Beam Measurements with CH4 an H2 Gas Strippers at the UNILAC

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The existing UNILAC gas stripper was operated with methane and hydrogen stripper gases to study the impact of low-Z gases on stripping of high current (up to 4 emA) U^{4+} ion beams at 1.4 MeV/u (100 µs, 2 Hz beam pulses). Since electron capture cross sections are considerably suppressed for low-Z gases, in particular hydrogen is promising higher equilibrium charge states compared to nitrogen [1–3]. As hydrogen gas has a very low density, hydrocarbons like methane or propane provide for higher hydrogen concentrations and may be better suited for gas stripper applications.

Gas Stripper Operation

To avoid explosive gas mixtures, nitrogen gas was injected as inert gas into the vacuum exhaust pipe of the gas stripper setup and of the neighbouring vacuum sections to provide for methane and hydrogen concentrations in the exhaust air below 2.2 % and 2 %, respectively – a factor of two below the lower explosion limits. The nitrogen gas was provided by the central GSI nitrogen gas distribution system fed by a LN2 tank and by additional bundles of N2 gas cylinders. An interlock system was installed to monitor the nitrogen gas flow, the pressure inside the vacuum exhaust pipe, and the vacuum pressure inside the gas stripper setup. The modified gas stripper was operated successfully for various ion beam measurements.

Beam Measurements

For increasing methane mass flow rates between 12 g/min and 23 g/min – corresponding to methane gas pressures between 2.4 bar and 4.5 bar at the gas inlet – the mean uranium charge states measured behind the stripper increased from about 23+/24+ to 25+/26+ (Fig. 1). For standard nitrogen operation of the stripper, higher mass flow rates around 26 g/min are routinely achieved at a gas pressure of roughly 4 bar resulting in mean charge states around 27+ (Fig. 1). A beam energy loss of 13 keV/u was measured for U^{28+} within the range of the methane flow rates given above, compared to 15 keV/u for the nitrogen gas stripper. Measured U^{28+} beam emittances were slightly increasing for increasing methane flow rates and were comparable to the values measured for the nitrogen gas stripper. The highest attainable methane flow rates were limited by the maximum pumping speed of the turbo pumps mounted at the gas stripper chamber.

For hydrogen stripper gas, a maximum mass flow rate of only about 1.4 g/min could be reached due to the low mass density of the hydrogen gas and because of the steeply rising vacuum pressures inside the stripper chamber and in the neighbouring vacuum sections, since hydrogen is only very poorly pumped by the vacuum pumps. Due to the low mass density of the hydrogen gas jet, the highest charge state which could be transported along the bending magnet installed behind the stripper was about U^{21+} (Fig. 2). The maximum of the charge state spectrum could not be measured due to the limited field strength of the bending magnet.

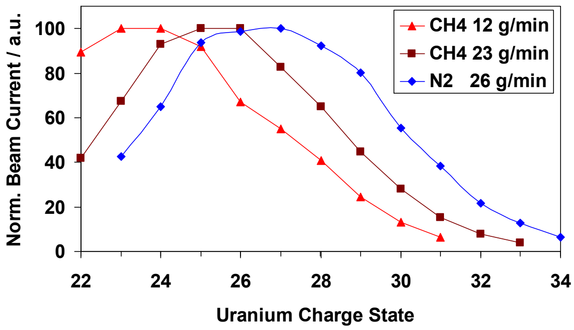

Figure 1: Uranium charge state distributions after stripping at different stripper gases and mass flow rates.

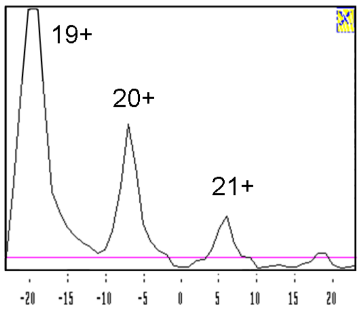

Figure 2: Measured uranium ion beam profiles behind the bending magnet with opened analyzing slits at the maximum attainable hydrogen stripper gas flow rate of about 1.4 g/min.

Finally, the experiments showed that currently neither methane nor hydrogen are serious alternatives to nitrogen for the existing UNILAC gas stripper since the highest uranium charge states and the highest U^{28+} beam currents were achieved with the nitrogen gas jet so far. To investigate higher mass densities for methane and hydrogen, substantial technical modifications of the gas stripper setup would be necessary (in particular for hydrogen).

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References

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