ACCELERATING STRUCTURE WITH CHAIN-LIKE ELECTRODE CONFIGURATION

M. Odera, M. Hemmi
RIKEN, Institute of Phys. and Chem. Research, Wako-shi,
Saitama, 351-01, Japan

Summary

A structure having a chain-like accelerating electrodeconfiguration fitted inside of cylindrical cavity resonating with an Alvarez-type TM-010 mode was proposed and is being studied. The structure was devised to utilize quadrupolar electric field produced by high frequency field by a particular electrode configuration for focusing of the heavy-ions at medium velocity region, instead of ordinary magnetic quadrupoles. Its study is only at a preliminary stage at present, nevertheless, possibility to get moderate effective shunt impedance for region of velocity of more than a few percent of that of light has been revealed.

Introduction

Recent success of the RFQ linacs which use high frequency electric field not only for acceleration but also for focusing has solved most problems associated with acceleration of intense low velocity ions.[1] There are many plans to apply this technology for acceleration of light and heavy ions to be used for variety of basic researches and applications.

On the other hand, the idea of spatially uniform acceleration and focusing scheme of Kapchinsky and Teplyakov[2] which forms basis of the RFQ linacs is known to be applicable only to a low energy region, 1 MeV/n or less because of its low effective shunt impedance. Acceleration to the higher energy is usually done by the ordinary Alvarez linacs. Boussard tried focusing by the high frequency accelerating field at the higher energies by attaching circular rods to the face of drift tubes.[3] Similar configuration was proposed by R. W. Muller for his split coaxial structure.[4] Realization of acceleration of intense beam of heavy ions with a small charge to mass ratio by the Muller's linac, proved feasibility of the RFQ linac other than the vane type, though its application was for low energy heavy projectiles.

We propose to study another structure. It looks like a chain which is composed by interlacing horizontal and vertical members which have four sides. The interlaced structure is different from that of the Boussard's configuration developed from the drift tube array of the usual linacs. Though its study still remains in a preliminary stage and its geometry is not optimized yet, relatively good acceleration efficiency has been found for geometries used for the two models studied.

Resonator

For the both models, a cylinder made of copper sheet reinforced with aluminum bar has been used as an common envelope. Only the electrode structures inside has been interchanged.

Electrode Structure

Figure 1 shows how to assemble the chain-like structure. The model constructed at first has this shape. Figure 2 is an outlook of a portion of the second model. Though it looks different from the structure of the first one, its principle of construction is the same with that of the latter. Main difference is cutting off of the various part of the electrode of the first, so that generation of too strong surface field may be avoided.

Stems are attached to the center of the longitudinal parallel members as shown in the photograph, Fig. 3.

Field Measurements

Magnetic analogue as well as high frequency models were used for study of the characteristics of the chain structure. The magnetic models are necessary to know axial and radial field components separately. The field configuration in the structure is expected to have azimuthal periodicity of pi, especially in the region of focusing. All the RFQ structures have such a periodicity. Detailed study of the behavior of the field components as a function of the radial, azimuthal and longitudinal coordinates is difficult with high frequency models.

Only constant velocity high frequency models have been constructed and no measurements of field tilt along the acceleration axis have been made until now.

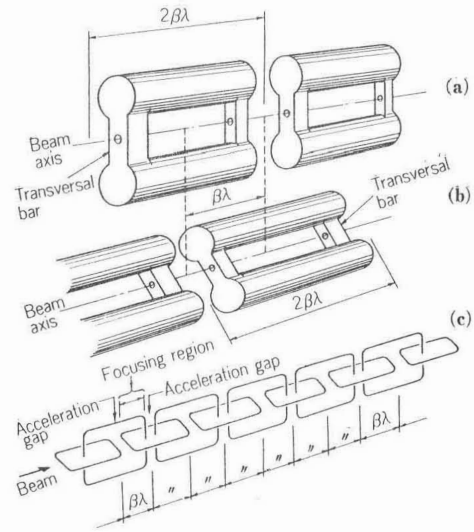

Fig. 1 How to combine electrodes to form a chain-like accelerating structure. (b) is rotated around the beam axis by 90 degrees compared to (a). (c) shows interlacing of (a) and (b).

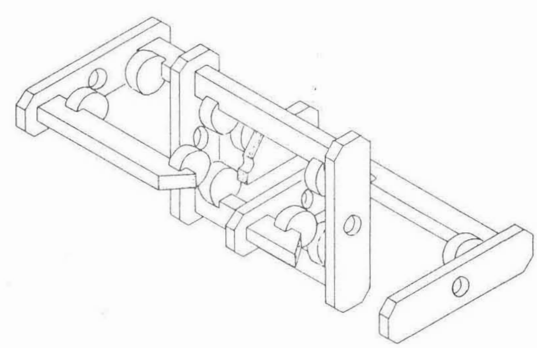

Fig. 2 Cut-away view of the Type 2 electrode structure.

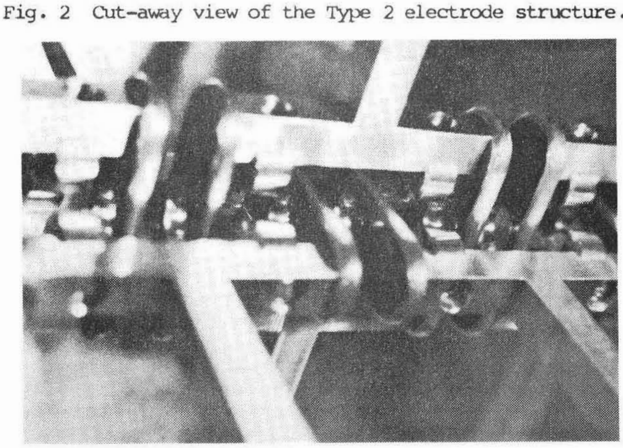

Fig. 3 Photograph of the Type 2 electrode array.

Axial Field. Fig. 4 shows axial field distribution in one cell along the central beam axis of the Fig. 1 which we name Type 1. Fig. 5 is a similar measurement for the second model which we call Type 2. Smoother transition from positive to negative field for the Type 2 than for the Type 1 is caused by a much larger beam aperture of the former than for the latter. It is 14 mm in diameter for the Type 1, whereas for the Type 2, it is only 6 mm. The large aperture was necessary to measure off-axis field.

Fig. 6 gives such an example of difference in axial field distribution along lines 3 mm off axis but on the azimuthal position different by 90 degrees.

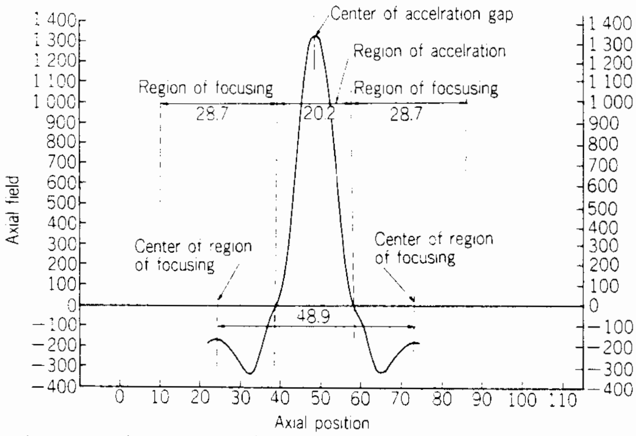

Fig. 4 Axial field distribution along the central axis of the Type 1 structure.

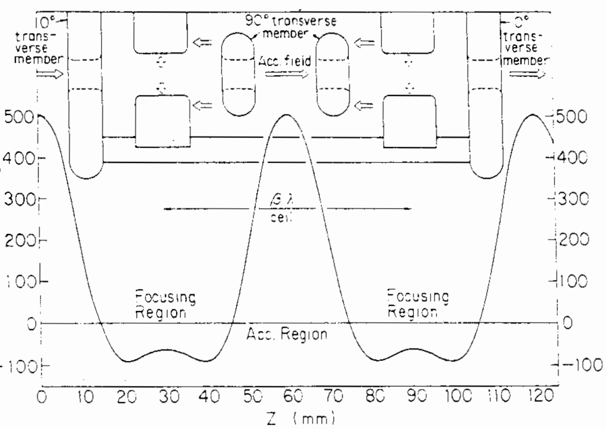

Fig. 5 Axial field distribution along the central axis of the Type 2 structure.

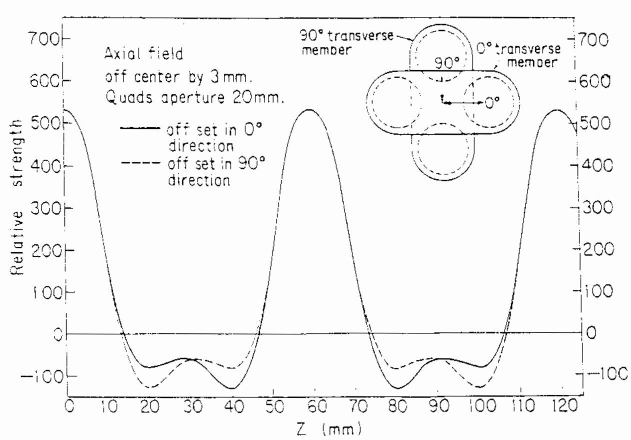

Fig.6 Axial field distribution along lines 3 mm off axis of the Type 2. In the focusing region, the distribution changes according to the azimuthal positions of the lines.

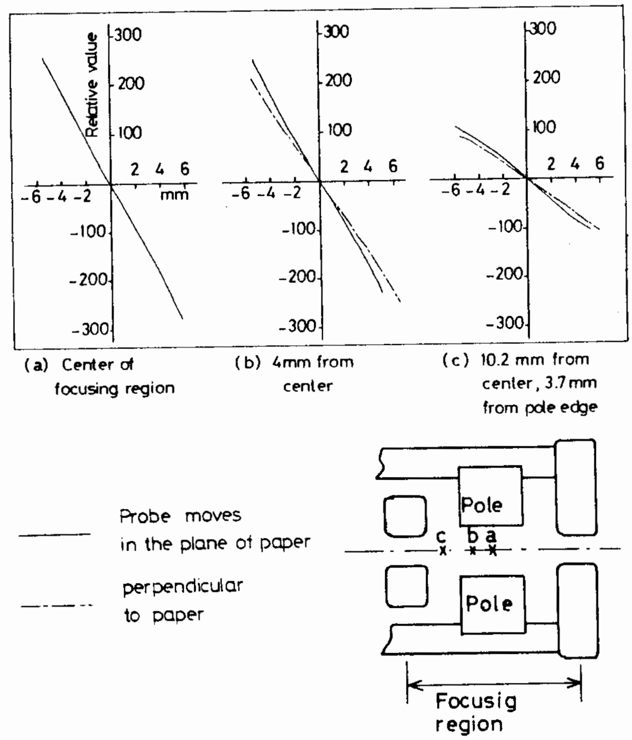

Fig. 7 Focusing radial field. (a) Center of the focusing region. (b) 4 mm from the center. (c) 10.2 mm from the center. Longitudinal length of the focusing electrode is 13 mm and distance between the electrode chips is 20 mm. Dependence of the focusing field on the azimuthal position is clearly seen.

Radial Field. Figure 7 shows measured radial field for the Type 2 at the two azimuthal angles 90 degrees apart. (a) is the distribution at the center of the focusing region. Longitudinal length of the pole which generates the quadrupolar field is 13 mm and distance between the pole tips in the opposite azimuthal angle is 20 mm. The radial fields for the two angles at the center almost coincides with each other. (b) is the measurements at the longitudinal position 4mm displaced from the center. (c) is for the position 10.2 mm from the center or 3.7 mm outward from the edge of the pole. Dependence of focusing strength on the azimuthal and axial positions is clearly seen in the figures.

Results and Discussions

Energy Gain

From the measured axial field distribution, energy gain per cell and focusing strength can be calculated. For instance, for an accelerating gradient of 1 MV/m of the TM-010 mode, we found 84 keV times phase factor of the synchronous particle as the gain of energy per cell for a singly charged projectile in the Type 2 structure. The gain corresponds to 1.4 MeV/m for the projectile with stable phase at the crest of the RF.

The calculated energy gain is larger than that expected for an Alvarez linac having the same field gradient and cell length, in this case 60mm and gap to cell ratio of 1/4.

Reason of the large energy gain is as follows: First, the potential difference which appears across the accelerating gap is larger than that corresponding to length of a cell, because distance between the stems supporting the electrodes is two cell instead of one cell for the Alvarez case; Second, as seen in Fig. 4 and 5, there exists axial field with reversed sign in the focusing region. Though it is not strong as in the accelerating gaps, still gives π-mode acceleration effect. Since axial length of the focusing region was made relatively large in the model, transit time factor is small and is 60% or less. Probably the value may be improved by choosing shorter length for the focusing region if focusing strength allows to do so. In the present geometry, the focusing field gradient is 18 kV/cm. The quadrupole gradient is adjustable by choosing distance between pole chips.

Effective shunt impedance

It was estimated by comparing Q-values of the structure with that of an Alvarez type for which calculation code can give fairly good prediction of distribution of power dissipation in the cavity. For the structure of Fig. 1 of which resonant frequency was 324 MHz, it was something around three times of that for an ordinary Alvarez type. For the type of Fig. 2, such a comparison has not be made yet. However, rough estimation shows the ratio of shunt impedance of this structure and the Alvarez type is smaller than the value for Fig. 1 mentioned above.

Items of Further Study

Effect of Geometrical Parameters On the other hand, we found considerable dependence of the energy gain on the various geometrical parameters of the cell like beam aperture in the accelerating electrode, thickness of electrode and so on. Correlation and weight of the parameters on the field distribution and energy gain must be studied in detail before fabrication of any velocity dependent model.

Orbit Dynamics There is a periodicity of π in longitudinal and transversal field around the beam axis in the focusing region as noted above. Its effect on beam trajectory must be studied numerically. Its code is being prepared. Since its field pattern is similar to the RFQ's, especially to that of Muller's split coaxial resonator loaded with thin drift tubes with fingers, probably no serious difficulty will be met.

Dependence on Velocity of the Effective Shunt Impedance. This structure looks like a multistem structure of Alvarez type. But its acceleration mode is 2π-mode between neighbouring acceleration regions helped with a small π-mode effect in the focusing region. Comparison between Fig. 1 and Fig. 2 suggests dependency similar to the Wideroe structures for the effective shunt impedance on velocity of ions. However, the two models have quite different shape and an exact comparison is not possible. Further study is necessary.

Acknowledgement

We are grateful to Mr. T. Chiba for his advice and help in design of the structure. Dr. M. Hara helped us by calculation of the cavity characteristics with his finite element code.

References

1 T.P.Wangler and R.H.Stokes: IEEE NS-28 1494 (1981)
2 I.M.Kapchinsky and V.A.Teplyakov: Pribori i Tekhn. Eksp. 17 19 (1970)
3 D.Boussard: IEEE NS-12 640 (1965) ; Compt Rend. Acad. Sci. 265 4665 (1965)
4 R.W.Muller: Proc. 1979 Linear Accelerator Conf., Ed. R.L.Witkover, BNL 51134 148 (1979)