions even at low frequencies. This makes the helix structure a possible candidate for the low-energy sections of a superconducting accelerator. The Karlsruhe group has fabricated helices out of niobium and these are being tested in a liquid-helium cryostat to 1.8°K. The problem of including quadrupole focussing in a helix accelerating structure has been solved by making the helix in short sections and alternating helix sections and quadrupoles. At least three problems were left unanswered at the time of the conference; the first relates to the production of niobium helices with satisfactory superconducting surface resistance at high fields, the second involves the development of a fast-servo tuning system for stabilizing the cavities, and the third involves mechanical problems in damping out vibrations resulting from the coupling of the electromagnetic fields to the mechanical vibration modes that detune the structure. If the helix problems can be solved, it is likely that the helix structure will play an important role in the German plans to build a π-meson factory in the energy range of about 500 MeV to 1 GeV and a current of about 1 mA at a duty factor of 1. With this goal, the Karlsruhe group is constructing a 60-MeV superconducting proton accelerator as a pilot project.

In the U.S., Stanford and SLAC continue to make gains in advancing the technology of more conventional superconducting linac structures. The Stanford High Energy Physics Laboratory's superconducting linac was described and the associated problems were discussed. This development has led SLAC to undertake a design study directed toward converting the two-mile accelerator into a 100-GeV superconducting accelerator using niobium cavities. In this effort, a short test cavity (52 cm) is being fabricated (Project Leap Frog), in which the structure is a constituent part of a traveling-wave resonant ring, rather than being operated as a standing-wave device. The SLAC group have also considered various schemes for recirculating the beam through the accelerating section to produce higher multiples of the basic energy.

As you know, the activity associated with the acceleration of heavy ions has recently escalated due to predictions that islands of mass stability exist beyond the present periodic table. This has set a design requirement that a heavy-ion accelerator be capable of accelerating ions of all masses up to 238 (uranium) to an energy of 8 MeV per nucleon. Heavy-ion accelerators received emphasis both in the program and during informal discussions during the conference. In particular, the plans for modifying the Berkeley HILAC were described. Efforts elsewhere were presented, including those in France and Germany. In Germany, the group working on the new Heavy-Ion Research Facility (GSI) near Darmstadt has considered the use of the helix structure for use in the region of low ion velocities. This structure was rejected in favor of the more conventional UNILAC design, mainly on the basis of the more complex control requirements of the separate helix sections.

Linac audiences continue to be interested in the developments associated with the Electron Ring Accelerator. The Berkeley experiments from Compressor II to Compressor V were described at the conference, as well as design work on an ERA for a high-energy proton accelerator.

The conference contained a good balance of theoretical papers. Computer programs continue to be developed for the computation and optimization of the rf properties of accelerating structures. SLAC has developed a program for the computation of the rf parameters of traveling-wave structures. CERN has found a way to compute, by relaxation methods, the electromagnetic fields and the frequency at any mode in the lower passband of a symmetrical periodic structure, for a traveling-wave as well as for a standing-wave structure. The greatest theoretical interest was centered on the papers where intensity and space-charge effects were discussed. Although no revelation appeared comparable to the one presented in the 1968 linac conference where the analysis in six-dimensional phase space revealed the effects of space charge in the early stages of linac acceleration, more work has been done since then along these lines. CERN, in particular, has been looking into the intensity problems in the preinjector and the early stages of the linac.

The question of whether it is now possible to make comparisons between the theoretical predictions and experiments was discussed at roundtable sessions. It was concluded, by most of the panel members, that for the first time we are beginning to make meaningful comparisons. This should have a pronounced influence on future linac design and measurements.

In the area of ion sources and preinjectors, the development toward beams of greater brightness has not been striking, although continual progress has been made. Best performance from ion sources has been obtained in Pierce geometry and in short columns using electric fields of 30 to 50 kV per centimeter. The proposal for adding a higher energy preinjector for the CERN proton synchrotron was presented.

Conclusions

The 1970 Proton Linear Accelerator Conference was commendable in bringing together reports on the engineering and construction details of the third generation of proton linacs. This generation of linacs is typified by their stabilized rf structures, copper-clad construction techniques, and their sophisticated digital-control systems. Operation experience was limited, but enough details were known to enable the designers to be jubilant over their successes. Many developments were reported that were left unresolved and that will continue to draw interest. A few of these include the new developments in superconductivity technology, the helix structure, the acceleration of heavy ions, the electron ring accelerator, and the phenomena arising out of space-charge forces and collective effects in beams of increasing intensity. It is certain that the Proton Linear Accelerator Conference will continue to draw great interest among accelerator builders everywhere.

References

1) Proceedings of the 1970 Proton Linear Accelerator Conference, September 28 - October 2, 1970, National Accelerator Laboratory, Vols. 1 and 2.

DISCUSSION

E. F. PARKER: In response to the request for a comment regarding the status or performance of the Argonne accelerating column, the severe sparking problem which existed at the time of the Linac Conference has been solved and the column is operating quite satisfactorily at this time. It does, however, have a vacuum-leak problem.

Fig. 1. NAL Conference Hall.

Fig. 2. Panel discussion on linac performance.

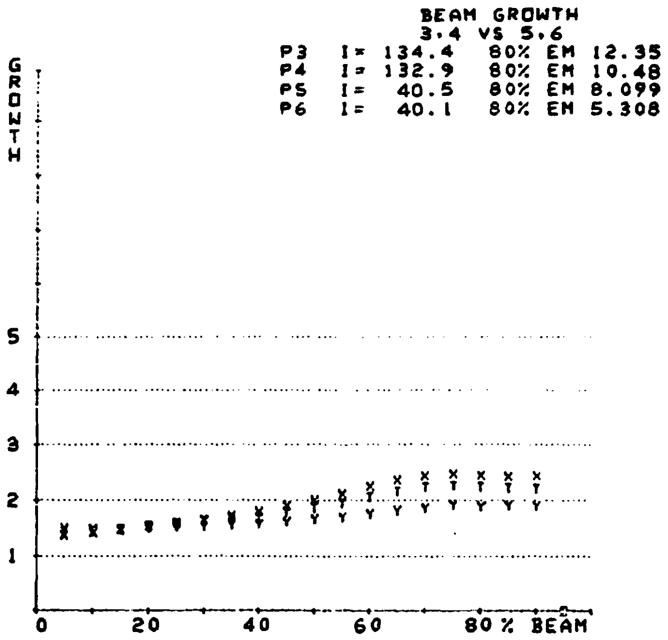


Fig. 3. Growth in normalized emittance through 10-MeV cavity for 40-mA beam in NAL linac (x) x-x' plane; (y) y-y' plane.

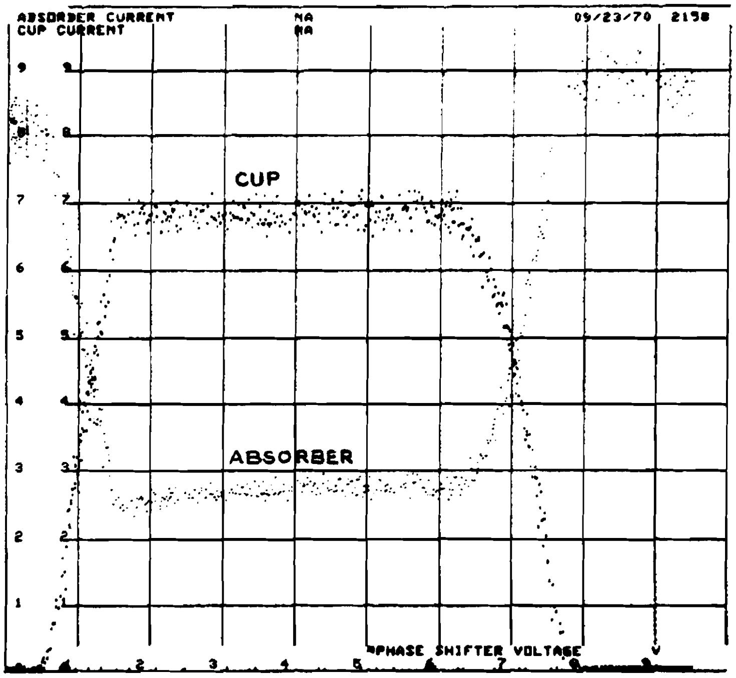
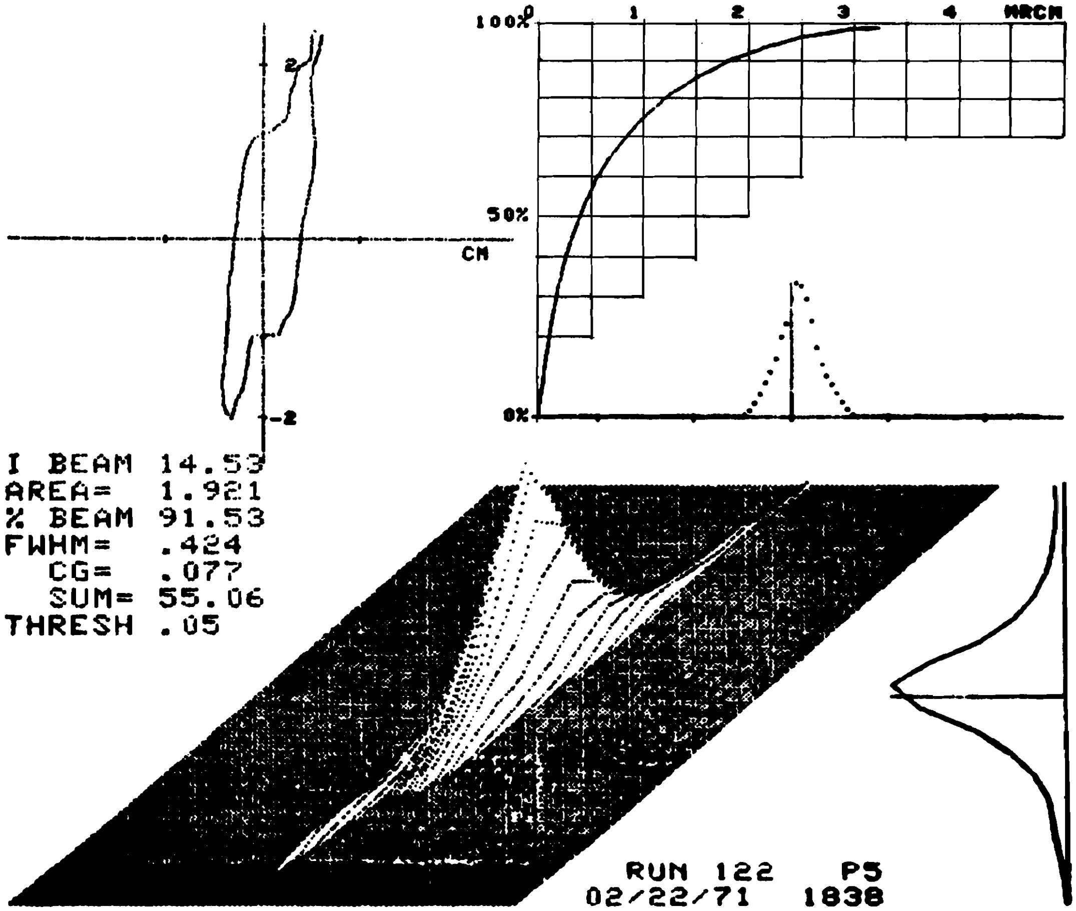


Fig. 4. Phase scan of cavity 2 for 37-MeV beam in NAL linac.



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FWHM=  .424
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 SUM=  55.06
THRESH .05
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02/22/71   1838
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Fig. 5. A 200-MeV horizontal emittance measurement in the NAL linac.