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1 GeV リニアック検討資料

1 GeV LINAC DESIGN NOTE

題目 (TITLE) Proposal of Two-Tank RFQ Linac

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概要 (ABSTRACT)

RF 的に独立な 2個のRFQ により、長さの長いRFQ の困難を解決する。2 cm のドリフトスペースによる透過率の低下は 10 % であり、許容出来る。

KEY WORDS:
Ion source, RFQ, DTL, CCL, Magnet, Monitor, Beam Dynamics,
Transport, Vacuum, Cooling
Klystron, Low level rf, High power rf, Modulator
Control, Operation, Radiation, Others

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Proposal of Two-Tank RFQ Linac

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A 3 MeV RFQ with two separated tanks (1.4m + 1.4 m in length) is proposed. The design has not yet been optimized. The achieved transmission ratio with a 20 mA- 1.5 πmm.mrad(100 %, normalized) beam is 80.2 % when the drift space between the tanks is 2 cm. The decrease of the transmission efficiency due to the drift space is about 10 %. The calculated results are satisfactory and allowable in comparison with the difficulties associated with an RFQ of 3m in length.

A long RFQ linac has some difficulties both in construction and operation.

1. Problem of $(L/\lambda)^2$.
   A 3 MeV RFQ is about 3 m in length , more than four times of the wavelength. If we divide the RFQ into two pieces of the same length, the difficulty is reduced by a factor of 1/4.
2. Problem of milling machine.
   A very precise milling machine has a bed length usually less than 2 m. Thus, if the length of the vane is less than 2 m, the best machine can be used, resulting improvement of the final accuracy of the vane.
3. RF power problem.
   A power of 700 kW is necessary for the RFQ. If we use rf-separated two tank RFQ, the handling power for an rf input coupler is reduced by a factor of two, that reduces difficulties with the input couplers.

Demerits of two tank RFQ

4. Precise alignment of the two tanks.
5. Mechanical problem of the center wall.
   rf contact, water cooling
6. Decrease of the transmission efficiency due to the free drift space between two tanks. However, the design of the longitudinal motion can be improved because the design is free from the total length of the tank, that is, rather longer bunching section of the vane can be adopted to improve the longitudinal capture efficiency.
7. Unknown factor arising from the motion between the center wall and the end of the vane. We have the similar problem for one tank RFQ. In the latter case, the ambiguity of the motion is compensated by the following focusing magnets.

The parameters of the model RFQ linac used in the calculation is listed in Table 1.

Table 1. The model RFQ with one tank.

Frequency	432	MHz	
Win	50	keV	
Wout	3.02	MeV	
Length	2.757	m	
No. of cells	325		
Intervane voltage	90	kV	
Min. bore radius	0.221	cm	
Max. modulation	1.8		
Stable phase	-90 ~ -30	degree	
Focusing parameter B	4.5		
Transmission			
I=0 mA	98.9	%	for ε_n(100%)=1.5 πmm.mrad
I=20 mA	89.7	%	for ε_n(100%)=1.5 πmm.mrad

The optimization of the RFQ has not been performed.The RFQ above mentioned is divided into two tanks of the nearly same length. The parameters are listed in Table 2.

Table 2. The model RFQ with two tanks.

	TANK-1	TANK-2	
Frequency	432	432	MHz
Win	50	1115	keV
Wout	1.115	3.02	MeV
Length	1.370	1.386	m
No. of cells	264	61	
Intervane voltage	90	90	kV
Min. bore radius	0.223	0.221	cm
Max. modulation	1.8	1.8	
Stable phase	-90 ~ -30	-30	degree
Focusing parameter B	4.5	4.5	

We show the transmission ratio for the above two tanks in Table 3. The parameters of the injected beam are listed in Table 4.

Table 3. Transmission results of the two tanks.

Drift space (cm)	No. of particle	Ratio (%)	Relative ratio (%)
0	3587	89.7	100
1	3512	87.8	97.9
2	3209	80.2	89.5
3	2718	68.0	75.8
(0	3957	98.9 <--------- I=0 mA)	

Table 4. Parameters of the injected beam.

Current	20 mA
$\varepsilon_n(100\%)$	1.5 πmm.mrad
$\varepsilon_n(90\%)$	1.0 πmm.mrad
$\Delta\Phi$	uniform
ΔW	0
No. of particles	4000.

Radial mesh interval is 0.048 cm.
Longitudinal mesh interval is 0.036 cm. These two values are borrowed from INS data.
Twiss parameters are the same for both transverse phase planes.

Figure 1 shows the absolute transmission ratio with a 20 mA-1.5πmm.mrad beam.
Figure 2 shows the relative transmission ratio due to the drift space between two tanks. The decrease of 10 % with a drift space of 2 cm in length is allowable.

The transverse emittances at the exit are listed in Table ~~4~~ 5. The longitudinal emittance has almost no effect by the drift space.

Table ~~4~~ 5 Comparison of transverse emittances.

	x rms	x 90%	x 100%	y rms	y 90%	y 100%	
no drift	0.299	1.253	2.853	0.297	1.231	2.755	πmm.mrad
2cm drift	0.281	1.166	3.782	0.290	2.919	3.607	

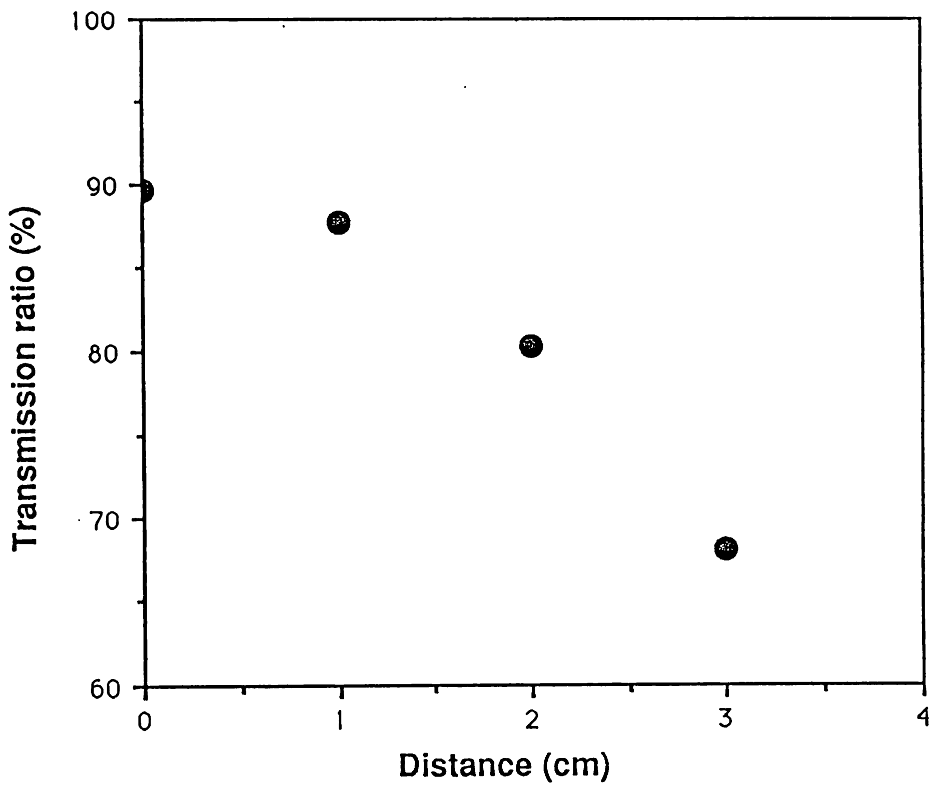

Fig. 1 Transmission ratio with a 20 mA-1.5πmm.mrad beam through two-tank RFQ.

It should be noted that the transmission ratio varies with the mesh interval in the space charge calculation. For example, the mesh interval of 0.03 cm for radial and longitudinal direction reduces the transmission ratio by 15% from the values listed in Table 3. Taking the effects of the neighbor bunches into the calculation or not has more drastic effects on the results of calculation. If we neglect the effects of the neighbor bunches, the transmission ratio reduces from 90 % to 70 %. Thus we should be careful with the results of calculation with space charge effects.

A merit of rf-separeted RFQ is that the design of beam dynamics can be done independently for each tank. Therefore, careful design of transverse beam dynamics near the transition region will reduce beam loss due to the drift space.

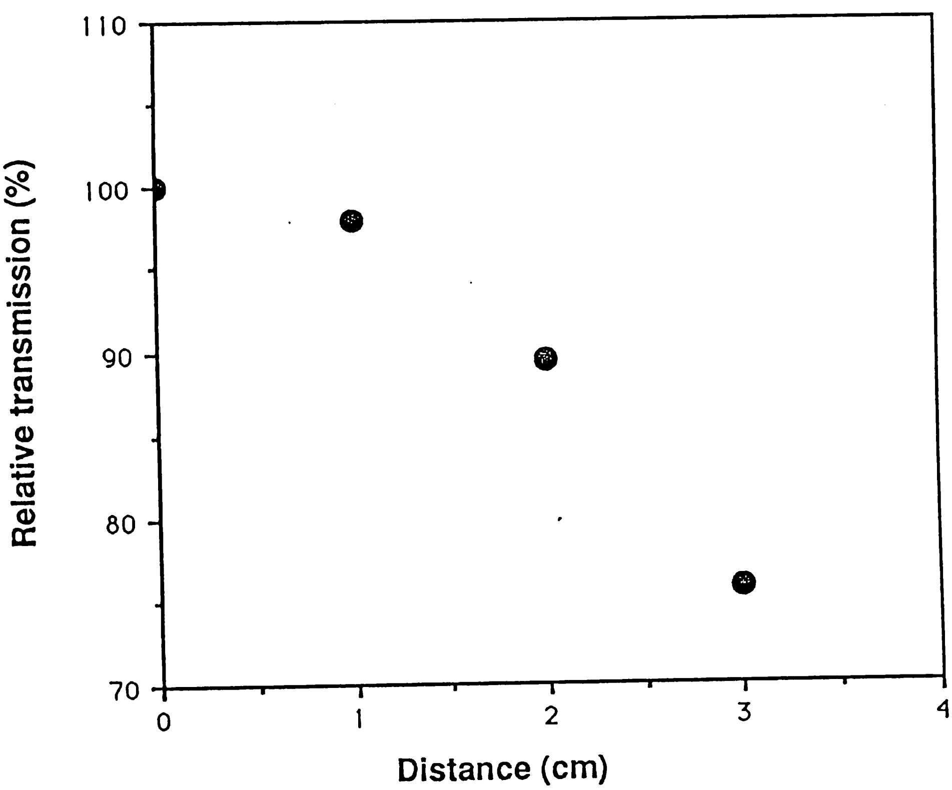

Fig. 2 Relative transmission ratio due to the drift space between two tanks.