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FIRST VERTICAL TEST OF A PROTOTYPE CRAB CAVITY FOR HL-LHC AT FREIA LABORATORY IN UPPSALA UNIVERSITY

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Abstract

We developed and commissioned a new vertical test stand at FREIA Laboratory for the High-Lumi LHC (HL-LHC) project. The first cold test was performed with a prototype crab cavity and the obtained result met the project specification. This opened a new opportunity at Uppsala University for superconducting radiofrequency (SRF) science and engineering. In this paper, the result of the first cold test and plans for future experiments are presented.

INTRODUCTION

The FREIA laboratory is a leading facility for accelerator development in Sweden. It actively supports the development of the European Spallation Source, CERN, and MAX IV, among others [1]. In particular, the HL-LHC project is presently one of the core projects and we contribute to testing corrector dipole magnets and crab cavities. The main objective of this paper is to qualify the newly commissioned vertical test-stand GERSEMI for the Double-Quarter-Wave (DQW) crab cavity testing [2], using a prototype cavity as shown in Fig. 1.

Figure 1: photograph of a prototype DQW cavity.

EXPERIMENTAL

GERSEMI is a general-purpose cryostat for testing both superconducting magnets and cavities and was cooled down to 2 K, for the first time, at the end of 2019 [3, 4]. Figure 2 shows a schematic of GERSEMI and a photograph of a cavity insert. The cryostat has large active diameter of 1106 mm and 2860 mm long filled with liquid helium volume of 2650 L. Thanks to these large dimensions, GERSEMI can accommodate different types of cavities and potentially multiple cavities at the same time. An insert dedicated to superconducting cavities was developed by using non-magnetic materials. Depending on the purpose and size of each cavity, the volume of the cryostat can be flexibly decreased with cryogenic foams to reduce the helium amount.

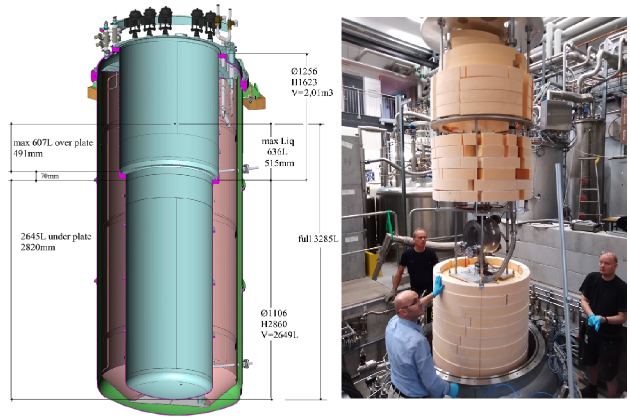

Figure 2: GERSEMI cryostat and a cavity insert.

The cryostat is equipped with active compensation coils without magnetic shields. We showed [5] that a very uniform (1.2%) and weak (<1 µT) field around SRF cavities can be achieved in a systematic way. A prototype 3-axis fluxgate sensor [6] was installed on a cavity and the magnetic field was monitored during cooling down. Figure 3 shows temperature history during cooling down monitored by four CERNOX sensors on the cavity, and 3-dimensional magnetic field components. The temperature gradient of the cavity was controlled to be below 60 K when the average temperature was above 120 K. All the components of the magnetic field were kept below 0.6 µT to avoid flux pinning at the superconducting transition.

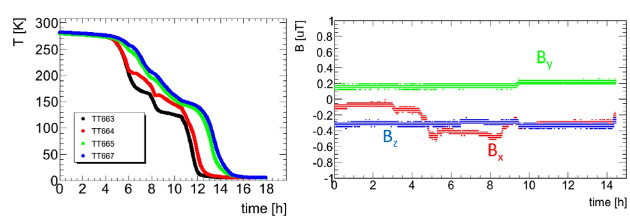

Figure 3: cooling down curve and magnetic fields.

After the cryostat was filled with liquid helium and well thermalized at 4.2 K, it was pumped down to 2 K and then 1.8 K. Figure 4 shows the stability of pressure at 2K. This very stable (standard deviation 4.7 µbar) allowed a conventional analogue phase-lock-loop (PLL) circuit to lock the cavity at resonant frequency as shown in Figure 5. This PLL circuit was originally developed for the LHC project at CERN and was used for this project with a 400 MHz solid state amplifier. In the future, digital self-excited-loop (SEL), which is currently in use for ESS cryomodule testing, will be deployed for cavity experiments at GERSEMI.

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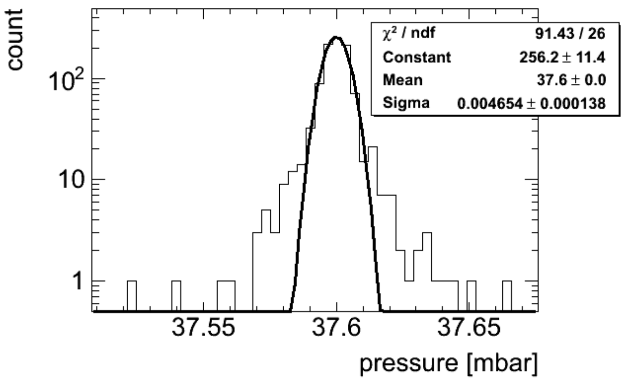

Figure 4: Pressure stability.

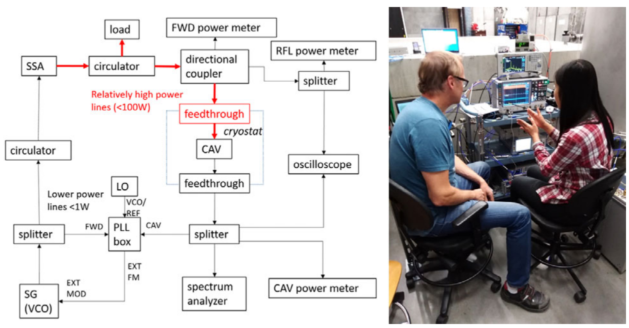

Figure 5: PLL circuit and photo of the RF measurement.

RESULT

Figure 6 shows the first experimental results on the prototype DQW cavity evaluated in GERSEMI. Both 2.0 K and 1.8 K results met the project specification. The highest field was limited by a quench. From these results, the newly commissioned GERSEMI cryostat was qualified for SRF cavity testing.

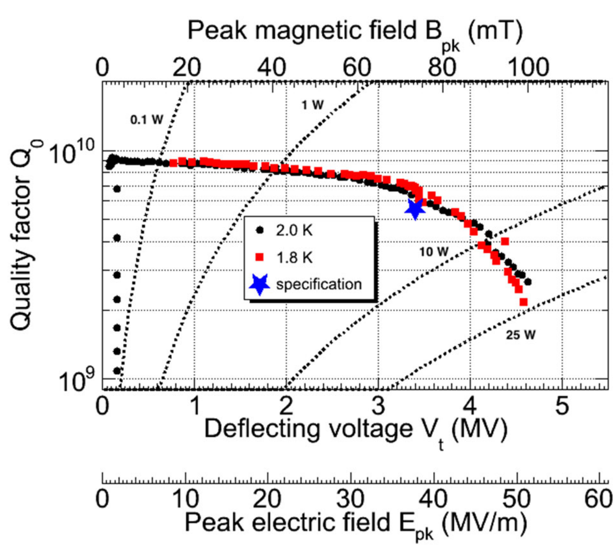

Figure 6: Performance of the prototype DQW cavity measured in GERSEMI.

Although the performance of the first test met the specification, several issues were recognized for future improvement. First, the Q-slope onset and quench field were lower than previous experiments of the same cavity in the US and at CERN. We localized a vacuum leak in a gate-valve that could contaminate the cavity surface during installation of the insert into the cryostat. The issue was already fixed after the first test. Secondly, an RF feedthrough selected for the first test was not optimal and caused corona discharge in some conditions. Another feedthrough is prepared for subsequent tests and eventually any use of RF feedthroughs will be avoided. Finally, after the first cavity experiment, GERSEMI was used for the first superconducting magnet tests. This dipole magnet reached over 2 T and gave rise to a concern on possible magnetization around the cryostat. The inserts of magnets and cavities are independent and local magnetization there is not considered. The coils can compensate homogenous magnetization around the cavity volume. 3-dimensional magnetic field mapping of the cryostat will be performed to evaluate inhomogeneous magnetization potentially generated by the magnet testing.

CONCLUSION

We tested the prototype DQW cavity in the GERSEMI vertical test stand in FREIA. The performance met the spec, and our experimental procedure and infrastructure are qualified for testing production crab cavities in the HL-LHC project. We found several minor issues to be easily improved by the next cold test. This was the critical milestone in the project and it also opens new opportunities for superconducting cavity testing in FREIA. Since GERSEMI can accommodate different types of cavities thanks to its large dimension, FREIA will be able to contribute to other SRF projects in the future.

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