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FUTURE ACCELERATORS USING MICRO-FABRICATION TECHNOLOGY*

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Historically, each generation of new accelerators has produced a thousand-fold increase over their predecessors. Thus, the d.c. accelerators were surpassed by weak focusing cyclotrons and synchrotrons. Then strong focusing machines surpassed the weak focusing ones, and now we are in theprocess of designing machines for 10-20 TeV. This paper is devoted to the study of the next generation of accelerators which we can contemplate will be in the range of 1000 TeV. The radiation loss in a circular machine would correspond to approximately 20 TeV/turn! It is clear then that the future generation of accelerators will have to be linear accelerators. Furthermore, since the center of mass energy of a 1000 TeV machine is only approximately 1.5 TeV, these linacs will be built in pairs and operated primarily as linear colliders. This means that the average beam power in one of the devices will be quite large. This in turn leads us toward high efficiency acceleration schemes, capable of high repetition rates. The poor efficiency of laser accelerators and other exotic proposals make them poor candidates for a future generation collider.

The most straightforward approach to the problem is to improve current linac technology. There are two directions to go which clearly are desirable. One is to go to higher acceleration fields, and the other is to go to higher frequency. A penalty one pays for higher frequencies is that the number of klystrons (or other rf device) increases rapidly. Not until the frequency is high enough, and hence the klystrons small enough that they can be built using micro-fabrication technology, does increasing frequency pay off. It is necessary to produce the entire accelerating structure, rf source, modulator, phase control and instrumentation on a single "chip". Frequencies between 300-100 GHz would allow one to have thousands ofindependently phased cavities/meter.

The klystron beam, as well as the accelerated beam, must be very small in diameter, i.e., much less than the wavelength at 300-1000 GHz, which is on the order of 300-1000 microns. Typical beam diameters will be less than 30-100 microns. The practical way to focus beams of this diameter is to use electrostatic quadrupoles. Hence, It will be important to learn how to produce electrostatic quadrupole transport systems using micro-fabrication technology.

If one can achieve 100 MeV/meter, than the 1000 TeV machine is 10,000 km long. However, the transverse dimension would probably be no more than 1 mm high and 1 cm wide. The accelerator cost would have to be less than $1000/meter to make such an accelerator practical (i.e., 10 billion dollars seems like a plausible upper bound). The accelerators would contain perhaps 10^{10} klystrons, each with a peak power of approximately 200 watts. The cost would have to be brought down to approximately 0.1$/klystron to make this practical. In the light of present microfabrication costs, this does not appear unreasonable.

The development of integrated accelerator components would have far-reaching effects in fields other than high energy physics. Small, inexpensive low energy accelerators would find considerable applications in medicine and other research areas.

Site selection will present a unique challenge for the next generation machine. The question is not if it should be built in outer space. The question is where in outer space. Tidal forces will be a major factor in siting. The advantages of siting a machine in outer space are clear. There is no need for a costly tunnel and shielding. Furthermore, solar energy in outer space is continually becoming more economical, and it is reasonable to expect that solar electricity in space will be considerably cheaper than electricity on earth.** If the weight of the accelerator is kept down to about 1 gram/cm, then the total weight is approximately 1000 Tonnes. NASA estimates future payload costs at approximately 2×10^5 \$/Tonne, so the total cost of launch from earth is 200 M\$, which is not unreasonable. To put this in context, the USSR put 300 Tonnes of payload into orbit last year. A dream of high energy physicists for many years has been a truly international or world accelerator. The concept has suffered from the problem that such a machine would have to be in someone's country. Since there are no national boundaries in outer space, this next generation machine is an ideal candidate for the truly "very large accelerator".

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**This is quite a different thing from converting solar electricity in space to microwaves, beaming to earth, rectifying and producing cheap electricity on earth.