

# DESIGN REQUIREMENTS AND EXPECTED PERFORMANCE OF THE NEW LANSCE H<sup>+</sup> RFQ\*

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## Abstract

LANSCE provides H<sup>-</sup> and H<sup>+</sup> beams to several user facilities for fundamental and applied research, including a 100-MeV, 250- $\mu$ A proton beam to the Isotope Production facility (IPF). Each beam species is initially accelerated to 750 keV in separate Cockcroft-Walton (C-W) accelerators. Due to the age and possible failure modes of the C-W's and the potential impact of a C-W failure to the IPF program, we have begun the process of replacing the aging H<sup>+</sup> C-W with a modern Radio Frequency Quadrupole (RFQ) accelerator-based system. In addition, the complexity of combined species operations imposes further restrictions on the beam performance and configuration that must be incorporated into the design process. This paper will cover the physics design requirements of this new RFQ and the expected performance based upon the results of PARMTEQM simulations.

## INTRODUCTION

The Los Alamos Neutron Science Center (LANSCE) facility has a diverse user program that is possible in part because of the dual species operation, i.e. acceleration of both H<sup>+</sup> and H<sup>-</sup> beams. IPF is one of those facilities and receives 100-MeV beam generated by our H<sup>+</sup> injector. IPF is one of only a few installations that produce a key radioisotope for medical procedures used across the nation and so high beam availability and reliability is critical to meeting their programmatic milestones. The H<sup>+</sup> injector utilizes an ~40 year old 750-keV C-W accelerator. The C-W has possible failure modes that include a failure of the accelerator column, which has already been replaced once and required 4 months to complete, and the collapse of a support leg that could lead to a catastrophic failure of the C-W. Concern over the potential likelihood of these types of failures and the severe impact to the IPF program has provided the impetus to pursue an RFQ-based replacement for the H<sup>+</sup> injector.

The RFQ is being designed and verified as a joint effort between the Institute of Applied Physics (IAP), Goethe University, Frankfurt, Germany and Los Alamos. The IAP team used a combination of PARMTEQM [1] and proprietary algorithms to develop the physics design for the 4-rod RFQ, which the Los Alamos team verified using

\*Work supported by US DOE under contract DE-AC52-06NA25396.

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PARMTEQM. Our project partner Kress GmbH, with input from IAP, is responsible for the engineering design and fabrication of the RFQ.

## REQUIREMENTS

The new H<sup>+</sup> RFQ will need to provide sufficient beam current to meet present and anticipated future programmatic needs and do so within the context of dual species operation. This includes the capability to operate the RFQ for a range of input beam currents depending upon the requirements of the user programs and the available beam duty factor. The LANSCE dual injector beam line layout that maintains the existing H<sup>-</sup> and common LEBTs requires the new RFQ to be located several meters upstream from the entrance to the next accelerating structure, i.e. the 100-MeV drift tube linac (DTL). This places additional constraints on the transverse and longitudinal emittances so that the beam can be transported and properly matched without significant losses. A list of the RFQ requirements and expected performance based upon PARMTEQM simulation results for the IAP-developed physics design are given in Table 1. The frequency and output energy were chosen to be consistent with our present linac base

Table 1: Comparison of the Final, 201.25-MHz 4-rod RFQ Design Parameters with the Design Specifications

Parameter	Specification	Final Design
Injection Energy	35 keV	35 keV
Final Energy	750 keV	750 keV
Transmission	$\geq 90\%$	96%
Peak Current	35 mA	35 mA
Current Limit	$\geq 70$ mA	60 mA
Output Energy Spread (FWHM)	$< 3.0\%$	2%
Length	$< 2.5$ m	1.75 m
Peak Electric Field ( $E_k$ )	1.7	1.6
Input Trans. Emittance rms (cm-mr, norm.)	0.020	0.020
Exit Trans. Emittance rms (cm-mr, norm.)	0.023	0.022
Exit Long. Emittance rms (deg-MeV @201.25 MHz)	$< 0.08$	0.071

frequency and nominal injection energy to the DTL. The RFQ injection energy was chosen with the desire to keep it low, which helps reduce the overall length of the RFQ, and taking into consideration the successes of other RFQ projects with similar peak current, injection energy and frequency specifications [2][3]. The transmission specification was chosen to help ensure that the integrated performance of the new RFQ and DTL would have an overall beam capture up through the DTL at least as good as the present C-W based system. The current limit in the design of the RFQ was specified to be twice the maximum design current as a general rule-of-thumb. The output energy spread and longitudinal emittance were chosen to ensure successful transport and capture of the beam from the RFQ and was based upon results from PARMILA [4] beam dynamics simulation of the MEBT and DTL using PARMTEQM beam distributions [5]. The limit on the peak surface electric field was chosen to ensure reliable operation at design field strength. The input emittance represents the maximum that we expect to inject and was based upon the performance of our present duoplasmatron ion source, which we will use with the RFQ injector, and an estimate of the maximum emittance growth that might be sustained in the LEBT. However, based upon measurements of the existing H<sup>+</sup> beam, we expect the nominal input emittance to be somewhat smaller. The RFQ output emittance requirement was based upon expected performance for a carefully designed RFQ and the desired to keep the beam emittance in the MEBT at a level that will allow for easy transport and matching of the RFQ beam into the DTL [5].

### EXPECTED PERFORMANCE

The IAP RFQ design was evaluated using the PARMTEQM design and simulation code. The simulations were done using the design parameters provided by IAP. The effects of the end regions that can be important in a 4-rod RFQ require the use of more sophisticated models that combine 3D EM fields with multiparticle tracking. This effort is in progress [6].

The results of the PARMTEQM simulations show the design meets our requirements in all but one aspect, the current limit, which is not significant as will be shown later. Figure 1 shows the beam dynamics along the RFQ and phase space distributions at the end of the RFQ for the design peak current and emittance input beam. The RFQ produces a good quality beam with high transmission. Figure 2 shows the results of the PARMTEQM simulation that indicate the design produces little transverse emittance growth along the RFQ. In initial studies performed by the Los Alamos team, we had found that an RFQ design employing equal transverse and longitudinal current limits, one common approach, produced significant transverse emittance growth. In a follow-on analysis we found that the emittance growth was due to parametric resonance conditions being met, but that could be avoided with properly chosen parameters [7]. This design effectively avoids the parametric resonance conditions and produces a beam with little, ~10%, emittance growth.

Because we plan on operating the RFQ for a range of input beam currents, likely values between 10 and 35 mA,

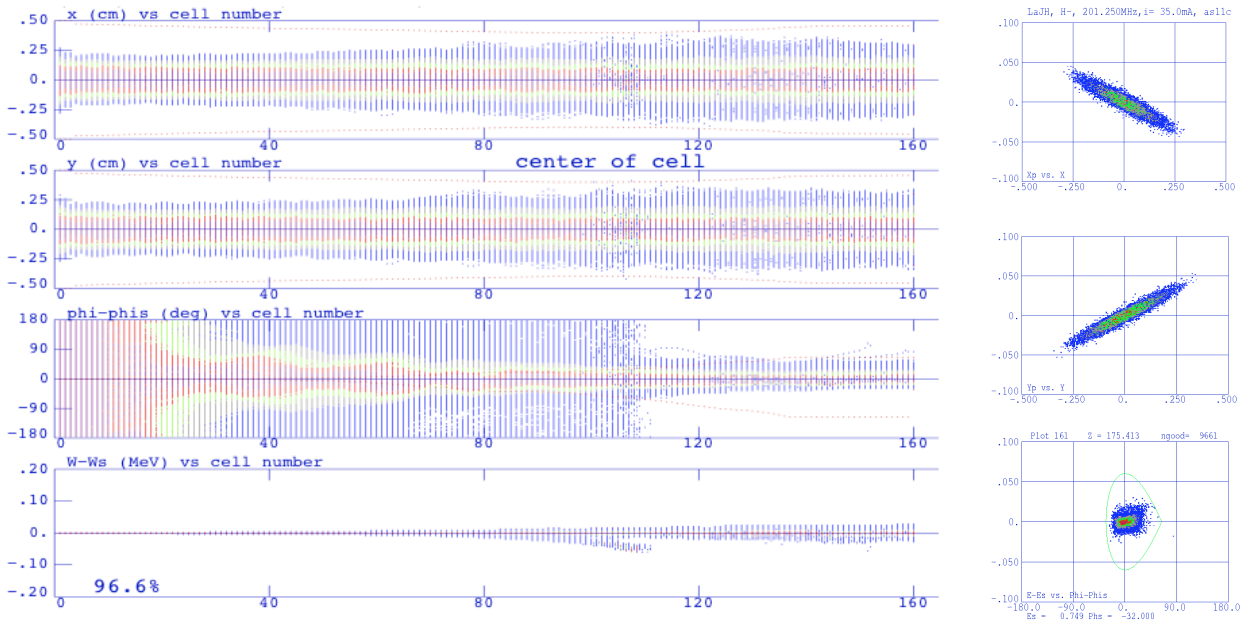


Figure 1: PARMTEQM beam dynamics results showing x, y beam size, phase and energy spread for the design input beam (left panel). RFQ output phase space distributions (right panel) x-x' (top), y-y' (middle) and phi-w (bottom).



Figure 2: Transverse (red, green) and longitudinal (blue) rms, norm. beam emittances along the RFQ for the design input beam.

depending upon the average current required and the duty factor available for the user programs, we desire good performance over that range. Although the current limit characteristic for this design is somewhat lower than desired, it does not appear to affect the performance well beyond the design point and is therefore not an issue. As shown in Figures 3, 4 and 5, the simulated performance is quite good for input beam currents up to 60 mA, with the transmission falling off to about 80% at that point.

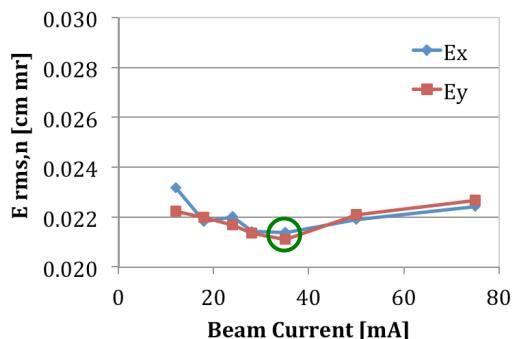


Figure 3: Transverse (red, blue) rms, norm. output beam emittance vs. input beam current. The green circle indicates the 35 mA design point.

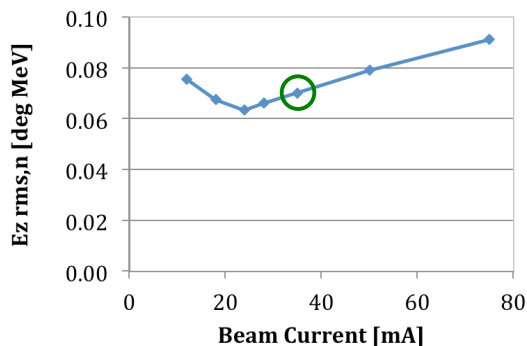


Figure 4: Longitudinal (blue) rms, norm. output beam emittance vs. input beam current. The green circle indicates the 35 mA design point.

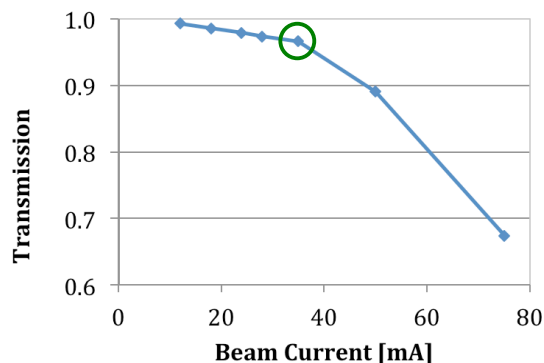


Figure 5: RFQ beam transmission vs. input beam current. The green circle indicates the 35 mA design point.

SUMMARY

The IAP approach has produced an RFQ design that has met the specified beam requirements as simulated with the PARMTEQM code. The performance is equally good for the range of beam currents over which we expect to operate.

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