Experimental Investigation of the HLI-RFQ

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Introduction

In 2010 the 4-rod Radio Frequency Quadrupole RFQ of the High Charge State Injector HLI at the UNILAC was replaced [1]. After solving serious thermal problems, the new RFQ was commissioned and operated successfully [2]. Yet there are still issues related to the thermal and mechanical stability, which have to be solved in order to reach full (design) performance.

Thermal Stability

Although all relevant parts of the structure are directly water cooled, the structure reacts rapidly to even small changes of the thermal load. The frequency changes by approx. 200 kHz from low to 50% design rf power. This has severe impact on the frequency controller, which acts on two plungers. During tuning of the machine, the average power $\bar{P} = P_{\rm rf} \cdot t_{\rm pulse} \cdot f_{\rm rep.}$ can only be changed in small steps to allow the controller to follow. For stable operation, all parameters have to be fixed. After rf breakdowns (sparking), the RFQ immediately loses resonance and has to be restarted from 'cold' position at low rf amplitude.

Estimates of the power loss and the cooling efficiency indicate a temperature change of 10–20 K. In order to verify this, parts of the structure were heated with warm water and the frequency change was monitored. The results agree well with the estimates. Further tests and simulations of the cooling, the power loss and resulting temperature distributions, and the frequency response are necessary to specify upgrade measures.

Mechanical Stability

The rf power reflected by the RFQ shows a modulation (Fig. 1), which is a feature already known from similar 4-rod RFQs. Here the magnitude of the modulation severely affects the frequency controller and limits the rf amplitude, while a nice flattop can still be provided. This modulation has a frequency of about 520 Hz, and most probably originates from mechanical vibrations of the electrode rods and/or the coupling loop. These are excited when the electric field is switched either on *or* off. First mechanical simulations of the rods agree well with the observations.

From routine operation at a pulse repetition rate of 50 Hz (Fig. 1 left), it was known that the modulation strongly depends on the pulse length, and operation with high rf amplitudes is only possible at certain values. By exchanging low level rf components, the RFQ could be operated at a pulse repetition rate of only 1 Hz (Fig. 1 right) [3]. With this, the modulation does not depend on the pulse length.

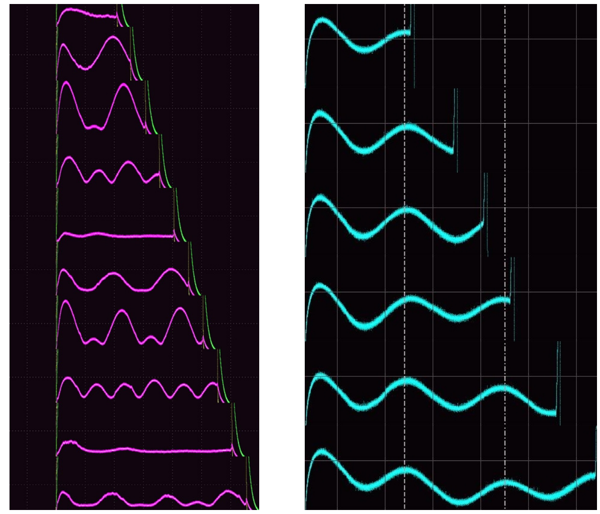

Figure 1: Rf modulation at $f_{\rm rep.}$=50 Hz (left) and 1 Hz (right) and $t_{\rm pulse}$ ≈2–6 ms.

At 50 Hz consecutive pulses interfere. By changing the pulse length, the relative phase between the interfering vibrations and hence the modulation is changed. A more detailed analysis of the rf signals revealed that the modulation is damped with a time constant between 6 and 10 ms. At 1 Hz the vibration is damped completely between two pulses, which are then uncorrelated, and the modulation does not depend on the pulse length.

Efforts were made to confine the region of the structure where the vibrations are excited. The RFQ was operated with clamps on the rods, but no influence could be observed. Only the damping time was slightly reduced [3].

Outlook

Further investigations are necessary before upgrade measures can be tackled. Emphasis will be on mechanical simulations, while tests on the vibrational behavior of the coupling loop are already in preparation.

References

[1] P. Gerhard, GSI-UPGRADE-ACC-03, p. 148, GSI SCIENTIFIC REPORT 2009

[2] P. Gerhard *et al.*, PHN-ACC-RD-05, p. 262, GSI SCIENTIFIC REPORT 2010

[3] P. Gerhard *et al.*, LINAC'12, September 2012, Tel Aviv, THPB035

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