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CERAMIC LOADED BUNCHER FOR LINEAR ACCELERATORS

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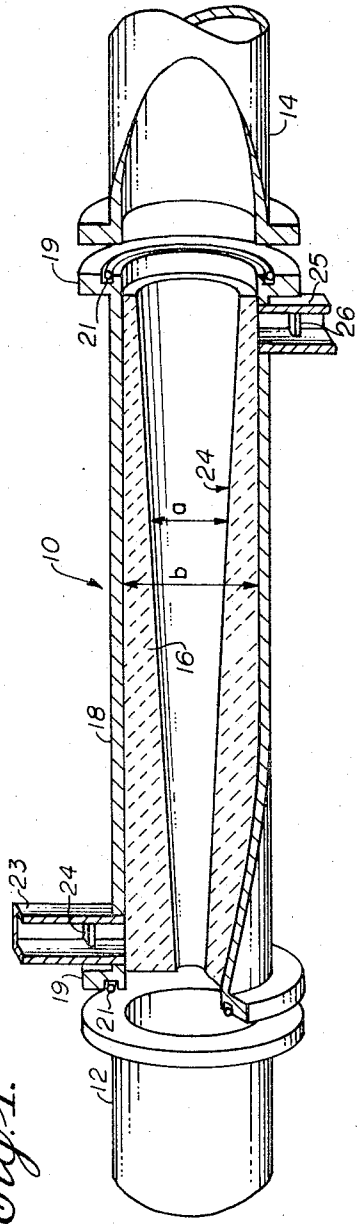


Fig. 1.

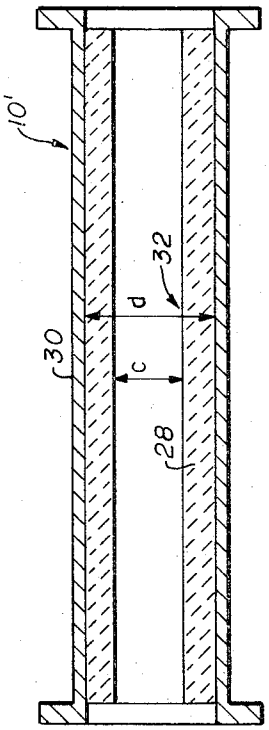


Fig. 2.

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CERAMIC LOADED BUNCHER FOR LINEAR ACCELERATORS

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ABSTRACT OF THE DISCLOSURE

A waveguide provided with an internal dielectric jacket having an aperture that has either a smooth cylindrical surface or a smooth tapered surface for bunching charged particles without generation of space harmonics. The dielectric constant of either type of jacket and its dimensions at the particle injection point are such as to enable propagation of radio-frequency driving power applied at the injection point to be at a velocity slightly greater than that of the injected particles. The tapered jacket causes the phase velocity of the driving power to increase along the diverging portion of the jacket to accelerate as well as bunch the particles.

The invention disclosed herein was made under, or in, the course of Contract No. AT(04-3)-363 with the United States Atomic Energy Commission.

The present invention relates generally to charged particle bunchers and in particular to a ceramic loaded buncher for bunching charged particles generated by a particle source prior to their injection into a linear accelerator.

Previously known bunchers consist of periodically loaded all-metal waveguide structures where the loading is either of tapered or constant dimension configuration. Such periodically loaded bunchers achieve bunching, viz., provide the desired phase velocity and bunching under constant or varying velocity conditions, but they also introduce space harmonics which tend to counteract the desired condition by causing a debunching effect on the beam. Furthermore, prior bunchers of the periodically loaded type are inherently quite difficult to match to the radio-frequency source and adjacent accelerator section, and to tune to the desired frequency.

The present invention overcomes the above-noted shortcomings by providing a constant velocity, or a varied-velocity, buncher of novel configuration constructed of a ceramic material which inherently generates no space harmonics.

Accordingly, it is an object of the present invention to provide a particle beam buncher employing a unique construction designed to generate a specific axial electric field having no space harmonic components.

It is another object of the present invention to provide a varied velocity beam buncher employing a continuous, tapered, ceramic jacket coaxially mounted within a length of waveguide.

It is yet another object of the present invention to provide a constant velocity beam buncher employing a continuous cylindrical ceramic jacket coaxially mounted within a length of waveguide.

It is a further object of the present invention to provide a charged particle beam buncher which is easily matched to a radio-frequency source and to an adjacent accelerator section.

Further objects and advantages will become apparent from the following description considered together with the accompanying drawing, in which:

FIGURE 1 is a simplified cross section schematic view

of an embodiment of the invention employing a continuous, tapered, ceramic jacket configuration, and,

FIGURE 2 is a simplified cross section schematic view of an alternative embodiment of the invention employing a continuous, cylindrical, ceramic jacket configuration.

Referring to FIG. 1 there is shown a ceramic buncher **10** embodying the mechanism of the present invention and disposed to receive a particle beam from a charged particle gun **12** at the entrance thereof, and emit the resulting bunched beam from the exit thereof to a first section of an accelerator tube **14**. A tapered jacket **16**, formed of ceramic material, and having a continuous, diverging inner surface starting from the beam entrance end and progressing towards the beam exit end thereof, is coaxially disposed within a cylindrical length of matching waveguide **18**. The jacket **16** must be formed of a material which is non-conductive, has a very high dielectric constant, and is capable of withstanding the relatively high temperatures generated within the buncher. Since ceramic material exhibits all the above properties, it is utilized in the construction of the jacket **16** although any other material which exhibits the aforementioned requisite properties could be likewise used. The waveguide **18** is secured in vacuum-sealed relation to the gun and to the accelerator by means of suitable flanges **19** disposed at either end thereof; the seal being provided by conventional gaskets, such as for example O rings **21**, or suitable all metal gaskets.

Radio-frequency driving power from a suitable power source, such as a klystron tube (not shown), is introduced to the buncher **10** through a radio-frequency transition or input coupler **23**, which is in essence a length of rectangular waveguide secured at one end within a suitable opening in the wall of the cylindrical waveguide **18**. An iris **24** is also disposed within the coupler to provide for suitable matching between the rectangular input waveguide and the circular buncher **10**. An output coupler **25**, similar to coupler **23** and having a matching iris **26**, is coupled to the opposite end of buncher **10** in like configuration, and provides for extraction of any remaining radio-frequency driving power which is introduced through coupler **23**. Since the coupling of power from a rectangular waveguide to a circular waveguide is well known in the art, further description thereof is believed unnecessary herein.

To achieve the desired phase velocity variation it is necessary to properly choose the variation of dimensions of the tapered ceramic jacket **16**, viz., the dimensions *a* and *b*, as well as the type, or density, of the ceramic employed in the construction of the jacket. That is, the dielectric constant of the ceramic utilized in forming the jacket **16**, taken in conjunction with the dimensions *a* and *b*, determines the particular phase velocity variation as a function of length and hence the buncher operating characteristics. The continuous-surface, tapered configuration of the buncher in accordance with the invention provides a unique design which operates to smoothly increase the phase velocity of the electron beam from its injection velocity at the entrance to substantially the velocity of light at the exit thereof.

FIG. 2 shows an alternative embodiment of the present invention, in effect, a constant velocity buncher **10'**. The buncher **10'** is placed between a gun (not shown) and a first section of a linear accelerator (not shown) as described in conjunction with the buncher **10** of FIG. 1. A cylindrical jacket **28** of constant diameter, preferably formed of ceramic, is coaxially disposed within a length of cylindrical waveguide **30**, which waveguide is adapted with flanges and secured in vacuum tight relation between the gun and accelerator. The desired constant phase velocity is achieved by use of the ceramic jacket **28** of constant diameter, viz., where *c* and *d* are made constant

as a function of buncher length, and specifically chosen in relation to the particular dielectric constant of the ceramic employed in the construction of the jacket. Radio-frequency power is introduced to, and extracted from, the buncher **10'** through a coupler system (not shown) in the same manner as heretofore described in conjunction with the buncher **10** of FIGURE 1.

There are various ceramic materials which exhibit satisfactory dielectric constants and high temperature characteristics and which therefore may be utilized as suitable material for forming the jackets **16** and **28** of the invention. For example, the preferred value of dielectric constant ϵ is generally within the range of from four to ten, i.e., $4<\epsilon<10$. Materials which exhibit dielectric constants within this range include; aluminum oxide with $\epsilon=9$; beryllium oxide with $\epsilon=7$, and very good heat conductivity characteristics which are desirous in a buncher which is to be used in a very high energy application; quartz with $\epsilon=4$, but which contains bubbles throughout its structure and is thereof not as desirable a material. There are in addition certain artificial dielectric materials of epoxy bases which exhibit a dielectric constant of satisfactory value but which exhibit generally a lower high temperature characteristic.

The following exemplify operating parameters for the invention of FIGURE 2 wherein the dimensions *c* and *d* are equal to 0.750 inch and 1.750 inches respectively, and wherein aluminum oxide with a dielectric constant equal to 9 is used as a material for forming the jacket **28**:

For: $v_p/c=\frac{1}{3}$, $f=10{,}000$ mc./sec.
$v_p/c=\frac{1}{2}$, $f=3{,}000$ mc./sec.
$v_p/c=1$, $f=2{,}400$ mc./sec.

Hence, for a beam emerging from a gun at a velocity

$$v_b=\frac{c}{3}$$

a constant velocity buncher of the above dimensions, designed to give a phase velocity

$$v_p=\frac{c}{2}$$

would operate from a radio frequency source at 3,000 mc./sec.

To remove any stray electrical charges collected by the inside wall of the ceramic jackets (**16, 28**) of the invention, a light coating or atomic layer (**24, 32**) of electrically conductive material such as for example copper may be disposed on the inside surface thereof. The coating or layer (**24, 32**) could likewise be a low-pitch, fine, helix wire wound within the inside surface of the ceramic jackets (**16, 28**) wherein the material forming the layer is of proper thickness compatible with the proper transmission of the characteristic TM_{01} mode which is propagated through the buncher.

While the invention has been disclosed with respect to a single and an alternative embodiment, it will be apparent that the spirit and scope of the invention is not intended to limit the invention except as defined in the following claims.

What is claimed is:

1. A continuously loaded beam buncher connected between a source of charged particles and an accelerator, comprising

(a) an elongated waveguide;

(b) a dielectric jacket coaxially fitted within said waveguide, said jacket defining a tapered aperture having a smooth surface that diverges from said source to said accelerator with a predetermined slope; and

(c) means for continuously applying radio-frequency driving power of a constant frequency to the portion of said waveguide adjacent said source for bunching and accelerating said charged particles for injection into said accelerator.

2. The buncher defined in claim **1**, wherein said source emits said particles at a velocity less than that of light, said jacket is comprised of a ceramic having a dielectric constant and dimensions such as to propagate said applied radio-frequency driving power from a velocity slightly greater than that of said emitted particles to a velocity nearly equal to that of light for acceleration of said particles to substantially the velocity of light.

3. The buncher defined in claim **2**, wherein said dielectric constant is within the range of four to ten.

4. The buncher defined in claim **3**, wherein the thickness of said ceramic jacket adjacent said accelerator is such as to propagate said radio-frequency driving power at a velocity nearly equal to that of light.

5. The buncher defined in claim **1**, wherein said jacket diverges from said source to said accelerator with a constant slope.

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