Summary of the 1990 Linear Accelerator Conference

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Before addressing the highlights of this most successful Linac Conference, it is fitting at this time to look back and reminisce some. This 1990 Linac Conference is the 15th meeting of its kind, and marks the 30th anniversary of such conferences. It is indeed a milestone. What is remarkable is that after rather modest beginnings, the field of linear accelerator technology is healthier and more rewarding than ever.

John Blewett organized the first informal Linac meeting at the Brookhaven National Laboratory (BNL) in 1960. The next year he organized the second Linac Conference which I attended, also at BNL. It had about 40 participants. It was an exciting time. That period had seen the successful completion of a host of "high energy" linacs: the 10-MeV/n heavy ion linacs at Yale and Berkeley, the 40-MeV and 50-MeV 3-tanks Minnesota and PLA Rutherford machines, the 50-MeV BNL and the European Center for Nuclear Research (CERN) injectors, etc., all these were drift tube or Alvarez proton linacs. At the same time, a 300-MeV travelling wave electron linac had been constructed and successfully operated to unheard of energies of 2-GeV at the Hansen Lab, Stanford University. These machines utilized state-of-the-art technologies including such things as home-made power amplifiers, oil and mercury diffusion pumps for vacuum, etc. The design of rf cavities was arrived at analytically and by extensive use of cold models. At that time, the still recent discovery of strong focusing by Courant and Snyder, and the Smith-Gluckstern phase stability diagram for linacs answered all possible questions concerning transverse as well as longitudinal beam dynamics. In addition, Cockroft-Walton dc accelerators and duoplasmatron ion sources had pretty well established the injection system technology. In 1960 great plans were afoot for even bigger and more powerful machines. Argonne National Laboratory (ANL) was building their 50-MeV ZGS linac injector. Stanford wanted to build a 20-GeV electron linac (ludicrous!), MURA wanted to build a 200-MeV linac injector for a device known as FFAG. Yale University had started thinking of an 800-1000 MeV linac for a meson factory. These were heady days, and most of these ambitious projects have actually come to see the light, albeit, perhaps not quite as conceived. More importantly, it is with pride that this community can look back at these "then advanced projects" and remark that their operating performance actually has exceeded the expectations.

Now! to the present!

As we now review and summarize this conference in light of the last 30 years we must ask ourselves: what's new; and where will it lead? In light of these questions one can almost answer "nothing much has happened during the last 30 years." However, I would like to point to three outstanding and entirely disconnected developments which open the way for future applications of linear accelerators to higher currents and energies, and/or more compact, energy-efficient machines.

The first and perhaps most important advance for linac technology has been the very large array of numerical calculational codes and the concurrent enormous increase in computational power available today. Cooper of Los Alamos gave a good review of available 2-D and 3-D codes which can be used for almost every conceivable design problem the accelerator designer faces. Thus, transport magnets can now be modeled with a high degree of accuracy. The same can be said of accelerating cavities and finally beam dynamics codes incorporating many forces, heretofore only grossly estimated (e.g., space charge) can now accurately predict the behavior and beam losses of linacs. This was vividly demonstrated by Garnett of LANL in a poster comparing the beam transport model and the actual performance of the Los Alamos Meson Physics Facility (LAMPF), where the calculational results actually agree with reality.

The second advance that is making a real difference to the present and future of the linac technology is the invention of the Radio Frequency Quadrupole (RFQ) by Kapchinskiy and Teplyakov of Institute for Theoretical and Experimental Physics (ITEP) and Serpukov and its development to full potential at Los Alamos. The RFQ has now become a mature technology and is used in every proton linac design presented at this conference.

Evolutionary improvements are still in progress, witness the more than 25 RFQ papers presented at this meeting. The invention and realization of the RFQ has overcome a fundamental limitation of linac technology permitting on the one hand to now produce small compact, relatively inexpensive multi-MeV ion linacs that outperform cyclotrons and on the other hand permit higher currents, high-energy linacs to be designed for higher efficiency and lower beam losses. Note Weiss's poster of CERN which demonstrated acceleration of 250 mA. Thus the RFQ has spawned a company like Accyss Technology Inc. which is successfully commercializing compact proton linacs, while making plans for very large proton accelerators such as the Accelerator Transmutation of Waste (ATW) proposed by Los Alamos realizable. A remarkable RFQ test described at this meeting is the 1-MeV RFQ developed at Los Alamos (BEAR) which operated while aboard a rocket to an apogee of 240 Km.

The third and unrelated highlight of this conference is the coming of age of superconducting rf cavity technology. Many years have gone by since Schwettman first promised wonderful things at Stanford. Since, much effort has been devoted to this technology with many disappointments. However, slowly but surely progress was made on a steady but continuous basis at many institutions. This effort is finally paying off as demonstrated by the daring decision at Continuous Electron Beam Accelerator Facility (CEBAF) to go superconducting. This decision is now vindicated by the successes achieved in reaching high fields (~9 MV/m) with increased reliability and reproducibility. Padamsee of Cornell gave an excellent review of the state-of-the-art of that technology while Hartline of CEBAF reported on the largest ongoing rf cavity Superconducting SC project, CEBAF, and Shepard of ANL described perhaps the most successful application of SC cavities to date, the ATLAS project at Argonne. It appears that this year has been a turning point in SC cavity technology in that it is now accepted as a viable option for many applications. Thus a number of projects are now being planned with SC cavities especially for electron storage ring upgrades. Superconducting niobium, rf cavity technology is here to stay and grow.

On the other hand, over the last few years, HiTc materials produced a great deal of enthusiasm, hope, and some snake oil in the linac community. However, it has become clear that if HiTc has applications in rf cavities, it is still far in the future. It is now recognized and accepted, thus the paucity of papers on the subject.

Now, I will try to pick from the more than 200 papers presented at this conference, those I thought worth highlighting. On the subject I polled six different attendees and asked them to give me their opinion. I received six different answers! This indicates the difficulty in choosing from the very rich menu presented at this conference. However, at the risk of missing some gems I will give my own biased comments.

On structures, the CERN Pb linac project is generating a resurgence of interest for low beta structures. Interesting work is going on at Gesellscchaft Fur Schwerionenforschung (GSI) on IH structures (paper by Ratzinger) and at CERN on a DTL variation called "Quasi Alvarez" (poster by Warner et al.). As mentioned earlier, there is still a lot of activity in improving RFQs, and in Japan, spurred by the JHP program, coupled cavity structures are being further developed in view of improving their performance (coupling, mode separation, etc.). This work appears to be leading towards rather fancy, expensive solutions. At this point, it is also worth noting the total absence of papers dealing with disk-and-washer. This type of accelerating structure appears to have been abandoned as being too messy (too many overlapping rf modes).

In a different context, the recent interest in linear colliders is generating totally new approaches in accelerating structure design. Experimental and theoretical studies are being pursued at a number of major institutions: Institute for High Energy Physics (KEK), Stanford Linear Accelerator Center (SLAC), Novossibirsk, CERN, etc. Perhaps the most interesting paper on the subject was that presented by Guignard of CERN. Whether these new microwave structures have a practical future remains to be seen. Their mechanical tolerance requirements of one to two orders of magnitude better than present technology is clearly beyond state-of-the-art, but it proves the point, "linacs have always been fun." Similarly, linear collider technology is generating all kinds of new, clever ideas in microwave rf power generation. Miller of SLAC really let his imagination run in presenting a paper on the subject.

On new acceleration techniques, there was very little. Coherent acceleration techniques which a few years ago generated so much enthusiasm have pretty well disappeared from the scene. However, work on wake field acceleration is continuing albeit at a slow pace. Simpson of ANL, the champion of that technology gave a good review of the field. It's still far off!

It should be noted that the incentive for these new approaches for accelerator structures is the potential for very high acceleration gradients (100's of MeV/m) which would make linear colliders look like a cinch. By the same token, one should note Weiland's paper of Deutsches Elektronen Synchrotron (DESY) for a 500 GeV linear collider based on existing technology. It doesn't look that preposterous! After all we have the Superconducting Supercollider! I believe that, as demonstrated by this paper, present technology and improvements thereon, can realistically do the job! It is worth pursuing.

Another strong push on electron linac technology albeit at lower energies is being generated by the Free Electron Laser (FEL) community. I counted 16 FEL projects currently in existence. FEL technology has very specific requirements for high brilliance, high peak current, very short pulses. The success of the technology is being driven by photocathode developments. There was a quite a number of good FEL presentations at this meeting, with few results however. I believe that the next conference, two years from now, will devote a larger portion to FEL technology. Watch for it!

Now, as we wrap up this meeting, I will add a few words on two applications which in the long run are, I believe, the drivers for the linac technology.

The first, near term application, is the development of linacs as neutron factories. It is clear that our future electricity generation will depend more and more on a nuclear power economy. That system, however, will be strongly influenced by safety considerations and institutional limitations. In this context, it is becoming evident that accelerators can play a role, whether as a fuel producer (ATP) or a waste burner (ATW) and replace fission reactors for specific applications, e.g., neutron scattering research! These ideas are not new, but their time may have finally come. Wangler and Lawrence of Los Alamos National Laboratory (LANL) gave two papers on the subject and several posters from the Soviet Union were presented as well.

In the same vein, I am sure, most of us remember the SNQ project at Julich. I will wager that the next generation neutron scattering sources will closely resemble that machine and worth noting is the design specification for the Japan Hadron Project (JHP) linac injector. It will be a high-energy, high-current, high-duty factor machine designed for neutron production. Yamazaki of KEK presented that design.

The second, longer term application, is the use of linacs for inertial confinement fusion. Work is continuing on the subject as described by Hoffmann of GSI and Bangerter of Lawrence Berkeley Laboratory (LBL). Progress is slow but steady. Lack of funding precludes leaps in the technology at this time. The induction linac versus the rf linac competition is still on. Which way to go is still unclear—on that, the jury is still out. What is important at this point in time is that there is no apparent showstopper and the effort on that technology should be further encouraged.

So, this brings us to the close of this conference. This summary does not do justice to the overall excellent quality and technical content of the more than 200 papers and posters presented here! It was a good meeting! Keep it up!