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CONDITIONING OF THE FRONTLINE CAVITIES OF THE MYRRHA INJECTOR

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Abstract

The MYRRHA Project (Multi-purpose hYbrid Research Reactor for High-tech Applications) in Mol, Belgium, is an upcoming accelerator driven system (ADS) for the transmutation of long-living radioactive waste. In the injector section of the accelerator, consisting of a 4-rod RFQ and a normal conducting CH-cavity section, the protons will be accelerated up to 17 MeV before entering the superconducting gap-spoke cavity section with an output energy of 600 MeV [1].

A shortened test-injector with an output energy of 5.9 MeV is currently being installed at the SCK•CEN in Louvein-la-Neuve, Belgium. This test-injector serves the purpose of testing the reliability of the planned injector [2].

When commissioning a cavity, it first has to be fed very little power to avoid damage to the structure by flashovers, discharges and multipacting. The power is then slowly increased up to full operation level. In this process, the surfaces are cleaned by heating/outgasing so that the effects disturbing operation described above do no longer occur. This paper will report on the status of the conditioning of the 176.1 MHz 4-rod RFQ up to 120 kW of the MYRRHA-injector and additional measurements concerning the gap voltage which are currently being performed at the SCK•CEN.

THE CONDITIONING OF THE RFQ UP TO 120 KW

The MYRRHA-RFQ has been conditioned up to 11 kW at the IAP, Goethe University Frankfurt, Germany [3], before being shipped to the SCK•CEN, Louvein-la-Neuve. The operating power level of the RFQ will be 110 kW, a solid state amplifier is used as power supply, a bidirectional coupler installed in the power line prevents reflected power from damaging the amplifier.

A control system is recording forward, transmitted and reflected power, the pressure measured by two Penning-gauges installed on flanges at the high and the low energy end of the RFQ, as well as the temperatures of the water flowing out of each of the 157 cooling channels of the RFQ. The latter is mainly used to detect blocking or pressure decrease that might occur in the channels and could lead to damage of the RFQ due to overheating.

The interior of the RFQ with the electrodes, tuner and pick-up loop can be seen in Fig. 1.

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Figure 1: The electrodes inside the RFQ, as seen from the high energy end. On the right, the tuner and a pick-up loop can be seen.

During the conditioning at Louvein-la-Neuve, the power was mainly fed into the RFQ in a pulsed mode. When using this way of commissioning a cavity, the variation of the average forward power is not only achieved by increasing or decreasing the forward power provided by the used amplifier, but also by variation of the rf-duty cycle. For example, the power is raised with a small pulse width to begin with up to a certain level, then the pulse width is slowly widened until finally cw mode is reached. This way, discharges can be avoided. Figure 2 shows the measured data at the beginning of the conditioning process, the overcoming of a multipacting barrier can be observed. Multipacting is a resonant electron phenomena between cavity walls, where electron avalanches are accelerated in resonance with the electric field.

The graphs show the measured power values over time as well as the pressure inside the RFQ. In the beginning from ca. 11:37 raising the forward power is no longer accompanied by an increase of the transmitted power, as the energy is used to built up the electron avalanche and is not available to built up the fields inside the cavity.

Feeding this power level into the cavity for some time decreases the secondary electron coefficient and thus damps the amount of multipacting occurring, until finally the barrier is overcome and the transmitted power is reacting proportionally to the forward power, which can be observed just after 11:55. At this point the transmitted power raises significantly.

The last part of the commissioning up to 120 kW in cw-mode is shown in Fig. 3.

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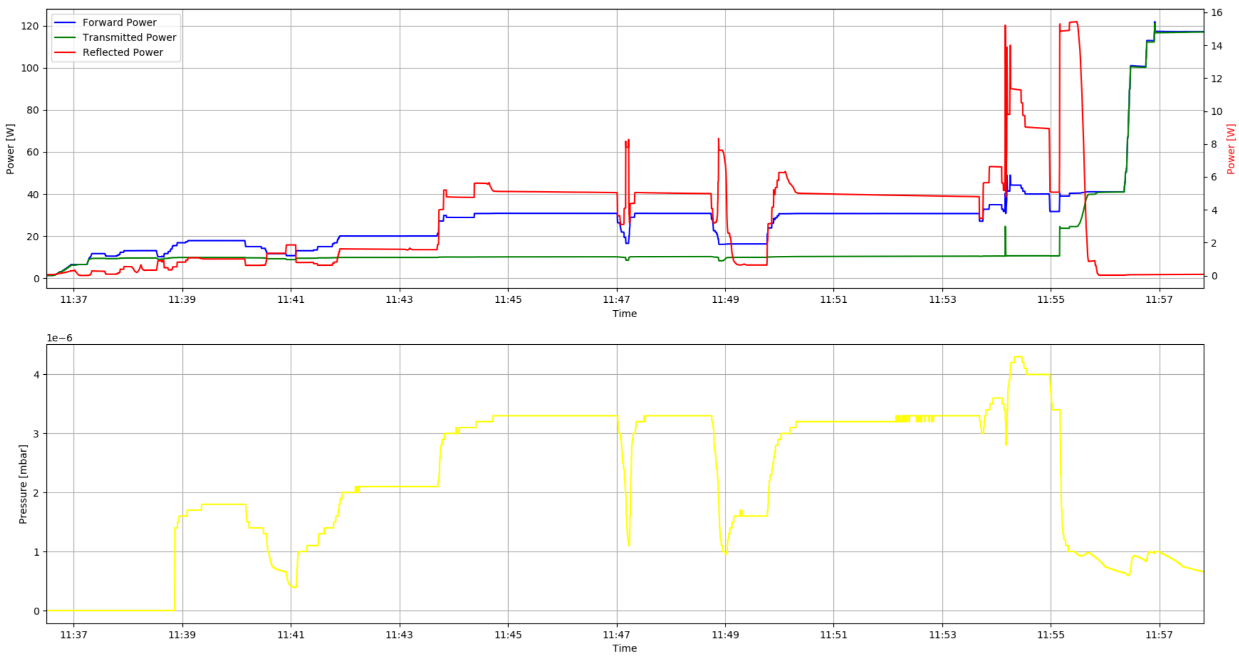

Figure 2: Measured power and pressure data showing the multipacting barrier observed at 20 W.

Figure 3: Measured power and pressure data for the commissioning of the MYRHHA-RFQ up to 120 kW.

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It can be observed that after several days of commissioning, the level of the forward power can be raised up easily to several kW within half an hour. From 09:00 on the forward power is kept constantly at 120 kW until 10:00.

During this period, several discharges can be observed, recognizable by the sudden rapid decrease of the transmitted power and a drastic increase of the reflected power.

During a discharge, the resonance frequency of the cavity shifts, leading to a mismatch of the forward power. The pressure can be observed to increase by an order of magnitude. When discharges occur, the forward power has to be lowered until it stops.

DETERMIATION OF THE GAP VOLTAGE OF THE RFQ VIA THE X-RAY SPECTRUM

As the free electrons of the vacuum inside a cavity are accelerated by the accelerating voltage, the maximal voltage of the structure can be determined by the maximal energy of the photons of the x-ray spectrum, which are produced by the accelerated electrons hitting the cavity walls.

A x-ray spectrometer was used to measure the spectrum from 0 up to 3 MeV. First, a background spectrum with the cavity switched of has to be recorded to substract background radiation from the measurements. For different measurement times, the recorded counts have to be scaled accordingly. The highest voltage is determined by the fastest electron or the photon with the highest energy respectively.

The RFQ is expected to have an electrode voltage of 44 kV at an operating power level of 110 kW [4]. Thus using the relation

$$U \propto \sqrt{P} \tag{1}$$

with the voltage U, the operating power P one can obtain the electrode voltage for any given power for the RFQ. The relation is shown graphically in Fig. 4.

The measurements where done for several different forward power levels, with the spectrometer being placed on the low energy end or the high energy end of the RFQ.

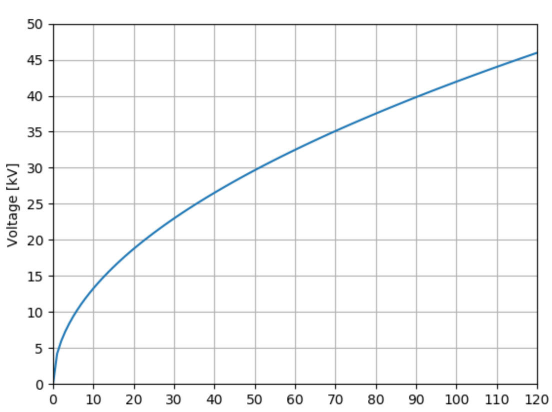

Figure 4: The calculated electrode voltage of the RFQ against the power.

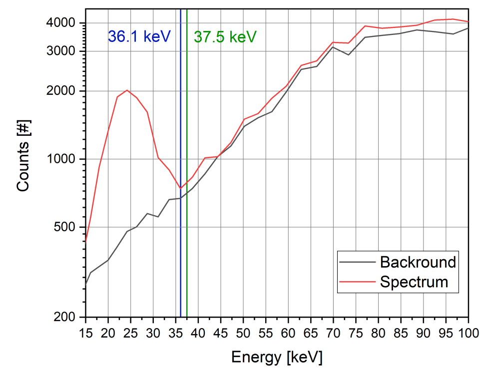

Figure 5: The measured x-ray spectrum of the RFQ for a forward power of 80 kW (red) and the background spectrum (black). Shown is the number of counts of photons as a function of their energy.

Figure 5 shows the measured x-ray spectrum for a forward power of 80 kW. According to equation (1) the expected electrode voltage is 37.5 kV. The data shows that the maximal energy x-ray radiation from the RFQ at this power is about 36 keV, which is well within the expected error range of 5 %.

CONCLUSION

The MYRRHA-RFQ was conditioned up to 120 kW at the SCK•CEN in Louvain-la-Neuve, Belgium. At this point, this power can be fed into the cavity without expecting any disturbances. A determination of the maximal electrode voltage using x-ray spectroscopy has been performed, which showed that the measured voltage matches the simulations within an acceptable error range.

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