

MASS SPECTROSCOPY OF A MIXED XENON-GOLD ION BEAM

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Abstract: An analysis of an ion beam produced through sputtering of gold by means of Xenon ions in a CHORDIS ion source was performed. The composition of the extracted ion beam was investigated via mass spectroscopy using a double focussing dipole magnet. From the high resolution mass spectrum the abundance pattern of stable Xe isotopes was verified and the amount of charge transitions from 2+ → 1+ could be estimated. A maximum gold current of 0,8 mA directly behind the ion source was measured.

Keywords: mass spectroscopy, ion source, ion beam, charge transition

1 INTRODUCTION

A proposal for an experiment for direct measurement of the atomic mass unit and the concept of monitoring and realizing the kilogram at an atomic level was described earlier [1].

The experiment will be realized by generating a high current ion beam of a specified nuclide, accumulating the ions by a collector up to a weighable mass and measuring the ion current integrated over the accumulation time. This integral represents the total charge of the accumulated ions. The experiment is based on the idea that the ratio between the mass and the charge of a simply charged ion is equal to the ratio between the mass and the total charge of accumulated ions. Gold, ^{197}Au , will be an appropriate nuclide because of its natural isotopical purity, chemical inert and large atomic mass. Nevertheless also other elements with only one stable isotope and a large atomic mass, like bismuth, are predestinated for the Ion-Accumulation-Experiment.

The realization of this experiment has been started at the Physikalisch-Technische Bundesanstalt by measuring the mass of a gold atom in terms of the kilogram. As an important step for this purpose, in a first accumulation experiment, the change of mass per time during the bombardment of a gold coated quartz crystal microbalance with gold ions and the ion current have been determined as a function of the ion energy. A result for the atomic mass of gold in the SI unit kilogram with the relative uncertainty of less than 2 pct has been presented earlier [2].

In this paper, a mass spectrum of the extracted ion beam and the ratio between the gold and the total ion beam current as a function of the ion source plasma density and the extraction voltage are presented. From these data, the maximum gold ion current extracted out of the ion source with seven apertures has been determined.

2 EXPERIMENTAL SET-UP

The experimental set-up is composed of a CHORDIS (Cold or HOt Reflex Discharge Ion Source) ion source [3], a quadrupole triplet lens, a beam monitor, a dipole magnet and a detector to measure the beam current. The sputter version of the CHORDIS ion source was used which comprises a gold electrode as sputter electrode.

Positive ions are extracted out of the CHORDIS ion source. The parameters of the ion source have been investigated previously [4]. The gold ions are focused with a quadrupole triplet lens. A beam monitor checks this focus. The ion separation according to their mass to charge ratio is done with a dipole magnet. The pressure within the beam transport chamber is normally around 10^{-4} Pa and below 10^{-6} Pa with and without the presence of the ion beam, respectively. The arrangement is schematically shown in Figure 1.

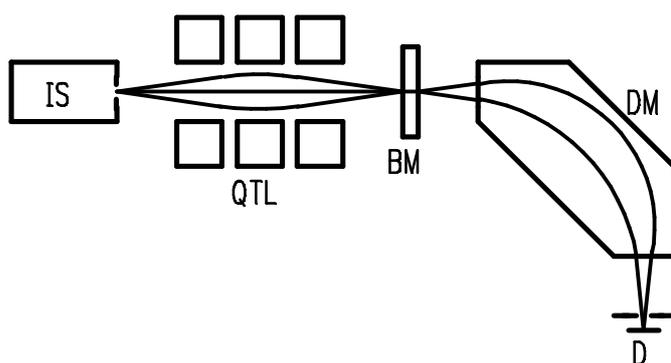


Figure 1. Scheme of the experimental system. IS ion source, QTL quadrupole triplet lens, BM beam monitor, DM dipole magnet and D detector.

The measurement of mass spectra is done by stepwise varying the magnetic fields of the quadrupole-triplet lens and the dipole according to a given mass to charge ratio. An aperture of a 1 cm hole was mounted in front of the dipole magnet to get a reasonable mass resolution. Behind the magnet the beam current was measured with a single wire with a thickness of 1 mm.

The obtained resolution ($A / \Delta A$, where A is the atomic mass of a singly charged xenon ion) was about 400. The arrangement of the extraction system of the CHORDIS ion source is schematically shown in Figure 2.

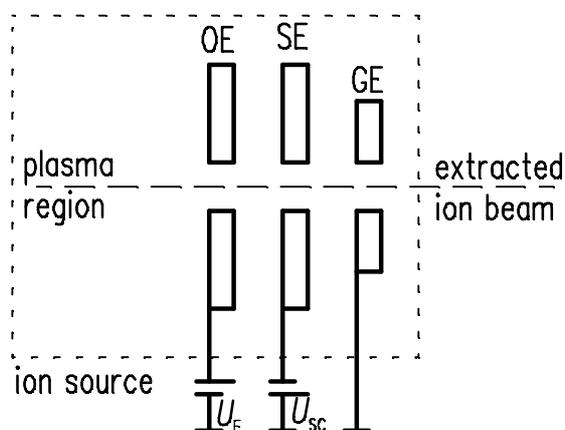


Figure 2. Scheme of the extraction system of the ion source. OE outlet electrode, SE screening electrode, GE ground electrode, U_E extraction voltage, U_{SC} screening voltage.

The ions are extracted from the plasma via acceleration from the outlet electrode to the extraction electrode and finally leave the ion source through the ground electrode. Each electrode has 7 holes with a diameter of 6 mm. The advantage of using a multiple hole system is, that higher ion currents with reasonable beam quality can be extracted.

The current measurement of all extracted ions was done by measuring the total current behind the ion source. For this purpose the voltage drop over a suitable resistor was measured.

3 RESULTS AND DISCUSSIONS

In a first step, mass spectra of the extracted ion beam have been measured. The main components of the ion beam were isotopes of the working gas xenon. The noise to signal ratio was less than 0,5 pct during the measurement.

Figure 3 shows a mass spectrum up to a mass to charge ratio of 300. The extraction voltage was 18 kV. The total current of the ion beam can be obtained by integration of the current over the whole mass-spectrum which leads to a value of 20,5 μA . The integration of the gold peak gives a current of 0,26 μA which is 1,3 pct of the total beam current.

In the measured mass spectrum 7 of 9 stable isotopes can be observed. Table 1 shows the experimentally determined relative abundance of the xenon isotopes in comparison with the literature values for the singly charged xenon isotopes.

Table 1. The relative abundance in pct of the observed xenon isotopes with different charge states.

Isotope	1+	2+	2+→1+	1+ [5]
¹²⁴ Xe				0,1
¹²⁶ Xe				0,09
¹²⁸ Xe	2,25	2,13	3,98	1,91
¹²⁹ Xe	28,04	27,34	25,64	26,4
¹³⁰ Xe	4,43	4,82	5,79	4,1
¹³¹ Xe	21,95	21,77	20,64	21,2
¹³² Xe	26,68	25,47	25,31	26,9
¹³⁴ Xe	9,23	9,97	9,64	10,4
¹³⁶ Xe	7,41	8,51	8,99	8,9

The mass spectrum shows 3 groups of xenon isotopes. The first group around the mass to charge ratio of 65 are doubly charged ions which were extracted from the ion source. The second group around 130 are singly charged extracted ions.

Doubly charged ions which picked up one electron during the flight from the ion source to the dipole magnet are to be seen in the third group. These ions have in contrast to the other singly charged ions twice the energy of a singly charged ion and occur therefore at twice the mass to charge ratio around 260. The fact that all 3 groups have nearly the same abundance pattern is a strong evidence for a charge transition from 2+ → 1+ in the 3rd group. This is not unusual because of the presence of electrons steaming from rest gas ionisations in the beam line. A surprising result is that the amount of ions which have changed their charge state from 2+ → 1+ is in the order of 11 pct relative to the total amount of originally extracted 2+ ions.

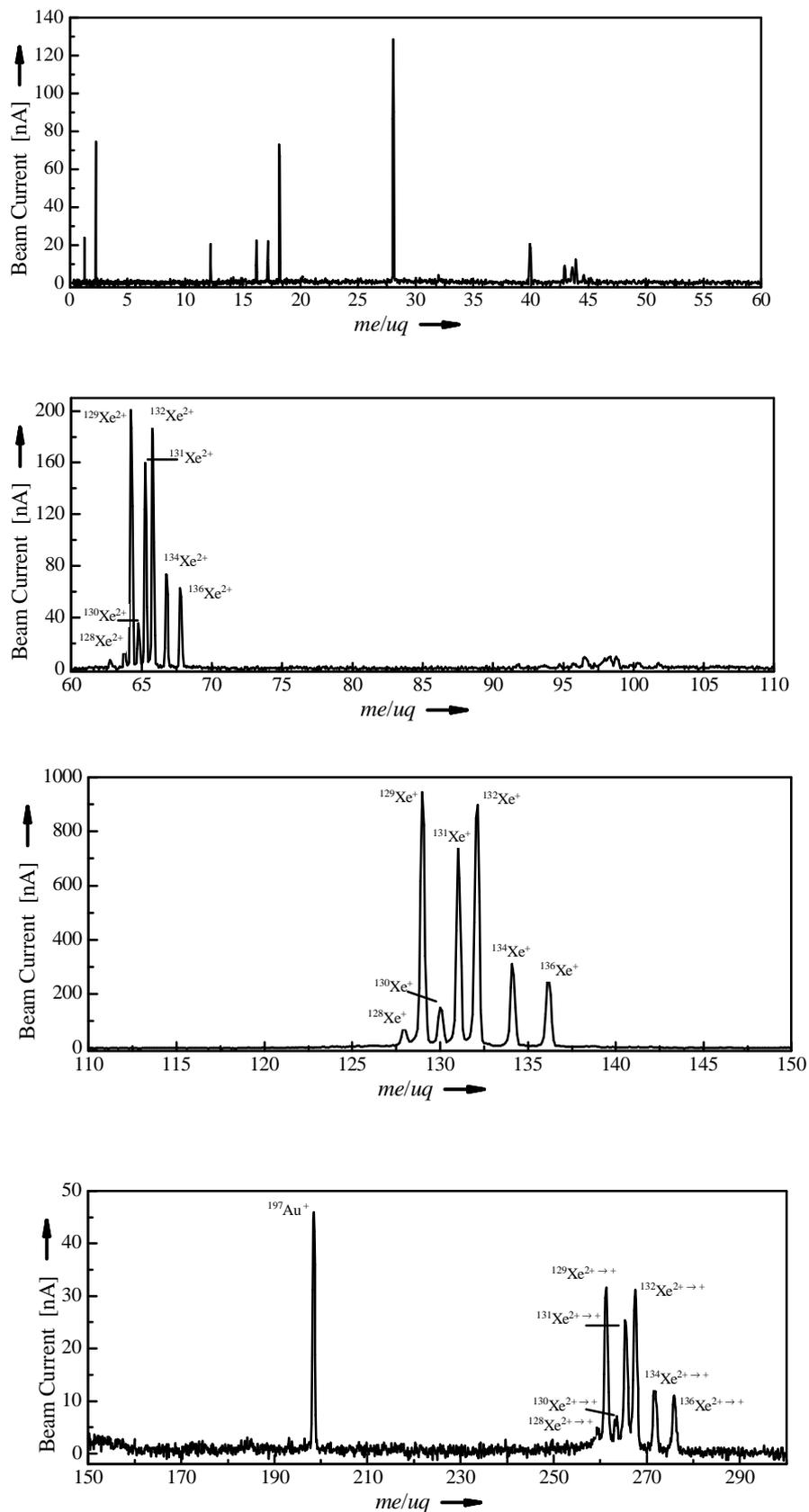


Figure 3. Mass spectrum of the ion beam extraction out of a CHORDIS ion source. The source was a sputter version with a gold electrode and a xenon working gas. The ions were extracted with a seven hole extraction system.

Figure 4 shows the total and the gold ion current as a function of the acceleration voltage. The total current was measured directly behind the ion source. The gold ion current is 1,3 pct of the total beam current. This value was taken from the measured mass spectrum.

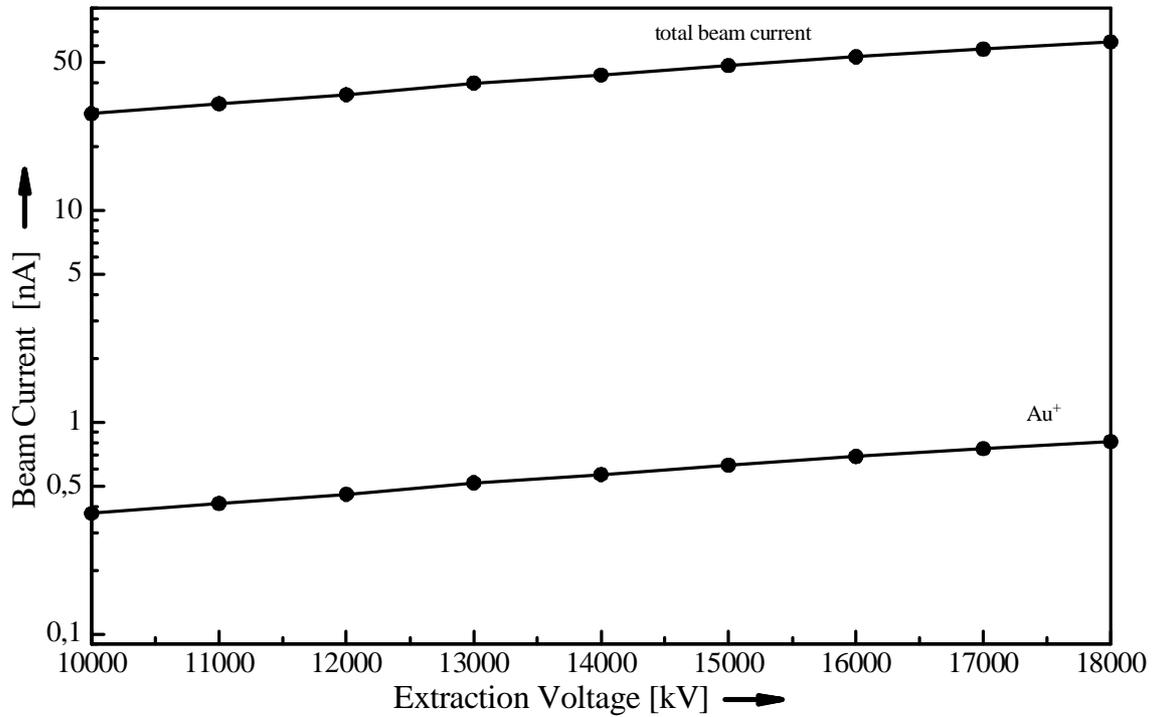


Figure 4. The total ion beam current and the gold ion beam as a function of the extraction voltage.

For acceleration voltages from 10 kV to 18 kV total currents of 28,6 mA to 62,5 mA were measured corresponding to gold ion currents from 0,37 mA to 0,81 mA.

4 CONCLUSION

In this article experimentally determined mass spectrum from a mixed xenon-gold beam extracted from a CHORDIS ion source were presented. The main aim of these measurements was to determine the amount of the gold current out of the extracted mixed ion beam. The obtained maximum value of 0,8 mA gold is a further important step toward a high ion current necessary for an accumulation of a weighable mass in a realistic time limit.

Another crucial information is the composition of the extracted ion beam. It was shown that with the existing experimental setup a very good mass resolution up to 400 can be obtained. This resolution is the basis for a very clean separation of the different stable xenon isotopes. In addition one has learned that the amount of charge transitions from 2+ \rightarrow 1+ is in the order of 11 pct relatively to the total amount of originally extracted 2+ ions.

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