HOM MEASUREMENTS ON THE ARIEL eLINAC CRYOMODULES

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Abstract

The ARIEL eLINAC is a 50 MeV, 10 mA electron LINAC designed for the creation of rare isotopes via photo-fission. Future upgrade plans include the addition of a re-circulating beam line to allow for either further energy increase of the beam beyond 50 MeV or to operate a free electron laser in an energy recovery mode. For both recirculating LINAC and ERL the higher order modes (HOM) have to be sufficiently surprised to prevent beam-break-up. The design of the 1.3 GHz nine-cell cavity incorporated this requirement by including beam line absorbers on both ends of each cavity and an asymmetric beam pipe configuration on the cavity to allow trapped modes to propagate to the beam line absorbers. Measurements of the higher order modes on the completed injector cryomodule and the first cavity in the accelerating cryomodules will be shown and compared to simulations.

INTRODUCTION

ARIEL will complement the existing accelerator complex at TRIUMF with its rare isotope program. With the addition of the eLINAC up to three out of ten experimental stations (currently one out of ten) can receive rare isotope beams (RIBs). The production of the RIBs is done via photo fission that utilizes the 50 MeV 10 mA continuous wave (cw) e^- beam from the eLINAC. In the finished eLINAC three cryomodules house five 1.3 GHz nine cell cavities. The cryomodules are split into one injector cryomodule (ICM) with one cavity and two accelerator cryomodules (ACM) with two cavities each. In the first phase only one ACM is available and recirculating the beam to use the first ACM a second time is an attractive option to reach 50 MeV. After the eLINAC is completed the recirulating beam line can be used to excite an FEL and run the eLINAC in an energy recovery LINAC (ERL) mode which layout can be seen in fig. 1. Both operation modes, recirculating and ERL, are vulnerable to multi-pass BBU [1]. Therefore it is necessary to study the HOM spectrum of the cavities.

Beam dynamic calculations have shown a limit in dipole shunt impedance $R_{Sh,d}$ (as defined as in Ref. [2]) of 10 MΩ to have a high enough threshold current. A fabrication tolerance study showed uncertainties of up to a factor of two in shunt impedance [3] therefore a lower limit of 1 MΩ is set as goal. Simulation with ACE3P [4] show that this can be reached using the TRIUMF cavity design [5] which utilizes beam line absorbers to reduce the quality factor Q of the HOMs. The damping material CESIC has been tested for its RF properties in a cryogenic environment [6] and found adequate to reach the goal.

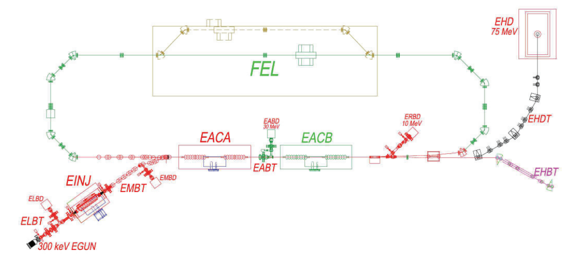

Figure 1: Proposed layout of the ARIEL accelerator with future recirculating beam lines for additional energy gain or ERL operation.

HOM MEASUREMENTS

Figure 2: Injector cryomodule of the ARIEL eLINAC.

HOM beadpulling measurements on a copper model of the ARIEL nine-cell cavity have agreed reasonable well with simulations [7]. For measurements on the cryomodules (fig. 2 shows the ICM), transmission measurements between the main power coupler and the pick-up probe are fitted to a Lorentz-function to extract the frequency and bandwidth. For the data acquisition a Labview program was written to automatically collect the transmission data from a network analyzer for a narrow frequency band and after the signal is sufficiently stable, move on to higher frequencies. This way the resonant frequencies were identified. To improve the resolution on high Q modes, high precision measurements of each resonance followed with a narrower frequency span to improve on resolution. Since the frequency is in the range of 1 to 3 GHz, the bandwidth for modes with Qs of 10^7 and higher is of the order of 100 Hz and lower. This makes measurements difficult as the resolution of the network analyzer is limited and frequency fluctuations cause by small Helium pressure changes or physical vibrations broaden the resonance. This sets the limitations

ISBN 978-3-95450-178-6

of the measurements to Qs of 10^7 to 10^8. Both the coarse and fine measurements were taken while outer conditions (cavity tuner position, helium pressure), that could change the frequency, were kept as stable as possible to avoid frequency shifts in the HOMs.

Figure 3 compares the measured frequencies on the ICM to

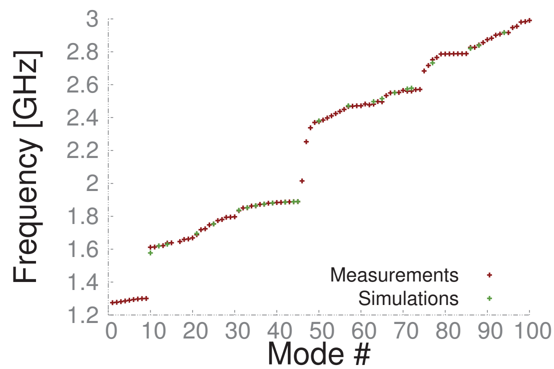

Figure 3: HOM frequencies measured on the ICM.

simulated frequencies. The simulations are limited to one polarization of dipole modes, while the measurements are not limited to these modes. The simulated frequencies can be matched well to a measured HOM. As predicted by the eigenmode simulations, no HOM is close to the beam frequency harmonics at 1.95 GHz and 2.6 GHz.

As a benchmark of the fitting procedure the accelerating TM010-π mode was measured and fitted to $2.6 \cdot 10^6 \pm 13\%$ as can be seen in fig. 4. This agrees well with manual measurements of a $Q_L = 3 \cdot 10^6$.

Measurements on the ICM and ACM can be seen in fig.

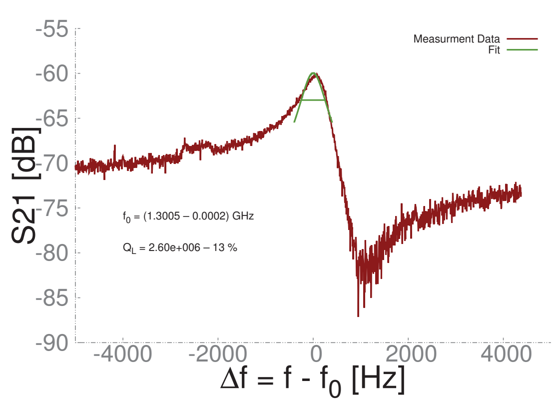

Figure 4: Fitting a Lorentz-curve to the resonance signal of the TM010-π mode reveals the Q_L.

5 and 6. The Q_L of mode with f > 2 GHz could not be successfully measured due to very low transmission signals even after signal amplification. Since no dedicated HOM couplers are used in this cavity design, the coupling of the main power couplers to the HOMs is weak.

A possible cause for the difference between measurement and simulation comes from a unfavorable measurement setup. Possible capacitive or inductive loading of the

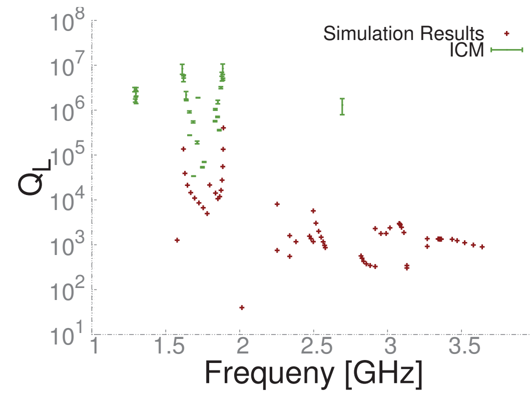

Figure 5: Q fitting results of the ICM compared to simulations show a difference for modes between 1.5 and 2 GHz of 2 orders of magnitude in Q_L.

measurement signal could decrease the observed bandwidth and therefore increase the fitted Q_L values. This could not be verified by the time of writing. Further measurements are planned.

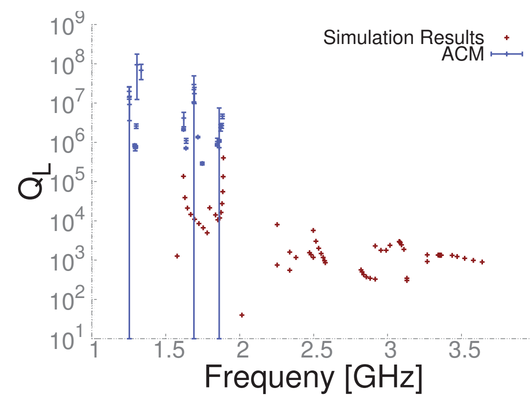

Figure 6: The results of Q measurements on the ACM compared to simulation results show similar results as the ICM.

BEAM BASED MEASUREMENTS

To fully verify the HOM design of the cavity, beam based measurements have to be done. [8] describes possibilities of using either a bunch offset (see fig. 7) or a bunch charge modulation to excite HOMs and extract the Q_L and R_d/Q of strong modes by measuring a kick of the beam after the cryomodule with a beam position monitor. Simulations of the added radial displacement of the beam after the cryomodule can be seen in fig. 8 for a HOM at 2.577 GHz with a Q of 10^5 and a R_d/Q of 77 Ω. Currently the realization of either method on the eLINAC is being investigated.

CONCLUSIONS

HOM measurements using the transmission signal through the cavity showed higher Q_L for modes between 1.5 and 2 GHz than expected. Additional transmission measurements are planned to study this difference. To finalize

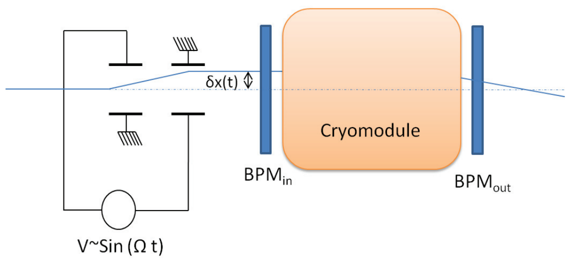

Figure 7: Potential setup for beam based HOM measurements. A pair of RF deflectors creates a modulation in the beam offset to the beam axis and excites a HOM if the modulation frequency matches to a HOM.

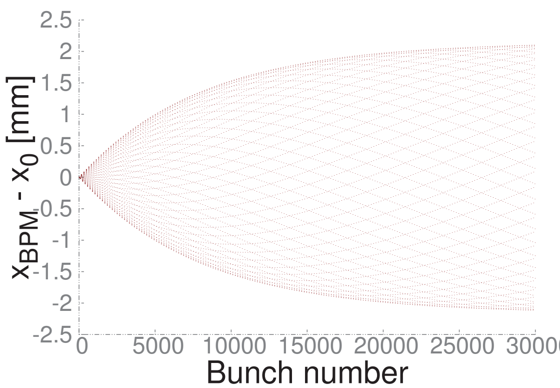

Figure 8: Simulated bunch position after the beam gets kicked by HOM in the ACM cryomodule.

the HOM characterization beam based measurements are needed. These measurements can reveal the Q as well as the R/Q of the HOMs. The realization of these beam based measurements is being investigated.

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ISBN 978-3-95450-178-6