guest comment

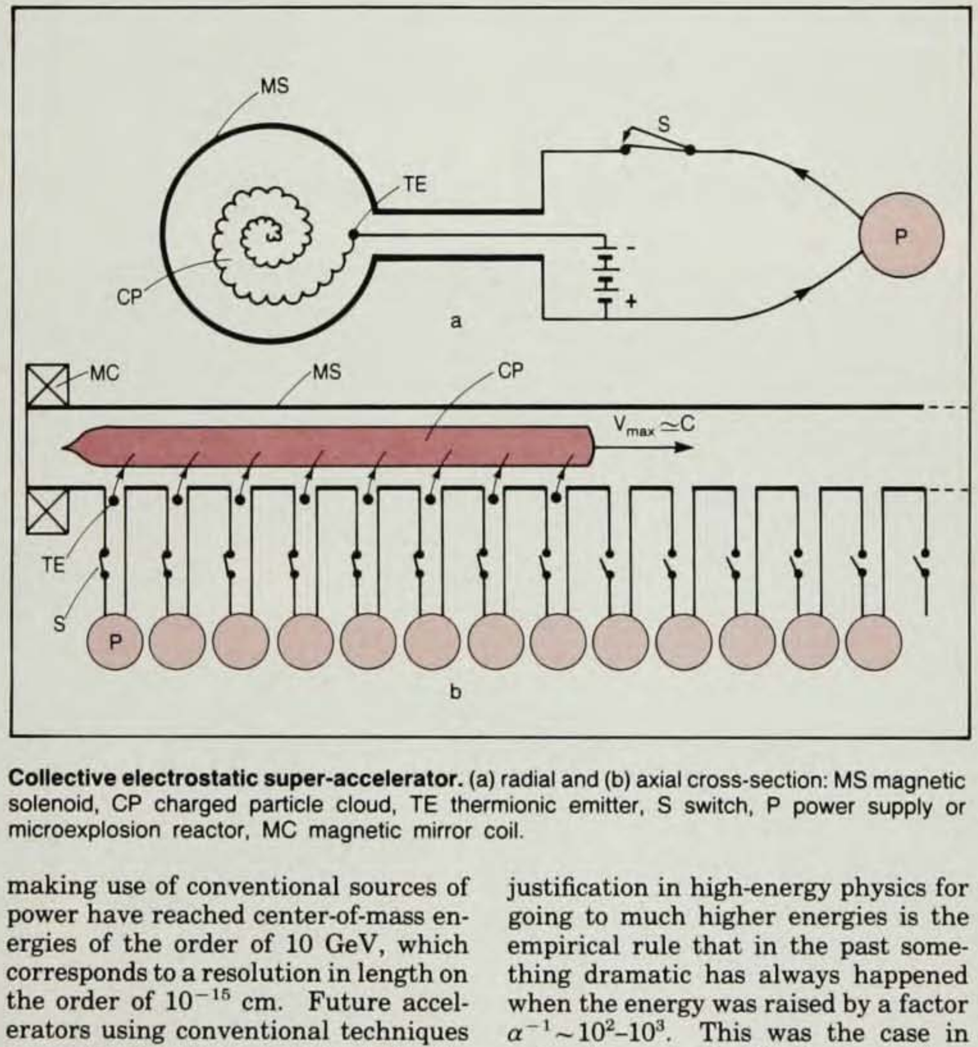
Inertial confinement fusion and basic research

Friedwardt Winterberg

It is obvious to everyone that the success of inertial confinement fusion in thermonuclear microexplosions will open the gate for an abundant unlimited source of energy and could lead to a new industrial revolution. It is less obvious, or at least less known, that inertial confinement fusion will also lead to breakthroughs in basic research.

One frontier of science is the exploration of the physical world at ever larger distances. This is the research area of space flight. Chemical propulsion has increased our knowledge up to distances of several 10^{14} cm. With the advent of inertial confinement fusion by thermonuclear microexplosions, a vastly more powerful propulsion system will come into existence that will enable us to explore nearby solar systems at a distance of a few light years (a few 10^{18} cm). Thus we see that the advent of inertial confinement fusion will increase our horizon in the macroscale by about 10^4 fold. This, in essence, is the conclusion of a study made by the British Interplanetary Society under the name Project Daedalus. Many years ago, Freeman Dyson argued that a propulsion system using large thermonuclear explosives (project Orion) might lead to a viable interstellar transport. The technical feasibility of this idea is greatly enhanced by combining thermonuclear microexplosion and superconducting magnet technology (the latter being used to reflect the fireball of the microexplosion) to obtain a high-specific-impulse, high-thrust propulsion system. This combination, which I had suggested more than ten years ago, was adopted in the Project Daedalus Study.

The other frontier in physics is in the opposite direction—to go to ever smaller distances. According to the uncertainty principle, this means ever higher energies. Particle accelerators making use of conventional sources of power have reached center-of-mass energies of the order of 10 GeV, which corresponds to a resolution in length on the order of 10^{-15} cm. Future accelerators using conventional techniques are expected to push the attainable energy up by at least one order of magnitude to 100 GeV in the center of mass. As chemical propulsion has its natural limits for space exploration, we may rightfully expect that conventional particle accelerators too have their limitations. It seems that these limitations are center-of-mass energies on the order of 10^3 GeV.



Collective electrostatic super-accelerator. (a) radial and (b) axial cross-section: MS magnetic solenoid, CP charged particle cloud, TE thermionic emitter, S switch, P power supply or microexplosion reactor, MC magnetic mirror coil.

I claim that by applying thermonuclear microexplosion techniques to particle accelerators we can achieve a breakthrough comparable to that in rocket technology. The justification for exploring the environment of neighboring suns is the well-founded belief that many of them are surrounded by planetary systems and would be very worthwhile objects of research. The justification in high-energy physics for going to much higher energies is the empirical rule that in the past something dramatic has always happened when the energy was raised by a factor $\alpha^{-1} \sim 10^2$–10^3. This was the case in going from atomic physics to nuclear physics and from nuclear physics to quark physics. Theoretically, the grand-unification energy turns out to be about α times the Planck energy, and we know that an energy jump to about 10^2 GeV is required to detect the intermediate vector boson. Using the same rule, we might expect that at an energy of 10^4–10^5 GeV new exciting things are going to happen.

A typical thermonuclear microexplosion could deliver an energy of about 10^9 Joule. The fireball of the microexplosion expands with a velocity of roughly 10^8 cm/sec and, if this energy is magnetohydrodynamically converted into an electromagnetic pulse by letting the microexplosion expand into

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a meter-size cavity permeated by a magnetic field, a gigajoule pulse with a power of 10^{15} Watt, lasting around 10^{-6} seconds, becomes a practical reality. From these numbers it is clear that this very powerful, non-classical nuclear energy source, if applied to drive accelerators, should lead to a breakthrough, analogous to the expected breakthrough in rocket propulsion. Conventional accelerator technology, however, seems unsuited for this novel energy source (just as conventional chemical-rocket technology is unsuitable for microexplosion propulsion). The collection-accelerator concept appears to have the greatest potential.

I have recently described one kind of collective accelerator that seems especially well suited to be driven by microexplosions. This concept is explained in the figure. As shown, a cloud of electrons, many-miles long, is radially injected and compressed by a solenoidal magnetic field rising in time. As a result of the buildup in electric space charge, the cloud expands axially. A radial expansion of the cloud is prevented by the confining axial magnetic field. During axial expansion more electrons are continuously injected as the head of the expanding cloud moves down the solenoid, with the front of the rising magnetic field in phase with the velocity of the expanding cloud. In the cloud, having the shape of a long cylinder, the axial electric field can become very large near the end of the cylinder, but falls off rapidly in an axial direction towards the center. Hence the electrons at the head of the cloud will be accelerated to high energies. The electrons at the center of the cloud merely provide electrostatic repulsion to accelerate the electrons at the head of the cloud. Therefore, the electric energy stored in the cloud goes selectively into a small fraction of the electrons at the head. These electrons can reach enormous energies if the cloud is made long enough. In the first generation of this novel collective accelerator, the compression of the magnetic field, and with it the compression of the electron cloud, can be done by inexpensive but large inductive energy-storage devices. However, in the second generation version these energy sources would be replaced by microexplosion reactors, positioned along the entire many-mile-long accelerator. With a maximum magnetic field on the order of 10^5 Gauss, attainable with conventional inductive energy-storage devices, the electric field at the front end of the cloud can be as large as 10^7 V/cm and if the accelerator is 10 km long, energies of 10^4 GeV could be reached. With thermonuclear microexplosion reactors, however, the magnetic field can be easily compressed to megagauss values and the final energies could exceed 10^5 GeV.

The maximum attainable beam power in such a particle accelerator would be also enormous, because the electron cloud is rather dense. For example, at an energy of 10^5 GeV, a current of about 3×10^5 A is possible with a power of roughly 3×10^{19} Watt.

To get very large energies in the center of mass, two single pass colliders, making use of this concept, would be required. With such accelerator energies, about 10^3 times larger than what is possible with conventional accelerators, the resolution of length would be pushed from the soon to be expected 10^{-16} cm down to 10^{-19} cm or less. This is about the same order of magnitude as the increase in the distances that could be achieved using rocket propulsion powered by thermonuclear microbombs. ☐