BUNCHERS

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Without prebunching, a linear accelerator operating at a stable phase angle 30 degrees from the peak of the rf wave can accept about 20% of the beam from its preinjector. With a conventional single gap buncher this fraction can be increased to about 50%. The present investigation which is still in progress has as its goal the design of more sophisticated bunching techniques to increase this fraction to a value as close as possible to 100%.

The solution of this problem is particularly important not only at the entrance to the linac but also at any point where frequency is changed and rebunching of the beam without loss is desirable.

It is possible to apply the bunching procedure used in electron linear accelerators, in which fields and stable phase angles are graded continuously from low initial values and 100% beam capture is achieved. The chief disadvantage of this technique, when applied to proton linacs is the length and complexity of the bunching element. In the Stanford buncher several phase oscillations are necessary before bunching is achieved. Scaled to the proton equivalent this buncher would be at least 20 feet long. Detailed analysis and determination of precise dimensions of this type of buncher have been postponed pending the investigation now in progress and to be described below.

The present study is an attempt to transfer the ideas of "wrong frequency" bunching used in proton synchrotrons to the linear accelerator case.

In the proton synchrotron* capture efficiencies of about 80% are achieved by setting frequency so that the beam in a Ø' vs Ø plot lies outside of the phase stable region. After a short time a strong bunching action takes place and the phase stable region is then shifted discontinuously to cover the proton bunch. In the linear accelerator the frequency shift appropriate in the synchrotron is replaced by a change in phase velocity.

Typical cases which have been considered are illustrated by Fig. 1, which is a plot of Ø' vs Ø for the case of a stable phase angle of 40° (50 degrees from the peak of the wave). Shown in the graph are the boundaries of the phase stable region and their extensions into the region of instability. The problem now is to establish a physically realizable set of initial conditions which will result in a tightly bunched particle beam in a reasonable distance.

Thus far this problem has been analyzed using only a single traveling wave component of accelerating field. When promising conditions are established with this approach, it is intended to proceed to the step by step analysis appropriate for a drift-tube accelerator.

Two sets of initial conditions are fairly easily realized. The simplest is a line representing the relation Ø' constant and corresponding to the constant energy output of a preaccelerator. The second is the roughly sinusoidal curve in the Ø' vs Ø plot obtained when a gap immediately ahead of the bunching structure is modulated at the radiofrequency. Inclusion of a drift space can lead also to the S-shaped curves characteristic of the conventional buncher.

Trying to guess a suitable set of initial conditions in the Ø' vs Ø plot has not proved to be profitable and now the procedure has been

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*1961 International Conference on High Energy Accelerators, K. Johnsen, p. 194; E. D. Courant p. 201

adopted of assuming a bunched beam and integrating backwards to establish what must have been the initial conditions.

Thus far integrations have been run back from the regions indicated in Fig. 1 by the numbers 1, 2 and 3. Integration back over a distance of about 1 meter from region 1 at no time yields a set of realizable starting positions. From region 2 the results are more encouraging. About 40 centimeters back one finds the situation labeled 2a, which can be fairly closely approximated by a sine wave corresponding to 130 kv modulation. When this is used as an initial condition in the region around 2a between 80% and 90% of the beam concentrates in the region around line 2. From the region labeled 3 initial conditions approximating constant injection energy result at distances some 40 to 70 centimeters earlier. The region in the neighborhood of 3 is now under investigation and is considered at present to be the most promising. Preliminary results indicate that little, if any, premodulation will be required to give a bunched beam in this region.

Discussion

K. Johnsen (CERN): I would like to make a remark on this process. Firstly, we should not forget that the process which we now use in the PS is a convenient process, but certainly not theoretically the best process. During this process we have no, or little acceleration. In fact this type of bunching would look better with a reduced $\dot{B}$, and for this reason, the AGS, with a small $\dot{B}$ has a better bunching action than the PS with a larger $\dot{B}$. But now this leads us to say that therefore instead of doing this, you would prefer, for example, to run a small linac section with a much lower phase velocity, but then you are back approximately to the original buncher. Are you not doing in a complicated way what is possible to do in a simple way? With the simple buncher all parameters are available for adjustment, but here you are limited to what you build into the machine.

J.P. Blewett (BNL): We assume that this would be a separate bunching unit, which would be of the order of 50 cm long; it would have a relatively small number of drift tubes and be a fairly simple device.

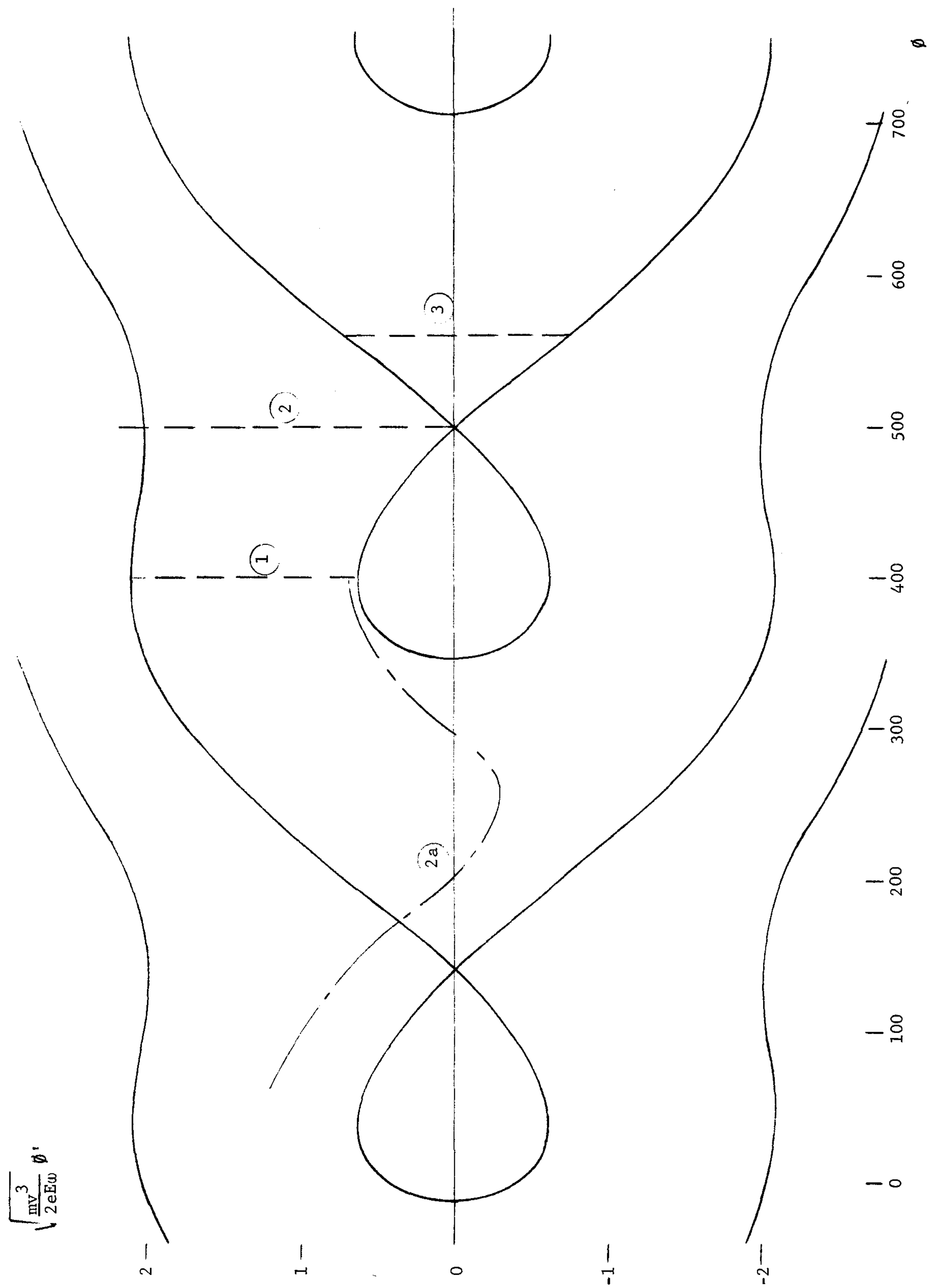
K. Johnsen (CERN): Yes, but I cannot see what you gain over a single gap.

J.P. Blewett (BNL): We hope to succeed in curling up the area in phase space into a region that can be enclosed in the linac's region of stable phase.

L. Smith (LRL): Have you ever tried to calculate two bunchers, one being excited at a third harmonic of the first?

J.P. Blewett (BNL): No. This is another possibility.

K. Johnsen (CERN): One remark I would like to make here and that is that normally we would say that the bunching efficiency is given by the relative number of particles you can get inside the bucket. From a buncher one obtains in phase space an S-shaped curve on which the linac bucket is superposed. Considerably more than 50% of the buncher output can be enclosed, therefore you should have a high trapping efficiency and you have a good buncher. However, for certain purposes, you may ask for a different thing, namely, maximum phase space density in a much smaller region. In other words, you are prepared to throw away 50%, maybe even 75% of your beam, if you can have a high phase space density. For instance this has become very important for our storage ring studies, because it does not matter too much for us whether we stack 500 of 1000 pulses; what does matter is the phase space density. Secondly, we seem to have a good memory through linacs, and I think we shall have to rely on this memory if we are to use a linac of above 1 Bev for injection into a big machine. There the energy spread, in other words the efficiency by which we can put the beam near the center of the bucket, is very important, because that affects directly the spectrum at the output end. If you can put 50% of the beam into the central 10% of the bucket it would be much better than 75% of the beam in the whole area. For this reason it may be desirable to reduce the buncher voltage and to increase the drift space accordingly.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2
1
0
-1
-2
0
100
200
300
400
500
600
700
ϕ
1
2
2a
3

Fig. 1