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Authors

Southon, J R
Santos, G M

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ION SOURCE DEVELOPMENT AT KCCAMS, UNIVERSITY OF CALIFORNIA, IRVINE

J R Southon[1] • G M Santos

Earth System Science Department, University of California, Irvine, Irvine, California 92697-3100, USA.

ABSTRACT. The Keck Carbon Cycle accelerator mass spectrometry facility at the University of California, Irvine, operates a National Electronics Corporation 40-sample MC-SNICS ion source. We describe modifications that have increased beam current output, improved reliability, and made the source easier to service.

INTRODUCTION

The Keck Carbon Cycle accelerator mass spectrometry (KCCAMS) system at the University of California, Irvine, is based on a compact AMS accelerator from the National Electronics Corporation (NEC) (0.5MV 1.5SDH-1 Pelletron) with a 40 sample MC-SNICS ion source (Figure 1). The NEC source (Norton et al. 1999) operates routinely in many AMS laboratories worldwide at outputs of a few tens of µA of C^- ions. Operation above 100 µA is possible, but the source is often unstable and requires frequent cleaning. We have modified the source to increase the beam current output and to improve reliability and serviceability, and further work is planned.

SERVICEABILITY

Source Body Support

As supplied by NEC, the 40-sample version of the MC-SNICS is difficult to maintain, since no provision is made for in-situ servicing, and the entire source must be dismounted for even minor routine maintenance. Building a system for in-place servicing (Figure 2) seems mundane, but is probably the most important single change we have made. We bolted NEC's mobile high-voltage rack firmly to the floor and built into it a track system to support the source, using filing cabinet slides; longer versions of the slides are used to support the sample changer during cathode wheel changes. This allows the entire source body, or the sample changer plus isolation valve, to be rolled back for servicing, with almost all of the electrical, pneumatic, and cooling connections left in place. One person can perform a complete source cleaning in 2 hr.

Internal Changes

Maintenance is further eased if the source need only be opened at one end. The insulators supporting the Cs focus electrode (Figure 1) are unshielded, and occasionally become tracked due to buildup of sputtered material and must be replaced. As supplied, both ends of the source must be accessed in order to remove these insulators. By lock-nutting the screws which secure the downstream ends of the insulators, we can now replace the insulators with only the upstream end of the source opened.

Likewise, removing the ionizer assembly for cleaning (from the downstream end of the source) was impossible without first removing the Cs focus electrode (from the upstream end) due to interferences between these 2 assemblies and the Cs feed tube. We have cut away portions of the focus electrode according to a University of Arizona design (W Beck, personal communication), reducing it from the dished shape shown in Figure 1 to a flat plate mounted from 3 narrow legs. This was done to improve local pumping, but it also increased clearances sufficiently that the ionizer assembly can now be replaced with the Cs focus left undisturbed.

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[1] Corresponding author. Email: jsouthon@uci.edu.

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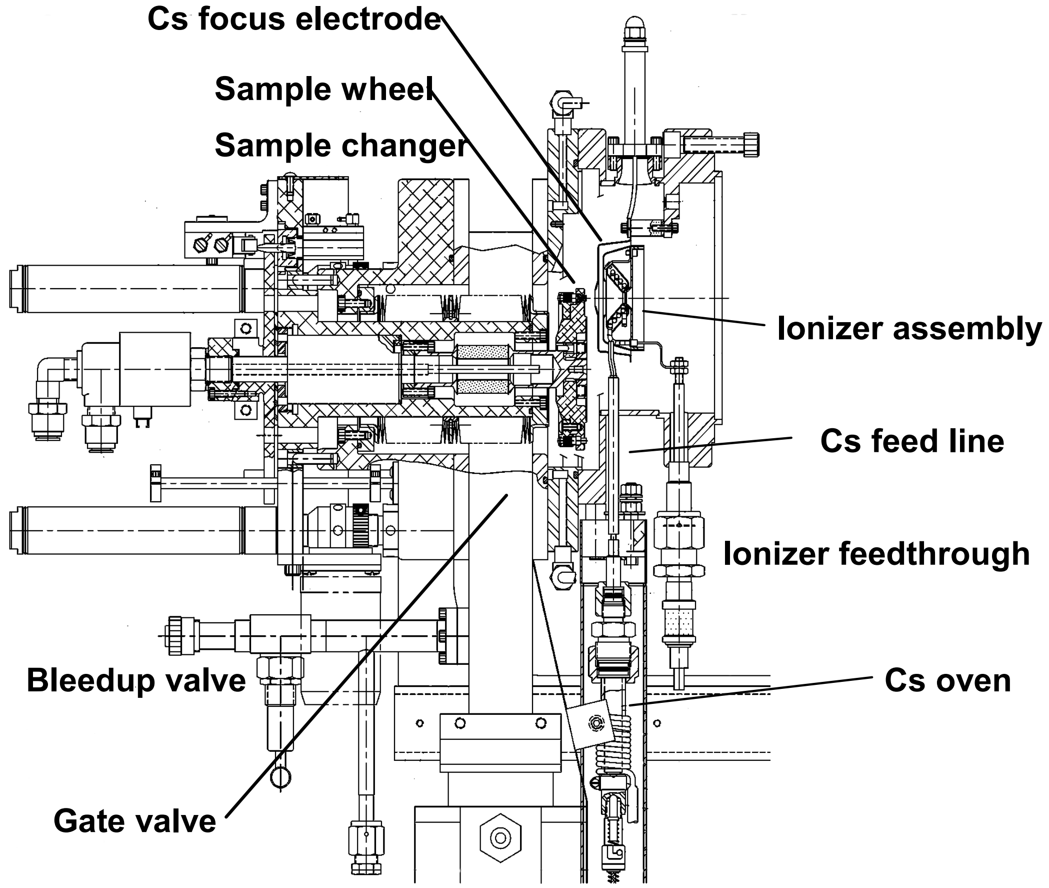

Figure 1 The NEC 40-sample ion source and sample changer. Note the tight clearances between the outer shroud of the ionizer assembly and the Cs focus electrode, and the lack of shielding of the post-type Cs focus support insulators (one of three is shown). The ionizer assembly is supported by 3 legs (not shown here) from the same internal lugs as the Cs focus electrode.

SPARKING AND INSTABILITY

After sample wheel changes, the source is often very unstable, with frequent arcing between the cathode wheel and the Cs focus electrode which can take hours to subside. The origin of the sparking remains obscure and there may be multiple causes. However, some of the instability may be due to poor contact between the aluminum sample wheel and a spring-loaded cathode voltage feedthrough. Sparking was reduced when a copper ring was temporarily bolted to the front of the wheel to make the contact. For a longer-term solution, we skimmed the front of the wheel flat on a lathe, and bolted on a stainless steel face plate (Figure 3). This has reduced (though not completely cured) the problem.

We have also found that the arcing is associated with progressive buildup over several weeks of a very hard insulating layer on the cathode side of the Cs focus. We speculate that arcing to the cathode wheel occurs due to buildup of stray charge on this layer, which is probably aluminum carbide from sputtered aluminum and graphite. We routinely swap out the focus electrode every few weeks, or when the instability becomes troublesome, and remove the deposit by grinding it with a diamond-tipped Dremel® tool.

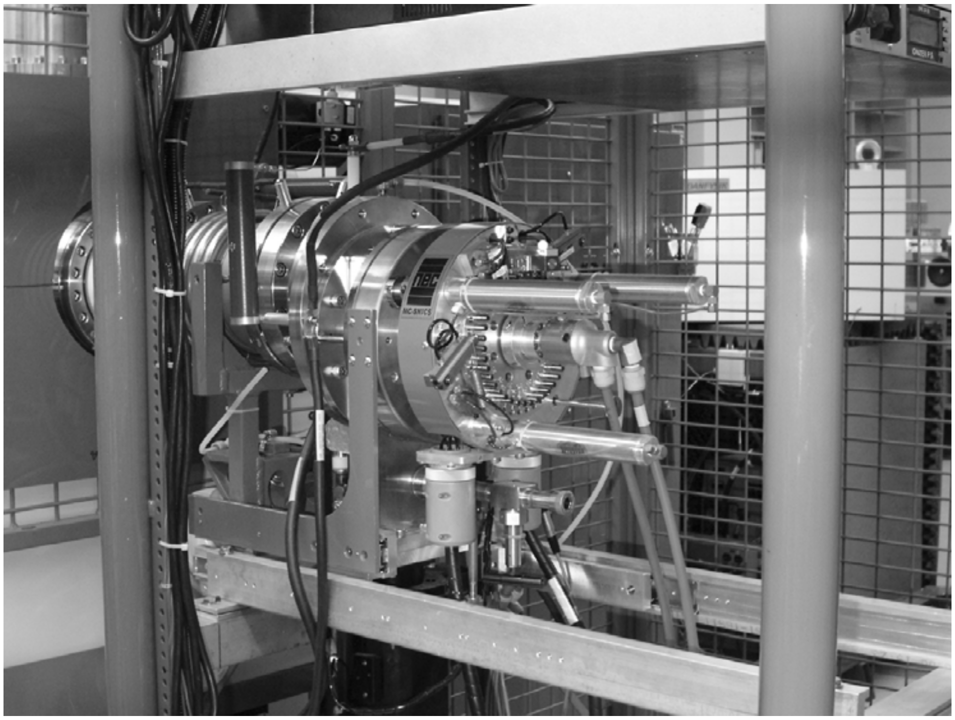

Figure 2 The track system built into the source high-voltage rack to allow the source to be serviced in situ.

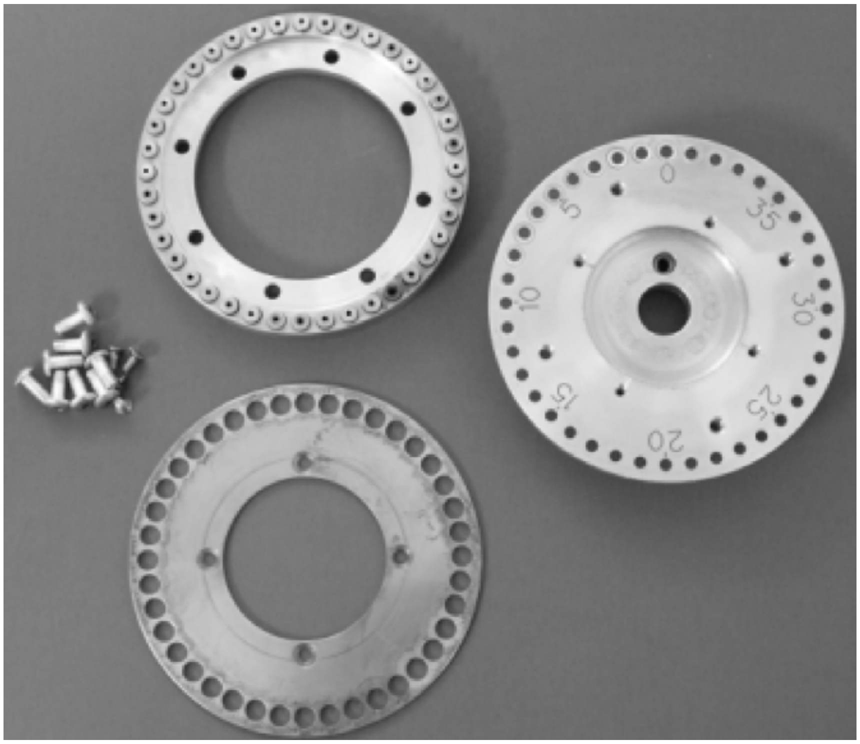

Figure 3 Modified sample wheel, sample clamp ring, and face plate.

Cs FEED

The Cs feed tube in the NEC source is actively heated but suffers from clogging problems, due in part to the small tube bore and the presence of a cold spot where the lower end of the assembly loses heat to the source body via the mounting bracket. This can lead to erratic operation at high outputs, and to frequent shorting out of insulators when the Cs oven is overheated in an effort to break through the liquid Cs plug in the line, and "burps" excess Cs into the source.

We are now running the Cs line heater at currents 40% above the original factory setting (45 A versus 33 A), following advice from other laboratories (D Knies; R Loger, personal communications). We have also added a layer of fiberboard to the existing heat shield around the Cs line and mounting bracket, and wrapped the VCR fitting at the top of the Cs oven with additional glass fiber and aluminum foil insulation. Together, these changes have raised the temperature of the cold spot where the VCR fitting attaches to the mounting bracket, and have made the Cs feed system much more controllable, though care is still required to prevent clogging. We are currently testing a new feed tube arrangement based on the double-walled, vacuum-insulated Lawrence Livermore (LLNL) design (Southon and Roberts 2000) which is completely free of this problem.

Cs OVEN

The Cs oven has been replaced to simplify and speed up Cs replenishment. The new unit (Figure 4) is based on a LLNL design (Southon and Roberts 1997), sealed with a 1.33" Conflat, and heated with an inexpensive band heater (Hotset Corporation, Battle Creek, Michigan, USA). It accepts full Cs ampoules that are opened under Ar and placed upright in the oven. It is not necessary to heat and pour out the Cs, as with the NEC design. This shorter oven is also less likely to act as a cannon when water is used to clean out residual Cs.

EXTRACTION ELECTRODE

Initially, the extractor, Cs focus, and cathode currents all tended to "run away" over time. When the source was cleaned, we saw signs of arcing (erosion) on the inside of the conical extractor snout and the end of its interior collimator assembly (Figure 5), the ionizer baseplate and the ionizer itself, the downstream side of the Cs focus electrode, and the cathode wheel. A likely explanation is that at high ionizer power levels, thermionically emitted electrons produce high space charge limited currents from sharp edges on the ionizer assembly (e.g. in the central aperture where 2 sheet-metal pressings overlap). These electrons can flow into the extraction gap and sputter positive ions from the extractor snout and collimator assembly. These positive ions then travel back upstream and strike the source. Under some conditions, this process becomes uncontrollable until the source is taken apart and cleaned.

R Loger (NEC) provided us with a new extractor electrode where the standard conical end was replaced by a large-bore tube (Figure 5), which alleviated the problem by reducing the electric field in the ionizer aperture. We have modified that design by shortening it and increasing the wall thickness to further reduce the electric field at the tip. The tubular double collimator assembly was removed to prevent arcing from the end, and was replaced by a single divergence-limiting collimator mounted at the downstream end of the electrode. Extractor currents still rise over time, but typically by 2–3 mA or less over a 12- to 24-hr run.

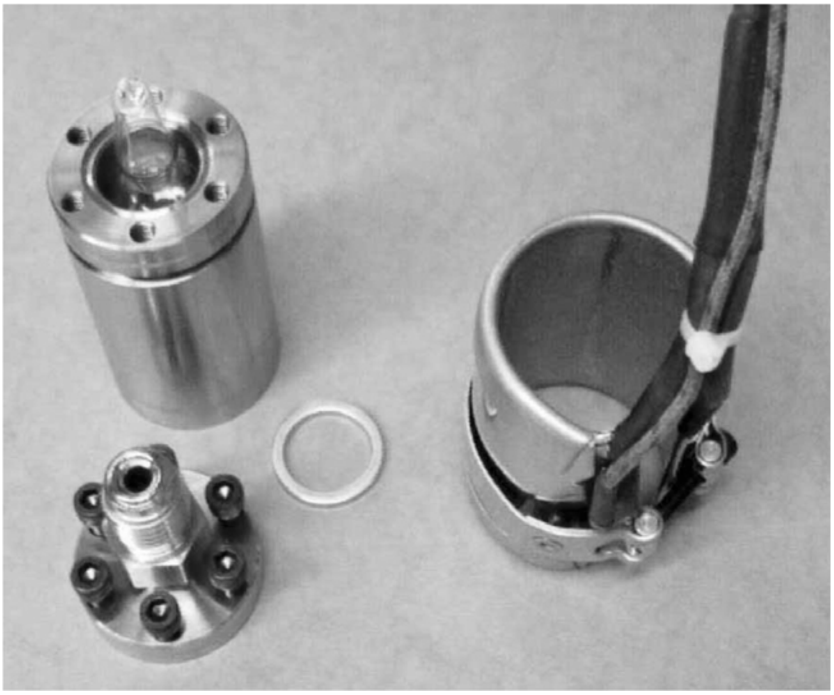

Figure 4 Cs oven and band heater. The new oven mates with the smaller of the 2 VCR nuts shown at the top of the NEC oven assembly in Figure 1.

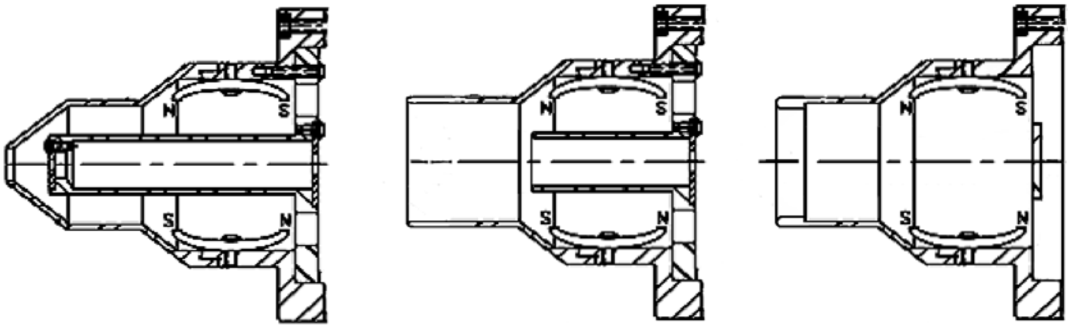

Figure 5 Extractor electrodes, with electron suppression magnets mounted above and below the beam path. Left to right: the original conical NEC design with internal 2-collimator assembly; the modified NEC straight-tube design (with shortened collimator assembly—front aperture removed); the shortened University of California, Irvine, design with a single collimator mounted on a transverse bar.

HIGH NEGATIVE ION OUTPUTS

Together, these changes have allowed us to run the source stably at higher cathode voltages and Cs oven settings to produce higher outputs. However, the key to high output currents is correct positioning of the sample wheel. As other researchers have found (M Roberts, personal communication), running with the wheel several mm back from the factory setting is necessary to obtain a suitably small (~1 mm) Cs spot at the sample for C– outputs > 100 μA.

This shift is required because as Cs currents in sputter sources increase, space charge moves the Cs beam waist (focus) back several mm further from the ionizer (Southon and Iyer 1990; Brown et al. 2000). In the NEC source, the Cs focus voltage can be varied to alter the position of the waist, but as Hausladen et al. (2002) have pointed out, when the "focus" lens is run at high voltages, it actually defocuses the Cs, pushing the waist back even further. If the lens is run at sufficiently low voltages, the waist can indeed be moved closer to the ionizer. However, since the focus voltage also determines the electric field at the ionizer surface, and hence the space charge limited Cs current, outputs are severely limited at low voltages. Moving the wheel back allows the lens to be run at high voltages, producing a correctly focused Cs beam at high intensities.

OPERATING PARAMETERS

Following these changes, typical running conditions for the source are as follows:

- Cathode voltage: 6.7 KV
- Cesium focus voltage: 3.9 KV
- Extractor voltage: 15.0 KV
- Einzel lens voltage: 1.2 KV
- Ionizer current: 24 A
- Cs heater (oven) voltage: 80 V (25 W)
- Cs oven temperature: 200 °C
- Cs line heater: 45 A
- Sample position: 3 mm back from factory setting.
- C^- output: 120–170 μA
- Cs consumption: 5 g per 6 weeks

FURTHER DEVELOPMENT

We are testing a new 40-sample wheel which is a bolt-in substitute for the NEC wheel, but uses 6.3-mm-diameter × 12.7-mm-long cylindrical sample holders held in place by spring-loaded ball inserts. These holders are large enough to be easily labeled, reducing the probability of inadvertently swapping samples. In addition, we have obtained funding from the National Science Foundation to work with NEC, Arizona, and Woods Hole on further source development. A complete new source body has been purchased from NEC and is being modified for improved cooling, provision of a vacuum-insulated Cs feed line, and changes to the Cs+ and negative ion geometries. We will also investigate the potential for better Cs focusing and increased negative ion output from spherical ionizers.

CONCLUSIONS

Our NEC ion source now runs with reasonable stability for periods of 2–3 weeks at 120–170 μA of C^- output, with results on secondary standards indicating 2–5‰ precision/accuracy for ^{14}C measurements. At these outputs, a typical wheel of 40 samples can be measured to 3–4‰ precision or better in well under 24 hr. Beam emittance has probably increased due to running the source harder, but the source output is still within the acceptance of the stripper canal of the 1.5 SDH-1 accelerator. Ion source sparking and instability have been reduced, so that stable operation is reached within 1–2 hr after a sample wheel change. Although maintenance is required every few weeks to allow the source to run at high outputs, servicing it has become relatively simple and far less time consuming.

ACKNOWLEDGEMENTS

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