MEASUREMENT OF THE LONGITUDINAL ACCEPTANCE OF THE REA RFQ


Abstract

The reaccelerator facility (ReA) at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU) will provide a unique capability to study low-energy beams of rare isotopes. A beam from the coupled cyclotron facility is stopped in a gas stopping system, charge bred in an Electron Beam Ion Trap (EBIT), and then reaccelerated in a compact superconducting LINAC. The beam is injected into the LINAC by a room-temperature Radio Frequency Quadrupole (RFQ) combined with an external Multiharmonic Buncher (MHB). In preparation for future upgrades to the capabilities of ReA, an accurate determination of the longitudinal acceptance of the RFQ was conducted using a stable ion beam from a test source. This paper presents the results of the acceptance measurement, including empirical confirmation of a predicted asymmetry in the shape of the acceptance window.

INTRODUCTION

Figure 1 shows the layout of the ReA accelerator facility. The first stage of acceleration at ReA is provided by a room temperature RFQ, specified to accelerate ions with charge to mass (Q/A) ratios in a range from 0.2 to 0.5 from an injection energy of 12 keV/u to 600 keV/u [1]. At present, the beam is bunched longitudinally into the RFQ by the MHB at the RFQ frequency of 80.5 MHz [2]. A proposed future upgrade to ReA would include a prebuncher operating at the 5th subharmonic of 16.1 MHz [3]. Since such a buncher will increase the energy spread of the injected beam, an empirical verification of the longitudinal acceptance of the RFQ is a critical first step in the planning for this device.

Energy Acceptance

The overall transmission efficiency of the RFQ versus relative energy (dE/E) with the MHB off is shown in Fig. 2. No decrease in transmission was observed until the beam energy was varied more than 5% from the design energy in either direction. The only likely source of potential error in the energy of the beam is from variations in the ion source regulation, which is measured to be less than ~0.1%.

Relative error in the measured transmission rate is more difficult to estimate. The accelerator was tuned at each en...
Figure 2: RFQ Transmission vs. Source Energy (MHB Off).

The energy level by an experienced operator, but there is nonetheless a possibility that greater transmission could have been achieved at each level, including the reference energy. It is estimated that the transmission achieved at each level is within 5% of the maximum achievable. The transmission at each level should be treated as a minimum, and the error in the ratio has been calculated accordingly.

Phase Acceptance

Figure 3 shows the results of three scans of the RFQ phase at different energies with the MHB on. The width of the time acceptance is narrower away from the reference energy, as shown in Fig. 4. The peak of the phase scan is offset due to the change of particle velocities, which changes the time of flight from the buncher to the RFQ and thus the measured phase.

One interesting result is that the phase scans at energies greater than 5% above the reference energy have a double peaked structure with two transmission maxima. This matches the prediction of the simulated phase space (see below) but had not previously been directly observed.

Comparison with Simulation

The initial simulation of the longitudinal acceptance for the RFQ was made by generating a simulated beam with minimal transverse emittance and large longitudinal emittance and transporting it through the simulated RFQ [4]. In Fig. 5, the particles which were not successfully transported through the model are shown in red, and the longitudinal acceptance consists of the white area in the center of the distribution.

A complete determination of this window would require a full measurement of the time structure of the probe beam, which could then be deconvolved with the phase scan. Without such a measurement, this window may be regarded as a minimum phase acceptance. Since the energy width of the beam used for the measurements is <0.1%, the same concern does not apply in the vertical direction.

CONCLUSION

A series of measurements was undertaken in November 2013 to characterize the longitudinal acceptance of the ReA RFQ. It was determined that the range of beam energies transmitted at optimum phase with minimal loss is +/- 5% relative to the design energy of 12 keV/u. This acceptance width is consistent with simulation, and should allow for the...
construction of a low frequency prebuncher with an energy spread of +/- 3-4%.

REFERENCES


