HIGH CURRENT TRANSPORT AND ACCELERATION AT THE UPGRADED UNILAC

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Abstract

The UNILAC will be upgraded as a high current injector for SIS. This paper focuses on beam dynamics studies in the newly designed stripper section, the poststripper Alvarez accelerator and the transport line to SIS considering space charge effects along the UNILAC. Simulation results for the matching to the Alvarez linac, emittance growth effects in the poststripper linac and the beam transfer line to the SIS including the modified foilstripper and charge separation system will be discussed. The beam brilliance loss due to foil straggling and space charge forces will be calculated. Beam experiments at the present UNILAC under comparable space charge conditions are reported.

1 INTRODUCTION

Within the GSI high-intensity program, the present prestripper linac will be replaced by an RFQ and two IH-tanks [1] designed for the acceleration of high current, low charge state beams. The beam behavior influenced by space charge forces is simulated for different input phase space distributions through the complete system to the SIS. Emittance growth occurs in all sections of the UNILAC. A reduction of emittance growth could be expected by the newly designed gasstripper section at $1.4\,\mathrm{MeV/u}$. Beam dynamics calculations within the poststripper and the transfer line will be presented.

2 HIGH CURRENT BEAM MEASUREMENTS

At the present UNILAC, beam experiments with neon ions were carried out under comparable space charge conditions as expected for the upgraded UNILAC, particularly in the stripper region. The SIS could be operated at the space charge limit with Ne^{10+} beam. Measurements in the gasstripper section at $1.4\,\mathrm{MeV/u}$ are shown in Fig. 1. The Ne^{1+} beam accelerated by the Wideröe linac passes the gasstripper and is transported through the charge state analyzing system by four 30° bending magnets. The most abundant Ne^{7+} is selected for further acceleration, the stripping efficiency is about 40%. The emittance growth rates are shown at different current levels. For intensities up to $10\,\mathrm{emA}$ total current behind the $9\,\mathrm{mm}$ stripper aperture, the emittance growth is in good agreement with computer simulations, neighbouring charge states are taken into account. Simulations have indicated that the emittance growth can be reduced by increasing the diameter of the stripper tube from 9 to $16\,\mathrm{mm}$. Experimental and simulation results supported the new design of the stripper section described in the following paragraph.

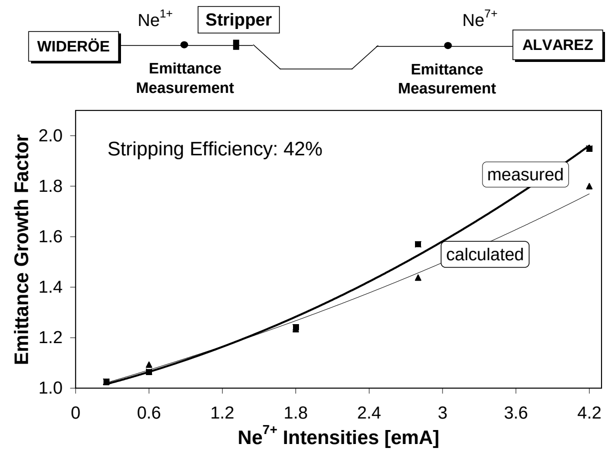

Figure 1: Measured and calculated emittance growth factors at different neon current levels.

3 THE NEW GASSTRIPPER SECTION

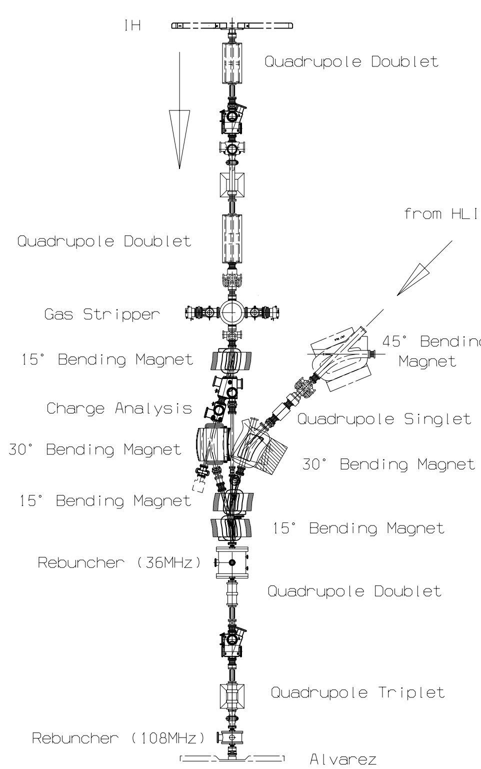

Figure 2: Layout of the new stripper section.

The design of the new transport line between the prestripper and the Alvarez linac is faced with different requirements: lowest emittance growth under considerable space charge forces, charge state separation, achromatic transport after the bending magnets, transverse and longitudinal matching to the poststripper. The new design has to cope with the ion time-share operation on a $50\,\mathrm{Hz}$ pulse-to-pulse basis. The layout of the gasstripper section is shown in Fig. 2. The beam from the IH section is matched to the stripper tube by two magnetic doublets. After stripping the beam goes immediately into the first 15° bending magnet. The analyzing slit is directly before the second dipole (30°). The last dipole bends the beam back to the UNILAC axis. In the following transport line the longitudinal matching (with two rebunchers) and the transversal matching (with a quadrupole doublet and a triplet) to the poststripper accelerator is accomplished without any particle loss. The beam from the second injector (HLI) is delivered to the poststripper by a 180° bending section. All magnetic lenses, dipoles of the stripper section and the kicker magnet of the HLI transport line allow the pulsed operation.

4 CALCULATED EMITTANCE GROWTH FROM THE PRESTRIPPER TO THE SIS

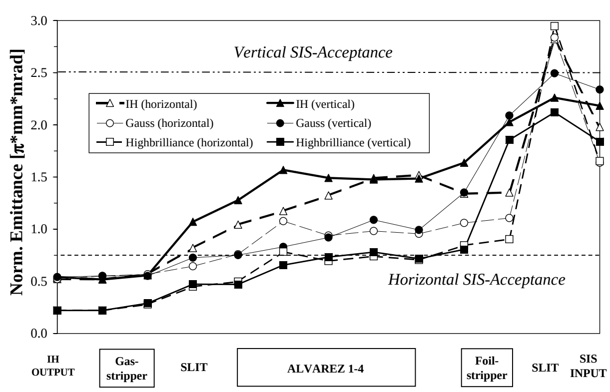

Figure 3: Variation of the horizontal and vertical 90% emittances from the UNILAC stripper section to the SIS input for different input beams. The transmission in all cases is approx. 95%.

For the simulations three input distributions are selected: the 'IH distribution' will be expected behind the new prestripper linac [2]. This particle distribution was calculated from an initial Gaussian distribution at the prestripper entrance with a current of $16.5\,\mathrm{emA}\ U^{4+}$. In order to exclude effects of the distorted IH distribution, simulation begin with an ideal Gaussian distribution with the same 90% values of emittance at the IH exit. The limit of the system is evaluated by a high brilliant transversal Gaussian distribution as expected from the RFQ. In all three cases the beam was transformed through the stripper section, the poststripper accelerator and the transfer line with the same settings of the quadrupole gradients and rebuncher fields. In Fig. 3 and Fig. 4 the development of the horizontal and longitudinal 90% emittance. The calculated beam transmission in all cases is approx. 95%. In addition the space charge parameter SPC (relatively) is exposed in Fig. 5: $SPC \sim Particle\,Current \cdot Charge\,State^2 \cdot \beta^{-1} \cdot Bunchvolume^{-1}$.

In the following the beam behavior in the several UNILAC sections is discussed.

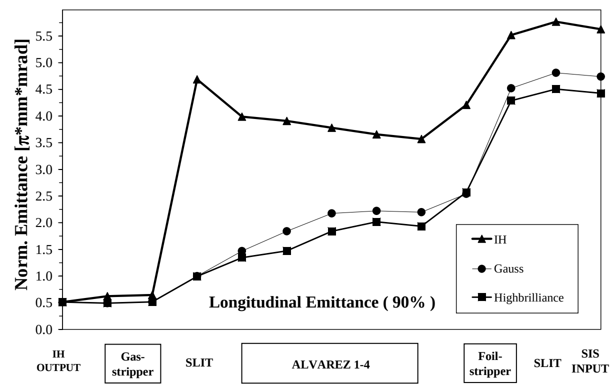

Figure 4: The longitudinal 90% emittances complementary to Fig. 3.

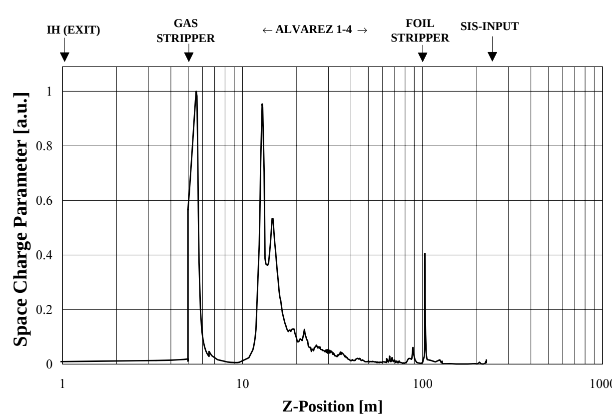

Figure 5: The Space Charge Parameter (SPC) along the stripper section, the Alvarez and the transfer line.

4.1 Gasstripper section

In the matching section to the gasstripper no significant emittance growth occurs, the jump of the charge state after stripping increases the SPC dramatically. Amplified by the reduction of the bunch volume, the emittance in all three planes accumulates until the slit of the charge state analysis, where the particle current abruptly decreases. To match the beam to the Alvarez a very small bunch length is indispensable. For the Gaussian distribution the transversal emittance growth factor at the Alvarez input is only 1.37, compared to 2.18 for the IH distribution, which occurs due to the longitudinal phase space aberrations in interaction with the strong space charge forces after the stripping process. The emittance growth factor is optimized by iteration of the transversal beam divergence at the gasstripper. The transversal emittance of the high brilliant beam increases by a factor of 2.2, but the absolute emittance growth is comparable with the Gaussian case.

4.2 Poststripper Accelerator

Particularly in the first Alvarez section emittance growth is high, thereafter the effect is moderate because the acceleration gain becomes higher. The stripper section is optimized for low horizontal emittance growth at the expense of vertical beam quality. Because of that equipartitioning takes place for the IH distribution in the poststripper accelerator caused by strong space charge forces. If the same transverse distribution combined with a matched Gaussian one in the longitudinal phae space (IH modified) is used, the transversal emittance growth is reduced from 30% to 15%. To minimize emittance growth for beams with higher brilliance (Gauß, High Brilliance) the zero current phase advance in the periodic structure has to be increased from 45° to 54°. This can be achieved by 11% higher quadrupole field strengths.

4.3 Transfer Line to the SIS

In the transfer line the transverse matching to the foilstripper is not critical. With a narrow upright beam spot on the stripperfoil the emittance growth in the horizontal plane is minimized, while an increase of the vertical emittance is tolerated in view of the acceptance of the synchrotron (see Table 1: IH distribution with and without stripping) [3, 4]. Comparing the Gaussian and the high brilliant distribution with the IH one, an conspicuous increase of the vertical emittance caused by stripping effects has to be considered.

Table 1: Emittance growth (90 %) in the transfer line

		Foil (in)	Foil (out)	Charge Sep.	TK (out)
IH	horizontal	0.88	0.89	1.86	1.30
(with stripping)	vertical	1.10	1.36	1.52	1.47
IH	horizontal	0.91	0.91	1.16	1.31
(without stripping)	vertical	1.11	1.11	1.11	1.07
Gauß	horizontal	1.11	1.16	2.97	1.71
(with stripping)	vertical	1.36	2.11	2.51	2.36
High Brilliance	horizontal	1.20	1.28	4.18	2.34
(with stripping)	vertical	1.12	2.59	2.96	2.57

Fig. 6 displays the emittance growth factor due to particle scattering as a function of the distribution fraction at the same vertical beam size. The IH distribution has a very intense core (peaked distribution), the emittance growth is much lower for the outer area of the distribution. An inverted characteristic for the emittance growth as a function of intensity results from a transverse homogeneous KV distribution.

Increasing the charge state from $28+$ to $73+$ entails in a SPC boost which is only 40% of the effect in the gasstripper section.

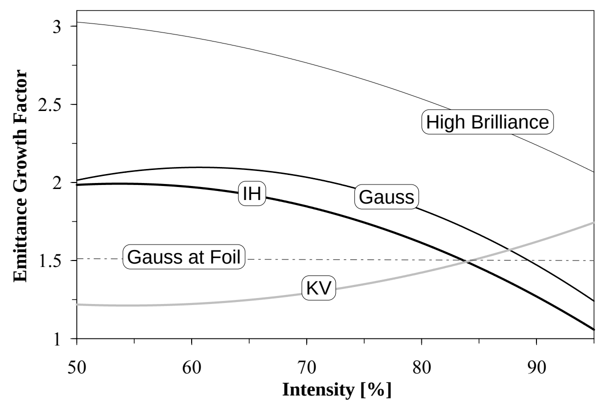

Figure 6: Emittance growth factor due to particle scattering at the foilstripper for several phase space distributions.

5 SUMMARY

The calculated deformation in the phase space distribution coming from the prestripper accelerator results in high emittance growth. The new stripper section may work very well for a Gaussian distribution. If a high brilliant beam is preserved the zero current phase advance in the poststripper has to be increased to minimize emittance growth. Beside the gasstripper section the first Alvarez tank is the most critical part due to space charge effects. The transport through the transfer line does not lead to considerable horizontal emittance growth. The vertical scattering effect in the foilstripper is much higher because of the upright beam spot and depends strongly on the phase space distribution. The final transverse emittance exceeds the acceptance of the SIS in all three cases. Nevertheless, the SIS can be filled up to the required 2×10^{10} particles per pulse U^{73+}.

6 REFERENCES

[1] U. Ratzinger,"The New GSI Prestripper Linac for High Current Heavy Ion Beams", Proc. of LINAC96, p. 288, Geneva, 1996

[2] W. Barth, J. Glatz, J. Klabunde, U. Ratzinger, "Space Charge Dominated Beam Transport in the 1.4 MeV/u-UNILAC Stripper Section", Proc. of LINAC96, p. 131, Geneva, 1996

[3] W. Barth, L. Dahl, J. Glatz, J. Klabunde, U. Ratzinger, A. Schempp, "High Current Beam Dynamics for the Upgraded UNILAC", Proc. of 1997 PAC, in press, Vancouver, 1997

[4] J. Glatz, B. Langenbeck, "A High Duty Foil Stripper System in the Injection Line to the Heavy Ion Synchrotron SIS at GSI", Proc. of EPAC96, p. 2406, Sitges, 1996