Ion Source Operation at the GSI Accelerator Facility

R. Hollinger, K. Tinschert*, J. Pfister*, A. Adonin, R. Berezov, M. Brühl, B. Gutermuth, F. Heymach, R. Lang, J. Mäder, F. Maimone, K. Ochs, J. Roßbach, P. Schäffer, S. Schäffer, M. Stork, C. Vierheller, A. Wesp, S. Zulauf*

GSI, Darmstadt, Germany

High Current Ion Sources

In 2012 ion sources from Terminal North (MUCIS, CHORDIS, VARIS, MEVVA) and Terminal South (PIG ion sources) were supplying the GSI accelerator with various types of ions. The following Table 1 gives an overview of the ion species, which were delivered for physics and accelerator development experiments. A good representative value for delivered intensity to the linear accelerator UNILAC is the analysed current in the accelerator section *UH1* in front of the RFQ.

Table 1: Ion beams generated with high current ion sources in 2012. Filament driven volume type ion sources: MUCIS and CHORDIS; Vacuum arc ion sources: VARIS and MEVVA; Penning type ion sources PIG

Ion species	Duration (days)	Ion source	Beam for experiment	Analyzed intensity (emA)
$^{6}D_3^+$	6	MUCIS	UNI	2-3
$^{14}N_2^+$	7	MUCIS	SIS	4
$^{12}C^{2+}$	7	PIG	UNI	0.06…0.08
$^{20}Ne^{+}$	7	PIG	ESR	0.1
$^{36}Ar^{+}$	6	CHORDIS	SIS	8
$^{40}Ar^{2+}$	14	PIG	UNI	0.2…0.4
$^{50}Ti^{2+}$	137	PIG	UNI/ESR	0.04…0.07
$^{58}Ni^{2+}$	20	VARIS	SIS/ESR	5
$^{84}Kr^{2+}$	9	MUCIS	SIS	3-4
$^{86}Kr^{2+}$	9	MUCIS	SIS	4
$^{136}Xe^{3+}$	15	MUCIS	UNI/SIS	2
$^{197}Au^{4+}$	39	VARIS	UNI/SIS/ESR	3-6
$^{197}Au^{8+}$	28	PIG	UNI	0.06…0.1
$^{208}Pb^{4+}$	11	VARIS	UNI/SIS	6-8
$^{208}Pb^{8+}$	10	PIG	UNI/SIS	0.1
$^{238}U^{4+}$	58	VARIS	UNI/SIS/ESR	8-12

Ion beams generated in the high current sources can be distinguished into standard elements and non-standard, which are much more challenging to produce and the ion source being operated. In 2011 and especially in 2012 standard titanium-50 operation from the PIG source was established completely with more than one ion source exchange per day.

Another element, which was established in 2012 from the VARIS high current ion source, is the four-fold gold beam, which was not available from this kind of ion source before. The same approach as for $^{209}Bi^{4+}$-ions [1] was taken and a proper mixture of elements was found. Same as for the gold beam production the creation of high current four-fold led beam from the VARIS was established upon experimentalists request.

From Table 1 it can be deducted that the most requested ion beams in 2012 were titanium, gold and uranium. It is also shown that most time of the year both terminals were operated at the same time with mostly different ion species.

With a view to the super heavy element experiment TASCA with the need of high amounts of particles the possibility of production of the titanium-50 sputtering electrodes inside GSI was developed. Melting and machining was done in the melting oven of the ion source department as well as the ion source mechanical workshop.

An average particle current of 0.75pµA at the experiment was reached with an uptime of the ion source of 95%. In front of the accelerator an ion beam of $^{50}Ti^{2+}$ with an intensity of 40-70eµA was reached.

Refurbishment of the PIG sources started in spring of 2012. These sources have been in operation at GSI since the first days of the UNILAC. The goal of this action is a better performance of these high-duty-cycle ion sources.

Furthermore it was finally possible to built up the new PIG service area, where the service of the source can be done under “cleanroom conditions”

For the establishment of the high current gold beam different mixtures of gold and other elements were checked in order to change the physical properties of the element and having the maximum of the charge state distribution in the four-fold peak. Admixtures of elements like Pd, Cr, Zr, Ti and Ta were tested. Best results were reached with mixtures of 50% gold with 50% of chromium. The ion beam current of $^{197}Au^{4+}$ in front of the RFQ was 6mA.

On led beam the same procedure was undertaken as for gold and bismuth before and it was possible to provide for the first time ever an intensity of up to 8mA of $^{208}Pb^{4+}$ was measured in front of the high current injector RFQ.

High Charge State Injector HLI

For the operation of the GSI accelerator the CAPRICE ECR ion source (ECRIS) at the High Charge State Injector (HLI) delivered the ion species listed in table 2 for various physics experiments in the regular beam time schedule as well as for accelerator development.

* Corresponding authors

Two beam time periods in 2012 dedicated to biophysics experiments at the SIS under therapy conditions and to biophysics experiments at the UNILAC were provided with $^{12}C^{2+}$ ion beams.

Table 2: Ion beams delivered from the HLI in 2012.

Ion species	Auxiliary gas	Duration (days)	Analyzed intensity (eμA)
D_2^{1+}	-	3	270
$^{12}C^{2+}$	O_2	12	100
$^{12}C^{3+}$	-	9	150
$^{20}Ne^{4+}$	He	4	270
$^{40}Ar^{7+}$	He	2	90
$^{48}Ca^{10+}$	He	55	120
$^{80}Kr^{13+}$	He	10	60
$^{136}Xe^{19+}$	O_2	11	30

Ion beams of $^{20}Ne^{4+}$ and of $^{40}Ar^{7+}$ were exclusively used for machine investigations at the HLI in different periods. This was dedicated to the preparation of forthcoming experiments with a module of a new type of superconducting linear accelerator, the sc cw-LINAC-Demonstrator [3].

After investigations on the feasibility of producing a $^{12}C^{3+}$-beam from pure CH_4 in 2011 the corresponding dedicated physics experiment was performed at the ESR in the present reporting period. Due to the experiment conditions the $^{12}C^{3+}$-beam had to be extracted from the ECRIS and had to be accelerated and transported to the injection of the synchrotron (SIS) without passing through a further stripping target. As the only mass-to-charge separation of the ion beam is performed in the analyzing dipole directly behind the ion source, different ion species of the same mass-to-charge ratio - like $^{12}C^{3+}$ and $^{16}O^{4+}$ in this case - cannot be separated. The amount of beam contamination with O^{4+} from the residual gas can only be derived indirectly from the mass-to-charge spectrum. It was estimated in the test run to be in the order of 8% oxygen as background contamination. The oxygen contamination is expected to be mostly related to residual gas and surface layers. Therefore an operating period of 3 days for precleaning the plasma chamber of the ECRIS was performed before the dedicated beam time. In fact the amount of oxygen contamination at the mass/charge ratio of 4 ($^{12}C^{3+}$, $^{16}O^{4+}$) could be decreased from 11% to 4%.

All other ion beams delivered from the ECRIS were produced from highly enriched isotopic materials upon experimental request for rare isotope ion beams. Ion beams of $^{136}Xe^{19+}$ were routinely delivered to experiments behind the SIS. A gamma spectroscopy experiment requested for the first time an ion beam from the rare isotope ^{80}Kr. $^{80}Kr^{13+}$ from the ECRIS had to be selected. As the isotopic enrichment of the sample material was limited to 51.4% it had to be confirmed that a proper separation of the desired isotope peak in the mass-to-charge spectrum can be achieved. As Figure 1 demonstrates a correct setting of the ion beam optics of the low energy beam transport line fulfils this demand. A minor contamination of this peak with $^{86}Kr^{14+}$ cannot be avoided, but only amounts to less than 0.7%.

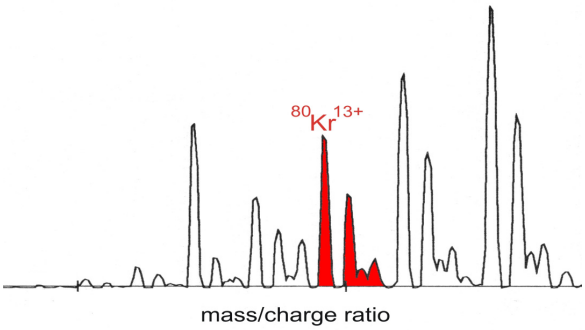

Figure 1: Separation of $^{80}Kr^{13+}$ in the mass/charge spectrum; Kr^{13+}-isotopes in red (mass 80, 82, 83, 84).

As last beam time in 2012 a long run with $^{48}Ca^{10+}$ was dedicated to experiments of the Super Heavy Element (SHE) programme at TASCA. This run was characterized by a very stable long time behaviour of the ion beam at high intensity. The mass/charge spectrum in figure 2 exhibits the very effective optimization on the desired charge state which also leads to a very high efficiency of material processing with an average material consumption of less than 200 μg/h.

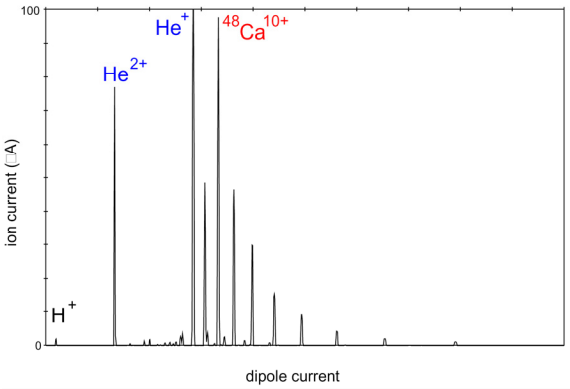

Figure 2: Mass/charge spectrum of ^{48}Ca.

References

[1] K. Tinschert, R. Hollinger et al., GSI Scientific Report 2011, GSI Report 2012-1, p.283

[2] A. Adonin, R. Hollinger, Challenges of Production of High Current four-fold Bi and Au Beams from Vacuum Arc Ion Sources at GSI Accelerator Facility, Proceedings of ISDEIV12

[3] S. Mickat et al., GSI Scientific Report 2011, GSI Report 2012-1, p. 292.