STATUS OF ACCELERATOR MASS SPECTROMETER AT BINP

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Abstract

Present status of the accelerator mass spectrometry (AMS) facility at BINP is described. The AMS facility with additional electric and magnetic analyzers into the high voltage terminal of tandem accelerator is dedicated for precise analysis of carbon isotopes. The results of experiments on ion beams acceleration and stripping are given.

INTRODUCTION

The accelerator mass spectrometry is an ultra-sensitive method of isotopic analysis for archaeology, environment science and another fields.

The AMS system consists of the ion sources, low energy channel, tandem accelerator and high energy channel. The low energy beam line is used for initial isotope selection. The tandem accelerator is necessary for rejection of the molecular ions and of course for obtaining required beam energy for the final detector. The high energy beam line is intended for the further ions selection and for radioisotopes detection.

In the present AMS [1,2] project, the negative ion beam is horizontally extracted from the ion source. Then the beam is vertically injected into the low energy accelerating tube through injection channel with 90° magnet. The negative ions are accelerated to the positively charged high voltage terminal and stripped to plus charge state in magnesium vapors stripper. Then they pass through the 180^0 combined bend and then again vertically accelerated into the high energy accelerating tube to the ground potential. The extracted radioisotope ions move horizontally to the final detector through high energy channel with 90° magnet.

Now the AMS facility is being constructed at BINP. The building work for specialized AMS center has started this year. The accelerator will be placed in the underground room with radiation shielding. The inner size of the room will be 6 x 6 x 7.5 meters.

The most distinguishing features of our AMS machine are the use of the middle energy separator of ion beams and the magnesium vapors target as a stripper. The aim of this innovation was described earlier.

LOW ENERGY BEAM LINE

The low energy beam line is installed and in operation [2], but some improvements are to be made. In AMS application, the ion source must be quickly replaced for cleaning and sample changing. For this purpose, the ion source should be separated from the injection channel by gate valve. Now the gate valve is located only at the exit of the first bend magnet and the vacuum conditions are obtained by 250 l/s turbo pump during the three hours period after connecting the ion source. In addition, the channel will be equipped with a differential pumping system to decrease the gas flow from ion source to the beam line. This system has been designed and now is under production. Recently, the RGA system was installed after bend magnet for residual gas analysis in the injection channel. At present time, the vacuum in the injection channel is about $5{*}10^{-6}$ Torr with gas ion source.

HIGH VOLTAGE TERMINAL

The tandem terminal is an important part of the BINP AMS system, because the beam will be pre-selected at medium energy by electric and magnetic fields. The electrostatic 180° bending system with 40cm orbit radius was recently installed into the high voltage terminal. The electrostatic plates with 2.5 cm width and 1 cm pole gap. are placed into the vacuum chamber. The required 30 kV/cm field of bending system was demonstrated. The 180° magnet will surround the vacuum chamber with electrostatic plates. The magnet has been manufactured and will be installed then the radiocarbon dating will start. The power supply for magnet is now under production.

The magnesium vapors stripper worked more than 100 hours on the BINP AMS facility at 400°C average temperature. It’s not necessary to change magnesium. The precise system for magnesium target positioning is under manufacture. The transverse position of the target will be adjusted by the beam transmission. For this purpose, the bellows are placed at the entrance and exit of the magnesium target. The stripper channel has the inner diameter of 3 mm. The new magnesium stripper with inner diameter 6 mm is under production.

The electrical power, required in the terminal, is generated by the 500W gaseous turbine. Recently, electronics for four electrostatic dipoles, electrostatic bend and for three ion pumps has been manufactured and installed. The control units of this electronics are connected to tandem optical link by ADAM modules. The electronics for electrostatic quadrupoles is now under production. The 15 l/s ion pump is installed just after terminal bending system. The vacuum in tandem accelerator is kept better than 10^{-6} Torr. The gas pressure was measured by vacuum gage at installation period and then is controlled by ion pump currents. The gate valve is placed after the terminal bend. The equipment in HV terminal works without forced cooling, but it is possible by the turbine gas. The basic parts of tandem terminal equipment was installed and are shown in Fig. 1.

Figure 1: High voltage terminal.

TANDEM ACCELERATOR

The tandem accelerator is a folded type vertical machine The absolute calibration for the tandem voltage was recently checked with one percent precision by passing of the beam through the 180° electrostatic plates. The injection energy of the beam was taken into account. The beam passed through the bend without stripping in magnesium target.

For the examination of the sparks locations, the small wireless video camera was mounted into the tandem terminal. The small lamp for illumination of the interior of the accelerator was installed, also.

At present, while in the commissioning stage, air at normal pressure is used as insulating gas. The maximum terminal voltage of 530 kV was achieved, but sometimes the maximum voltage was little more than 400 kV. We suggest that the reason is that the accelerator tank is not sealed and the air conditions change from day to day. The process of sealing of the tank flanges is to be started. At this stage, we don't plan to use sulphur-hexafluoride gas, because the AMS room have no radiation shielding. The specialized AMS center will be build next year and the work with high terminal voltage more than 500 kV will start.

HIGH ENERGY BEAM LINE

The high energy beam channel have now only the beam diagnostic block. The 100 l/s water cooled ion pump has been recently installed at the exit of the tandem accelerator. All system from ion source to the high energy exit of the accelerator are under vacuum conditions. At the first stage, we plan to study the quality of the accelerated beam after tandem accelerator and then install the high energy channel.

The beam line will have 90° analyzing magnet for additional background filtration. Now we have an old magnet for this purpose, but the radial aperture of this magnet is not enough for simultaneous passage of the ^{14}C and stable carbon ions. The magnetic field will be changed for passage of each isotope. If the dating precision is not good enough, the new magnet with larger aperture will be manufactured. The carbon radioisotope particles will be measured by a silicon surface barrier detector placed at the end of the beam line [1]. The basic parts of vacuum chamber for high energy channel have been manufactured. For operation with the tandem voltage below 500 kV the second stripping of positive ions to create highly positive charge states will be added to this channel. At the next stage only the magnesium vapors stripper in the high voltage terminal will be used for conversion of ion charges.

SOFTWARE

The software used for control of the AMS facility is based on LabVIEW. Now ~100 parameters of the beam line elements, correctors and diagnostics probes are controlled and stored in a database. Recently, the remote control from the BINP net was added. All accelerator parameters can be monitored by any computer in local net and some setups can be distantly managed.

EXPERIMENTAL RESULTS

The previous experimental results demonstrated, that the negative carbon beam can be accelerated and stripped into high voltage terminal of BINP AMS facility. The charge state fractions of carbon beam stripped by the magnesium vapors stripper was obtained [2] and are shown in Fig. 2. It was measured by the electrostatic dipole scanner at the exit of the magnesium stripper.

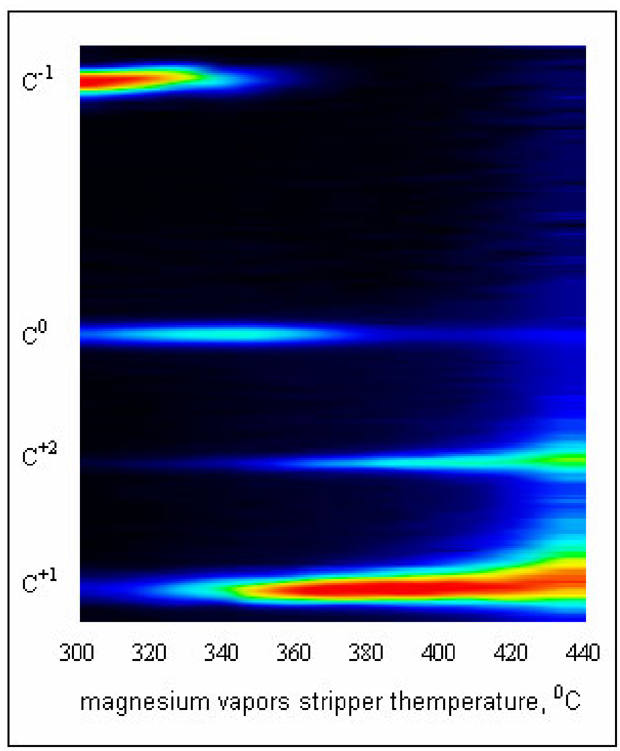

Figure 2: Charge states spectrum of 400 keV carbon beam as a function of stripper temperature.

Since then, the 180° bending system has been installed into the high voltage terminal, so the positively charged ions can be again accelerated to the ground potential. The negative oxygen ions from Penning ion source [1] are used for adjustment of ion-optics system of the AMS facility. At the first stage, we used 14keV ion beam without acceleration into tandem accelerator and without stripping in magnesium target, whose heating was off. In that case, the position of beam line elements can be easily corrected in compliance with signals of beam position by bellows. Moreover, the signals of beam from electrostatic dipoles and other electrodes can be used as additional detectors for optics adjustment by temporary connection of measuring devices.

The ion beam extracted from the source passes through the double focusing 90° bend magnet. The position and angles of the beam are slightly corrected by four electrostatic dipoles. The beam position after the magnet is measured by a single wire profile monitor with use of the stepping motor. The four-segment detector in the terminal is used for beam positing at the entrance of the magnesium stripper tube. The beam is directed by correction of the magnetic bend field and electrostatic dipole. The position and angles of the beam passed through magnesium stripper device are corrected by two electrostatic dipoles and one bellows. In future the additional two dipoles will be installed for full electrostatic beam orbit correction. For the initial beam passing between 180° bending electrostatic plates, the signal from outside plate was used as a beam monitor. The voltage was applied only to the inner plate. After obtaining dipole correctors values the opposite voltages were applied to both bending plates. The beam passed through the bending system was detected by plates of electrostatic dipoles placed at the exit of bending plates. When beam position is detected, the beam is deflected to the Faraday cup, located at the exit of tandem accelerator. The inner diameter of the Faraday cup is 10 mm. The 0.5 mm wire with a retarding potential is used for beam profile measurements. The first beam at injection energy was put into Faraday cap in July 2006.

For obtaining of the accelerated beam, all electrostatic correctors and bend system into the HV terminal had increased values for the new beam energy. The sign of the voltage was reverse, because the negative ions are converted to positive ions by stripping in magnesium target at 395°C. The beam intensity at the exit of the accelerator with 100kV tandem terminal voltage as a functions of the electrostatic field in 180° bend is shown in Fig. 3.

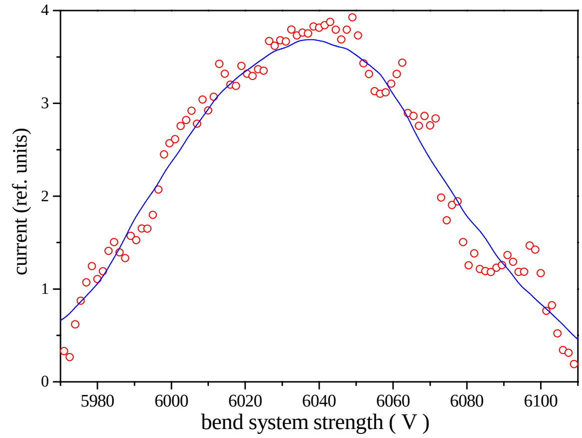

Figure 3: The first extracted beam from tandem accelerator.

The bend voltage was adjusted to the 1+ ion charge. The FWHM of beam size at the exit of the accelerator is about 1 cm. The ions in charge state 2+ was extracted from the accelerator by increasing of tandem voltage for doubling of the beam energy at tandem terminal. Other accelerator setups were not changed. Recently, 2+ ion beam has been accelerated to the 330kV terminal for obtaining 1MeV extracted beam. We plan to begin radiocarbon measurements with 1.5MeV beam.

SUMMARY

The first accelerated beam has been observed at the exit of the BINP AMS tandem accelerator.

ACKNOWLEDGMENTS

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