ISBN: 978-3-95450-227-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2022-THPOTK026

DEVELOPMENT AND TEST OF A PROGRAM FOR AUTOMATIC CONDITIONING OF ROOM TEMPERATURE CAVITIES

K. Kümpel†, H. Podlech, A. Rüffer, M. Märcz, C. Wagner, S. Wagner, Institut für Angewandte Physik (IAP) at Goethe-University Frankfurt am Main, Frankfurt am Main, Germany

Abstract

The conditioning of room temperature cavities is a time-consuming process that can take several weeks and requires the supervision of experienced experimenters. To simplify this process for future cavities, a program is currently being developed at the IAP Frankfurt that will simplify the experimenter's work and eventually will take it over completely. This paper describes the basic setup of the program as implemented so far, as well as the tests performed on different cavities. In addition, an outlook for the next development steps and their application is given.

INTRODUCTION

Conditioning is the process of slowly increasing the power injected into the cavity until the power levels necessary to create the electric fields required by the beam dynamics are reached.

During the conditioning process, undesirable effects can occur within the cavity, with multipacting, outgassing and discharges being among the most common. These undesirable processes not only disrupt the conditioning process, but also pose the risk of permanent damage or destruction to the cavity itself or the measuring equipment used. [1] Therefore, conditioning should only be carried out extremely carefully and by trained personnel.

During conditioning, as is usually carried out at the IAP Frankfurt, the forward power P_f, the reflected power P_r and the transmitted power P_t are monitored by the experimenter in addition to the pressure p inside the cavity, while the conditioning can be controlled by the level of the forward power P_f and its frequency *f*.

Typically, conditioning takes between a few days and several weeks, whereby the required conditioning times can vary greatly even for structurally similar cavities.

In order to be able to reduce this large amount of time for the experimenter in future conditioning, a program should be written that supports the experimenter.

PROGRAM

The new program is based on a LabView-based readout software that was developed as part of a master's thesis at the IAP Frankfurt and has already been successfully used to condition cavities for the MYRRHA project. [2]

Several functions should be added to this program:

Emergency Stop

The most important function for the safety of the cavity and the connected measuring equipment is the implementation of an emergency stop, which completely shuts down the conditioning.

Since the measured values for the pressure p and the reflected power *Pr* increase during problems that occur during conditioning, these values are particularly suitable to be used for the emergency stop.

In its present form, the program can be given limit values for the pressure *p* and the ratio of P_r/P_f during operation, and if these are exceeded, the conditioning is immediately terminated.

For this purpose, an interface between the program and the signal generator used has been implemented in order to be able to switch off the forward power here, while another interface with which the amplifier can be switched off directly is conceivable, but has not yet been implemented.

Frequency Adjustment

Due to thermal effects, the frequency can change with the level of transmitted power P_t, which is indicated in an increase in reflected power P_r, while the pressure *p* usually shows little to no change.

The necessary adjustment of the frequency is achieved within the program by a simple algorithm that searches for a minimum of the ratio P_r/P_f in a predefined number of iteration steps. Of course, it must be considered that this frequency adjustment does not lead to success in all cases. Especially with larger deviations, this method is still too slow.

Automatic Conditioning

The automatic conditioning builds up from a gradual increase of the forward power P_f, checking the pressure p and the ratio P_r/P_f at fixed intervals. Two limits can be set for each of these measured values, defining three ranges. In the first range, where both values are below the lower limit, P_f is increased further. If at least one value is between the two limits, the program waits for another measuring cycle before measuring again. This range is used to "wait" until the values normalise while there is still no danger to the cavity and the equipment used.

As soon as one of the values is above the second limit, the conditioning is aborted and the forward power P_f is switched off.

ISBN: 978-3-95450-227-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2022-THPOTK026

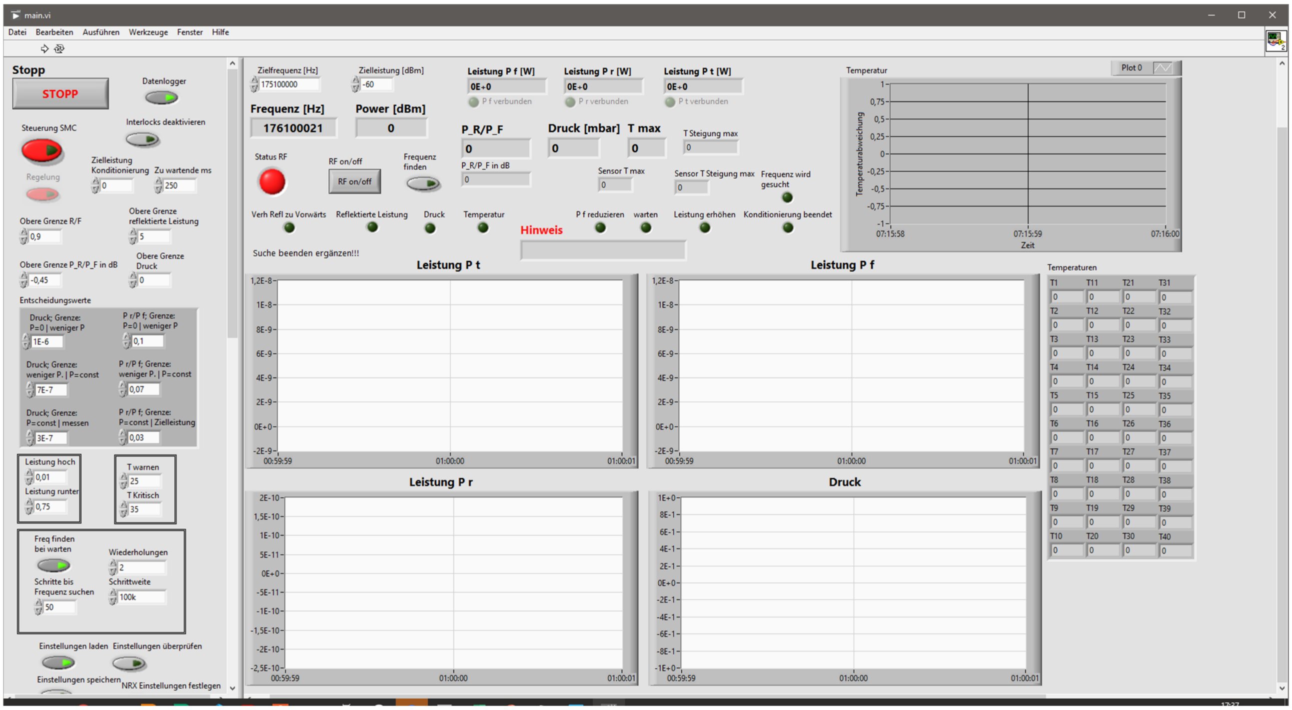

Figure 1: Current Graphical User Interface (GUI) of the program in German.

GRAPHICAL USER INTERFACE

Figure 1 shows the current version of the Graphical User Interface (GUI) of the program in German.

On the left side are the settings for automatic conditioning and frequency adjustment, whereby in addition to the already mentioned freely adjustable limits, there are also limits for maximum temperatures of the cooling water.

In the middle are the graphical displays for the three powers P_f, P_r and P_t, as well as for the pressure p. Above this are the values for the frequency f and the level of the output power in dBm read out from the signal generator.

On the right-hand side, the temperatures for currently up to 40 temperature sensors are displayed, whereby this number can be expanded if required.

EXPERIMENTAL SETUP

In order to be able to test the functionality during the development of the program, an experimental setup was built in the experimental hall of the IAP Frankfurt, as shown in Fig. 2. In this setup, a 4-rod RFQ prototype with 4 stems was conditioned with a 500 W amplifier, whereby the signal generator was operated either by the experimenter or the program.

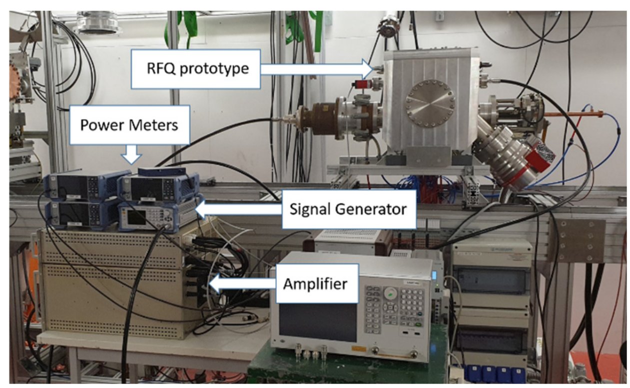

Figure 2: Experimental setup in the experiment hall of the IAP Frankfurt consisting of an RFQ prototype powered by a 500 W amplifier. Control is via a signal generator and the power is measured via three power meters.

During the tests, it proved to be advantageous that the individual limit values for the pressure p and the ratio P_r/P_f could be adjusted and changed during the ongoing measurements, as this allows individual circumstances of the cavity and its behaviour during conditioning to be addressed. Functions were also implemented to affect the step size of the power increases and the readout rate of the recording software.

ISBN: 978-3-95450-227-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2022-THPOTK026

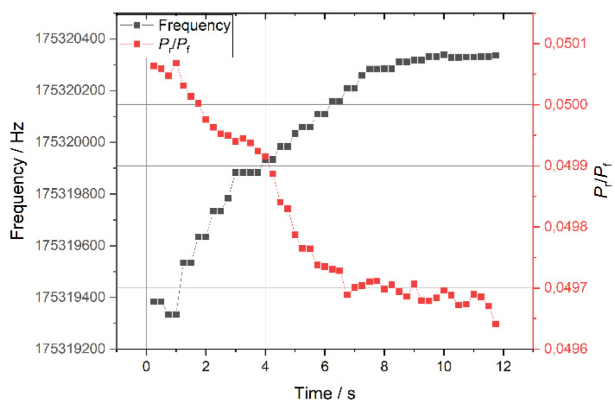

Figure 3: RFQ with Laser-vibrometer. The Setup is the same as during HF-Power tests involving Vibrometer measurements.

Figure 3 shows a test run of the automatic frequency adjustment. Within 12 s, the frequency *f* was changed in such a way that P_r/P_f could be significantly reduced. As can be seen very clearly, the changes in frequency become smaller and smaller with increasing adjustment. The limiting factor of the frequency adjustment was the fact that currently a maximum of 4 values per second can be transmitted from the measuring devices to the program, which leads either to insufficient results or to a very long adjustment time.

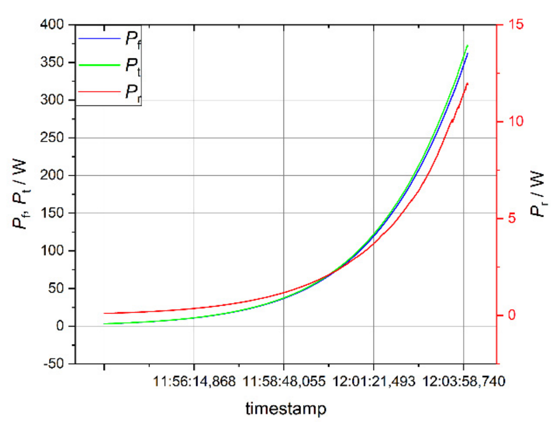

Figure 4: Test run of the automatic conditioning of the programme up to approx. 370 W.

The test run shown in Fig. 4 shows an automatic increase of the transmitted power P_t up to about 370 W at the end of the test series with the 500 W amplifier.

At this point, the conditioning of the RFQ prototype was already so far advanced that no undesirable processes occurred in the power range under consideration, which is why the power ramp-up could take place without interruptions.

CONCLUSION AND OUTLOOK

In order to support the experimenter in future conditioning of normally conducting cavities, a program was developed at the IAP Frankfurt that should fulfil two main tasks.

On the one hand, it should be possible to define thresholds at which the program automatically triggers an emergency stop, thus protecting the cavity and the connected measuring equipment, and on the other hand, it should be possible to carry out the conditioning automatically via a simple algorithm, whereby it should also be possible to carry out automatic frequency adjustments.

During several test runs, in which an RFQ prototype was conditioned, the program could be tested extensively, whereby the emergency stop proved to be extremely reliable, especially because of its individually adjustable thresholds.

Automatic conditioning also proved useful, although it is so far far from being able to replace an experienced experimenter.

The frequency adjustment is functional in principle, but needs further improvement due to its current limitations, such as the maximum recording of 4 values per second.

It is planned to further develop the program during future conditioning at the IAP Frankfurt, whereby the use of machine learning is currently being considered.

ACKNOWLEDGEMENTS

We would also like to thank the Helmholtz Research Academy Hesse for FAIR (HFHF) for their financial support.

REFERENCES

[1] K. Kümpel, “Untersuchungen am MYRRHA Injektor”, Doctoral Thesis, Institut für Angewandte Physik, Goethe Universität Frankfurt, Germany, 2022.

[2] S. Zimmermann, “Automatisierung von HF-Leistungstests der MYRRHA CH-Driftröhrenkavitäten”, Master Thesis, Institut für Angewandte Physik, Goethe Universität Frankfurt, Germany, 2020.