AN UPGRADE FOR THE 1.4 MeV/u GAS STRIPPER AT THE GSI UNILAC

P. Scharrer*[1,2,3], W. Barth[1,2], M. Bevcic[2], Ch. E. Düllmann[1,2,3], L. Groening[2], K.-P. Horn[2], E. Jäger[2], J. Khuyagbaatar[1,2], J. Krier[2], A. Yakushev[1,2]
[1]Helmholtz Institute Mainz, Mainz, Germany
[2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany
[3]Johannes Gutenberg-University, Mainz, Germany

Abstract

The GSI UNILAC will serve as part of an injector system for the future FAIR facility, currently under construction in Darmstadt, Germany. For this, it has to deliver short-pulsed, high-current, heavy-ion beams with highest beam quality. An upgrade for the 1.4 MeV/u gas stripper is ongoing to increase the yield of uranium ions in the desired charge state. The new setup features a pulsed gas injection synchronized with the beam pulse transit to increase the effective density of the stripper target while keeping the gas load for the differential pumping system low. Systematic measurements of charge state distributions and energy-loss were conducted with ^{238}U-ion beams and different stripper gases, including H_2 and He. By using H_2 as a stripper gas, the yield into the most populated charge state was increased by over 50 %, compared to the current stripper. Furthermore, the high gas density, enabled by the pulsed injection, results in increased mean charge states.

INTRODUCTION

The GSI Universal Linear Accelerator (UNILAC), together with the SIS18 ring accelerator, will serve as an injector system for the future Facility for Antiproton and Ion Research (FAIR) [1]. For this, it has to meet high demands in terms of beam brilliance at a low duty cycle ($\leq 100\,\mu$s beam pulse length, ≤ 2.7 Hz repetition rate). For $^{238}U^{28+}$, as a reference ion for FAIR, $\approx 3 \cdot 10^{11}$ particles per pulse have to be delivered by the SIS18.

As part of an extensive upgrade program of the UNILAC [2] towards high beam intensities, the 1.4 MeV/u gas stripper was redesigned with the aim to increase the output beam intensity [3]. Pulsed gas valves were utilized to realize a pulsed gas injection synchronized with the beam-pulse transit through the stripper. With this, the gas load for the pumping system was reduced and the back-pressure on the gas inlet could be increased significantly. This enabled increased gas densities for the stripping process and, therefore, the practical use of H_2- and He-gas as stripper targets [4]. In a first measurement campaign, the pulsed H_2-gas target was used for the stripping of U-ion beams. Increased average charge states as well as significantly increased stripping efficiencies were measured [5, 6].

However, the achievable average charge state was limited by the applied back-pressure on the gas inlet. Further increased average charge states were expected at even higher gas densities. Therefore, the setup was modified again and two additional measurement series were conducted.

* p.scharrer@gsi.de

EXPERIMENTAL SETUP

At the GSI UNILAC, heavy-ion beams are delivered by several ion sources. For high-intensity U-ion beams, a Vacuum Arc Ion Source (VARIS) is used [7]. After acceleration up to 1.4 MeV/u in the High Current Injector (HSI) [8], the ion beams enter the stripper section, including the gas stripper, before injection into an Alvarez accelerator structure (see Fig. 1).

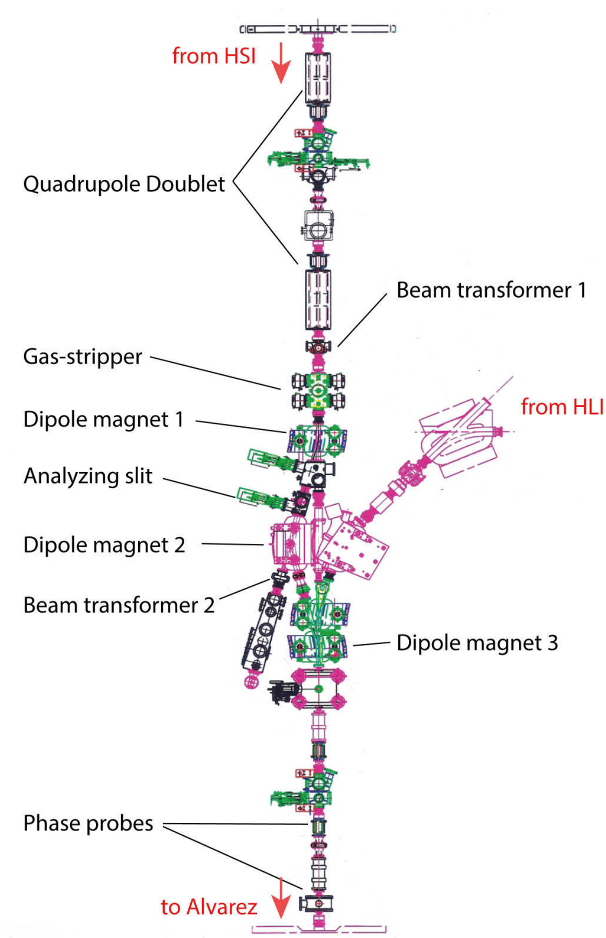

Figure 1: The UNILAC gas stripper section [6].

To secure an optimal charge separation the ion beams are horizontally focused on an analyzing slit behind the stripper by two quadrupole doublets. The beam current in front of the stripper is measured by a beam transformer. In

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the stripper, the charge state of the ions is changing due to charge-exchanging processes in collisions between the ions and atoms or molecules of the gas target. Behind the stripper, the ions are distributed over a wide range of charge states, depending on the type of ion and target, the ion energy, and the density profile of the target. To separate the desired charge state for further acceleration, a system of three dipole magnets is used in combination with an analyzing slit. The beam current of the ions with the selected charge state, is measured by a beam transformer behind the first dipole magnet. A slit-grid system behind the third dipole magnet is used to measure the beam emittance. To obtain the energy loss, the beam energy is measured by a time-of-flight measurement using a set of phase probes behind the charge separation system (see Fig. 1) with and without gas injection in a straight line.

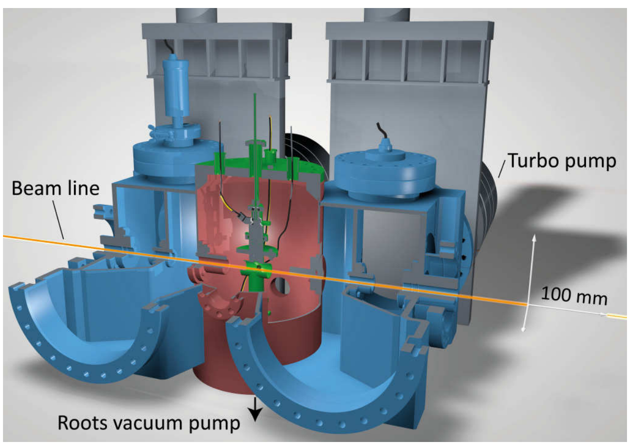

Figure 2: Schematic model of the main setup of the UNILAC gas stripper: the pulsed gas injection is mounted on the top flange (green) of the main chamber (red). Together with the adjacent sections (blue) a four-stage differential pumping system is provided.

The pulsed gas stripper is realized by exchanging the top flange on the UNILAC gas stripper with a new setup, featuring a pulsed gas injection [3]. A schematic model of the main stripper setup is shown in Fig. 2. The pulsed gas stripper is utilizing a four-stage differential pumping system, as used for the former N_2 gas-jet stripper. The main stripper chamber is evacuated by a roots vacuum pump, positioned below the beam line. Each adjacent section is evacuated by a turbo pump, as indicated in the front and the back of the model in Fig. 2.

To enable for increased target densities in the gas stripper, the flange on top of the main stripper chamber, mounting the pulsed gas valves, was redesigned. A new generation of gas valves is used, allowing to increase the applied back-pressure up to 30 MPa. Additionally, a specialized power supply is used, specifically designed for operating the pulsed gas valves. This allowed for an increased reliability for the valve operation and an improved control of the opening time of the valves. The layout of the new setup is shown in Fig. 3. As a main modification, two pulsed gas valves

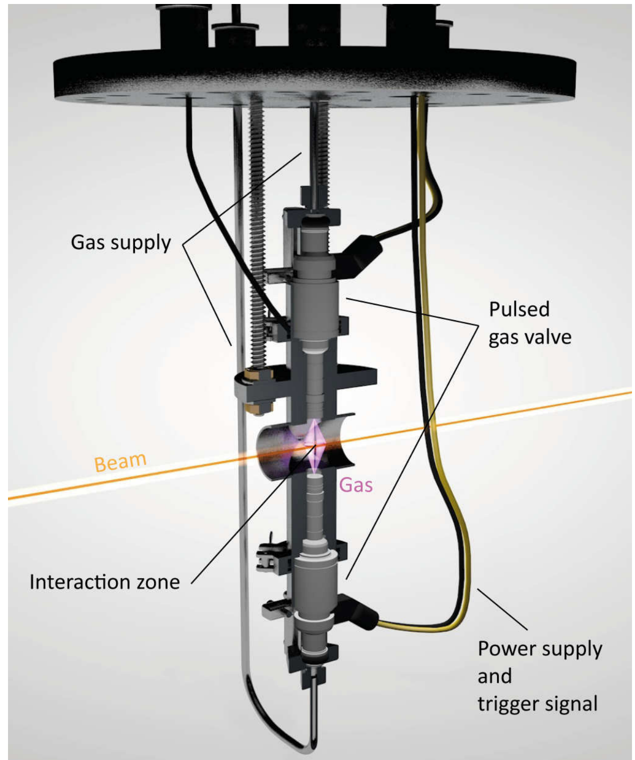

Figure 3: Schematic model of the redesigned top flange of the pulsed gas stripper

are used, on top and on the bottom of the beam line. The valves are pointed at each other with the gas inlet slightly tilted against the beam direction (≈ 10°). Both valves have a seperate power and gas supply as well as seperate trigger signals. For high-density stripper operation, both valves are used simultaneously. The interaction zone has a diameter of 22 mm and a length in beam direction of 44 mm, unchanged to the previous setup. A piezo electric pressure gauge is positioned close to the interaction zone (in the front, but not shown, in Fig. 3).

MEASUREMENTS

With the new setup, measurements of the energy loss and gas pressure were conducted to characterize the gas target. The thickness of the gas target is estimated with SRIM2013 [9] by using energy-loss measurements. In Fig. 4, the pressure, measured at the interaction zone, as well as the estimated target thickness are shown depending on the back-pressure on the gas inlet. In both cases, a linear slope and, therefore, a linear increase of the gas density in the gas stripper is observed in the measured back-pressure range.

With the achieved, increased gas densities, the charge distributions of U ions after passing through the H_2-gas target were obtained by plotting the measured particle-stripping efficiencies for each populated charge state. The charge state distribution for different target thicknesses of the H_2-gas target is shown in Fig. 5. The recent experimental data are plotted as well as data from former measurement series

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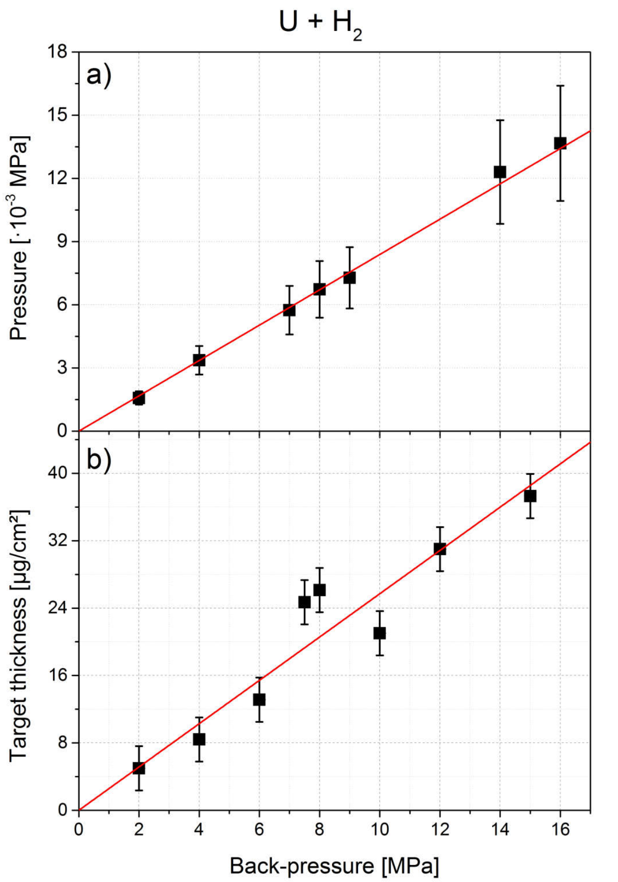

Figure 4: Measured gas pressure (a) and estimated target thickness (b) depending on the back-pressure on the gas inlet, using two gas valves simultaneously. Linear fits are added to guide the eye (red).

covering a wide range of target thicknesses. To obtain the corresponding target thickness for each distribution, the linear fit, shown in Fig. 4, was used. Therefore, the error on the target thicknesses shown in Fig. 5 is about 6 %. For increased target thicknesses, the charge state distribution saturates at an average charge state of about 29+ and does not change significantly anymore. The corresponding target thickness is about 19.4 μg/cm^2. The maximum particle-stripping efficiency of about 21 % is increased by 50 % compared to the N_2 gas-jet stripper. The shape of the charge state distribution does not change significantly above 6.9 μg/cm^2. Therefore, the maximum particle-stripping efficiency does not change as well.

CONCLUSION

A modified setup of the pulsed gas stripper cell was tested at the GSI UNILAC. A further increased gas density is accomplished by using two gas valves simultaneously. The charge state distribution of U ions, after passing through the H_2-gas target, was measured at increased target thicknesses. The shape of the charge state distribution does not change significantly over a wide range of the measured target thickness. Therefore, the maximum particle-stripping efficiency of about 21 % does not change significantly within the error range. For this, it is possible to adapt the back-pressure on the pulsed gas inlet, to obtain U^{28+} and U^{29+} ions with a maximum achievable beam intensity. Additionally, the yield into the 30+ charge state can be increased up to about 18 %.

However, the applicable target thickness is limited by the beam energy loss. Certain requirements, to be met for injection into the adjacent Alvarez accelerator, are discussed in [10].

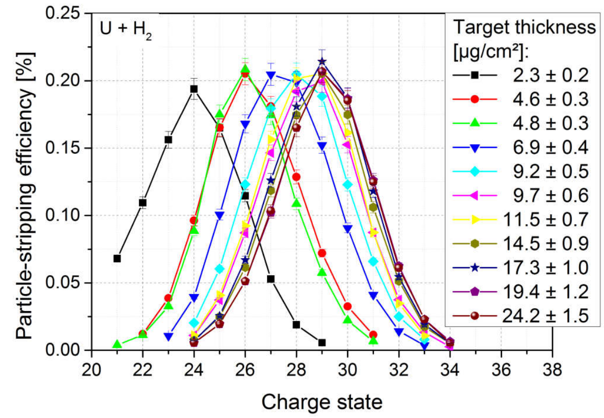

Figure 5: Measured charge state distributions of U ions for increasing target thicknesses of the H_2-gas target.

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