

## STATUS OF THE RUSSIAN ACCELERATOR MASS SPECTROMETER PROJECT

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### Abstract

The status of the first Russian accelerator mass spectrometer being developed at BINP for SB RAS (Novosibirsk) is described. The scheme of the spectrometer includes two types of ion sources (sputter and gaseous ones), electrostatic tandem accelerator with accelerating voltage up to 2 MV and magnesium vapors stripper and also includes the high-energy and low-energy beam lines with analyzers. The results of the experiments with the ion beams are given.

### INTRODUCTION

The status of the BINP AMS facility and the recent development are described. The construction work started in 2003, and the project was presented previously [1]. The AMS is based on the electrostatic tandem accelerator. One of the most distinguishing features of our AMS machine is the use of additional separator of ion beam, located inside the HV terminal after charge exchange target (stripper). The combination of electric and magnetic analyzers with crossed fields can essentially decrease the background. Interfering isobaric molecules are destroyed by collisions in the stripper and their fragments are removed by the separator. It is important to decrease the background caused by molecular fragments before the second stage of acceleration, because otherwise they can get a big energy spread by recharging on residual gas into electric field. The ions of 3+ charge state will be used for isotope analysis of Carbon-14. Another important distinguishing feature is the use of magnesium vapors stripper instead of the gas one. It simplifies vacuum system of AMS, since the turbo-pump is not necessary for operation of the stripper.

### INJECTION SYSTEM

A photo of the injection system is shown in Fig. 1.

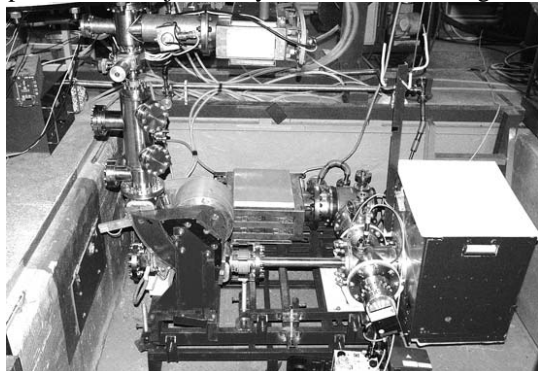


Fig. 1. Injection system of AMS.

The AMS system is equipped by two ion sources. The sputter ion source is used for analysis of solid samples. The gas ion source is used for direct analysis of gas samples and for adjustment of the system. The energy of the extracted negative ions from ion source is 15 keV. The ion beam extracted from the source passes through the double focusing 90° analyzing magnet with 40 cm radius and 2.5 cm pole gap. The position and angles of extracted beam are slightly corrected by four pairs of electrostatic plates. The fast isotopes switching system is considered for precise measurements in future. The stable isotopes currents are measured by off-axis Faraday cups. They are placed just after the analyzing magnet.

In order to pass through narrow stripper channel the system of three-electrode electrostatic lenses and electrostatic dipoles has been manufactured and placed at the entrance of the first accelerating tube. The vacuum in the injection channel is kept better than  $5 \cdot 10^{-6}$  Torr by 400 l/s ion pump and 250 l/s turbo-molecular pump installed just after ion sources. The beam-line from ion source to accelerator tube has been completed and tested.

### TANDEM ACCELERATOR

The AMS tandem accelerator is a folded type vertical machine with 180° bending system in the high voltage terminal. It is shown in Fig. 2.

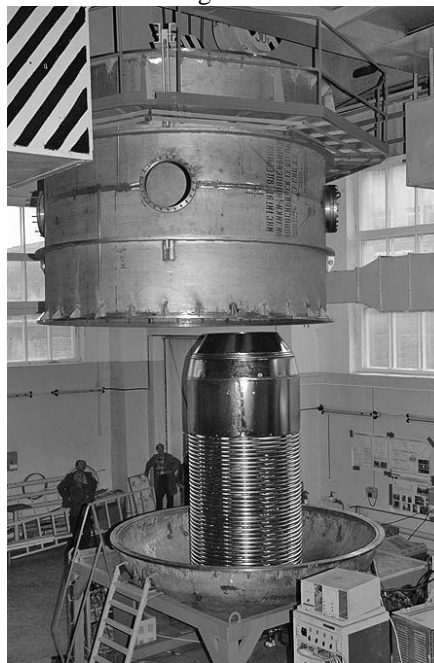


Fig. 2. Tandem accelerator.

The negative ions will be accelerated to the positively charged high voltage terminal and then stripped to 3+

state in charge exchange target. Then they pass through  $180^\circ$  combined bend and then accelerated again in the second accelerating tube. Two accelerating tubes and cascade generator are enveloped by shielding column, with 200 cm height and 140 cm outside diameter of shielding rings, and placed into a pressure tank. The pressure tank is 4.6 m high and 3.2 m in diameter. The accelerating tube consists on five sections, with 21 mm electrode gap. The electrodes are divided by ceramic rings with 18 cm inner diameter. The channel aperture of accelerator tube is 3 cm. The potential gradients across the columns and tube electrode gaps is obtained by resistor chains. The maximum designed gradient in the tube is a little larger than the 10 kV/cm. The accelerating voltage is generated by the symmetrical cascade generator with a resonant frequency  $\sim 20$  kHz. The design value of terminal voltage is 2 MV. It is to be achieved with  $\text{SF}_6$  insulating gas at 1.7 bar pressure. Now, on the adjustment stage, air at normal pressure is used as insulating gas. The maximum terminal voltage of 500 kV was achieved in our experiments. The  $\text{SF}_6$  gas system including gas transfer system, compressor and dryer has been prepared. The accelerating tubes, cascade generator, shielding column and HV terminal shell have been installed into the accelerator tank.

### MAGNESIUM VAPORS STRIPPER

The use of magnesium vapors stripper allows obtaining the vacuum level in accelerating tubes being comparable with systems with solid targets, because the magnesium vapors are condensed in special "cold" containers (at room temperature), which are placed at the entrance and exit of the hot stripper tube. Solid targets at these energies have a short lifetime and therefore are not applied usually. The high gas flow into the high-energy tubes leads to big energy spread in the beam thus limiting the sensitivity and accuracy of spectrometer. The magnesium vapors stripper was installed into the terminal. It is shown in Fig. 3.

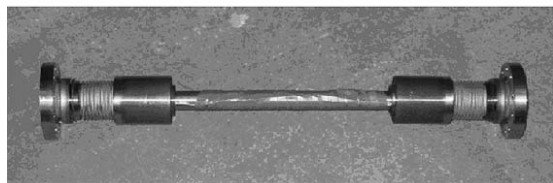


Fig. 3. Magnesium vapors stripper

The stripper channel has a 30 cm length and 3 mm inner diameter. The stripper tube is surrounded by container with solid magnesium. When the container is heated, the magnesium vapors penetrate to the stripper tube through small holes in container. The magnesium vapors pressure is  $\sim 10^{-10}$  Torr at room temperature and rises up to  $\sim 5 \cdot 10^{-2}$  Torr at  $\sim 500^\circ\text{C}$ . The temperature range  $400\text{--}500^\circ\text{C}$  provides the sufficient thickness of target for radiocarbon dating measurements. The heating time up to  $450^\circ\text{C}$  is  $\leq 1$  hour. The previously developed analogue of such a target have worked more than 500 hours in the electron cooling investigation facility. [2]

### HIGH ENERGY BEAM SELECTION

The filter with crossed electric and magnetic fields was mounted after the magnesium stripper, both have 40 cm radius and  $180^\circ$  bending angle (combined bend). The electrostatic plates are placed inside the magnet. The gap between the electrostatic plates is 1 cm. At first, these plates were designed with spherical form for double focusing action, but recently after experiments we've decided to change them to the cylindrical ones more convenient for adjustment stage. The magnet has uniform field in the gap (600 Gs max.); it is enough for mass selection. The 90 % of centripetal force are obtained by electrostatic field with  $\sim 30$  kV/cm maximum field strength at 2 MV accelerating voltage for 3+ ions. The cylindrical plates of combined bend have been manufactured and will be installed soon. The most part of the unwanted particles should be removed by this filter. For the further background damping the  $90^\circ$  double-focusing analyzing magnet will be placed at the exit of the tandem accelerator. Finally, the Carbon-14 particles will be measured by silicon surface barrier detector placed at the end of high-energy beam line. [1].

### CONTROL SYSTEM

The fully computer controlled system was designed and its main parts were manufactured. The software used for the control system is based on LabVIEW. The system is equipped with ADAM and CAMAC modules. The experimental parameters and running conditions are displayed on-line. This data is stored in a database and can be used as initial values for the beam tuning. All the devices under HV potential are computer-controlled through the optical ADAM link system. The  $\sim 500$  W gaseous turbine is placed into the tandem terminal for powering of the magnesium stripper, bending system, ion pumps and another equipment in HV terminal. The turbine is fed by compressed air flow generated by compressor placed at ground potential.

### EXPERIMENTAL RESULTS

The beam energy in experiments described below was 400 keV. The gas ion source [1] was used for  $\text{C}^-$  ions production. The vacuum near magnesium stripper is controlled by ion pump currents, which are placed at the entrance and exit of the stripper tube. These pumps are mainly used for degassing during the first heating of the magnesium stripper after obtaining required vacuum condition of AMS facility. The ion pumps currents did not increase during next heating cycles.

The charge states fractions measurements were carried out using electrostatic dipole scanner at the exit of the magnesium vapors stripper. The negative potential was added to the off-axis wires and to the central electrode of beam monitor to measure electron emission of beam interaction. In this way, the neutral atoms can be measured as well as charged ions. In calculation of charge distribution the electron emission is set equal to 5. This factor was obtained by changing the sign of wire potential

during measurements of  $C^-$  beam. So, the weight factors for particles with charge  $-1, 0, +1, +2$  are  $5/4, 5/5, 5/6, 5/7$  correspondingly.

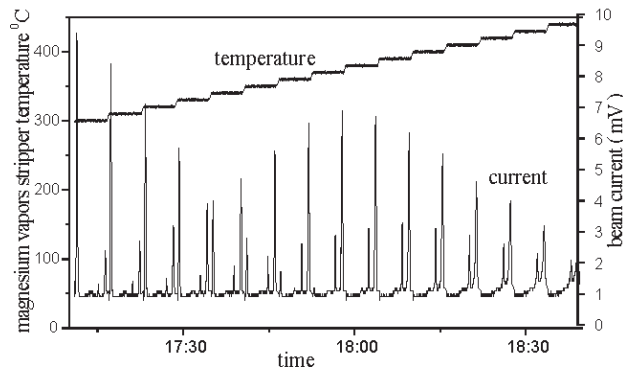


Fig. 4. The ion currents of different charge states vs. stripper temperature.

Fig.4 shows a signal from off-axis wire during magnesium stripper heating. The beam was scanned for each temperature setting. The stripper temperature was increased with  $10^0C$  step.

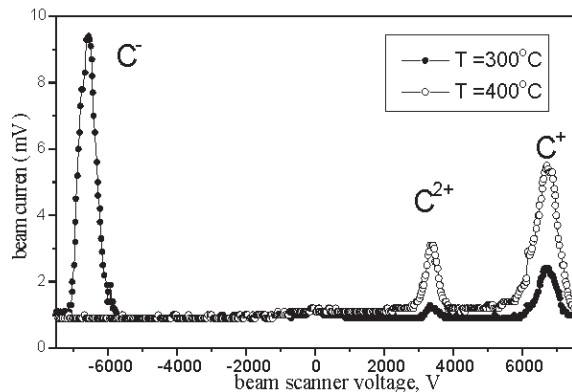


Fig. 5. Carbon ion currents at 300°C and 400°C temperature of stripper as a function of scanner voltage.

The signal from wire at temperatures 300 °C and 400 °C are presented additionally in Fig.5. As it is seen from the figures, the negative ions disappear with magnesium heating.

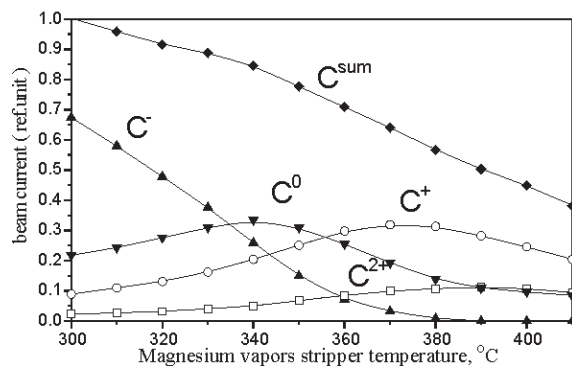


Fig 6. Carbon ion currents at 400 keV energy as a function of stripper temperature.

The charge distribution in the beam is shown in Fig.6. On can see that the beam intensity decreases with increasing of the heating temperature of the magnesium.

It is caused by beam scattering in magnesium vapors. At designed voltage value of 2 MV the beam losses will be decreased significantly. Fig. 7 shows the charge-states fractions values in the beam, which are normalized to the beam intensity after stripper. The old data for stripping of 1 MeV hydrogen beam [2], whose velocity is equal to 12 MeV carbon beam is presents in Fig. 7 too.

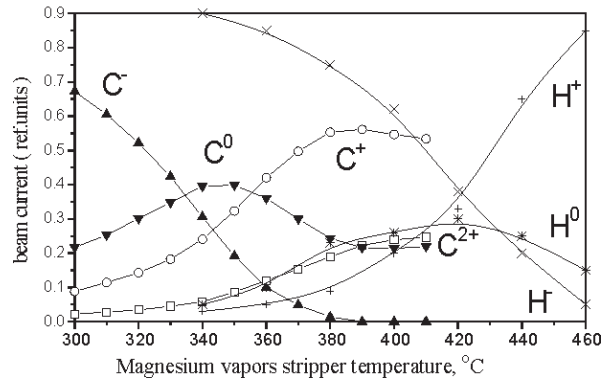


Fig. 7. Charge state fractions for carbon at an energy of 400 keV and hydrogen at an energy of 1MeV as a function of stripper temperature (normalized to the beam intensity, see Fig. 6).

### SUMMARY

- The low-energy beam line and main parts of tandem accelerator have been installed and now in operation.
- The maximum terminal voltage achieved with air as insulating gas – 500 kV.
- The carbon beam was accelerated and stripped into high voltage terminal at 400 keV energy.
- The magnesium vapors stripper was tested, the vacuum outside it did not worsen during the heating process.
- The results of the experiments undertaken allow to expect that the magnesium vapors stripper can be used at 2 MV terminal voltage for stripping  $C^-$  ions into 3+ ones without vacuum deterioration.

### ACKNOWLEDGMENTS

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### REFERENCES

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2. V. Parkhomchuk, A. Seriy. Strip target based on magnesium vapors. Instruments and Experimental Techniques., v. 5, p. 59-61, 1989.

<sup>#</sup> [www.fasie.ru](http://www.fasie.ru)

\* IA 03-59-120

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