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CURRENT STATUS OF THE MYRRHA PROJECT AT IAP FRANKFURT

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Abstract

As part of the MYRRHA project, which is being implemented in Mol, Belgium, two of the planned 17 normal-conducting CH cavities have been built and tested at several kilowatts of RF power. Since the cooling concept for the stems was revised after their construction, concerns arose that the two existing cavities might have suffered a degradation in performance during high-power testing due to the outdated cooling system. Consequently, it was decided to subject cavity CH02 to renewed LLRF measurements at IAP Frankfurt to ensure that its performance has not deteriorated. The cavity is then scheduled for high-power testing at the newly established high-power station at IAP. This will not only serve to commission the test stand but also recondition the cavity

This paper summarizes the recent LLRF measurements performed on CH02 and reports on the current status of preparations for the upcoming conditioning.

INTRODUCTION

The MYRRHA (Multi-purpose hYbrid Research Reactor for High-tech Applications) project is a planned accelerator driven system (ADS) that will deliver in its final form a 4 mA proton beam with 600 MeV for neutron production for the transmutation of long-living radioactive waste. [1] A critical passage for the beam quality and especially for the emittance is the injector, which for the MYRRHA project consists of a 4-rod RFQ, two Quarter Wave Resonators (QWR) and a total of 16 normal conducting CH-DTL cavities [2].

Two of these cavities have already been built, tested, and conditioned at IAP Frankfurt.

The New Cooling Design for the Stems

Since the construction of cavities CH01 and CH02, the cooling concept for the stems has been further developed. To this end, so-called inserts were designed to locally increase the heat transfer coefficient at previously identified hotspots by inducing additional turbulence. This significantly reduces the simulated maximum temperature at the stems. [3]

Fig. 1 shows a cross-section of a stem with an insert and the insert itself. In exemplary simulations performed on a CH03 stem, the maximum temperature was reduced by 37.3 K using this new insert design. [3]

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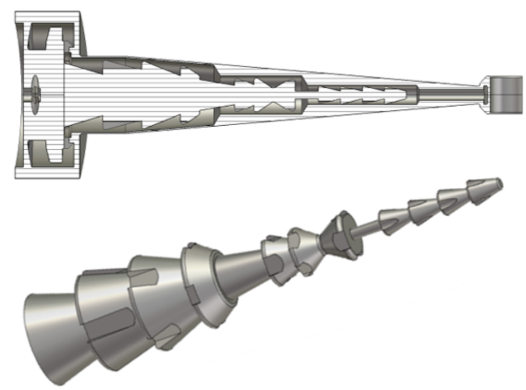

Figure 1: Top: Cross-section of a stem with an insert. Bottom: Perspective view of the insert.

LLRF MEASUREMENT OF CH02

During Low-Level RF (LLRF) measurements, the fundamental properties of a cavity are characterized at low power levels.

CH02 underwent extensive LLRF measurements in 2019, followed by conditioning with more than 8 kW in continuous-wave (cw) operation. To assess whether the cavity experienced any degradation in performance during conditioning due to the absence of the later-developed inserts, the LLRF measurements were repeated. In principle, performance degradation caused by insufficient cooling would be expected to manifest as a shift in the resonance frequency without tuners or as a change in the voltage distribution, since such parameters would be measurably affected by permanent thermal deformation.

Resonance Frequency and Q-value

Since reconditioning was planned, a critical coupling of $\beta = 1$ was chosen for the coupling loop. Prior to this, it was verified that an overcoupling of approximately $\beta \approx 1.10$ - including beam loading for future beam operation - is feasible. Fig. 2 shows the result of the calibrated S11 measurement using a network analyzer (NWA). The cavity, measured without the tuners, exhibits a resonance frequency of 176.8 MHz. Taking measurement uncertainties into account, this value is consistent with the results obtained in 2019 before the conditioning.

To determine the quality factor Q_0, calibrated S21 measurements were performed using the coupling loop and, subsequently, both pick-ups. From these measurements, values

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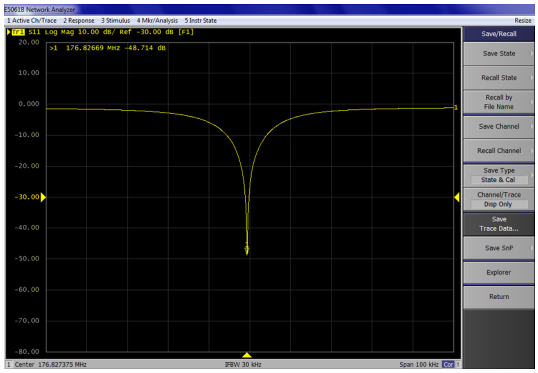

Figure 2: Calibratet S11 measurement of the resonance frequency performed on CH02.

for the loaded quality factor Q_L were obtained, allowing the calculation of the intrinsic quality factor Q_0, which was found to exceed $1.3 \cdot 10^4$. This result is also consistent with the 2019 measurements, within the expected measurement uncertainties.

Tuner Position and Tuning Range

To compensate for potential deviations from the simulated resonance frequency—caused, for example, by manufacturing tolerances or the copper-plating process—and to maintain a stable frequency during operation, the normal-conducting MYRRHA CH cavities are designed to be equipped with two tuners. These tuners are symmetrically positioned within the cavity to achieve the target resonance frequency of 176.1 MHz under vacuum conditions. This position is referred to as the "working point." One of the two tuners functions as a dynamic tuner, which can be adjusted under vacuum during operation to stabilize the frequency.

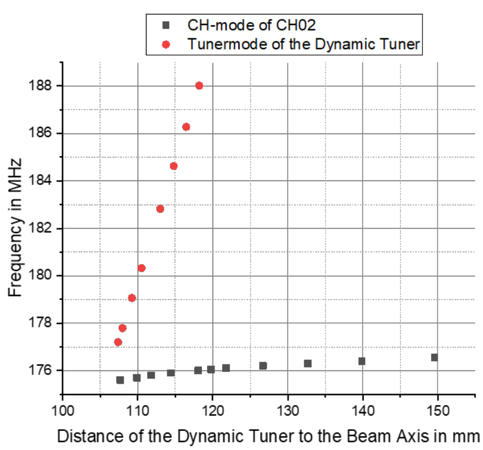

Figure 3: Evolution of the CH mode and the tuner mode as a function of the distance of the dynamic tuner to beam axis.

Fig. 3 shows the evolution of the CH mode and the tuner mode as a function of the dynamic tuner's distance from the beam axis. The tuning range spans from 175.6 to 176.5 MHz, which is sufficient for future beam operation. The tuner mode, shown in red, remains well separated from the CH mode throughout the entire tuning range, posing no risk to the cavity's reliable operation.

Bead Pull Measurements

In the bead-pull measurement, a small perturbing object is moved along the beam axis through the cavity at constant speed using a thin nylon string, while the phase shift is recorded by a network analyzer (NWA). Exemplary results of such measurements are shown in Fig 4, where the left image shows a measurement in the beam direction and the right image shows one in the opposite direction for CH02.

Table 1: Comparison of the Relative Voltage Distributions From Beam Dynamics Simulations and the Averaged Results of the Bead-Pull Measurements

Type	**Gap 1**	**Gap 2**	**Gap 3**	**Gap4**
Beam Dyn.	17.33 %	32.72 %	33.47 %	16.53 %
Bead Pull	16.79 %	33.29 %	33.96 %	16.96 %

Due to the mechanical setup—where the nylon string is guided through the cavity via several deflection pulleys and driven by a stepper motor—bead-pull measurements are subject to non-negligible errors caused by slippage and fluctuations in the string tension. Taking these uncertainties into account, the bead-pull results for CH02, as shown in Table 1, are consistent with the predictions of beam dynamics and RF simulations within the expected measurement tolerances.

NEXT STEPS

The remaining normal-conducting CH cavities for the MYRRHA injector — either still under construction or yet to be built — are planned to be tested at IAP Frankfurt. For this purpose, as described in [4], a Low-Level Station, a Preparation-Station, and a High-Power Station have been installed in the experimental hall at IAP Frankfurt.

Following the completion of low-level measurements on CH02 in the Low-Level Station, the cavity will next be sealed vacuum-tight in the Preparation Station and equipped with cooling water lines and temperature sensors. After vacuum integrity is confirmed — and a leak test is performed if necessary — CH02 will be transferred to the High-Power Station, located in the IAP cryo bunker, where it will be conditioned at several kilowatts of RF power. According to current planning, the conditioning is expected to be completed in the second half of the year.

SUMMARY

To verify whether CH02 had experienced any degradation in performance during earlier conditioning due to the absence of the improved cooling system, the cavity was subjected to renewed LLRF measurements. No deviations beyond the measurement uncertainty were observed compared to previous results. The cavity is currently being prepared for reconditioning, which is scheduled to take place later this year. This will serve both to finalize the commissioning of the test setup in the experimental hall at IAP Frankfurt and to prepare the cavity itself for its future operation in the MYRRHA injector.

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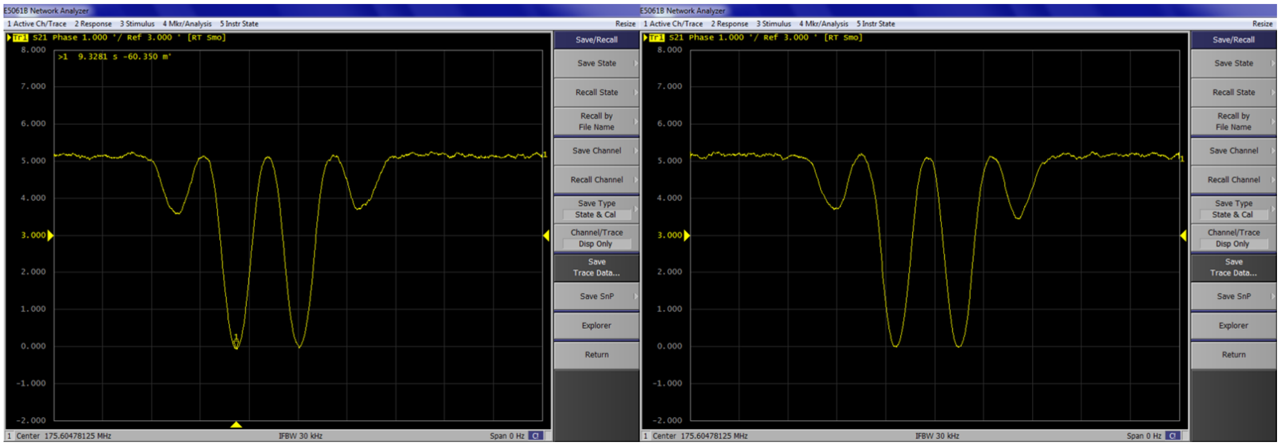

Figure 4: Exemplary results of a bead pull measurement on CH02. Left: Performed in beam direction. Right: Performed against the beam direction.

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