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UPGRADE OF BEAM DIAGNOSTIC SYSTEMS OF JULIC CYCLOTRON

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Abstract

The JULIC cyclotron is in operation since already more then 50 years. Many subsystems of the cyclotron have been upgraded since then, to meet a requirements of the users or simply to the state of the art. In this contribution status of upgrade of the cyclotron beam diagnostic and magnet field control system is presented. Besides that, an example of application of laser doppler vibrometer and proof-of-principle experiment for none-destructive low beam current and position measurement are described.

JULIC CYCLOTRON

The Institute für Kernphysik (IKP) of Forschungszentrum Jülich exploits JULIC cyclotron since already more than 50 years. The JULIC cyclotron is build as a classical isochronus cyclotron with axial injection from the external particle sources. It has a large normal conducting magnet, 100 kW power HF-system with three Dee's for the acceleration and electrostatic extraction system. Almost last 30 years JULIC is mainly used as injector for the accelerator and storage ring COoler-SYnchrotron Jülich (COSY-Jülich) [1]. This is why presently JULIC is only used for acceleration of light negative H - and D - ions for the stripping injection into the COSY ring, at the energies of 45 and 55 MeV, respectively.

Besides operation as COSY injector, JULIC is frequently used for the irradiation of the electronic components, new materials, and for the development of the new generation of the accelerator driven High Brilliance neutron Source (HBS) [2].

VIBRATION OF THE CYCLOTRON INTERNAL ELEMENTS

Since significant time JULIC users have been confronted with a 33 Hz noise ripple in the extraction pulse of the cyclotron. This strong intensity fluctuation disturb COSY operation and due to the injection scheme of the storage ring (20 ms injection pulse every two seconds) did not allow beam intensity optimisation in the machine. The ripple was sudden appearing and disappearing in the extraction pulse of the cyclotron in unpredictable manner, making search for the source of the noise extremely difficult.

To find a noise source, a special action to measure vibrations in the cyclotron bunker has been undertaken. Using commercial laser-doppler vibrometer [3] a presence of strong 33 Hz vibration at the internal parts of the cyclotron has been detected (see blue spectra in Fig. 1). With the help of the special microphone and frequency spectrum analysis software the source of the vibration in the cyclotron bunker has been identified and removed (red and green spectra in Fig. 1). The three scroll pumps in the cyclotron bunker, used only during regeneration of the main cyclotron cryo-pumps, have not been equipped with original vibration dampers and were producing strong vibrations at 33 Hz harmonic. After installation of standard and additional vibration dampers the level of the vibration at 33 Hz harmonic at the internal elements of the cyclotron even in case of simultaneous regeneration of all three cryo-pumps has been reduced to the insignificant level. As a result of this action, 33 Hz noise in the extraction pulse of the JULIC have completely disappeared and did not return.

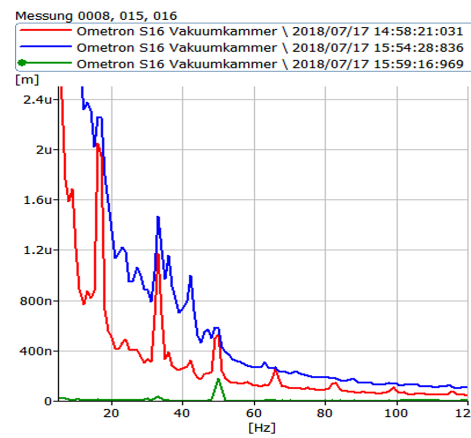

Figure 1: Vibration frequency spectra measured through the vacuum window at the HF-elements of the cyclotron using Omertron S16 vibrometer. The blue spectra is measured before any modification, red - after the first improvements, green - after all the dampers have been installed.

UPGRADE OF THE JULIC MAGNET FIELD CONTROL SYSTEM

The JULIC cyclotron magnet field control system is used to keep field in the cyclotron constant to the 0.1 ppm using a high precision magnet field measurement, special coil, and precision power supply. In this upgrade program an NMR magnet field measurement system has been upgraded using the newest Metrolab PT-2026 system [4]. Besides improvement in magnet field measurement resolution, the new system is capable to measure magnet field of the cyclotron magnet in a complete range of operation. However, this advantage only became available once the sensor with fluoride sample material has been specially produced for JULIC by the Metrolab. Detail of fluoride sample parameters are presented in the Table 1. Standard sensors with H2 and D2 samples was coupling to the cyclotron HF and was not usable for the normal cyclotron operation. The new Metrolab NMR system with fluoride as a sample material and new specially developed LabView based software are now in use in the magnet field control system of the JULIC cyclotron.

Table 1: Magnet field and Larmor frequencies of the atoms in fluoride sample in comparison to the standard JULIC parameters. Parameters of the cyclotron: main magnet field B [T] and acceleration frequency F [MHz] in three standard mode of operation are presented. Calculated Larmor frequency F_L [MHz] for the atoms in fluoride sample and critical field B_K, then Larmor frequency is equal to the acceleration frequency of the JULIC cyclotron are presented. The new fluoride sensor from Metrolab can be used for all the standard modes of the JULIC.

Mode	B [T]	F [MHz]	F_L [MHz]	B_K [T]
H-	0.345	29.94	13.78	0.740
D- (55 MeV)	0.555	23.66	22.21	0.589
D- (75 MeV)	0.650	27.37	26.03	0.683

UPGRADE OF THE JULIC BEAM CURRENT MEASUREMENT SYSTEMS

To meet growing requirements of the JULIC users for the more stable cyclotron operation and better beam transport significant investment in cyclotron beam current measurements system has been made. In total, there are more than 59 channels with different diagnostic signals distributed across the cyclotron and it beam lines. Old custom build analogue electronic has been upgraded using 24 bit four channels TetrAMM devices from CAENels [5], distributed across the facility. All the TetrAMM ADC are implemented into the common EPICS based data acquisition and control environment developed by the COSY controls team. The beam current pulse measured using TetrAMM and new software are presented in Fig. 2. Significant improvement in the handling of the diagnostic information using TetrAMM devices has been achieved. However, new electronics is relatively sensitive to the noise figure in the diagnostic lines and still require special measures to show the complete performance in a noisy cyclotron environment.

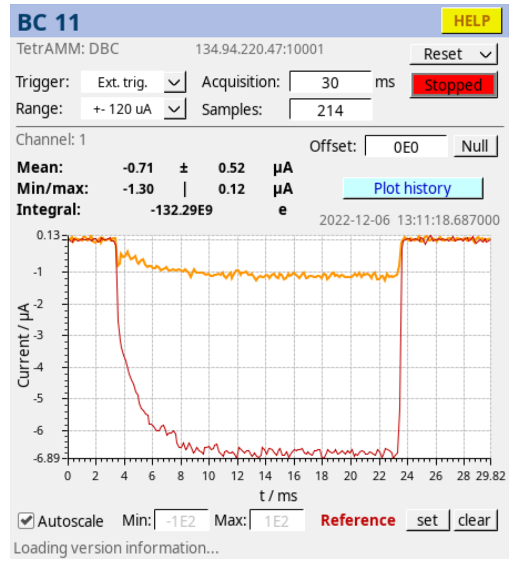

Figure 2: Beam current measurement with TetrAMM at one of the cyclotron cups. Standard readout TetrAMM parameters, measured spectra and reference curve are presented.

NON-DESTRUCTIVE LOW CYCLOTRON BEAM CURRENT DIAGNOSTIC

For the normal operation of the cyclotron usually destructive beam current measurements methods are used. However, for various reasons it is not always possible to readout current from the irradiated materials. In this case it is even more difficult to obtain information about the position of the cyclotron beam during irradiation without usage of the special apertures or collimator in front of the target.

The first experiments of the High Brilliance Source collaboration [2] has been made using maximal cyclotron proton beam current of 10 nA. Under this conditions in a single cyclotron bunch (30 MHz) there only about ≈ 2000 protons. Hence, none-destructive beam diagnostics of such a low intensity beams is a special challenge which can only be solved by a measurements in frequency domain.

To meet this challenging requirements of the HBS experiment a high resolution lock-in amplifier based data acquisition (DAQ) system, developed for the TRIC experiment at COSY [6], has been used. The Fast Current Transformer (FCT) and Integrating Current Transformer (ICT), developed by the Bergoz company, and standard COSY Beam Position Monitor (BPM) have been installed in the HBS beam line. The chain of custom build preamplifiers and commercially build amplifiers, presented in Fig. 3, connects none destructive beam sensors with DAQ. The DAQ was located as close as possible to the beam sensors but at the same time in location with moderate radiation conditions.

Noisy cyclotron environment does not allow any kind of significant diagnostic measurement using FCT, ICT or BPM in time domain. Furthermore, due to the presence of the strong signal from the cyclotron HF system in all the signals at the cyclotron, diagnostic measurements in the frequency

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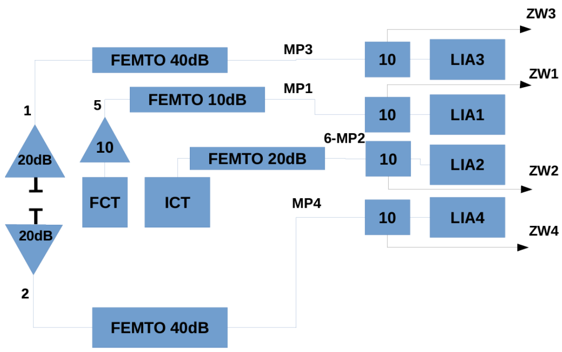

Figure 3: Non-destructive beam current and position measurement readout scheme during HBS experiment in 2018. The signals from the BPM, FCT, and ICT are amplified using custom build and FEMTO amplifiers before they are connected to the Lock-In Amplifiers SR844 from the Stanford Research. The Lock-In Amplifiers (LIA) are readout using DAQ running on a server PC.

domain are only possible starting from the second harmonic of the signal.

In the particular HBS experiment it was demonstrated that relative beam current and position can be measured using lock-in [7] based technique and DAQ discussed in Ref. [6] up to the DC beam currents of the 2 nA.

CONCLUSION

The diagnostic systems of the JULIC cyclotron has undertaken significant upgrade program. The beam diagnostic system has been upgraded using TetrAMM instruments. The newest NMR system from Metrolab is in use in the JULIC magnet field control system. Commercially available doppler vibrometer has been applied to find a source of disturbing 33 Hz vibrations in the cyclotron. Finally, during one of the HBS experiments a lock-in based high resolution DAQ has been successfully used for none-destructive beam current and position diagnostic up to the DC currents of 2 nA.

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