DEVELOPMENT OF AN EXPERIMENTAL RFQ ACCELERATOR

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Abstract

On an experimental basis, a 150 keV, deuteron RFQ accelerator, henceforth called as RFQE is being developed. RFQE uses the four rods structure for the electrodes which are shaped trapezoidally in the longitudinal direction. The resonator is based on the "o-mode-$\lambda/2$ concept". The straight stems have been incorporated in the design. The theoretical studies indicate that about 60% of the beam in a beam bunch will get bunched to a final R.F. phase width of ± 15 degrees. The fabrication of electrodes and stems has been completed. The fabrication of R.F. tank has been undertaken. The design of a deuteron ion source has been completed. The details of the R.F. system and the required network is being worked out. This accelerator is intended to be used as a 14 MeV neutron generator/1/.

Details of the Design

Electrodes profile and Beam properties

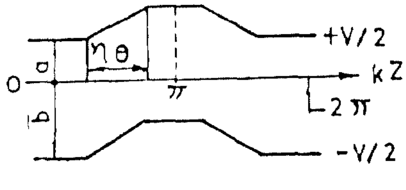
Kapchinskii expansion for the RFQ potential/2/, under the quasi-stationary approach can be written as,

$$U(r,\theta,z,t) = \psi(r,\theta,z)\cdot \cos(\omega t+\phi)$$

$$\psi(r,\theta,z) = (V/2)\sum_{\substack{N=0\\M=0}} A_{NM}\, F_{NM}(r,\theta,z)$$

$$F_{NM} = \begin{bmatrix} r^{2M}\cdot \cos 2M\theta & , N=0 \\ I_{2M}(Nkr)\cos 2M\theta\cdot \cos Nkz, & N \geq 1 \end{bmatrix}$$

where V is the potential difference between the adjacent electrodes. By adopting to the lowest order potential, expanded in the fourier Bassel series, this function can be reduced to two terms. The configuration of the electrodes generated from such a potential is sinusoidal in nature/3/ and for the fabrication of the electrodes, numecarically controlled lathe become essential. To avoid such complication and to make the fabrication easy, the approach of four cylindrical rod structure/4-6/, suitably shaped in the longitudinal direction, has been adopted for the RFQE. The potential function in this case is no longer a two term function but has to include the higher order harmonics also. The equations of motion and the beam properties thus derived, take into account, the effects of higher hamonics also. A typical cell with trapezoidal configuration for the RFQ is shown below.



The potential function has been computed for $a\eta_\theta=0.4$. To obtain the beam properties and the design parameters, the equations of motion are solved under the constraints of constancy of longitudinal length of the beam and keeping the constant value of transverse phase advance, as the beam traverses various cells of the accelerator. The modulation parameter and the minimum radius of beam aperture of a cell thus computed are used to get the configuration of the electrodes. In fig. 1 is shown the profile of the electrodes in the x and y planes. Along with this are shown the beam envelopes of the synchronous particles for abeam current of 25 mAmp. As is evident from this figure, the beam is more or less properly matched to the accelerator.

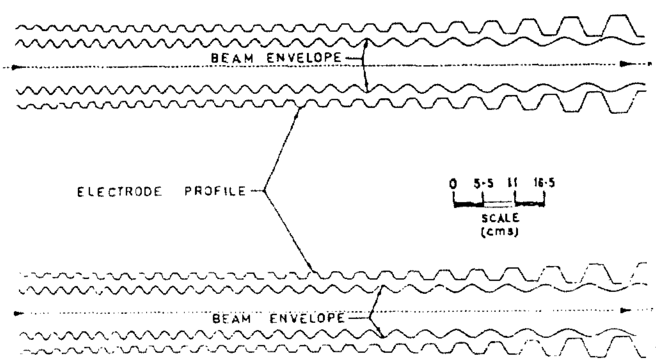


Fig.1: Electrodes profile and beam envelops in x and y planes.

The phase space ellipses in both the transverse planes through the shaper, buncher and accelerator parts are given by fig. 2. The maximum amplitude of the beam is observed to be $\simeq$9 mm. for a phase space area of 100 mm. mrad. The behaviour of the longitudinal phase

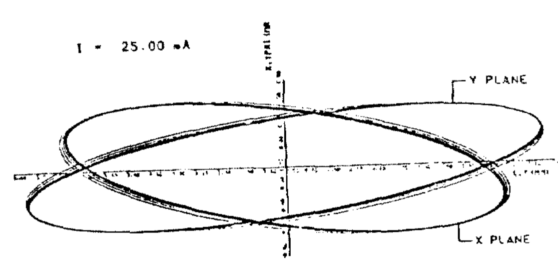


Fig.2: Beam phase space ellipses in x and y planes.

++ Electronics division BARC Bombay 400085 space ellipses as the beam traverses through the various cells of the RFQE is shown by fig. 3 .

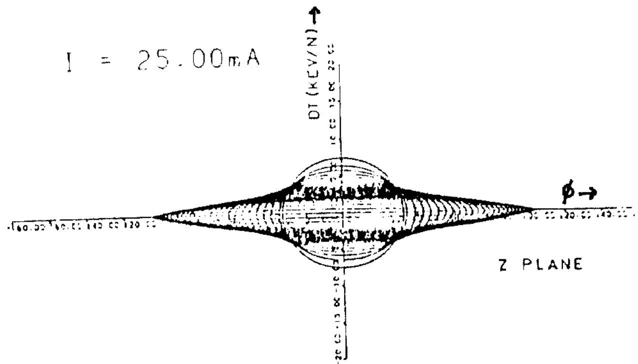


Fig.3

The adiabatic bunching of the beam through the RFQE is depicted by fig. 4. About 6o% of the beam in a bunch is bunched to a R.F. phase width of $\simeq$3o deg. Similarly the intensity distribution in the $(\Delta E, \Delta\phi)$ space is shown by fig. 5 . The approximate time spread and energy spread in a beam bunch are 1n.Sec. ,1o keV . respectively.

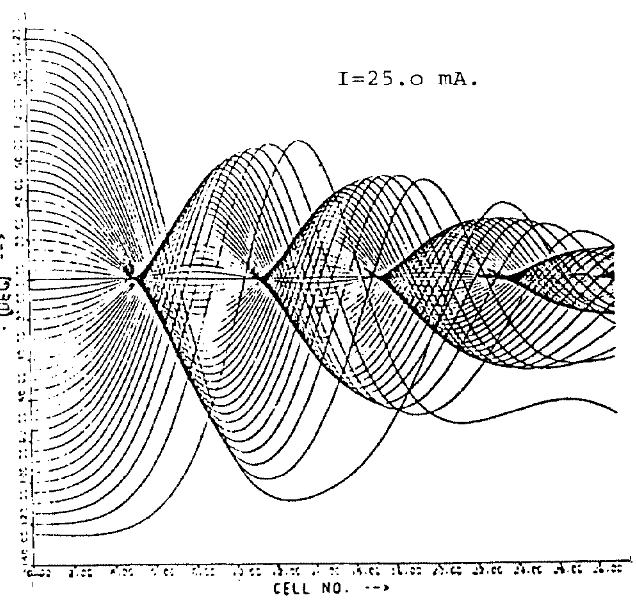


Fig.4: Adiabatic bunching of beam in RFQE .

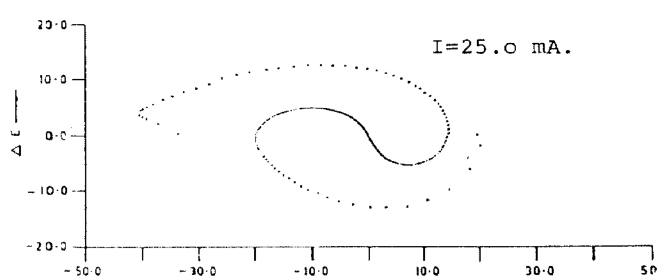


Fig.5: Intensity distribution .

The other major parameters of the RFQE are listed below .

total length of the electrodes	= 1.o46	m.
total no. of cells	= 28	
maximum modulation	= 1.774	
min. radius of aperture	= 1.o	cm.
max. radius of aperture	= 1.774	cm.
max. length of a $\beta\lambda$ cell	= 7.993	cm.
min. length of a $\beta\lambda$ cell	= 2.757	cm.
max. diameter of the electrode rod.	= 34.72	mm.
min. diameter of the electrode rod .	= 2o.8o	mm.
length of radial matcher	= 4	$\beta\lambda$
frequency of operation	= 45	MHz
voltage of operation	= 55	kV
μ_0 ,transverse phase advance	= 35	deg
space charge limited current	= 45	mA.

R.F.Details

For the resonator, "o-mode, $\lambda/2$ concept" ,developed by Schempp/7/ has been adopted. Accelerator is divided into identical and symmetrical R.F. cells in such a way that each one of them resonates longitudinally in the "o mode" and transversely in the "π mode" . Half the wave length fits into the length of each R.F. cell.The stems which connect the opposite pair of the electrodes, are positioned linearly.By optimising the geometery of the stems and the tank diameter, the details of resonator structure have been computed. Given below is the list of some of the major parameters.

no. of stems	= 7	
centre to centre length between two consecutive stems	= 16.666	cm.
height of stems	= 24.o	cm.
breadth of stems	= 13.o	cm.
thickness of stems	= 1.4	cm.
tank diameter	= 6o.o	cm.
estimated Q value	= 79oo	
shunt impedance	= 31o	kΩ.
R.F. power	= 1o	kW .
max. R.F. current	= 28oo	Amp.

Mechanical Details

The assembly of the RFQE is shown in fig. 6. The electrodes are fabricated from solid copper rods and the stems are fabricated from copper plates. ETP copper has been used for all the above assemblies. The top portion of the stems have the curvature reverse to the electrodes so that stems can be fitted properly to the electrodes.The stems will be brased to the electrodes. The details of one of the stem is shown in fig.7. The electrodes along with the stem assembly will be brased to a 2.5 cm. thick copper plate which will serve as a ground R.F. plate. This plate has been provided with four cooling circuits. The whole assembly can be screwed in position to a 4.75 thick S.S. plate. This sub-assembly is shown in fig.8. S.S. plate will be welded to a 6o cm. diameter R.F. tank which is made from the mild steel. The inner portion of the tank will be electro-plated. The tank is provided with ports for the coupling loop ,vacuum pump, R.F. pick up probe and the tuning cylinder. The mechanical assembly of the RFOE follows the HERA four rod RFQ /5,8/ design. A

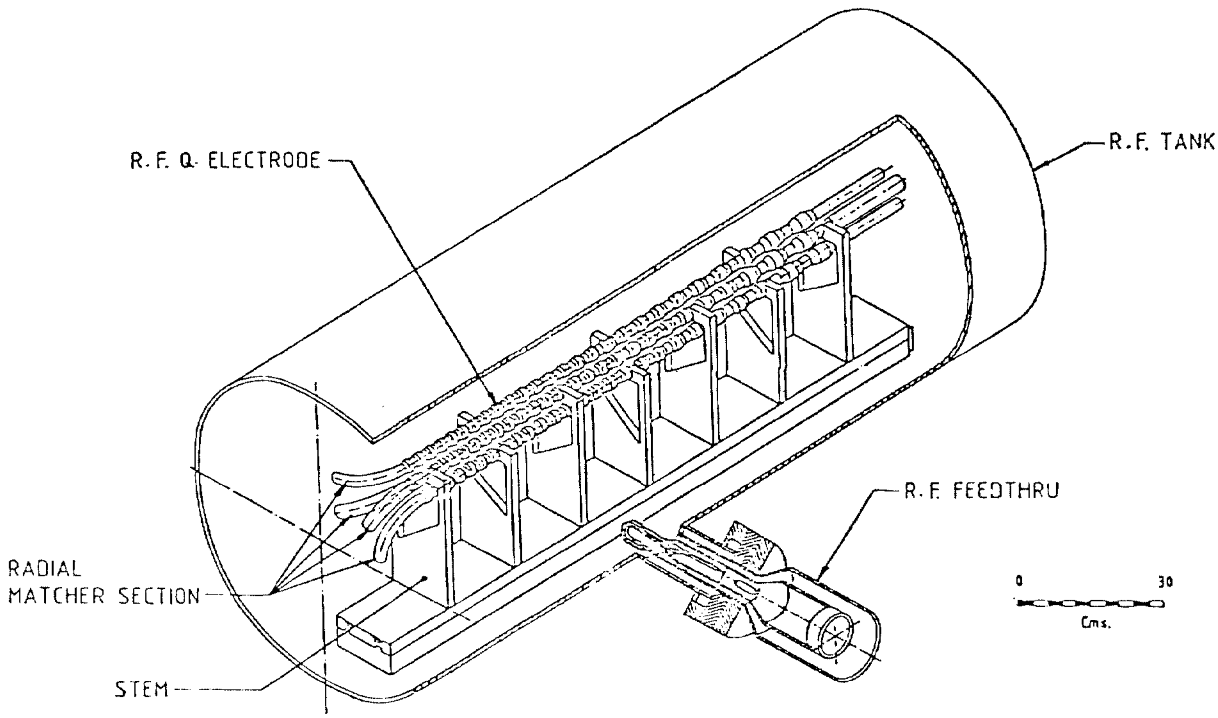


Fig.6: Assembly of RFQE

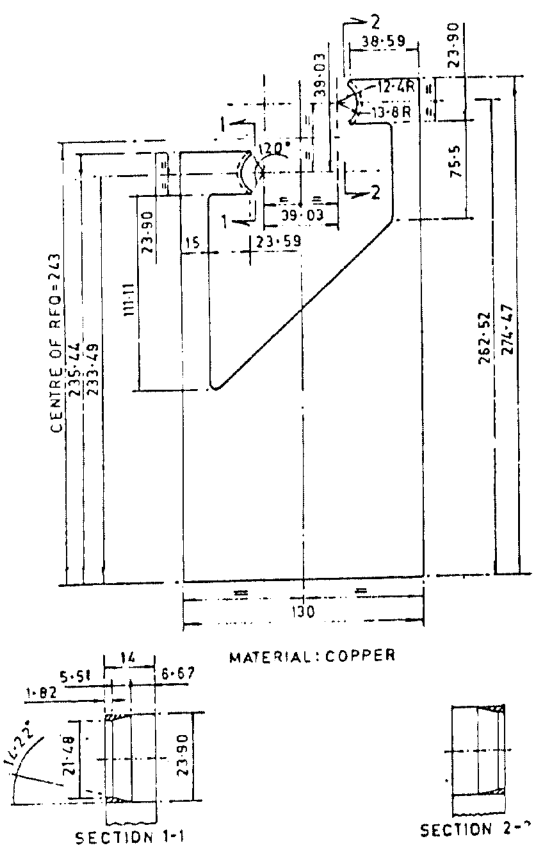


Fig.7: The details of one of the Stem.

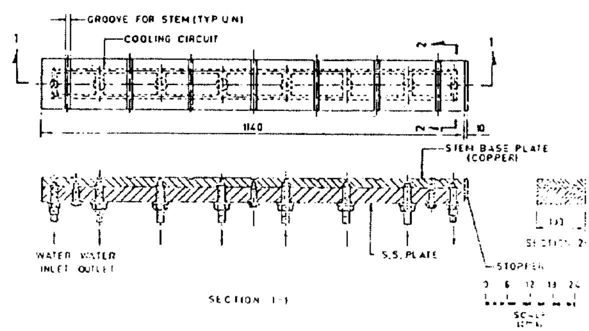


Fig.8: Mechanical details of the copper-S.S. plate assembly.

2o keV duoplasmatron ion source for the deuteron beams has been designed speCifically for this purpose.

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