ted, one with a wiggler (0.85 T field) and the other with an undulator (6.5 cm wavelength) and the X-ray ring will have four additional straight section insertions – a superconducting wiggler (5 T field), two hybrid wigglers (1 T field), and an undulator (8 cm wavelength). These NSLS extensions are part of a funded 'Phase II' upgrade which also includes urgently required square metres to relieve the congestion in the experimental areas and to provide more office and laboratory space.

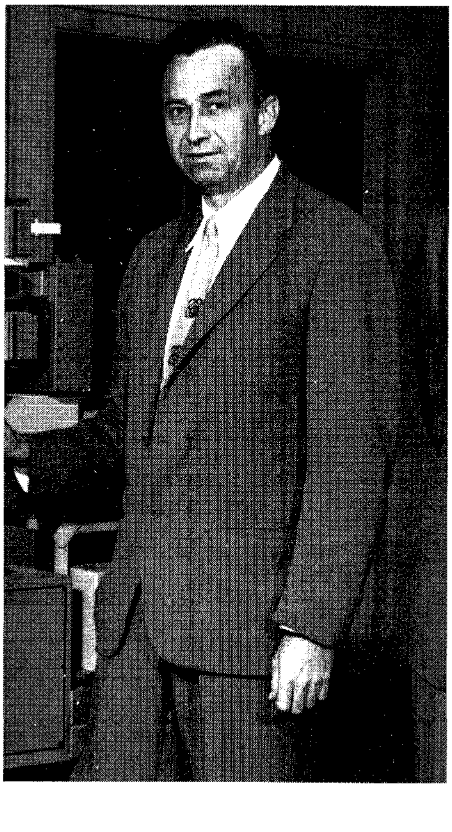
This reflects the explosion in the exploitation of synchrotron radiation for experiments and for practical applications over a wide range of areas. It is one of the most fruitful areas of 'spin-off' of the accelerator technology developed for particle physics.

Focus on focusing

The discovery and impact of the principle of strong focusing was celebrated at a history Symposium at Stanford on 25 July in the course of the 1985 US Summer School on Particle Accelerators. Burt Richter, Stanford Linac Director, who introduced all the speakers with well chosen reminders about their various contributions related to the theme of the symposium, remarked that it was an appropriate time to be lauding the great contributions of accelerator physicists following the Nobel Prize award to Simon van der Meer for outstanding achievements in accelerator physics.

Donald Kerst was the first speaker reviewing the years prior to the discovery of strong focusing when, motivated by the urge to reach higher energies and to handle particle beams more effectively, a long list of scientists helped increase knowledge of beam behaviour and of what magnetic fields do to beams. Vital steps en route to our present machines were the discovery of the cyclotron principle around 1930 (E. O. Lawrence and S. Livingston) and the discovery of phase focusing in 1945 (E. McMillan and V. I. Veksler).

In cyclotrons, the particle beams were kept focused fortuitously by the shape of the magnetic fields at the edges of the magnets in which they orbited. The effect was used more conscientiously in the weak focusing synchrotrons, like the 3 GeV Cosmotron built at Brookhaven in the early 1950s, by contouring the polefaces of the ring magnets. This was the state of the art in the summer of 1952; Stanley Livingston and Ernest Courant described the days of the discovery of strong focusing which then followed.



An album shot of Stan Livingston, architect of the strong focusing technique.

Stan Livingston had gone to Brookhaven to do physics on the 3 GeV Cosmotron and found himself working on ideas to improve the design of the weak focusing Cosmotron magnets. An additional spur was the imminent arrival of a delegation from the embryonic CERN (Odd Dahl, Rolf Wideroe, Edouard Regenstreif and Frank Goward) who were looking for ideas for the design of the projected CERN 10 GeV proton accelerator. He thought of switching the orientation of the C-shaped magnets around so that their gap faced alternately towards the inside and then towards the outside of the accelerator ring. The anticipated problem was that the focusing fields, since they would now be alternately focusing and defocusing in a particular plane of the beam, would no longer hold the beam confined.

Ernie Courant had been working on the Cosmotron straight sections and knew the mathematics to apply to the tricks Stan Livingston was trying to do. To their surprise, successive calculations with progressively stronger focusing/defocusing effects showed that, rather than being destroyed, the focusing was increased. Hartland Snyder added his contribution by generalizing the work and showing that alternating gradients gave a stable dynamic situation. What was happening was similar to sending a beam of light through a series of equal strength concave and convex lenses – the focusing effects of the concave lenses operate more powerfully than the defocusing effects of the convex lenses.

Strong focusing was born. The European delegation was first to realize the implications and rushed back to upgrade their planned accelerator to become the CERN 28 GeV proton synchrotron. Brookhaven soon followed with their proposal for the 33 GeV alternating gradient synchrotron. All the high energy accelerators from then on have had strong focusing built in.

The essence of the strong focusing idea had already been worked out independently by Nick Christofilos in a paper which was then unknown in the accelerator Laboratories (see July/August issue, page 234). In some ways, this was an even greater intellectual achievement because he was working without the immediate spur of practical problems and the interplay of ideas with his colleagues.

The first one on the ball (and not for the last time) was Robert Wilson. Bob Wilson at that time was working on a 1 GeV electron synchrotron at Cornell; he converted the design at high speed and proved the strong focusing principle in practice. He spoke at the Symposium about the big synchrotrons, a task he was eminently qualified to do since he has been a leader in the field from that electron machine through to the Fermilab Tevatron. (He also recounted his vital contribution to Ed McMillan's paper on phase stability. They were both working at Los Alamos at the time and Ed dreaded the censor's delays on getting his work through for publication to Physics Review. Bob Wilson took the paper off-site and dropped it in a mail box!)

The strong focusing principle did not only open the door to higher energy fixed target machines, it also made the era of the particle colliders possible. Fernando Amman (for leptons) and Kjell Johnsen (for hadrons) described these impacts. Fernando Amman led construction of the Adone electron-positron machine at Frascati where an adventurous leap to a 1.5 GeV machine was taken from the tentative work on AdA in 1961. He paid tribute to the contributions of Bruno Touschek and he also made the thought-provoking remark, 'If one is required to make progress, one must be allowed to make mistakes.' Kjell Johnsen led construction of the CERN ISR proton-proton Intersecting Storage Rings, perhaps the most perfect particle beam machine yet constructed. He recalled some of the staggering achievements – beam currents up to 58 A, luminosities to 1.4×10^{32}, beam-lifetimes up to 345 hours, average vacuum of 3×10^{-12} torr, etc. He compared lepton and hadron machines to cats and dogs respectively; the lepton machines somehow have their individual personalities and there isn't much we can do about them but the hadron machines if handled carefully will do whatever we want.

Finally Nicola Cabibbo and Norman Ramsey covered aspects of the early project decisions on either side of the Atlantic. Norman picked out development in accelerator technology, like the strong focusing principle, as criterion number one to urge on favourable decisions for new projects. He also picked out another criterion which perhaps deserves particular attention on both sides of the Atlantic in the present situation – 'the projects need excellent and enthusiastic proponents.'

The Symposium moved into a celebratory phase in the evening with a 'luau', traditional Hawaiian feast, which included a performance by Polynesian dancers at which the accelerator specialists were able to continue indulging their interest in coupled motion in several dimensions.

An awards ceremony followed with Burt Richter as Master of Ceremonies and Matt Sands, distinguished accelerator physicist from Santa Cruz, giving the keynote address. Honorary awards were made to Courant, Livingston and Wilson for their roles in the strong focusing discovery and proof of principle. Finally, prizes for achievements in accelerator physics were presented to Helen Edwards of Fermilab (in absentia) 'for essential contributions in making the world's first superconducting synchrotron a reality' and to John Madey of Stanford 'for the invention and demonstration of the free electron laser.'