A TRIPLE-ISOTOPE INJECTOR FOR ACCELERATOR MASS SPECTROMETRY

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Abstract

Performance of the newly installed 40 keV negative ion injector for the three isotopes (masses 12,13 and 14) of natural carbon is discussed. A cesium sputter ion source and an achromatic arrangement of four dipole magnets with two electric slot lenses is being used, to achieve minimal aberrations for the injected beam into a tandem.

I. INTRODUCTION

As part of the new AMS system built for the National Ocean Sciences AMS Facility [1] at Woods Hole Oceanographic Institution (Woods Hole, MA) by US-AMS Corporation [2] (Topsfield, MA), an injector for simultaneous acceleration of the three natural isotopes of carbon was designed. The extremely low abundance of carbon-14 compared to carbon-13 (times 10^{10}) and carbon-12 (times 10^{12}) makes ratio mass spectrometry difficult. Sequential measurements are subject to differences in beam-loading as well as the usual short-term tandem accelerator instabilities. The frequently used electrostatic "bouncer" has limited efficiency. Since the carbon-13/12 ratio is stable, and varies only slightly from sample to sample, simultaneous acceleration of all three isotopes with online measurement of the 13/12 ratio makes a useful diagnostic indicator of fractionation effects and other systematic problems.

II. PHYSICAL DESCRIPTION

A. Ion Source

The cesium sputter ion source was based on work by Middleton [2] and is similar in principle to that built by Genus Corporation for Lawrence Livermore National Laboratory. It has an hemispherical ionizer, through the center of which the negative ion beam is extracted. Cesium vapor is stabilized by regulating the temperature of both the reservoir and the transfer tube closely. The cesium ions are accelerated through about 8 kV from the ionizer to the target. The graphite sputter targets (containing the samples for analysis) are pressed into 2 mm diameter holes in aluminum cartridges. A carousel holds 59 of these targets. The target changer is operated by DC servomotors on the high voltage deck. The sputtered negative ions emerge through the hole in the ionizer and pass through a 32 kV extraction gap, so that the total energy is 40 keV. The acceptance half-angle is 22 milliradians, limited by an aperture plate at the exit of the source. A cylindrical einzel lens brings the beam to an object point for the recombinator. There is an insertable Faraday cup to measure source output.

B. Recombinator

This arrangement of magnetic and electrostatic elements was optimized by the Toronto group (It is sometimes referred to as a Brown achromat)[3]. Although not the first application of a recombinator to AMS, this one is simple to set up and align, because of the separated functions of the vertically focussing electric slot lenses and horizontally focussing dipole magnets. The tilt of the horizontal focal plane with respect to the plane of symmetry, due to second order aberrations, is partially corrected by concave exit faces of the magnet poles. As a result, the emerging isotopes should diverge by no more than 3.7 milliradians, which is within the acceptance of the accelerator. The four 45° magnets which make up the spectrometer have 260 mm bending radii for

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This work is supported by National Science Foundation Grant OCE-8802509
0-7803-0135-8/91$01.00 ©IEEE

mass 13, 50 mm apertures and normal entrance and exit angles. The two slot lenses operate at 20 kV and cause a vertical cross-over at the center of the system. They also incorporate vertical steerers. The horizontal separation of the three parallel beams in the mirror plane of the recombinator is 19 mm. An aperture plate at this location removes mass 15 (NH^-) and higher masses. There are no defining apertures for mass 12, 13 and 14. A chopper wheel was introduced at this location to attenuate the mass 12 beam by a factor of 85, which makes it approximately equal in intensity to the mass 13 beam. Faraday cups are inserted to measure the mass 12 in the mirror plane, and at the entrance lens to the accelerator. Insertable flags can block the mass 13 and 14 beams for testing purposes.

III. PERFORMANCE

A good vacuum in the ion source is necessary for low backgrounds. We use a 400 L/s turbopump which keeps the pressure below 2 x 10-6 Torr. In addition, a 150 L/s turbo is located at the center of the recombinator. A fully loaded target wheel takes at least an hour to outgas. At the exit of the source, total currents of nearly a milliampere are seen. At the center of the recombinator, we typically obtain 40 to 50 microamperes of analyzed mass 12 beam (before attenuation) from our graphite targets, which contain 2 mg of carbon; these beams persist for several hours. (Beams as high as 200 microamperes are possible, with suitable target material.) The beam spots at the center of the recombinator are 3 mm diameter, so the mass resolution is about 15%. At the exit of the recombinator, the beam which is injected into the accelerator contains 35% mass 12 (^{12}C), and 65% mass 13 (^{12}CH, ^{13}C) with a trace of mass 14 ($^{12}CH_2$, ^{13}CH and ^{14}C). The total current at this point is about 2 microamperes. The beam diameter is less than 3mm. Use of the chopper wheel as an attenuator for the ^{12}C beam does not affect the stability of the measured carbon 13/12 ratio, which can be measured to one part in a thousand. With no attenuator, the transmission of a ^{13}C beam switched through the three separate trajectories of the injector showed equal transmission. The first injector has been operational with the rest of the AMS system at Woods Hole since early 1991.

A second injector leg is now under construction, and is expected to be operational in mid-1991. Figure 1 shows the complete dual leg injector. A switching magnet is used to select the injector.

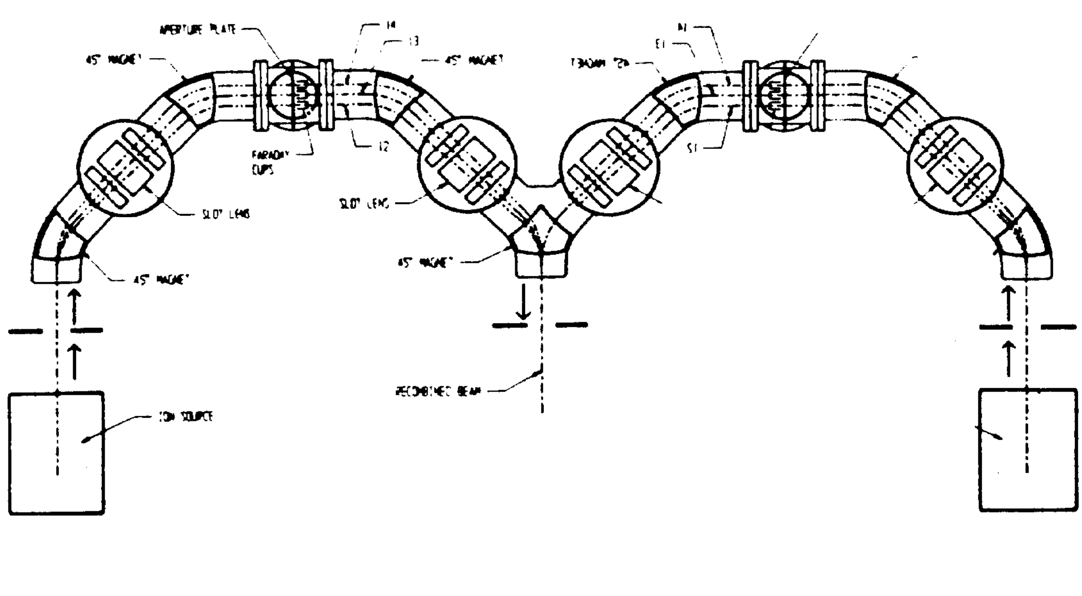

Figure 1. The dual-leg injector, with two recombinators, two ion sources and a switching magnet. The two ion sources are separated by 3.5 meters.

IV. REFERENCES

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This work is supported by National Science Foundation Grant OCE-8802509