Ion Source Development and Operation at GSI

P. Spädtke, J. Bossler, H. Emig, K.D. Leible, M. Khaouli, C. Mühle,
S. Schennach, H. Schulte, K. Tinschert
GSI Darmstadt

At GSI different ion beams are delivered to the UNILAC, the synchrotron SIS or to the storage ring ESR. For that purpose three different injectors are in use for the UNILAC, equipped with different ion sources. The standard injector with a Penning ion source and the high current injector (with CHORDIS or MEVVA ion source) supply the Widere accelerator (pre-stripper section of UNILAC) with an injection energy of 11.7 keV/u. The newly built high charge state injector HLI is equipped with an ECR ion source (CAPRICE). The injection energy for the succeeding RFQ and IH accelerator is 2.5 keV/u. Both beams are further accelerated in the Alvarez accelerator (post-stripper section of UNILAC) with an injection energy of 1.4 MeV/u. For ion source tests and developments additional test benches are available. The specific advantages of each injector, recent improvements and specific operating modes are described.

Standard Injector

The regular injector is equipped with a Penning ion source (fig. 1). This source is operated in a pulsed mode, typically 50 Hz with pulse length from 2 to 6 ms. Extraction voltage is between 10 and 15 kV. For SIS-operation such a high repetition rate is not necessary, and the extracted ion current within the pulse can be increased by reducing the duty cycle allowing higher peak discharge power.

Typical ion currents measured in front of the Widere are listed in Tab. 1. The absolute acceptance of the analyzing and transport system is about 100 π mm mrad.

Table 1: Ion currents from the PIG source. Different operation modes are not distinguished.

Element	eμA	Element	eμA
$^{12}C^{1+}$	500 ... 680	$^{16}O^{1+}$	700 ... 890
$^{18}O^{3+}$	1000 ... 1100	$^{20}Ne^{1+}$	1000 ... 4000
$^{40}Ar^{2+}$	700 ... 820	$^{40}Ca^{3+}$	400 ... 570
$^{50}Ti^{2+}$	50 ... 81	$^{52}Cr^{3+}$	30 ... 42
$^{56}Fe^{4+}$	60 ... 72	$^{58}Ni^{3+}$	400 ... 450
$^{121}Sb^{7+}$	10 ... 12	$^{162}Dy^{7+}$	3 ... 5
$^{187}Re^{8+}$	100 ... 165	$^{197}Au^{8+}$	300 ... 410
$^{207}Pb^{9+}$	100 ... 150	$^{209}Bi^{9+}$	200 ... 240
$^{238}U^{10+}$	350 ... 400		

We hope to increase the available intensities, especially in the low repetition mode for SIS, by further development of the PIG ion source. These investigations and developments will be carried out at the newly built PIG test bench in close collaboration with the JINR in Dubna. The following modifications are planned:

- A pulsed gas feeding system should decrease the base pressure within the source and the beam line. The optimum case would be to have enough atoms to ignite the source and to decrease the pressure during the pulse to shift the charge state distribution to higher charges.
- A higher peak discharge power should yield an increased plasma density. Together with higher extraction voltages and an improvement of the extraction system higher ion currents should be achievable.
- Different cathode materials will be tested in order to improve the life time of the source.
- A splitted anode with an additional electric field perpendicular to the magnetic field will be tested to improve the extraction efficiency[1].

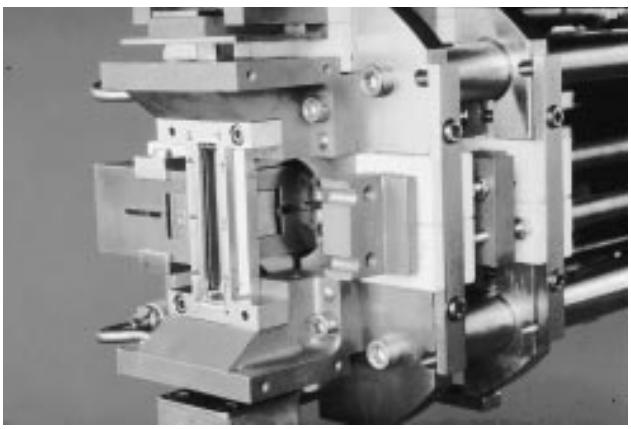

Figure 1: GSI Penning ion source.

High Current Injector

To increase the available ion currents for the synchrotron the Widere pre-stripper section will be replaced by a RFQ/IH accelerator in the near future [2]. The injection energy will be reduced from 11.7 keV/u to 2.2 keV/u. This implies the use of lower charge states from the ion source (design ion U^{4+}, el. current 15 mA). The total extracted current from the ion source will be in the range of 100 mA. To minimize beam transport problems at low energies, there is no charge or mass separation on the

high voltage platform. To preserve the beam quality during post-acceleration, the acceleration column is equipped with a movable single gap and a screening electrode[3]. The present 320 kV high voltage power supply limits the current to 40 mA. It will be replaced by a new one with a maximum voltage of 150 kV and maximum load current of 150 mA in 1997.

Like the PIG source, the CHORDIS (shown in fig. 2) is regularly operated in a pulsed mode up to 50 Hz and pulse length from 0.5 to 5 ms. Extraction voltage is between 20 and 40 kV.

Typical ion currents from the CHORDIS for D and Ne are given in table 2. The currents are measured at the same location as for the PIG source.

Table 2: Ion currents from the CHORDIS.

Element	emA	Element	emA
D_3^+	0.4 ... 0.5	$^{20}Ne^+$	4 ... 5.5

For high current investigations at the UNILAC and SIS we use the Ne-beam delivered by the CHORDIS. The molecular deuterium beam has been used instead of the atomic one for two reasons:

- The operation regime for the atomic beam is not favorable (very low rf and magnetic field level).
- Passing the gas stripper behind the Widere at 1.4 Mev/u the electrical current is increased by a factor of 3 by braking up the molecule and ionizing the atoms. Thus we have had a higher particle current at the experiment.

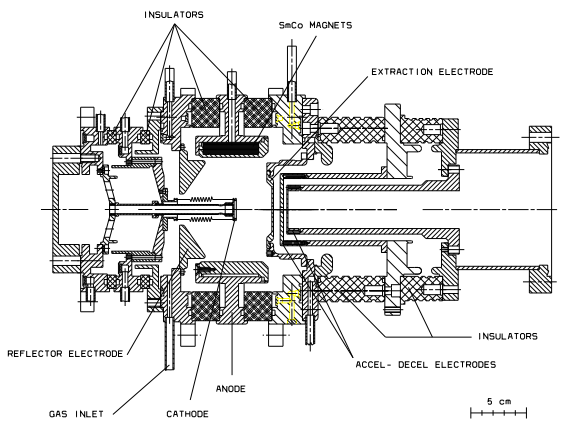

Figure 2: Gas version of CHORDIS.

For all beams from metallic elements we are using the MEVVA ion source [4]. Our version of that source type (see fig. 3) is operated in a pulsed mode with a repetition frequency of up to 5 Hz and pulse length from 0.5 to 2 ms [5],[6]. Extraction voltage is between 20 and 40 kV. The same extraction system as for the CHORDIS is used.

Typical ion currents for the MEVVA ion source are listed in table 3.

Table 3: Ion currents from the MEVVA.

Element	emA	Element	emA
$^{24}Mg^+$	15 ... 20	$^{24}Mg^{2+}$	50 ... 70
$^{48}Ti^{2+}$	25 ... 35	$^{48}Ti^{3+}$	25 ... 35
$^{58}Ni^{3+}$	25 ... 35	$^{238}U^{4+}$	20 ... 30

The Mg^+ beam has been measured at the UNILAC injector, whereas all other data have been taken at the high current test bench (analyzed current after 5 m beam transport).

For the Ti-beam the maximum of the charge state distribution is at the required charge state, for other elements special measures are necessary to get the maximum current in the desired charge state. Higher charge states can be achieved by applying a high magnetic field close to the cathode region. To decrease the charge state (1+ desired for the Mg-beam) additional gas is fed into the discharge chamber. This is shown in fig. 4.

The development of the MEVVA ion source is made in close collaboration between TASUR in Tomsk, LBL in Berkeley and GSI. After achieving the desired currents, the main activity is now to decrease the noise level on the beam as well as the pulse-to-pulse reproducibility.

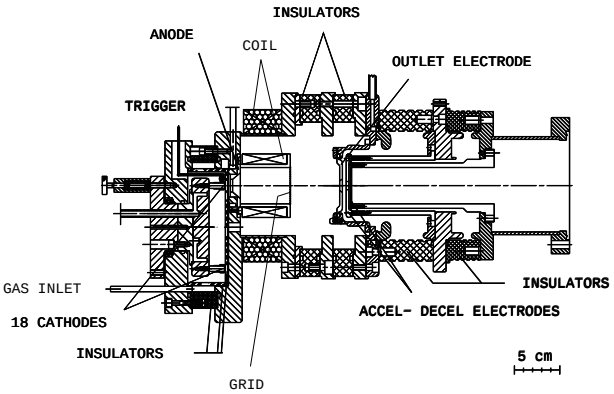

Figure 3: MEVVA ion source.

High Charge State Injector

The extraction voltage from the ECR source (shown in fig. 5) is chosen to match the specific input energy of the RFQ (2.5 keV/u). Because of the high charge states available from this source no high voltage platform is necessary. The most important features of the ECR ion source are the stable production without interruptions for weeks and the low material consumption for the desired element. Typical ion currents are listed in table 4. These ion currents are not always the maximum achievable currents, but they were sufficient for the specific experiment.

The main activity for that source is to develop different techniques to create ions from solid materials [7].

Tests at the ECR test bench revealed that for Se (vapor pressure 10^{-3} mbar at $\approx 200^{\circ}$C) the regularly used oven did not yield stable operating conditions, even with some modifications

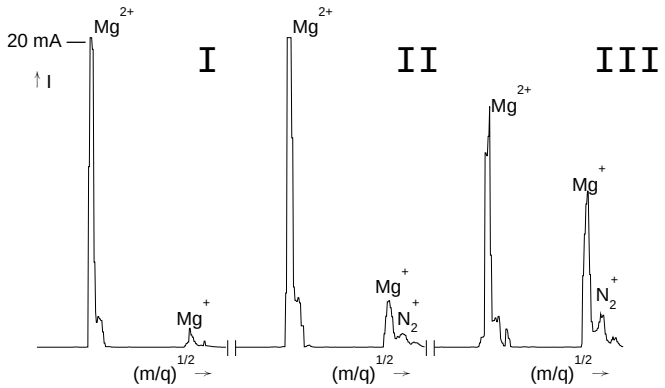

Figure 4: Mg spectra from MEVVA ion source. I: no additional gas, II: nitrogen pressure at the gas inlet is $3 \cdot 10^{-1}$ mbar, III: $7 \cdot 10^{-1}$ mbar.

Table 4: Ion currents from the ECR ion source. Enriched isotopes are marked by an asterisk.

Element	eμA	Element	eμA
$^{12}C^{2+}$	70 ... 100	$^{20}Ne^{4+}$	200 ... 250
$^{22}Ne^{4+*}$	200 ... 250	$^{40}Ar^{8+}$	200 ... 250
$^{58}Ni^{9+}$	5 ... 13	$^{62}Ni^{9+*}$	10 ... 20
$^{64}Ni^{9+*}$	10 ... 20	$^{70}Zn^{10+*}$	20 ... 50
$^{82}Se^{12+*}$	30 ... 40	$^{118}Sn^{16+}$	2 ... 5
$^{129}Xe^{18+*}$	25 ... 30	$^{136}Xe^{18+*}$	17 ... 20
$^{197}Au^{24+}$	15 ... 20	$^{208}Pb^{27+}$	5 ... 7
$^{238}U^{29+}$	2 ... 3		

to minimize the influence of the discharge on the sample temperature. For such high vapor pressure materials we built a new low temperature evaporator (fig. 6) in which the sample is placed outside the source and the vapor is guided to the standard quartz gas feeding system through a long heated quartz capillary. Thus the source operation is very similar to that for normal gases with the supplementary condition that a minimum microwave power of around 200 W should be applied to the source to avoid condensation of the material in the front part of the feeding system.

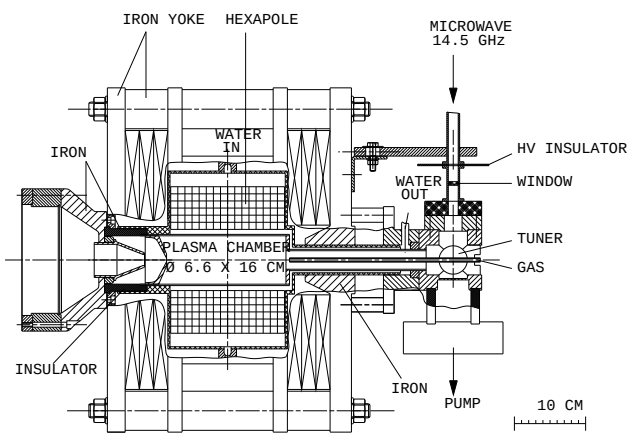

Figure 5: ECR ion source CAPRICE.

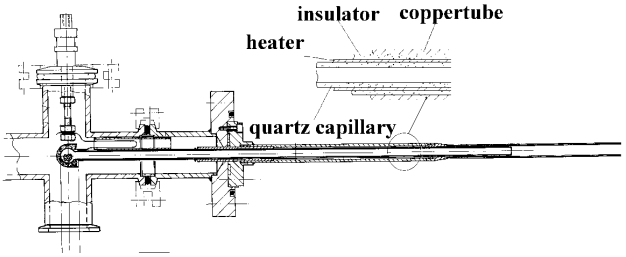

Figure 6: Evaporator for ECR ion source CAPRICE.

Comparison between test bench and injector beam line is not satisfactory. Therefore we are building an injector test bench, which will allow to transfer results to injector operation.

References

[1] S.L. Bogomolov et.al., Rev. Sci. Instr., **67(3)**, 1996, 1381.

[2] U. Ratzinger, The new GSI pre-stripper LINAC for high current heavy beams, this proceedings.

[3] P. Spädtke et.al., Rev. Sci. Instr., **67(3)**, 1996, 1146.

[4] Ian G. Brown, Vacuum arc ion sources, Rev. Sci. Instrum. **65 (10)**, 1994.

[5] E. Oks et.al., Rev. Sci. Instrum. **65**, 1994, 3109.

[6] B.H. Wolf et.al., Rev. Sci. Instrum. **65**, 1994, 3091.

[7] C. Baru et.al., Rev. Sci. Instr., **67(3)**, 1996, 1368.