Direct measurement of mechanical vibrations of the 4-rod RFQ at the HLI

P. Gerhard[1]
[1]GSI, Darmstadt, Germany

Introduction

The high charge state injector HLI at the UNILAC was equipped with a new 4-rod Radio Frequency Quadrupole RFQ in 2009. It has been in operation since 2010 [1]. At higher rf amplitudes, strong modulations of the rf matching with f_{mod} ≈500 Hz were observed, limiting the pulse length and rf amplitude achievable. They are attributed to mechanical oscillations of the rods, excited by the rf pulse. As these modulations could only be seen *during* the rf pulse, a direct, independent observation of the mechanical vibrations was needed.

Measurements

A laser vibrometer was used to investigate any movement of the rods independent of rf operation. The vibrometer uses the interference of a laser reflected from the surface of interest with the original light to determine the velocity of the surface. By pointing the laser through a vacuum window onto e. g. the back edge of a rod, we were able to measure the vibration of the rods in situ for different operational states [2].

Results

Fig. 1 shows the effect of the rf pulses on the rods, measured with the vibrometer continuously running, i. e. without synchronization to the rf pulses. Without rf power only some minor vibrations below 100 Hz are visible, excited by cooling water, pumps etc. With rf on, a strong line emerges at 500 Hz. For the inset, only data *between* the rf pulses were analysed. The spectrum shows the 500 Hz signal and a dominant feature at ≈350 Hz. We attribute these lines to different vibrational modes of the rod, with only the 500 Hz mode affecting the rf. Fig. 2 shows the amplitude of the vibration at 500 Hz for different pulse lengths at 50 Hz pulse repetition rate, according to standard operation. The periodic behaviour of the amplitude is consistent with operational experience, especially the minima indicate pulse lengths were operation of the RFQ is most stable. The periodicity of 2 ms matches the vibration frequency of 500 Hz. Together with the small linewidth corresponding to a decay time of 0.3 s (Fig. 1), this confirms the interference of sequentially excited vibrations, which cancel out during the rf pulse at certain pulse lengths [1].

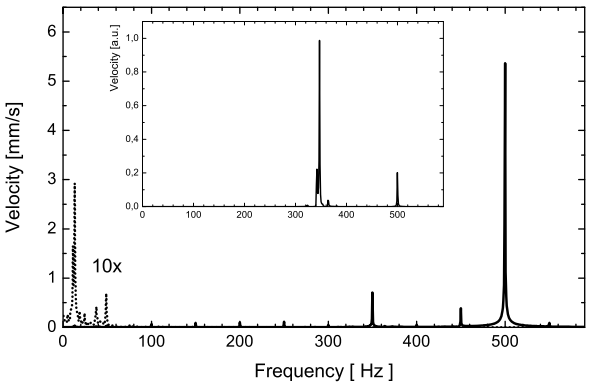

Figure 1: Frequency spectrum of the vibration velocity of the RFQ rod with rf off (dotted, 10 times magnified) and with rf pulses at 50 Hz pulse repetition rate (solid). Inset: Frequency spectrum of the free decay of the oscillations between the rf pulses at 1 Hz pulse repetition rate.

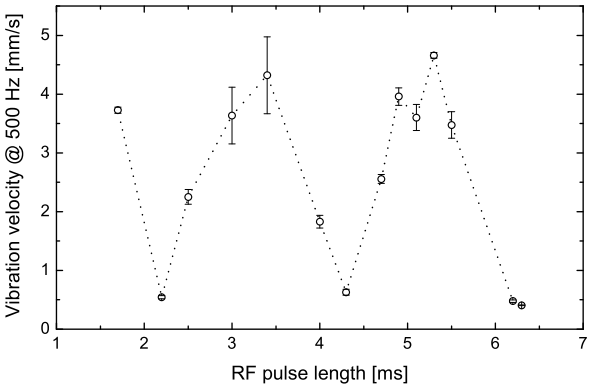

Figure 2: Velocity of the mechanical vibration as a function of the rf pulse length at 50 Hz pulse repetition rate.

Outlook

Mechanical and rf simulations of the present RFQ structure will be conducted to understand the vibration modes and their effect on the rf properties. Based on this, new electrodes will be designed to mitigate these effects.

References

[1] P. Gerhard *et al.*, "Experience with a 4–Rod CW RFQ", LINAC'12, Sept. 2012, Tel Aviv, THPB035

[2] We appreciate the extensive help and assistance of Kay–Obbe Voss, who also provided the laser vibrometer and other equipment.

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