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RECENT UNILAC UPGRADE ACTIVITIES

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Abstract

The GSI UNILAC is the section of the GSI accelerator facility that has been in operation the longest. UNILAC (Fig. 1) is able to accelerate ions from hydrogen to uranium up to 20 MeV (p+) and 13 MeV/u (uranium). The main focus of the recent upgrade measures is to meet the FAIR requirements and to provide reliable and long term beam operation conditions. Besides post stripper upgrade and upgrade of the UNILAC controls, a particular attention is paid to improve the performance of the High Current Injector (HSI) [1-7] and to intensify spare part management for the ageing accelerator. In order to ensure operational reliability, the main focus lies on extensive spare part management and replacement of outdated equipment. Modified beam dynamics design for the frontend system and the use of advanced technologies are needed to improve the UNILAC performance. Among other things, a modified Low and Medium Energy Beam Transport section design for the HSI and installation of reliable (non-destructive) high intensity beam diagnostics devices are in progress. This paper addresses the status of current development efforts and specific plans for the UNILAC upgrade.

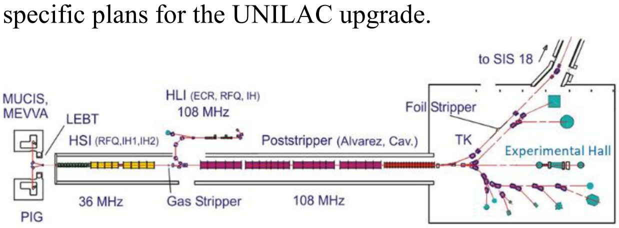

Figure 1: Overview of the UNILAC accelerator sections.

INTRODUCTION

In its more than 50 years of operation, the UNILAC (Fig. 1) has experienced extensions and optimizations in almost all sections. This has resulted in a diverse mix of components of different ages. The current strategy for maintaining and improving operational reliability can be classified into several categories. Complex components of the accelerator structures are being repaired or even replaced. Moreover, measures are being taken towards a complete system renewal. These include the installation of a new vacuum control system, the implementation of the current FAIR accelerator control system and the successive upgrade of the RF amplifier systems. Furthermore, two major linac projects have been started, which aim for the replacement or connection of a complete accelerator section such as the reconstruction of the Alvarez section (poststripper upgrade) [8] and the link of the HELIAC (HElmholtz LInear ACcelerator) to supply the experimental hall with cw-heavy ion beams. Finally, a comprehensive UNILAC upgrade program was defined that aims to achieve FAIR operating parameters, including the installation of the hydrogen gas stripper [9-12], increasing the intensity of the HSI and the development of non-destructive beam diagnostics to permanently monitor high current operation [13-17]. In particular, this proceeding reports on the individual measures of spare parts procurement and the upgrade activities to increase the beam intensity at the HSI.

SPARE PARTS MANAGEMENT

At the UNILAC Alvarez DTL accelerator section, about one drift tube per year has had to be replaced in the recent past due to water leakages. Operation is still possible, depending on which cooling circuit is affected. As a result, the focusing strength and/or the duty cycle is limited. In addition, two manufacturing types - solid copper body or stainless steel hollow body - are available for installation (Fig. 2). These are then brought to the specific length of each drift tube. In the last three years one type each has been newly manufactured. Especially for the copper version, drawings were required to be corrected and manufacturing processes had to be re-established, so that a relatively long manufacturing time of 12 months was required.

Figure 2: Drift tube of Alvarez section, as installed (left); opened drift tube with defective quadrupole lens (right).

In front of the three beam branches of the UNILAC experimental hall, a complex magnet septum has been in operation for decades, which deflects the beam into the three beam branches accordingly. So far, the water leaks that occurred at the coils of this septum magnet (see Fig. 3) could be repaired selectively, which is no longer successful due to the age-related poor condition of the coils. A complete rebuild of the beam section with the aim of separating the coils and the vacuum section is considered to be unaffordable at present. Thus, the 40-year-old manufacturing technology had to be reactivated. With regards to this it is crit-

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ical to ensure dimensional accuracy of the individual conductive tracks and the vacuum suitability of the insulation. Here, the focus is once again on aluminum oxide. With the support of an external partner, manufacturing can now be implemented, the installation of the first coil is scheduled before start of the 2023 beam time period.

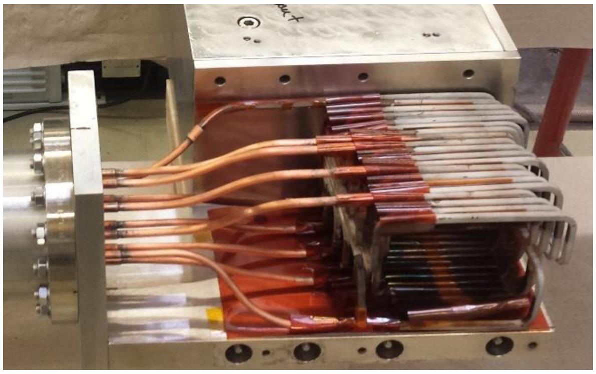

Figure 3: Septum coils with water supply (on the left) and the white insolation surface consisting of aluminum oxide.

The baffle plates in almost all dipoles of the previous generation are also affected by leakages. Besides preventing chamber destruction their ability to measure intensity has not been used for years. Re-manufacturing and replacement of the plates is very costly. In more recent chamber designs, a modified constructive solution is used, which ensures both the protective function and the separation of the vacuum area from the cooling channels. This option has to be manufactured and installed successively for the dipole chambers concerned over the next few years.

The failure rate of the dipole power supplies in the LEBT area of the HSI (the dipoles are needed for charge and mass separation) has increased in recent years. Due to the age of the power supplies, sustainable repair is becoming increasingly difficult. A failure would make beam operation in the affected source branch impossible. For this reason, a call for tender is currently being issued in order to replace these power supply units. The goal is to install them also before start of the 2023 beam time.

The lifetime of high duty/high current operable RFQ accelerators is typically 5-10 years depending on the damage due to the mode of operation. At the HSI RFQ, the 4th set of electrodes has been installed in 2018 (Fig. 4). Thanks to the proper preparation, the installation time requiring an interruption of operation could be reduced to 6-8 weeks. Before restarting the beam operation, an extensive RF conditioning program must be carried out.

Other critical components are the HSI-IH-DTL internal drift tubes housing quadrupole triplet lenses. Although spare parts have been manufactured in the course of previous failures, they are currently not sufficient to be installed. Therefore, a check of the magnetic properties is currently taking place and the copper surface is being refurbished. One drift tube still has an earth fault, here the possible repair approach still has to be coordinated and organized. The drift tube of the High Charge State Injector (HLI)-IH-DTL, which was recently destroyed due to overheating, must be remanufactured. Fortunately, only one coil is affected, smoothly limited operation with only two quadrupoles is possible, as already practiced earlier at HSI-IH-DTL.

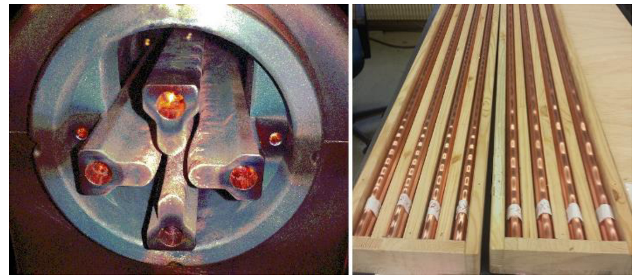

Figure 4: Installed HSI RFQ electrodes after 10 years' operation (left); newly fabricated electrodes just before assembly (right).

INTENSITY UPGRADE OF HSI

In order to provide for the requested Uranium beam intensity for FAIR, upgrade measures at HSI-frontend (Fig. 5) are initiated. The PRIDE project [24], consisting of an advanced Uranium terminal and a compact transport line to the existing LEBT has already been started. Increased ion source beam intensities are always associated with an increase of the beam emittance. However, even the resent high intensity Uranium beam emittance from the existing high current terminal cannot be fully matched to the HSI and must be collimated. In order to overcome this restriction, an increase in acceptance of the HSI RFQ and improved emittance is required. Technically, an increased aperture of the switching dipole and the exchange of the RFQ electrode design by trapezoidal shaped electrodes is foreseen. This measure also gains in the reduction of the tank voltage, while keeping the fields constant. Reversing the polarity of the quadrupole quartet used for beam matching to the RFQ significantly increased the overall high-current performance in heavy ion operation [2]. However, the Uranium record intensities achieved in 2016 cannot be obtained with the quadrupole quartet (with large aperture) installed in 2018.

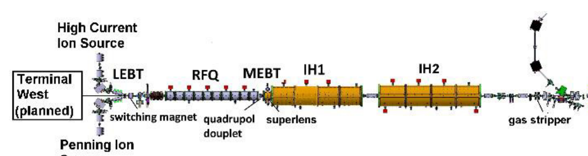

Figure 5: Sketch of the HSI, comprising existing LEBT with PIG and high current ion source terminal, as well as Terminal West and its compact transport line.

A further bottleneck is located at the MEBT comprising a quadrupole doublet and the superlens (SL). In addition to beam loading, operation of the SL is constrained by beam losses due to beam mismatch to the RFQ, resulting in additional transmitter power requirements of up to 20%. Beside improved RFQ-matching, the acceptance and quadrupole field strengths must be increased in order to ensure

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matching conditions to the following two IH tank. A redesign of the quadrupoles is needed and a trapezoidal rod structure is also proposed for the SL, as well as for the RFQ.

Converting the gas stripper to hydrogen operation provides the key contribution to intensity increase and reduces the strong heavy ion HSI intensity requirement (> 30emA, $^{238}U^{4+}$) to a feasible level. Applying a pulsed hydrogen stripper gas target with high target density, the yield of $^{238}U^{28+}$ions is increased from 12.5% to 21.0% [12]. The principle function has recently been verified in several beam times with different accelerated ion beams.

HIGH CURRENT BEAM DIAGNOSTICS

Currently, the UNILAC delivers up to 20% of the FAIR heavy ion beam brilliance [2]. The achieved intensities already place immense demands on beam diagnostics, requiring for the development of non-beam destroying diagnostics. Thus three systems move into the center of attention. First of all, the transmission measurement based on existing beam transformers is to be revised in order to provide for a pulse-exact beam current measurement. Due to the low repetition rate and intensity fluctuation of the beam pulses, only in this way a well-founded evaluation of the accelerator setting and its monitoring and optimization is possible.

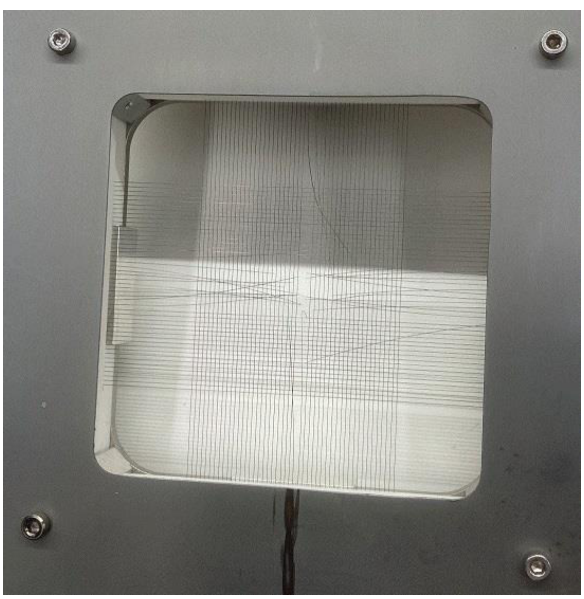

Figure 6: Damaged SEM profile grid.

Wire profile grids currently used for beam position and width measurements can only be operated to a limited extent. This is also reflected by an increased number of repairs due to defective wires. After the 2021 beam time 12 SEM-grids (Fig. 6) had to be dismantled, repaired and reinstalled. During recent beam time period, again five profile grids have already been destroyed.

For enabling high current operation, six BIF (Beam Induced Fluorescence monitor) stations are already installed, although the handling and optimization of the operating parameters is currently ongoing and extensive efforts are required for an adequate integration into the operating environment. The existing four split phase probe system used for beam energy measurement by ToF (Time of Flight) is also capable for beam position measurements along entire UNILAC. A corresponding display software is currently being developed. To improve the operability, the limitations in the measurement accuracy due to the fluctuation in the bunch intensity have to be addressed.

CONCLUSION

The presented upgrade measures refer to many different single tasks. As not all of this subprojects can be performed in parallel, the preparation, prioritization, coordination and realization is in an ongoing process to be managed in parallel to the strong efforts taken to realize the FAIR project. UNILAC upgrade for FAIR is the most important in the line of several GSI linac projects [18-23].

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