

New developments in design and applications for Pelletron accelerators

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Abstract. Most of the developments over the last several years related to Pelletron accelerator are in the field of accelerator mass spectrometry (AMS) and other low beam current applications with the exception of a very high DC electron recirculation Pelletron. High precision AMS systems based on tandem Pelletrons from 500 kV to 5 MV terminal potential are now in use for routine high precision AMS measurements. Their performance will be reported. In addition, there has been significant advancement in the design of the multi-cathode SNICS source for the use of both gas and solid samples within a single source. The latest performance of these sources will be discussed. New diagnostics is being developed for very low beam currents. The latest design of the low current beam profile monitor (LCBPM) will also be presented.

Keywords. Pelletron; AMS; ion source; BPM.

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1. Introduction

Up until the late 1970's electrostatic accelerator development was concentrated primarily in reaching higher beam energies to overcome the Coulomb barrier necessary for the study of nuclear structure. Over the years, applications for the use of electrostatic accelerators have broadened into a wide variety of fields including materials modification, materials characterization, radioisotope ratio measurement, and many others. These applications have required improvements in beam transmission, beam quality and beam quantity. This in turn has led to further developments in the ion beam sources, beam monitoring components as well as the overall basic design of the electrostatic accelerator system.

This paper will address the activities of National Electrostatics Corp. over the last few years in the area of new Pelletron accelerator systems, ion source developments and a new low current beam profile monitor to meet the requirements of current applications.

2. New Pelletron systems

Recent applications have put severe demands on the enhancement of beam transmission efficiency. The first application involves the use of an electron beam for the cooling of an antiproton beam in the accumulator ring at the Fermi National Laboratory. The second



Figure 1. The 5UR Pelletron which is housed in a pressure vessel, 7.7 m high by 3.66 m in diameter. The column has two parallel acceleration tubes. The first tube allows the beam acceleration from the terminal electron gun. The second tube allows the beam deceleration to the terminal charge collector. (Photo courtesy of Fermi National Accelerator Laboratory.)

application involves the transmission of stable and radio isotopes, sequentially or simultaneously, for the precise and accurate measurement of the radio isotope-to-abundant isotope ratio.

Antiproton cooling – A Pelletron Model 5UR, 5 MV, single-ended electron Pelletron accelerator was manufactured for the Fermi National Laboratory (figure 1) to provide a high current, 5 MeV electron beam for injection into the antiproton accumulator ring. The cool electron beam is used to absorb the transverse momentum of the antiprotons, resulting in higher currents in the accumulator ring. For this application, hundreds of milliamps of DC electrons are required. To accomplish this, the 5 MV Pelletron has an electron gun and a collector in the terminal. Four to five MeV electrons are produced and accelerated into a 10 m or 20 m interaction region in the proton accumulator ring. The electron beam is then extracted and decelerated back to the terminal to conserve the electrical charge. In this way, hundreds of milliamps of a DC electron beam can be produced with only $300\text{ }\mu\text{A}$ of charging current to the high voltage terminal.

The 5UR Pelletron is undergoing testing on-site. The Fermi National Laboratory recently reported that a 3.5 MeV DC electron beam at a beam current of 500 mA was recir-

Table 1. Dedicated tandem AMS Pelletron systems.

Laboratory	Model	Terminal potential
M.A.L.T. at University of Tokyo (Japan)	5UD ^a	5 MV
National Institute of Environmental Studies (Japan)	15SDH-2	5 MV
Tono Geoscience Center (Japan)	15SDH-2	5 MV
CBAMS Ltd. (UK)	15SDH-2	5 MV
Scottish Universities Environmental Research Centre (UK)	15SDH-2 ^b	5 MV
Vienna Environmental Research Accelerator (Austria)	9SDH-2	3 MV
Accelerator Mass Spectrometry Laboratory, University of Arizona (USA)	9SDH-2	3 MV
Institute for Accelerator Analysis Ltd. (Japan)	9SDH-2	3 MV
Commissariat A L'Energie Atomique (France)	9SDH-2 ^b	3 MV
Center for Accelerator Mass Spectrometry, LLNL (USA)	3SDH-1 ^c	1 MV
Laboratorium für Kernphysik, ETH (Switzerland)	1.5SDH-1 ^d	500 kV
Center for Applied Isotope Studies, University of Georgia (USA)	1.5SDH-1	500 kV
Poznan Radiocarbon Laboratory (Poland)	1.5SDH-1	500 kV
Earth System Science, University of California, Irvine (USA)	1.5SDH-1 ^b	500 kV

^aPartial system, multi-purpose; ^binstallation in progress; ^cpartial system, ³H capability in manufacture; ^dpartial system, Pelletron and source.

culated for 1 h in a 10 m long beam line [1,2]. The relative beam loss during this test was about 2×10^{-5} . Work is continuing on the overall development of this system.

Accelerator mass spectrometry – Ion beam systems for use in accelerator mass spectrometry (AMS) also require exceptional ion beam transmission. This technique relies on the identical transmission of the various isotopes for a given ion beam species. The most common usage is for $^{14}\text{C}/^{12}\text{C}$ measurements. Originally, carbon AMS was used almost entirely for archaeological measurements, i.e., carbon dating. AMS has proven to be far more efficient for routine carbon dating than the original disintegration counting techniques [3]. In recent years however, accelerator systems are being used increasingly for biomedical carbon AMS [4]. In addition, a wide variety of AMS applications have opened up requiring the measurement of radio isotopes of beryllium, aluminum, calcium, iodine, chlorine, the actinides and others [5]. Of the more than 150 Pelletron systems built, approximately 27 are performing AMS for a significant amount of the beam time available. Sixteen of these systems are primarily dedicated to AMS applications (table 1). The maximum rated terminal potential of accelerator systems used for AMS range from 25 MV for new experiments related to AMS development [6] to 500 kV for the new compact NEC AMS carbon systems (figure 2).

Of the dedicated systems, the most versatile have a maximum terminal potential rating of 5 MV. There are now three dedicated 5 MV tandem Pelletrons in use and a fourth undergoing installation. An additional 5 MV tandem Pelletron is designed for multiple applications including AMS. These systems were all designed to accommodate measuring isotope ratios for beryllium, carbon, aluminum, silicon, chlorine, calcium, and iodine. The most recent of these Model 15SDH-2 Pelletrons for the Scottish Universities Environmental Research Centre (SUERC) to complete its factory beam tests demonstrated a precision

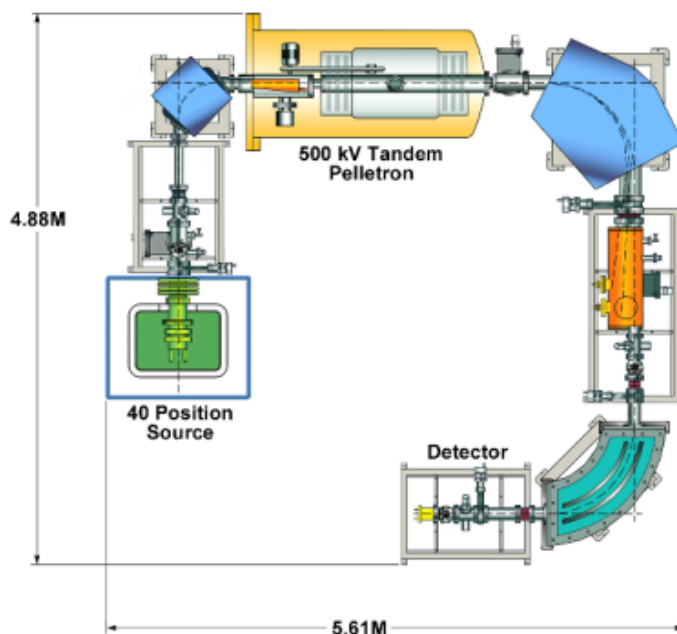


Figure 2. The compact AMS system uses sequential injection and measures ^{12}C , ^{13}C and ^{14}C beam currents. The 500 kV terminal is equipped with a dual, turbo-molecular recirculating gas stripper to assure an adequate stripper thickness to break up all molecular ions.

for chlorine of better than the 3% precision required. This 5 MV AMS system ran the chlorine tests at a terminal potential of 5.2 MV with beam currents for $^{35}\text{Cl}^{+7}$ of 7 to 22 μA , cathode dependent. The individual chlorine runs were relatively short, on the order of 2 min each. Using blank chlorine cathodes from ANU and ETH, the background was measured to be 2 to 5 $\times 10^{-15}$ for $^{36}\text{Cl}/\text{Cl}$.

For carbon AMS, the specification of the 5 MV and 3 MV systems requires a precision of 0.3%. During tests on-site precisions from 0.15% to 0.25% were achieved for carbon using common standards [7]. The accuracy of these standards was measured to within 0.12% and backgrounds of better than 60,000 years were obtained. For high throughput applications, primarily related to biomedical samples, the system at CBAMS Ltd. is equipped with the 134 sample multi-cathode source of negative ions by cesium sputtering (134 MC-SNICS) and has measured 2000 samples within five days to 2% precision.

The AMS group at ETH/PSI in Zurich under the direction of Prof. Martin Suter has shown that high precision radio carbon AMS can be achieved using terminal potentials of less than 500 kV [8]. The NEC compact AMS system based on a 500 kV tandem Pelletron, can be accommodated in a 6 m \times 6 m room. The compact AMS systems (figure 3) have far fewer lenses and other beam handling components than the more conventional higher voltage machines while still achieving routine precisions from 0.3% to 0.5% with a background of better than 50,000 years. The Poznan Radiocarbon Laboratory has listed their results at their web site, <http://www.radiocarbon.pl>.



Figure 3. The high throughput carbon AMS system equipped with 134 sample, multi-cathode source of negative ions by cesium sputtering (134 MC-SNICS). This system is presently in operation at the Center for Applied Isotope Studies, University of Georgia, USA.

3. Ion source development

Although most of the ion source development in recent years has been to accommodate applications in AMS, there has been some recent modification to the NEC toroidal volume negative ion source (TORVIS). As reported earlier [9,10], this source is capable of 300 to 500 μA for H^- and $^2\text{H}^-$. It has been shown in other sources of this type that the addition to cesium in the plasma of ion enhances the beam current output. This same modification has been made to an existing TORVIS source under less than optimum conditions. The ten year old source was modified to allow the addition of cesium through a 1 mm ID stainless steel pipe in the source gas inlet. The $^2\text{H}^-$ beam was enhanced from the 300 to 400 μA region to better than 600 μA . It is expected that the enhancement would be far greater in an ion source originally designed for the addition of cesium.

Over the last ten years there has been a continuing program on the improvement of the overall reliability and capability of the multi-cathode SNICS source to increase beam output, number of cathodes that can be accommodated in the vacuum at one time, and the added capability for both solid and gas samples.

About thirty of these ion sources are presently in use. Beam currents up to 130 μA for C^- have been injected for AMS applications and beams of BeO^- , Al^- , AlO^- , Cl^- , and I^- have been obtained for AMS applications. The multiple cathode SNICS is presently available in a 40 sample and 134 sample configuration. Both of these configurations are now available to accommodate gas samples. The valve which isolates the cesiated volume during cathode wheel change has been modified to allow the addition of pumping on the cesiated volume. The gas sample is introduced through the cesium focus electrode via a



Figure 4. The low current beam profile monitor (LCBPM) which is under development for the cross-sectional measurement of ion and electron beams from the particle/s to the microamp range.

stainless steel pipe to the back of the cathode wheel. The gas sample flows through a hollow aluminum/titanium cathode assembly. During recent tests, 10 to 20 μA of C^- have been obtained from a CO_2 gas sample. Under these same conditions, a solid graphite sample produces 125 μA . Work is continuing to increase the efficiency of beam production from CO_2 .

A complete gas sample handling system is presently in development for use with the 5 MV tandem Pelletron AMS system for SUERC. This gas distribution system is pneumatically controlled and is designed to operate at source potential. It is equipped with a reservoir for helium dilution and flushing. There are ten gas aliquot positions. CO_2 can flow directly from its source of production into the gas MC-SNICS or it can be accumulated in one of the ten reservoirs. The system is pumped with a 200 l/s turbo pump. Final design is complete and manufacturing is underway for delivery in late 2002.

4. Low current beam profile monitor

The Pelletron accelerator group at the Johannes-Kepler-Universitat Linz Institut fur Experimental Physik under the direction of Dr. Manfred Geretschlaeger have modified a

standard NEC beam profile monitor to measure very low beam currents (LCBPM). This is accomplished by the addition of a solid state detector in the close proximity of the rotating scanning wire.

In the picoamp range, it is expected that the LCBPM will operate in the same mode as the standard NEC beam profile monitor. The secondary electrons from the grounded rotating wire are collected and the signal is displayed on a standard oscilloscope. In the particle/s mode, a solid state detector is used to accumulate counts from several passes of the scanning wire. The signal is fed into an MCA card in a standard personal computer. The display of the accumulate counts is very similar to that obtained in the standard mode on an oscilloscope.

The support electronics for the LCBPM are still in development and have not yet been beam tested. The LCBPM has been built and occupies the same beam line length as the standard NEC beam profile monitor (figure 4). It is expected to be sensitive to better than 10^4 particles/s which would make it ideal for any application involving very low beam currents such as radioactive ion beams and AMS.

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