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RFQ DEVELOPMENT AT LOS ALAMOS*

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1. INTRODUCTION

We report recent progress on the two radio-frequency quadrupole (RFQ) structures being developed at Los Alamos. First, we report on the second 425-MHz RFQ for H^- acceleration, which is being built in a research effort to understand and further develop the RFQ. Second, we discuss progress on the 80-MHz cw RFQ for deuterons, which is being built for the Fusion Materials Irradiation Test (FMIT) facility.

2. PROGRESS FOR THE 425-MHz RFQ

A second 425-MHz RFQ accelerator[1] has been designed and constructed at Los Alamos National Laboratory. The accelerator's design parameters represent a major extension from the original Los Alamos RFQ,[2,3] with the new accelerator being 2.5 times as long, having 3 times the output energy, and with 2.5 times the current limit. The design specifications of the RFQ are given in Table I.

The primary objective of tuning for an RFQ structure is to obtain a field pattern characteristic of a quadrupole TE_{210}-like cavity mode at the desired resonant frequency. This implies an equality in the magnitudes of the magnetic fields in the four quadrants and the electric fields in the four vane gaps. In addition, the field distribution ideally should be independent of longitudinal coordinate.

The rf magnetic field measurements were made by a perturbation technique using a brass rod inserted through holes in the outer cavity wall at a sequence of longitudinal points in each quadrant. We observed large field differences in the four quadrants, characteristic of a large admixture of the nearby dipole modes. In addition, a large longitudinal nonuniformity of the magnetic fields was measured. Total variations of about a factor of 2 were observed in the data.

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TABLE I

ATS RFQ DESIGN PARAMETERS

Frequency	425 MHz
Ion	H^-
Number of cells	356
Length	289 cm
Vane voltage	111 kV
Average radius r_o	0.394 cm
Final radius a_f	0.270 cm
Final modulation m_f	1.830
Initial synchronous phase ϕ_i	-90°
Final synchronous phase ϕ_f	-30°
Duty factor	1%
Peak surface field	41.4 MV/m (2.06 Kilpatrick)
Nominal current limit	167 mA
Nominal acceptance at 100 mA	0.232π cm•mr (normalized)

After these initial difficulties in tuning the quadrupole mode to the proper accuracy, an analysis indicated the source of the problem. Briefly, in tuning the rf structure, errors in vane positioning influence vane voltage V by their effect upon the structure's local capacitance C. This effect can be parameterized by Eq. (1):

$$\frac{\delta V}{V} = -\frac{1}{6}\frac{L^2}{\lambda_o^2}\frac{\delta C}{C} \quad , \tag{1}$$

where L is the vane length and λ_o is the rf wavelength divided by 2π. If one substitutes the appropriate values for the present RFQ, assuming only that $\delta C/C \sim -\delta g/g$ where g is the average intervane gap, then if one wishes to hold the intervane voltage error to less than 10%, it follows that the vane position error must be held to less than 0.003 mm. For a 3-m-long structure, this proved to be a difficult positioning problem.

Although the residual field errors were large, the RFQ was operated at 650 kW, which is about 20% higher than the design power value, with 1-ms pulses at a 5-Hz rate. An 18-mA beam was accelerated to 2 GeV at 60% transmission efficiency. Higher transmission is expected after improvements in matching and in the low-energy beam transport. The RFQ was taken off-line for installation of vane-coupling rings[4] to reduce the dipole mode admixture and for vane position adjustments to improve longitudinal field uniformity. No problems are now foreseen that would prevent design operation. Beam tests are scheduled for February 1984.

3. PROGRESS FOR THE FMIT 80-MHz RFQ

An 80-MHz RFQ has been designed and constructed for cw operation for the FMIT[5] project. The design specifications are given in Table II.

TABLE II

80-MHz CW RFQ PARAMETERS

Frequency	80 MHz
Ion	D^+
Number of cells	135
Length	388 cm
Vane voltage	185 kV
Average radius r_0	1.42 cm
Final radius a_f	0.998 cm
Final modulation m_f	2.129
Initial synchronous phase ϕ_i	-90°
Final synchronous phase ϕ_f	-30°
Peak surface field	17.6 MV/m (1.7 Kilpatrick)
Nominal current limit	205 mA
Nominal acceptance at 110 mA	0.73π cm•mr (normalized)

Starting in late May 1983, a series of tests was conducted to demonstrate the performance of the FMIT RFQ. Using an unmatched cw beam from the injector and pulsing the applied rf power at 3.5% duty factor (7 ms at 5 Hz), the beam was accelerated to 2 MeV with 70% transmission efficiency. Difficulties in pulsing the injector beam led to this mode of operation and also prevented proper matching of the beam to the RFQ; hence, the transmission efficiency was lower than the design value of about 90%. In July, the testing program was redirected towards obtaining cw operation at the design power level of 350 kW of rf power. The program was terminated in November by a vacuum leak at the end closure of the manifold tank. During this period, the average power was increased to 150-kW cw rf operation. Increase of the average power was limited by outgassing and by thermal overheating of some components.

Repair of the vacuum seal required removal of the RFQ from the beamline and at least partial disassembly; therefore, an extensive inspection of all internal surfaces was performed, especially for those regions observed to be overheating. This inspection resulted in the following observations: (1) The gold wire used for the rf joint on the end closure for the manifold tank was melted in the area adjacent to the access boxes used to connect water cooling to the vanes. The resultant overheating of the viton O-ring and its exposure to the rf fields caused its destruction and the loss of vacuum integrity. (2) The tuning straps on the ends of the vanes, which were used to obtain the proper operating frequency and field configuration, had severely overheated. One strap had melted through.

Disassembly has revealed the RFQ's fundamental design to be sound with the only major problem areas noted above. These observations and other minor ones have led to a modest redesign in the areas noted. No problems are now foreseen that would prevent cw operation soon after operation is resumed. These tests are scheduled to begin in March 1984.

4. ACKNOWLEDGMENTS

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5. REFERENCES

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