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A new dual injection system for AMS facility

Lin Liu [a,b,c], Weijian Zhou [a,c,*], Peng Cheng [a,b], Huagui Yu [a,b], Maobai Chen [a]

[a] State Key Laboratory of Loess and Quaternary Geology, Institute of Earth Environment, Chinese Academy of Sciences, P.O. Box 17, Xi'an 710075, China
[b] Graduate School of the Chinese Academy of Sciences, Beijing 100039, China
[c] Xi'an Jiaotong University, Xi'an 710049, China

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Abstract

In order to measure long-lived radioisotopes such as ^{10}Be with high sensitivity using an HVEE model 4130 AMS system, as well as to guarantee ^{14}C measurements of high precision, a new dual injection system for the AMS system is proposed. The proposal is to add a Wien filter located between the ion source system and the recombinator of the HVEE model 4130. When a pulsing voltage is optionally applied to the Wien filter, a sequential injection mode is turned on. The isotopes would alternately pass on different trajectories through the recombinator. When the pulsing voltage and magnetic field are turned off, the Wien filter acts as a field-free drift space and the standard simultaneous injection mode is on. Beam optics calculation show that the new dual injection system will increase the number of radio-nuclides which can be analyzed, keep the high precision capability for radiocarbon dating and achieve high sensitivity for ^{10}Be and ^{26}Al measurements, together with simplifying the layout as compared to existing dual-injector and dual high-energy beam line systems.

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Keywords: New dual injection system; Wien filter; AMS; Recombinator

1. Introduction

Jointly established by the Institute of Earth Environment, Chinese Academy of Sciences and Xi'an Jiao-Tong University, the Xi'an AMS Center will be equipped with a 3-MV multi-element AMS system, with a measurement precision of better than 0.3% for modern radiocarbon and an abundance sensitivity of 3×10^{-15} for ^{10}Be and ^{26}Al analyses in applications of earth sciences, environmental sciences and archaeology [1–4]. We have installed an AMS system with a sequential injection. A new injection system as described here is not yet installed at our laboratory.

The 3-MV Tandetron Model 4130 manufactured by High Voltage Engineering Europe (HVEE) is a commercially available facility dedicated to AMS measurements of radiocarbon [5–10]. However, it has been suggested that the simultaneous injection system based on the technology of the recombinator [11,12] may be unsuitable for other radioactive nuclides (e.g. ^{10}Be, ^{26}Al, ^{129}I), because the simultaneously injected stable isotopes may introduce interferences effecting the rare isotope background. Nevertheless, high-sensitive measurements of the long-lived radionuclides can be achieved using a sequential injection system. Therefore, some AMS facilities are equipped with both, a simultaneous injection system for high-precision ^{14}C-AMS and a sequential injection system for high-sensitivity measurements of other radioisotopes [8,13,14]. Such AMS facilities, having dual-injectors and dual high-energy

* Corresponding author. Address: State Key Laboratory of Loess and Quaternary Geology, Institute of Earth Environment, Chinese Academy of Sciences, P.O. Box 17, Xi'an 710075, China. Tel.: +86 29 8832 0778; fax: +86 29 8832 0456.
E-mail address: weijian@loess.llqg.ac.cn (W. Zhou).

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beam lines sharing a common tandem, appear to be rather expensive, complicated and occupy considerable space.

Recognizing the different attributes of these two injection systems, this paper presents a patented new dual-injection system for AMS facilities by adding some improvements to the injector of the existing HVEE model 4130 AMS system [15]. The new system will allow high sensitivity measurements ^{10}Be, ^{26}Al and other nuclides and also allow high precision ^{14}C dating. It turns out that this new system is much simpler than the dual-injector combination. It might provide a basis for the functional expansion of other AMS facilities, as well as some inspiration for AMS technology researchers.

2. System description

The original injection system of the HVEE model 4130 AMS consists of a negative ion source and a recombinator. In the newly designed system Wien filter and an electrostatic quadrupole doublet lens are mounted between the ion source and the recombinator, as shown in Fig. 1.

The system includes a cesium sputter negative ion source and an Einzel lens. The HVEE Model 846B ion source or the new HVEE model SO-110 ion source are suitable, producing a 35-keV negative ion beam with a maximum output current of more than 100 μA for $^{12}C^-$.

The Wien filter is operated when running under the sequential injection mode. A Wien filter as manufactured by the National Electrostatics Corporation (NEC) [16] is convenient for serving this purpose. Its maximum electric field strength is 35 kV/cm and the maximum magnetic field is 0.4 T. Under the sequential mode, fast injection cycling is required for an accurate ratio measurement. Accordingly, a pulsing voltage (100 Hz), similar to ''bouncer'' systems [17], is applied to the electrodes of the Wien filter in order to ''match'' the fixed magnetic field and select individual isotopes to pass through the central trajectory of the Wien filter and be injected into the recombinator. Under the simultaneous injection mode, the bouncing mode of the Wien filter is switched off and it then acts as a field-free drift space. Hence, an electromagnet must be used in the Wien filter rather than a permanent magnet.

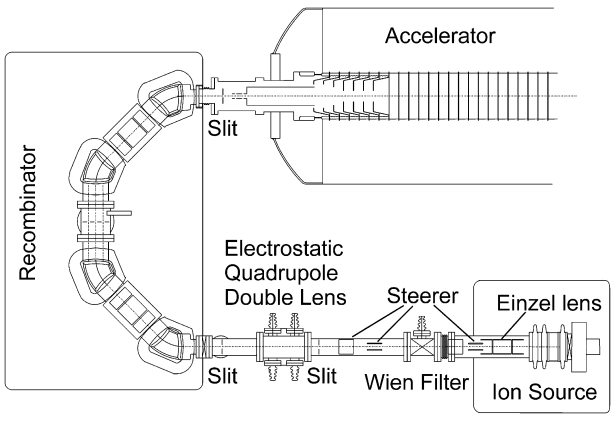

Fig. 1. Schematic layout of the new dual injection system.

The electrostatic quadrupole doublet lens could be a NEC Model EQD 5-1515 [18], with a voltage rating of 25 kV and a length of 60 cm. The quadrupole doublet lens in combination with X and Y steerers is intended to accurately focus the ions of interest at the object of the recombinator.

The recombinator consists of a combination of four 45° magnets having normal entry and exit shim angles and a radius of curvature of 26 cm [5]. During the measurement of radiocarbon, the individual carbon isotopes are separated by approximately 2 cm at the intermediate focal plane, making possible the complete rejection of any nitrogen hydride ions. The standard HVEE recombinator is modified by two sets of adjustable slits placed at the two sides of the central symmetrical plane to eliminate background ions. In addition, a retractable Faraday cup is placed behind these fixed slits on the central trajectory to allow the measurement of stable isotope currents.

3. Detailed design

In this study, some improvements have been made only on the injector of the HVEE model 4130 AMS system. Hence, only the design of the Wien filter and the electrostatic quadrupole doublet lens will be described. For more detailed information is referred to [5,6,19].

3.1. Design consideration

(1) The new system should cover a broad range of isotope masses. ^{10}Be and ^{26}Al should be measured using the basic parameters of the existing 4130 AMS with some adjustments.
(2) It is appropriate to combine a single focusing Wien filter with a following electrostatic quadrupole doublet lens for flexibly in adjusting the positions of the beam waists as the design of a double focusing Wien filter is complex.
(3) During a radiocarbon measurement using the simultaneous injection mode, the C^- beams are focussed by both the Einzel lens behind the ion source and the electrostatic quadrupole doublet lens. They form waists in both horizontal and vertical directions at the object plane of the recombinator.
(4) During AMS measurements of beryllium (or aluminum) using the sequential injection mode, the $^9Be^{16}O^-$ and $^{10}Be^{16}O^-$ (or $^{26}Al^-$ and $^{27}Al^-$) beams form two separate waists at the entrance to the quadrupole doublet lens, which are clearly separated in horizontal direction due to the isotope dependent deflection introduced by the Wien filter. The separated isotope beams travel through the quadrupole lens sequentially and form horizontal and vertical waists at the object position of the recombinator.