LOW-BETA STRUCTURES FOR CW OPERATION

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Abstract

Arcing problems and mechanical instabilities may limit the output energy of cw RFQ's even below 2 MeV. Between 2 and 10 MeV, Alvarez type DTL's are not convenient. The proposed structures are derived from slot-coupled, iris loaded, π-mode, 5-cell resonators. But the noses are shaped so that they provide a large enough space at atmospheric pressure to accommodate a magnetic quadrupole, to insure a FODO-type focusing. The beam sees a 3π or a 5π delay-line. Those structures are well suited for 350 MHz, or above, operating frequency, where there is enough space for water pipes to insure a sufficient cooling for cw operation. The focusing quadrupoles are entirely in the air and easily accessible. Fabrication is substantially the same as slot-coupled CCL's and beam dynamics is intermediate between 2π and 4π Alvarez structures.

1 INTRODUCTION

CW operation at room temperature concerns, at least, the low-energy part of any linear proton accelerator, even when superconductivity is used above about one hundred MeV.

The injector part of a long and powerful accelerator used for production purposes must be essentially reliable, stable, immediately available, and especially free from abrupt changes in current due to arcing. The design has to be exaggeratedly safe :

- cw operation at room temperature implies drastic cooling problems on the accelerator RFQ as well as the following Alvarez structures in order to maintain good mechanical stability,
- cw reliable RF power sources are actually klystrons, whose lower frequency is 350 MHz,
- a conventional Alvarez linac requires a minimum of space for the drift tubes, at least 10 cm of geometric period, for a reliable construction. At 350 MHz, $\beta\lambda$ = 10 cm corresponds to 6.5 MeV.

Consequently, in the conventional state of the art, one is faced with the unevitable situation of a rather long RFQ with rather high voltages on the vanes, followed by an Alvarez-type tank with focusing quadrupoles fitted into the drift tubes. The technology of these two structures has yet to be validated for a cw operation. The next limitation is arcing when the Kilpatrick coefficient Kp reaches values around 1.8. Published experimental results [1,2] seem to recommend to stay below 1.3-1.4 Kp for cw safe operation.

After these considerations may come the cost optimization: low-voltage DC kilowatts for the quadrupole magnets vs RF-klystron-produced kilowatts for the RFQ. One way out is to go to much lower frequencies, and try to fabricate powerful enough RF sources.

The situation becomes different and the technology easier when, as in the TRISPAL project [3], the required current is around 40 mA; then, good, reliable, easy to cool accelerating structures can be built down to ßλ=4 or 5 cm, which would correspond to 1.5- 1.6 MeV at 350 MHz. The RFQ output energy could stay below 2 MeV, eventually down to 1.6 MeV. At these reduced currents, a Kilpatrick coefficient of 1.4-1.45 will drastically reduce the risk of arcing.

2 LOW-BETA STRUCTURES

A possible structure is represented in Figures 1 to 3. Compared to the conventional DTL, the "posts" are made big enough to contain the quadrupoles and are vacuum-tight so that the quadrupoles are in the air , easy to fabricate and cool, with relaxed limitations in volume and easy access for maintenance of all individual quadrupoles.

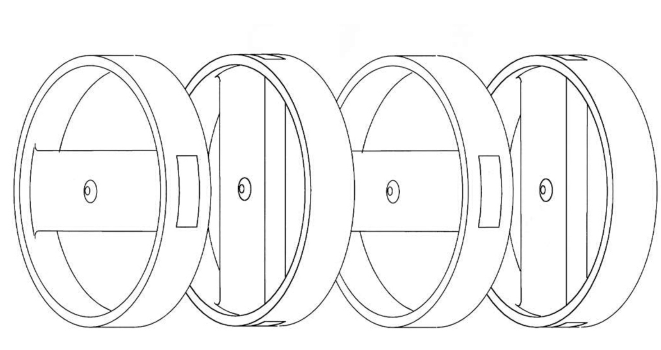

Figure 1 : Cells assembly with 90 degrees rotation between cells.

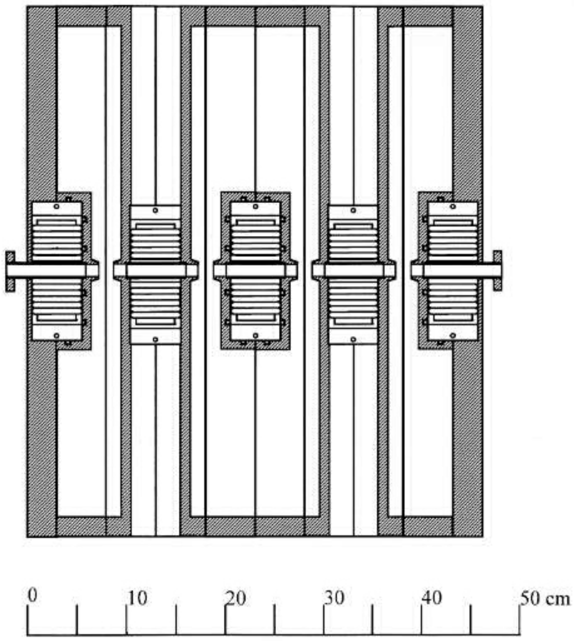

Figure 2 : 4-cells assembly in 2 βλ zero mode at 1.6 MeV with FODO focusing.

Compared to the iris-loaded waveguide, there is no fondamental difference except that the irises are partially thicker. RF-wise, when used as a resonant structure made of a certain number of cells coupled together, only the zero and the π-modes are of interest. As seen by the beam, the interaction can occur on any of the π , 2π , 3π , 4π , 5π , ... modes . As seen by the engineer, the mechanical period must have a minimum length of 10 cm to allow for the quadrupole, the flanges and the accelerating gap. The region of interest of this kind of sructure is given in Figure.4.

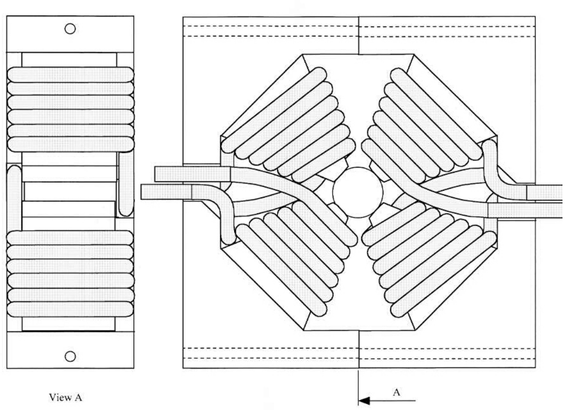

Figure 3 : Quadrupole assembly.

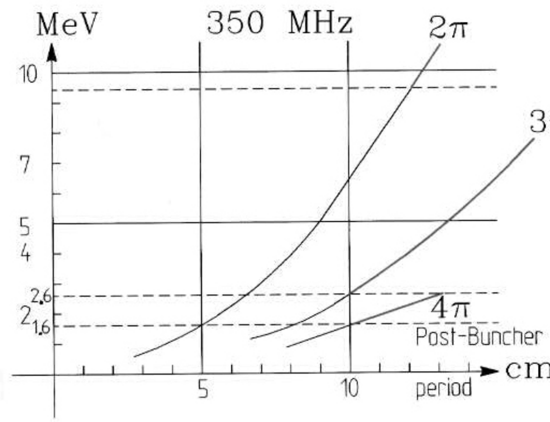

Figure 4 : Validity region of the structure.

3 HIGH-POWER INJECTOR

Figure 5 shows the general layout of the proposed injector for a cw high-power accelerator. The resonant tanks are separated in units of 125 kW-RF inputs as has been safely decided in the TRISPAL project. The RFQ output energy is limited to 1.6-1.8 MeV to reduce mechanical and cooling difficulties and save RF power. As it seems convenient for RF distribution purposes and mechanical stability concerns, to safely limit the RFQ output energy below 2 MeV, then a short 4π structure, about 100 cm long, must be inserted as a "post-buncher" to cover the gap up to 2.6 MeV. The matching transition between the RFQ and the following line is considered as a critical place, more critical at lower energy. After that,a 3π-line is adequate up to 10 MeV. A chicane can then be installed for a "clean up" of the bunches to drastically reduce their contribution to a "halo" forming downstream.

The beam out of the RFQ is divergent radially and the space charge causes an increase in the axial dimension of the bunches. Mechanical requirements imply flanges and alignment infinitely short. The solution taken here is conventional :

- control of the phase oscillation at the output of the RFQ so that the beam is not divergent, and if possible slightly convergent,
- modify the last cell of the RFQ to reduce and equalize the divergence in x and y directions,
- use a very short but powerful triplet of qudrupoles transforming the divergent into a convergent beam and re-arrange the gradients of the three first quadrupoles of the FODO structure to transform a convergent or parallel beam into what fits the FODO line taking into account

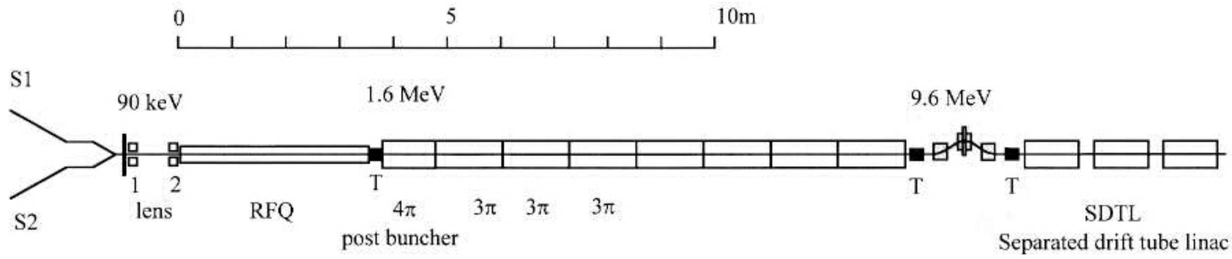

Figure 5 : General layout of the cw injector.

both the RF defocusing lens and space charge effects. The control is made by using a "macro-particle" code.

The next most difficult transition region which cannot be avoided when using this scheme, is the FODO to doublet focusing transition which is planned here in the 10 MeV-region. By taking advantage of this necessary difficulty, this transition can include a "clean up" system cutting "tails" and "feathers" of the bunches, to prevent any contribution to halo formation downstream.

Above 10 MeV, the "short-DTL" structure, as described in Reference [4], can be used.

REFERENCES

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[3] M. Promé : ‘Major projects for the use of high-power linacs’, Proc. LINAC-96 Conference, Geneva, August 26-30, 1996, CERN-SIR, p.9.

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