Ion Source Development and Operation

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The past year was characterized by a a reliable ion source operation serving the accelerator and the beam time schedule. Ion source development took place mainly to produce the desired beams, in addition, collaborations have been established and continued to improve the different ion source types.

Operation

ECR Ion Source

The ECR ion source (ECRIS) at the High Charge State Injector (HLI) delivered ion beam to the accelerator facilities without interruption during all beam time blocks in 2000. Most of the time was dedicated to the cancer therapy. The production of C^{2+} beams for this purpose has become routine operation and worked without any problems. Besides therapy the HLI predominantly had to provide beams for the production of Super Heavy Elements (SHE) and for nuclear chemistry experiments.

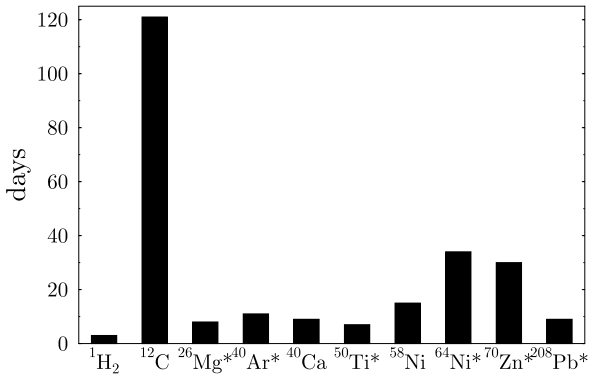

Figure 1: Element statistics of the ECRIS in 2000. An asterisk indicates the use of enriched isotope material.

Long periods were covered by $^{58}Ni^{9+}$ (natural) and $^{64}Ni^{9+}$ (enriched material) beams which could be performed with high reliability getting intensities of several tens of eμA. The usual material consumption of typically 5...6 mg/h for Ni could be considerably reduced for ^{64}Ni to ≤ 3 mg/h by carefully recycling condensated sample material from the orifice of the oven.

Another long time run for the production of SHE was $^{70}Zn^{10+}$. It was routinely produced from ^{70}ZnO pellets. A very constant beam of 70 eμA was obtained.

^{50}Ti was also requested for the production of SHE. Following the experience obtained from former experiments isotopic material of very high purity was used. However, the need for a high operating temperature of 1700 °C again showed that this is almost beyond the limit of the standard oven.

A solution of this problem appears to be a new type of high temperature oven which is being developed [1]. Its main features are an operating temperature of up to 2000 °C and a heating process by thermal radiation from a heater spiral of 10 mm diameter without any mechanical support. Thus any ceramics in the hot parts of the oven is avoided.

Tests was performed which proved the principal function of this oven. Nevertheless further modifications are necessary to improve its technical reliability in order to achieve satisfying long time operation. A 70 hours run could be performed at the test bench using natural Ti contained in a tungsten crucible. The achieved stability and intensity were comparable to the operation of Ni.

$^{208}Pb^{27+}$ was delivered to the SIS operating the ECRIS in afterglow mode. It was possible to reproduce the intensity and beam quality of a long beam time in the preceding year. However, the long time for preparation and optimization until sufficient stability is obtained demonstrates that it is not useful to schedule short beam time periods for the afterglow mode.

Two experiments at the UNILAC requested the alkaline earth ions ^{40}Ca and ^{26}Mg, respectively. The $^{40}Ca^{7+}$ ion beam could be reproduced under the same good conditions as it was done once before in 1999. A $^{26}Mg^{4+}$ ion beam was produced for the first time. Previous tests with natural Mg sample material had been encouraging. As for Ca the hot screen inset inside the plasma chamber is used for Mg, too. 60 eμA of $^{26}Mg^{4+}$ were achieved, but an increase of the intensity upon request by the experiment led to instable operating conditions caused by uncontrollable passive heating of the oven by the ECR plasma. This behaviour showed that further development work is necessary to improve the reliability of operation.

For ^{40}Ca as well as for ^{26}Mg the efficiency of ion beam production turned out to be very good compared to other metal ion operation. For ^{40}Ca 18 % of the sample material is transformed into ion beam distributed in the charge states 1+ ... 12+. 1.8 % of the material can be analyzed in the requested charge state 7+. For ^{26}Mg the corresponding values are 11.8 % in all charge states including 1+ ... 9+ and 2.5 % in the requested charge state 4+.

As further experiments are planned for the future which require beams of alkaline earth metals investigations were continued at the test bench. A common problem of these elements is the low operating temperature causing big difficulties to control the evaporation. Therefore, several modifications of the standard oven were applied in order to decrease the influence of passive external heating of the oven.

Experiments at the test bench (EIS) had shown that H_2^+ ions can be extracted from the ECRIS with 5 kV. This low extraction voltage is suitable for injection into the RFQ. An accelerator experiment at the HLI proved that a H_2^+ ion beam of good stability can be accepted and transported by the accelerator.

Penning Ion Source

The PIG source was used for standard beams as shown in Fig. 2. The particle current for several elements could be increased by the lower charge state required by the new prestripper accelerator. For the heaviest elements we are able to use charge state 6+ instead of 10+, nearly doubling the particle current in front of the accelerator.

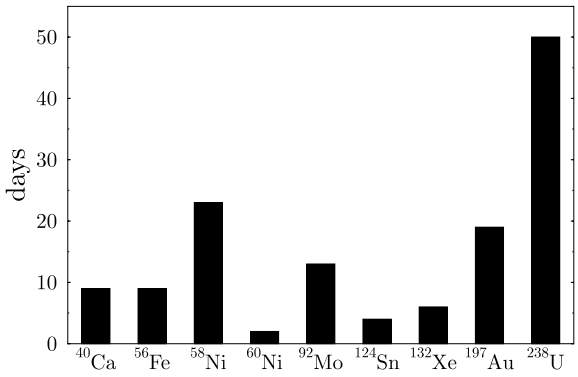

Figure 2: Element statistics of the PIG ion source in 2000.

High Current Ion Sources

For the commissioning of the high current injector up to 18 mA $^{40}Ar^{1+}$ have been produced by the MUCIS and transported to the RFQ. This beam is very reproducible and stable. For an experiment a $^{92}Mo^{2+}$ (15% isotope) was required. We checked three different ion sources for that purpose. It turned out, that the MEVVA delivered the highest ion currents in front of the RFQ (see table 1 and fig. 4.). Note, that all sources were operated with natural Mo. For a $^{197}Au^{4+}$-beam we found a different classification, showing that each source might have different capabilities for different elements.

Tab. 1: Comparison of different ion sources (regular PIG source, Half PIG type [2], MEVVA) for different elements. The current in front of the RFQ are given in emA.

	PIG	H-PIG	MEVVA
$^{92}Mo^{2+}$	0.1	0.2	1.0
$^{197}Au^{4+}$	0.3	$\leq$0.1	$\leq$0.1

The motorized remote cathode changer was taken into operation to prolong the operating time of the MEVVA ion source.

Ion Source Development

Several collaborations to improve our ion sources and to investigate the applicability of new types of ion sources are in progress:

- A new development for ECR sources with 28 GHz micro wave heating promises higher particle currents and is investigated in a European collaboration[3].

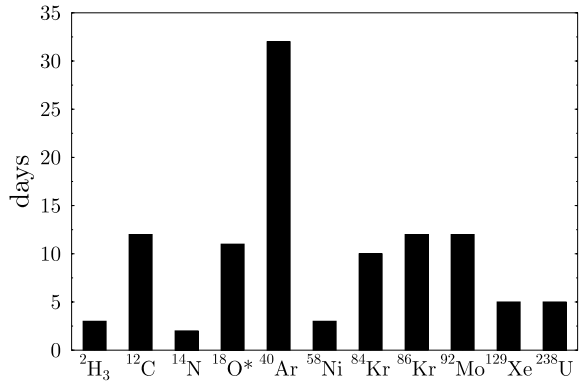

Figure 3: Element statistics of the high current ion sources. All gases have been provided by the MUCIS, whereas for all metals the MEVVA was used. For ^{18}O enriched material has been used.

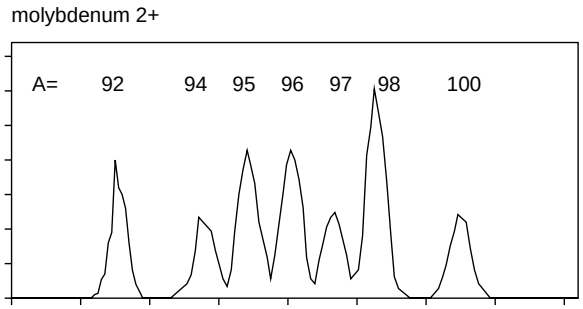

Figure 4: Isotope separation for Mo^{2+}. Note, that not a single pulse was missing during the measurement and the detected pulse currents reflect the natural isotope distribution, showing the good shot-to-shot reproduceability.

- A laser ion source [4] was investigated to demonstrate high particle currents with a charge state distribution suitable at the high current injector. In this experiment with a 100 J laser up to 20 emA Pb^{4+} with a pulse duration of 80 μs was a remarkable result.
- The subject of further improvement of the MEVVA ion source was a better noise reduction even for the high B field operation necessary for the production of U^{4+}[5]. This item is still to be improved.

References

[1] R. Lang, J. Bossler, H. Schulte, and K. Tinschert, RSI **71**, 651 (2000).

[2] M. Müller, Dual HCD Ion Source, this report.

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[4] K.N. Makarov, et. al., Feasibility study of U^{4+} pulsed ion beam generation in Laser Ion source. Internal report, ITEP, TRINITI.

[5] E. Oks, MEVVA ion source in the space charge limited operation mode. Internal report.