New accelerator ideas

In the past, providing higher particle beam energies meant building bigger accelerators. It is now universally accepted that with the current generation of accelerator projects either under construction (such as LEP at CERN) or proposed (such as the Superconducting Super Collider in the US), conventional techniques are reaching their practical limit.

With the growing awareness that progress in particle physics requires new methods to accelerate particles, workshops and study groups are being set up across the world to search for ideas for the machines of tomorrow (see, for example, December 1984 issue, page 436).

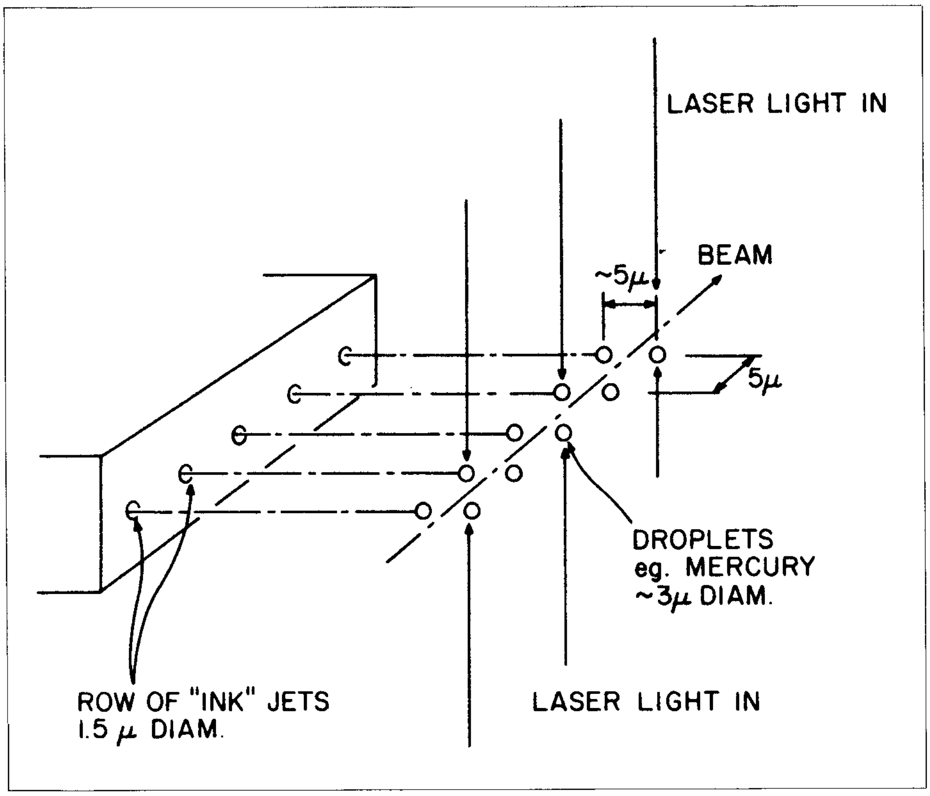
The Second Workshop on Laser Acceleration of Particles was held at UCLA (Los Angeles) from 7-17 January, the first having been held almost three years ago, at Los Alamos. This latest workshop was attended by some 120 physicists and engineers experienced in particle accelerator and laser technology, twice the number that attended the Los Alamos meeting.

In the meantime, there has been tremendous progress in the field of laser acceleration methods. This progress is a direct result of the effort by research institutions and the strong support given by funding agencies on initiatives in this area.

Despite its title, the workshop was broadened to include studies of all novel acceleration schemes irrespective of whether lasers are involved.

Substantial progress, both theoretical and experimental, has been made on all three basic types of laser accelerators: so-called near field and far field types and plasma machines. Understanding gained from detailed studies of problems on laser excitation and propagation, and on particle beam containment and stability have pointed to potentially promising schemes.

In the droplet accelerator idea, the beam passes through a miniature open linac structure formed by liquid metal micro-droplets ('ink jets') ionized by exposure to laser light.



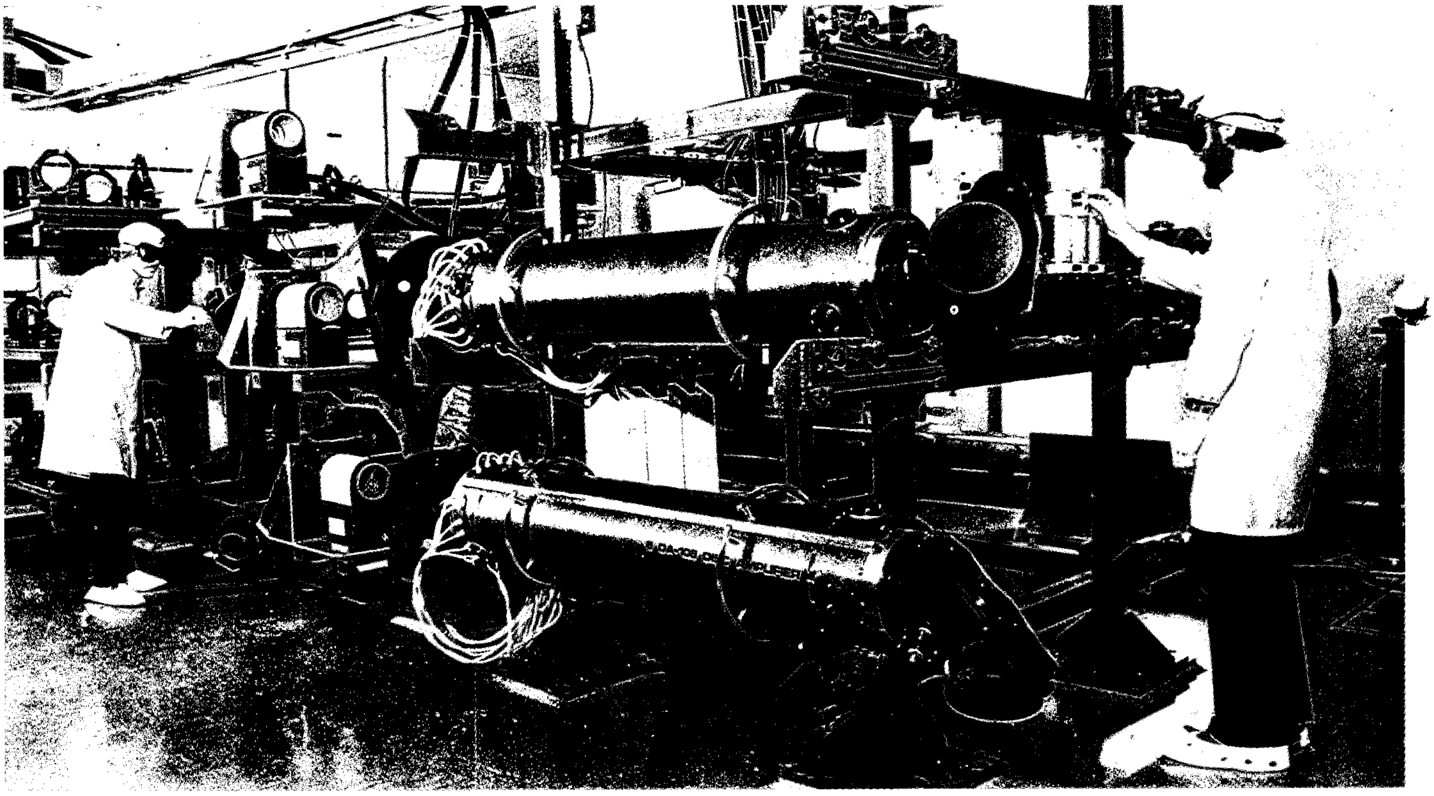
Near field accelerators are miniature open linac structures which support longitudinal accelerating field components (non-plane wave). Here the possibility of forming miniature open linac structures with liquid metal micro-droplets is under close scrutiny. The accelerating gradient in such structures is limited to about 1 GeV/m by droplets turning into plasma.

In far field accelerators the particle motion is wiggled laterally so that the particles are synchronously accelerated by the alternating transverse electric field of a plane laser wave. The main scheme is the inverse free electron laser (IFEL) in which the electron beam is wiggled by a series of alternating static magnetic fields (undulator). Since the first workshop FEL experiments have verified the theory, and the mechanism of IFEL has been observed. The acceleration rate for an IFEL accelerator is limited to less than a few hundred MeV/m and the maximum energy is restricted by synchrotron radiation loss to less than a few hundred GeV. The idea of using a gaseous medium to lower the synchrotron radiation loss was studied theoretically but experimental verification is needed. A proposal to use a wave guide with dielectric walls to keep the laser beam focused was investigated. The concept looks all right on paper, but again, should be confirmed experimentally.

The use of an IFEL to reduce the emittance of an electron beam was discussed. The damping effect is indeed present but rather weak. With presently available technology

The Vulcan laser at the Rutherford Appleton Laboratory, UK, where a beat-wave plasma accelerator experiment is underway.

(Photo RAL)



the damping length is too long to be useful. Further studies are required.

Plasma-laser accelerator concepts have been distilled down to a single scheme, the beat-wave plasma accelerator. Particles are accelerated by the very high electric field in a highly modulated high density plasma wave which is, in turn, resonantly driven by the beat-wave of two interfering laser beams. A great deal of analytical and numerical simulation work has been done since the first workshop. On the experimental side the UCLA experiment using 10.6 and 9.6 micron CO_2 radiation generated and detected the fast beat wave reproducibly over a length of 1.5 mm (limited by the size of the plasma). The electron density modulation in the wave was measured to correspond to fields in the 300 MeV/m to 1 GeV/m range.

A similar experiment is planned at the Rutherford Appleton Laboratory in the UK using 1.06 and 1.05 micron radiations from glass lasers. An unsuccessful experiment at Los Alamos using a single frequency and a long pulse from the HELIOS laser was analysed by two dimensional computer simulation and the outcome of the experiment was found to be predictable. The transverse focusing of the particles by the plasma tends to be excessively strong, making matching between stages rather difficult. This prompted people to look into very long self-focused laser channels, which appear feasible.

For non-laser accelerators, the wakefield or two-beam acceleration schemes are the most promising and have received the most attention. In a two-beam accelerator the electric field (wake field) generated by one low energy high current beam is used to accelerate a low current second beam to high energies. The two beams could travel in separate cavity structures and the field is transmitted from one cavity to the other through couplers, or the two beams could be travelling in the same cavity. In either case the ratio of the electric fields on the two beam trajectories must be very large. This is equivalent to having a large transformer ratio in a voltage step-up transformer. Experiments are being carried out at DESY (single cavity arrangement) and at Berkeley (dual cavity arrangement).

To gain full benefit from high energy colliding beams one must also have sufficiently high luminosity, hence high beam intensity and low emittance, to provide easily detectable event rates. A sizeable part of the workshop's effort was therefore devoted to examining means to fulfil requirements for repetition rate, average beam power and beam emittance.

A central problem is the production and retention of a small electron beam emittance (compactness and potential beam spread). Several methods were investigated and limiting the emittance in a damping ring looks best.

The requisite high average beam power calls for high efficiencies both in the production of laser energy and in the energy transfer from laser to particles. Although capable of extremely high peak electric field, lasers are not yet energy efficient and the construction cost per unit average power is rather high.

Energy efficiency considerations point to two new directions. The laser-to-particle energy transfer efficiency could be improved by going to lower peak accelerating field and hence, longer accelerating structure. This also accentuates the need for staging the accelerating structure and the laser source. Millimetre and centimetre waves could be used instead of optical lasers. The energy efficiency of microwave sources are much higher than that of lasers although the peak field attainable may be lower. The microwaves are induced in cavities by tightly bunched intense electron beams produced from photocathodes irradiated by pulsed laser light.

Nevertheless possibilities of developing high efficiency, high repetition rate, short pulsed lasers continue to be investigated and received much encouragement at the workshop.

The need for high luminosity also points to very low beam emittance and very strong focusing lenses and the possibility of using lasers to provide the required strong focusing is being investigated. It appears possible to obtain a focal length of 5 m for a 50 GeV electron beam.

This second workshop confirmed the promise and likely payoff of a variety of schemes. Faced with the gargantuan proportions of the SSC it is clear that the development of new methods of acceleration are the only hope for the survival of high energy accelerators and particle physics beyond the SSC. The continued support of ongoing efforts need to be supplemented by additional and intensified new activities.

From Lee Teng

Around the Laboratories

DESY
Linacs upgraded

At the German DESY Laboratory in Hamburg a plan was started two and a half years ago to improve the performance of the linear accelerators LINAC-I and LINAC-II used to inject electrons and positrons respectively into the two synchrotrons DESY-I and DESY-II (see May 1984 issue, page 151).

It was then proposed to use the energy storage cavities scheme originally developed at Stanford. This allows higher particle energy to be reached in linear accelerators without increasing power consumption, but at the expense of the length of the particle pulse.

The two DESY linacs have now been modified and storage cavities were added to improve their performance.

The 450 MeV LINAC-II was already upgraded over a year ago. There was no need for an increase of the final particle energy at this linac, but the number of emitted positrons was improved by 60 per cent and at the same time the length of the linac was reduced from 14 to 12 sections. The higher positron rate is essential to reach acceptable injection times for the HERA project, where large positron currents are required if positron-proton collisions are wanted.

The two remaining sections from LINAC-II were moved to LINAC-I, also now fitted with storage cavities, and increase the energy of the electrons provided by this machine from 55 to over 220 MeV. The efficiency of the injection into the synchrotron is much higher at 220 MeV; reaching almost 100 per cent. It was about half this value at 55 MeV. This system is