Ion source operation at GSI

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High Current Ion Sources

In 2014 ion sources from Terminal North (MUCIS, CHORDIS and VARIS) 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 transfer section *UH1* in front of the RFQ.

Table 1: Ion beams generated with high current ion sources in 2014. Filament driven volume type ion sources: MUCIS and CHORDIS; Vacuum arc ion sources: VARIS; Penning type ion sources PIG

Ion species	Duration (days)	Ion source	Beam for experiment	Analyzed intensity (emA)
$^{3}H_3^+$	8	CHORDIS	SIS	0.9
$^{6}D_3^+$	7	CHORDIS	UNI	2.4
$^{15}CH_3^+$	33	CHORDIS	UNI/SIS/ESR	3
$^{28}N_2^+$	52	CHORDIS	SIS/ESR	5
$^{20}Ne^+$	5	PIG	UNI/SIS/ESR	0.1
$^{56}Fe^{3+}$	3	PIG	UNI	0.15
$^{58}Ni^{2+}$	32	VARIS	SIS	5.8
$^{86}Kr^{2+}$	16	MUCIS	SIS	9.5
$^{132}Xe^{3+}$	19	PIG	UNI/ESR	0.05
$^{152}Sm^{3+}$	15	PIG	UNI/SIS/ESR	0.03
$^{197}Au^{4+}$	11	PIG	UNI/SIS/ESR	0.3
$^{197}Au^{8+}$	45	PIG	UNI	0.07
$^{209}Bi^{4+}$	16	PIG	UNI/SIS/ESR	0.07
$^{238}U^{4+}$	53	VARIS	UNI/SIS/ESR	15

From Table 1 it can be deducted that the most requested ion beams in 2014 were gold, uranium and nitrogen. It is also shown that most of the time both terminals were operated at the same time with mostly different ion species.

One of the main highlights of 2014 was the development of CH_3^+ molecular ion beam operation from MUCIS ion source for production of intense proton beam behind the gas stripper [1,2]. This approach allowed reaching up to 25% of the FAIR design proton beam intensity with the existing UNILAC [2].

Another notable highlight is an upgrade of MUCIS new (design 2010) ion source for better performance with heavy gases (Kr, Xe). Stronger Nd-Fe-B permanent magnets (1.4 T instead of 1 T) have been used for generation of multi-cusp field in the plasma chamber. The geometry of filament holder was improved. External magnetic coil was installed around the plasma chamber to focus the plasma bunch and to increase the emission current density in the extraction region. Due to these improvements new record intensities in front of the RFQ of 9.5 mA for Kr^{2+} and of 6.5 mA for Xe^{3+} ion beams have been established. That beats the previous intensity record more than 30% for Kr-case and more than 150% for Xe-case.

Notable performance improvement of VARIS source for $^{238}U^{4+}$ beam was successfully demonstrated in Oct.-Nov. 2014 [3]. Implementation of a new multi aperture (7-holes, ø4 mm) extraction system in the ion source allowed to reduce the horizontal beam emittance (measured in UH1) by 15%, while the vertical beam emittance remained comparable (less than 2% difference) with standard extraction system. Also the source performance with various duty cycles: 1 Hz, 2 Hz and 3 Hz have been tested, showing the principle possibility of high duty cycle operation with existing uranium ion sources.

To fulfil the requirements of future FAIR-experimental programs the tests with Fe^{2+} (required by BIOMAT) and Ag^{2+} (required by CBM) ion beams from high current VARIS ion source have been performed. As the result, stable operation with new intensity records in front of the RFQ of 9 mA and 12 mA for Fe^{2+} and Ag^{2+}, respectively, has been achieved.

Renewing and development of the PIG sources is in process. Two sources are successfully putted into the operation after the complete renewing. For further investigations and development of PIG sources the construction of the new test bench is in process. The investigations will be focused on compactification of the source as well as increasing the beam current and the life time. For these purpose the compact PIG source will be tested on the new test bench.

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 1 for various physics experiments in the regular beam time schedule as well as for dedicated ion beam development.

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Table 1: Ion beam operation of the HLI-ECRIS in 2014; additional time for tests and beam development in brackets.

Ion species	Auxiliary gas	Duration (days)	Analyzed intensity (eμA)
$^{12}C^{2+}$	O_2	24	100
$^{12}C^{5+}$	He	13(17)	50
$^{14}N^{3+}$	He	16	210
$^{22}Ne^{4+}$	He	8	250
$^{40}Ar^{8+}$	He	23	200
$^{48}Ca^{10+}$	He	26(7)	120(170)
$^{50}Ti^{8+}$	He	21	70

After the long shut down period in 2013 an $^{40}Ar^{8+}$ ion beam was used for machine commissioning at the HLI.

Two beam time periods in 2014 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.

Due to a special constellation of parallel ion beam operation with protons from the high current injector and C ion beam from the ECRIS for experiments of biophysics and material research at the UNILAC $^{12}C^{2+}$ could not be accelerated in the Alvarez section of the UNILAC. The charge state had to be increased to $^{12}C^{5+}$. Such a hydrogen-like C ion beam had not been operated with the ECRIS before. Therefore extensive investigations were necessary for optimization of the operating conditions of the ECRIS before the dedicated beam time. As the ECRIS test facility was not available due to upgrade activities an ion beam development period was performed at the HLI during a gap of the beam time [4].

Upon a request from an experiment at the PHELIX LASER facility a $^{14}N^{3+}$ ion beam had to be established for the first time and could be delivered from the ECRIS in a very stable mode.

The major part of the beam time in 2014 was dedicated to various experiments on Super Heavy Element (SHE) research at SHIP, TASCA and SHIPTRAP, respectively. After the dedicated development of a $^{50}Ti^{8+}$ ion beam from highly enriched isotope material during the past years this beam was delivered to experiments for the first time. Figure 1 shows a mass/charge spectrum taken during this run. An average material consumption of 3.6 mg/h was determined for the whole run.

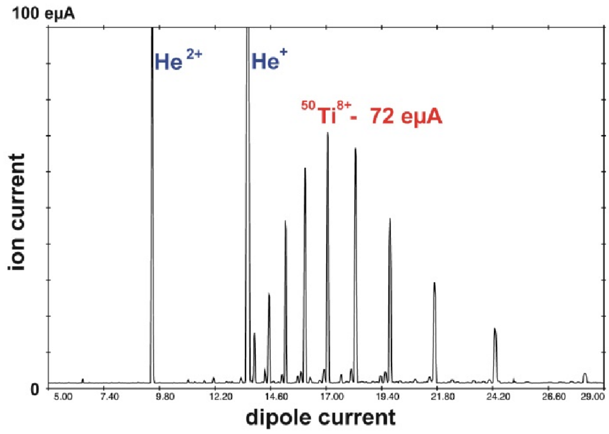

Figure 1: Mass/charge spectrum of ^{50}Ti.

Finally in 2014 a long run with $^{48}Ca^{10+}$ was dedicated to experiments of the Super Heavy Element (SHE) program at TASCA and at SHIPTRAP. This run was characterized by very stable long time behaviour of the ion beam at high intensity with the typical low average material consumption of less than 200 µg/h. For a thermal load test of the target during the final stage of the experiment the intensity of the analyzed $^{48}Ca^{10+}$ in beam could be increased to 170 eµA, a value as high as it could never be obtained before.

During the long shut down period in 2013/14 a major upgrade of the ECRIS facility at the HLI had been performed including the implementation of new TWTA-based microwave transmitters and a new high precision gas injection system for the working gas and for the auxiliary gas, respectively. All components of the new equipment could prove its reliable long term operation.

References

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