Experimental check on the method of accelerating charged particles in a backward wave

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Results are presented of the first experimental investigations of a new method of heavy-particle acceleration, with the backward harmonic of a traveling electromagnetic field.

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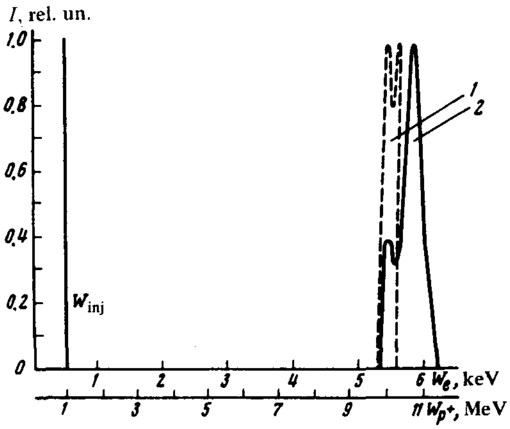
In the development of linear accelerators, the designers constantly strive to raise the specific energy increment of the particles (this decreases the accelerator length), to increase the frequency of the employed HF generator (to decrease the transverse dimensions), and of course to increase the accelerated-particle beam current and the over-all efficiency of the apparatus. For heavy charged particles at nonrelativistic energies, the traditional approach, accelerators using resonators with drift tubes, ensures a rate $\Delta W/\Delta z \sim 2$ to 3 MeV/m (for protons and a current $I \sim 150$ to 200 mA, using HF sources of frequency $f \sim 150$ to 200 MHz. On the other hand, traveling-wave electron accelerators have $\Delta W/z \sim 10$–15 MeV/m, and I up to 10 A and more. They operate at $f \sim 1.3$ to 10 GHz. The desirability of using a traveling wave and the difficulties associated with it are well known.[1-3]

The problem is formulated in the following manner: produce along the particle trajectory large accelerating fields ($E_z \gtrsim 100$ kV/cm) at large decrease of the phase velocity of the wave ($n = c/v_{ph} \sim 35$ to 3) and at moderate HF energy dissipation.

The method of acceleration with a backward spatial harmonic, in which the HF energy flux is directed *opposite* to the particles, proposed in[3], called for the development of methods of "synthesizing" an accelerating structure and of calculating the particle dynamics in it,[4] as well as experimentally verifying the correspondence of the mathematical formulation of the problem to the physical acceleration process. In accordance with the calculations,[4] an accelerating structure of the "two-row interdigital transducer in a rectangular waveguide" type, and "cold" and "hot" investigations were made of its characteristics. In the "hot" measurements we injected into a structure of length 126 cm and 5.2 cm diam, intended for the acceleration of protons (p_+) from 1 to 10 MeV with a current 300 mA, an electron beam with $W = 545$ eV (relative velocity $\beta = 0.046$, corresponding to 1-MeV injection of the p_+ beam (and a current 55 μA (equivalent of 0.1 A of p_+).

To prevent loss of particles, we used a longitudinal magnetic field. The electron beam of 2 mm diam "passed through" the system (in the absence of HF fields) at $B = 32$ G (corresponding to 58.7 kG for p_+).



Theoretical (1) and experimental (2) energy spectra of particles accelerated with a backward spatial harmonic of a traveling electromagnetic field.

The beam diameter at the exit was less than 3 mm. When HF power (6.5 W, $f = 1.82$ GHz) was applied on the exit end (i.e., opposite the injection end) of the structure, the particle energy increased by 10 times (to 5.5 keV, corresponding to $W_{p_+} = 10$ MeV). The electron energy was measured by applying a blocking potential on an insulated ring mounted in front of the current receiver. The figure shows the theoretical (1) and experimental (2) energy spectra of the particles accelerated with the backward wave.

By the same token, we have experimentally demonstrated the feasibility and prospects of a method of accelerating heavy charged particles with a backward spatial harmonic of a traveling electromagnetic field.

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