

BNL--51692

DE84 000820

BNL 51692

UC-21

(Inertial Confinement Fusion — TIC-4500)

DESIGN AND OPERATION OF A LAMINAR- FLOW ELECTROSTATIC-QUADRUPOLE- FOCUSED ACCELERATION COLUMN

A.W. Maschke

June 20, 1983

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ACCELERATOR DEPARTMENT

MASTER

BROOKHAVEN NATIONAL LABORATORY
UPTON, LONG ISLAND, NEW YORK 11973

~~DISTRIBUTION OF THIS DOCUMENT IS LIMITED~~

DISTRIBUTION OF THIS DOCUMENT IS LIMITED

184

Design and Operation of a Laminar Flow Electrostatic Quadrupole Focused Acceleration Column*

A.W. Maschke

June 20, 1983

The traditional way of accelerating beams in electrostatic devices have been based on Pierce-type focusing. This suffers from the problem that as the voltage is raised, higher and higher electric fields are necessary in order to maintain the current density. Most high-current-density ion sources work best at the highest electric fields obtainable in the extraction region. This typically occurs for voltages of 10-20 keV. If higher voltage is required, the Pierce-type acceleration column will require one to lower the current density. This problem is completely eliminated for the case of a quadrupole-focused acceleration column. In a previous paper¹ it was reported that essentially laminar flow could be obtained in a 25 cell FODO structure. This report deals with the design principles involved in the design of a laminar-flow electrostatic-quadrupole-focused acceleration column. In particular, attention will be paid to making the parameters suitable for incorporation into a DC MEQALAC design.

In a previous report,² it was shown that the space charge limited current in a quadrupole channel was proportional to $\mu_o^2 r_b^2 v^{3/2}/L_{cell}^2$. In order to have laminar flow, we must maintain this relation throughout the column. Now the thin lens approximation gives $\mu_o \propto v_Q \frac{L}{Q_{cell}} / (r_Q V)$. Therefore, the laminar flow condition becomes:

$$\frac{r_b^2}{r_Q^4} \frac{v_Q^2 \frac{L}{Q}^2}{v^{1/2}} = \text{constant}$$

The basic assumption made below is to keep r_Q and r_b constant throughout the column. This is not absolutely necessary, but the construction of a MEQALAC column is considerably simplified if this is the

*Work performed under the auspices of the U.S. Department of Energy.

case. For a spherically focusing array, one might actually want all the radii to taper appropriately. The basic relationship is that $V_Q L_Q \propto V^{1/4}$. For the model acceleration column that was tested here, it was convenient to use identical quadrupoles, and hence we had $V_Q \propto V^{1/4}$. In a column with a large ratio of input voltage to output voltage, this rising quadrupole voltage could get awkward. Therefore, in general, one would prefer to keep V_Q constant, and let $L_Q \propto V^{1/4}$. The natural thing, in this case, is to keep the ratio L_Q/L_{cell} constant. Therefore, in general, we would like to have $L_{\text{cell}} \propto V^{1/4}$.

The parameters of the model acceleration column were $V_{\text{out}} = 4 V_{\text{in}}$, and the voltage increased by approximately 15% per quadrupole. Strictly speaking, a voltage gain of 4 in 10 gaps. The initial quadrupole parameters were taken from our previous work that indicated where we got the brightest beams. This was with $r_Q/L_{\text{cell}} \approx 0.106$, and $\mu_0 \approx 75^\circ$, or $V_Q \approx 0.1 V_{\text{in}}$. The cell length was put proportional to $V^{1/4}$, as was V_Q , since ℓ_Q remained constant. Note that μ_0 is proportional to $V^{-1/2}$.

Now if one continued to increase the voltage in steps of constant ratio, the electric fields in the gap between quads would increase. Before one reaches the sparking limit, one would reduce the acceleration rate to avoid this. Remember, that unlike a Pierce column, there is no requirement on the acceleration rate in a quadrupole focused column.

The ultimate performance of an acceleration column can be compared with the performance of an ideal Pierce column. For a Pierce column one has, from the Child Langmuir law that the current density J , in amperes/m², is given by:

$$J = 5.44 \times 10^{-8} \frac{V^{3/2}}{A^{1/2} d^2}$$

where A is the atomic number of the ion, and d is the length of the acceleration column.